FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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PROGRAMME REVIEW
REPORT 2018

The FCH-JU Programme Office has asked the Joint Research Centre of the European Commission to develop an improved programme review methodology and to perform the full review for the year 2018. This report is an edited version of the full 2018 Programme Review Report produced by the JRC. The Joint Research Centre (JRC) performed the 2018 Programme Annual Review Assessment under the Framework Contract approved by the FCH-JU Governing Board on 23/12/2015.

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FCH JOINT UNDERTAKING

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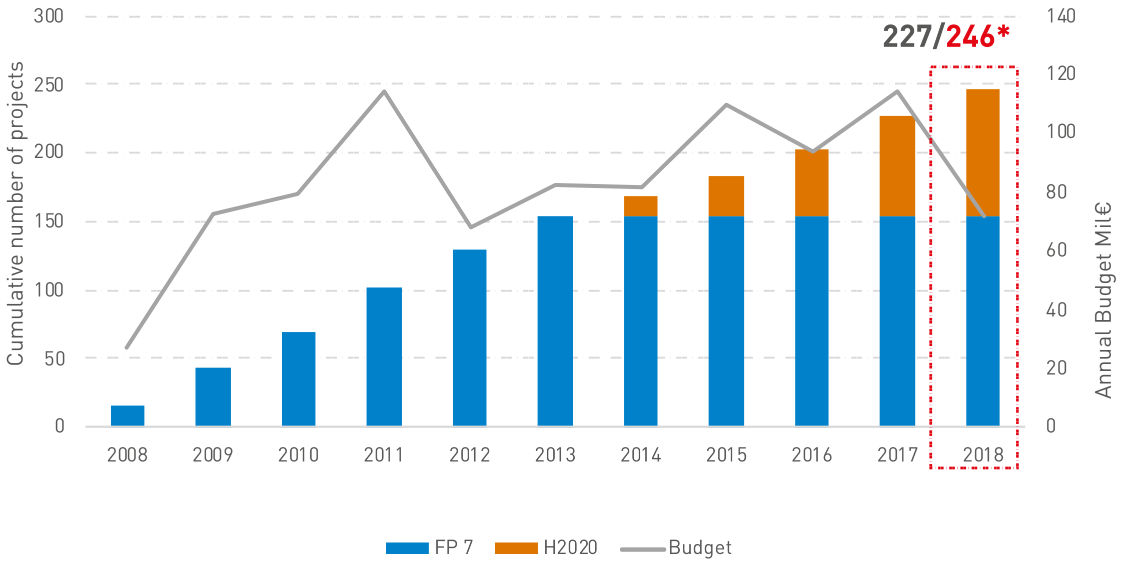
EXECUTIVE SUMMARY

As the European Union (EU) aims to guarantee secure, sustainable, affordable energy for every citizen, fuel cell and hydrogen (FCH) technology has a major role to play. Hydrogen, as a versatile, flexible and clean energy carrier, and fuel cells, as an efficient conversion technology, have significant potential to help fight carbon dioxide emissions, reduce dependence on hydrocarbons and contribute to economic growth.

The Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU) aims to facilitate the market introduction of FCH technologies in Europe and realise their potential in a carbon-clean energy system. To date (calls 2008-2017), 227 projects have been funded by FCH 2 JU (see the graph below – Figure 2 in the report), with a total budget of EUR 844 million complemented by more than EUR 886 million from other sources.



* Projects included in the Programme Review 2018 covering calls 2008-2017/Projects singed on 1/9/2019.

The 2018 Programme Review Report presents the findings of a review into activities supported by the FCH 2 JU under the EU's Seventh Framework Programme and Horizon 2020 by the European Commission's Joint Research Centre (JRC). It pays particular attention to the added value, effectiveness and techno-economic efficiency of FCH 2 JU projects, assigned to six review panels under two main pillars – Transport and Energy – and support for market uptake (cross-cutting) activities such as standards and consumer awareness.

Two of the panels fall under **Transport** (trials and deployment of fuel cell applications and the next generation of products); three under **Energy** (trials and deployment of fuel cell applications, next generation of products, and hydrogen for sectorial integration); and one under the **Support for Market Uptake** (cross-cutting pillar).

This report covers all 87 projects that were ongoing for any time between April and October 2017 and assesses the strengths and accomplishments of each panel and areas that would benefit from further attention.

Activities under the Transport pillar are designed to accelerate the commercialisation of FCH technologies in transport applications through a programme that includes demonstration and research projects. These 26 projects aim to reduce system costs, increase their lifetime and reduce the use of critical raw materials.

The demonstration activities covered in this report explore FCH in relation to cars, buses, material-handling vehicles and refuelling infrastructure. Research projects focus on membrane electrode assemblies, catalysts, bipolar plates, advanced refuelling, auxiliary power units, FC system integration, and design, manufacturing and process development.

The review highlights a number of general strengths in this pillar, including:

- commitment to FCH technology and its commercialisation;
- strong links with national and regional programmes;
- good practice and expertise sharing;
- the balance of competences among partners;
- efforts to harmonise testing procedures.

The goal of the 52 projects assessed under the Energy pillar is to accelerate the commercialisation of FCH technologies for stationary fuel cells and for the production of low-carbon hydrogen as an energy source, by increasing efficiency while cutting costs.

Among the strengths observed in this pillar are:

- increased average lifetime and lower capital costs of certain applications;
- established companies featuring fuel cells in their product portfolio;
- active participation of industry;
- large-scale demonstrations furthering public acceptance and commercial interest.

Within the Support for Market Uptake (cross-cutting) activities, the report highlights progress made by projects in defining potential cost reductions, producing educational tools and developing analytical methods and test procedures, as well as overall impact and dissemination of results.

At programme level, some general trends can be observed. The contribution to demonstration activities has increased and projects focusing on manufacturing have received a relatively higher level of financing than in previous years. The contribution to research activities on transport applications increased significantly under H2020.

Realising the EU's ambitious energy and climate targets and ensuring a sustainable transition to a carbon-neutral economy requires a coordinated approach from policymakers, industry and investors. The review therefore recommends a number of follow-up actions.

LIST OF ACRONYMS

AC	Alternating current
APU	Auxiliary power unit
BoP	Balance of plant
CAPEX	Capital up-front expenditure (investment)
CHP	Combined heat and power
CO_2	Carbon dioxide
EU	European Union
FP7	European Union's Seventh Framework Programme for research and technological development
FC	Fuel cell
FCH	Fuel cell and hydrogen
FCH 2 JU	Fuel Cells and Hydrogen Joint Undertaking[1]
GHG	Greenhouse gas
H2	Hydrogen
H2020	Horizon 2020
HHV	Higher heating value
HRS	Hydrogen refuelling station
HT	High temperature
JRC	Joint Research Centre of the European Commission
KPI	Key performance indicator
kW	Kilowatt
LCA	Life-cycle assessment
LHV	Lower heating value
LT	Low temperature
MAWP	FCH 2 JU's Multi-Annual Work Plan (2014-2020)
MEA	Membrane electrode assembly
MHV	Materials handling vehicles
MW	Megawatt
NOx	Nitrogen oxides
OEM	Original equipment manufacturer
PEM	Proton exchange membrane

1. FCH JU has been replaced by FCH 2 JU, which has taken over all rights and obligations of its predecessor.

PEMFC	Proton exchange membrane fuel cell
PGM	Platinum group metals
PNR	Pre-normative research
PO	FCH 2 JU Programme Office
PoC	Proof-of-concept
R&I	Research and innovation
R&D	Research and development
PRD	Programme Review Days
RCS	Regulations, codes and standards
RCS SCG	Regulations, Codes and Standards Strategy Coordination Group
SoA	State-of-the-art
SOEC	Solid oxide electrolyser cell
SOFC	Solid oxide fuel cell
SOx	Sulphur oxides
TEN-T	Trans-European Transport Network
TIM	Tools for Innovation Monitoring
TRL	Technology readiness level – See Annex E TRL 1 – basic principles observed TRL 2 – technology concept formulated TRL 3 – experimental proof of concept TRL 4 – technology validated in lab TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies) TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies) TRL 7 – system prototype demonstration in operational environment TRL 8 – system complete and qualified TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

01
INTRODUCTION

1.1. EU POLICY CONTEXT

The overarching strategic vision of the European Energy Union, launched in 2015, aims to guarantee 'secure, sustainable, competitive, affordable energy for every European'. This strategy shaped the legislative initiatives of the last years and is translated into targets for renewable energy, energy efficiency and reduction of greenhouse gas (GHG) emissions.

The European Union (EU) is also a signatory of the Paris Agreement, which came into force in November 2016. Its aim is to enhance implementation of the United Nations Framework Convention on Climate Change by limiting temperature increases to below 2 °C above pre-industrial levels and aiming to remain within a 1.5 °C rise. Before this, the EU had been active in targeting reductions in carbon dioxide (CO_2) emissions by setting increasingly ambitious objectives, the latest being those in the 2030 Energy Strategy published in 2015 and partially updated with the third Clean Energy Package legislation of December 2018[2]. This includes:

- New targets for renewable energy as set in the revised Renewable Energy Directive. The role of guarantees of origin and green certificates[3] is defined in the directive.
- The revised Energy Efficiency Directive (EU) 2018/2002 sets a 2030 target of 32.5 % for energy savings.
- A revised Energy Performance of Buildings Directive (EU) 2018/844
- The Governance Regulation (EU) 2018/1999 requires Member States to draw up integrated National Energy and Climate Plans for 2021-2030.
- The new Electricity Market Design proposals (a Directive and a Regulation), which introduce a new limit for power plants eligible for subsidies[4].

The role of energy storage and self-consumption is recognised and enabled by the new legislation, in particular the revised Renewable Energy Directive and the Electricity Market Design Directive.

The maritime sector is also impacted by efforts aimed at reducing greenhouse gas emissions. In 2018, the International Maritime Organisation (IMO) adopted the resolution MEPC.304(72) 'Initial IMO Strategy on reduction of GHG emissions from ships'. The target is a reduction of at least 40 % by 2030, pursuing efforts towards a reduction of 70 % by 2050 (baseline 2008). Other targets involve reducing total annual GHG emissions by at least 50 % by 2050 (2008 baseline).

The European transport sector is also impacted by the Directive on the deployment of alternative fuels infrastructure (2014/94/EU)[5]. This aims to facilitate a functional internal market for alternative fuel vehicles and technologies, and infrastructure build-up.

Hydrogen is included in 15 national policy frameworks. The Clean Mobility Package adopted on 8 November 2017 included a detailed assessment of the frameworks as well as an action plan and investment solutions for deploying alternative fuels infrastructure in the EU[6]. In parallel, the EU is aware of its dependence on oil and gas imports and has set targets to reduce the related risks, as stated in the 2014 Energy Security Strategy; it also aims to reduce air pollutants, with the latest objectives set out in the 2013 Clean Air Policy Package. In 2018, the Commission adopted the

2. https://ec.europa.eu/info/news/new-renewables-energy-efficiency-and-governance-legislation-comes-force-24-december-2018-2018-dec-21_en
3. https://www.certifhy.eu/
4. Subsidies to generation capacity emitting 550 gr CO_2/kWh or more will be phased out under the new rules.
5. Directive 2014/94/EU of the European Parliament and of the Council, of 22 October 2014 on the deployment of alternative fuels infrastructure.
6. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Towards the broadest use of alternative fuels - an Action Plan on Alternative Fuels Infrastructure under Article 10(6) of Directive 2014/94/EU, including the assessment of national policy frameworks under Article 10(2) of Directive 2014/94/EU, COM/2017/0652.

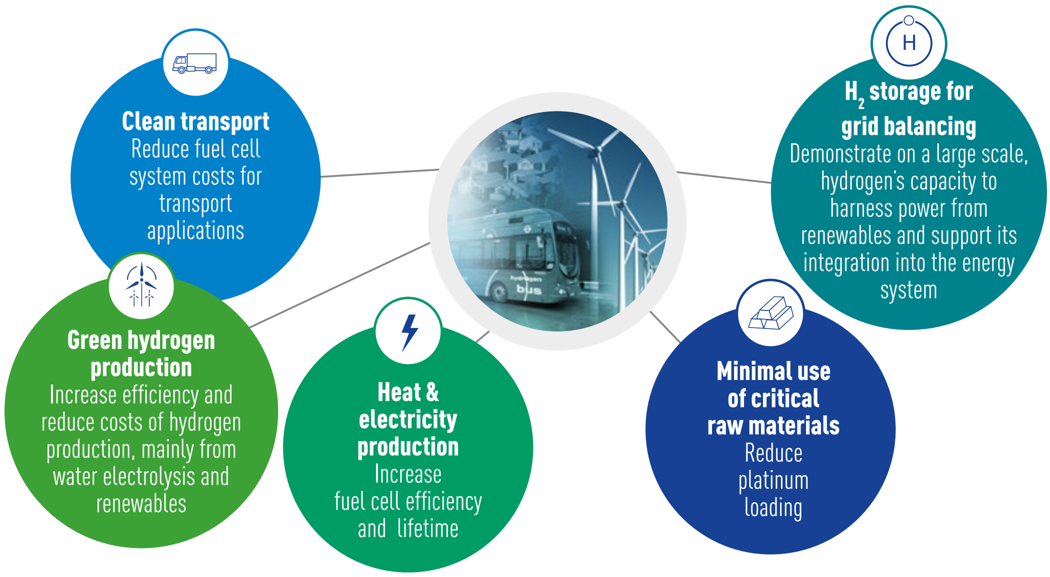
Communication 'A Europe that protects: Clean air for all', which provides national, regional and local actors with practical help to improve air quality.

Fuel cell and hydrogen (FCH) technologies can play a major role in achieving these goals. Fuel cells (FCs) enable the production of electricity more efficiently than internal combustion engines, reducing CO_2 emissions when fuelled with traditional fuels and eliminating them altogether when fuelled with hydrogen. The development of technologies for producing hydrogen from renewable sources would make hydrogen FC power totally carbon-neutral. Further, such 'green hydrogen' can act as a store for renewable electricity and allow offsetting of potential power-grid instability caused by the fluctuating nature of renewable electricity production. The Commission had identified this potential in 2004 when it set up the European Hydrogen and Fuel Cell Platform. In 2008, this became the FCH JU, renewed as FCH 2 JU in 2014.

1.2. THE ROLE OF THE FCH 2 JU

The FCH 2 JU's goal is to implement an optimal research and innovation (R&I) programme in order to develop a portfolio of clean, efficient solutions that exploit the properties of hydrogen as an energy carrier and FCs as energy converters, to the point of market readiness. This will support EU policies on sustainable energy and transport, climate change, the environment and industrial competitiveness as embodied in the Europe 2020 strategy, and will help achieve the EU's over-arching objective of smart, sustainable and inclusive growth.

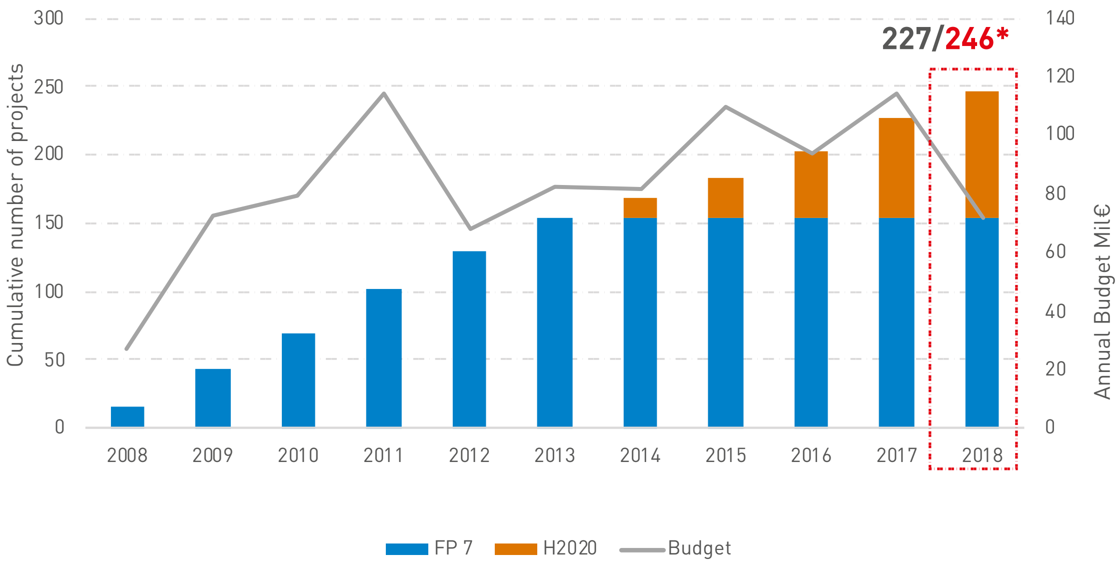
Figure 1: The core objectives of the FCH 2 JU programme.



The number of projects supported by the FCH 2 JU since its foundation in the EU's Seventh Framework Programme for Research and Technological Development (FP7) is shown in Figure 2. To date (calls 2008-2017), 227 projects have been funded by FCH 2 JU, with a total budget of EUR 844 million complemented by more than EUR 886 million from other sources. FCH 2 JU counts 1 084 participants from industry (64.1 %), research organisations (12.4 %), public sector (4.5 %) and academia (15.3 %)[7] from 26 EU and 11 non-EU countries.

7. 3.6 % legal entities have been categorised under 'others'.

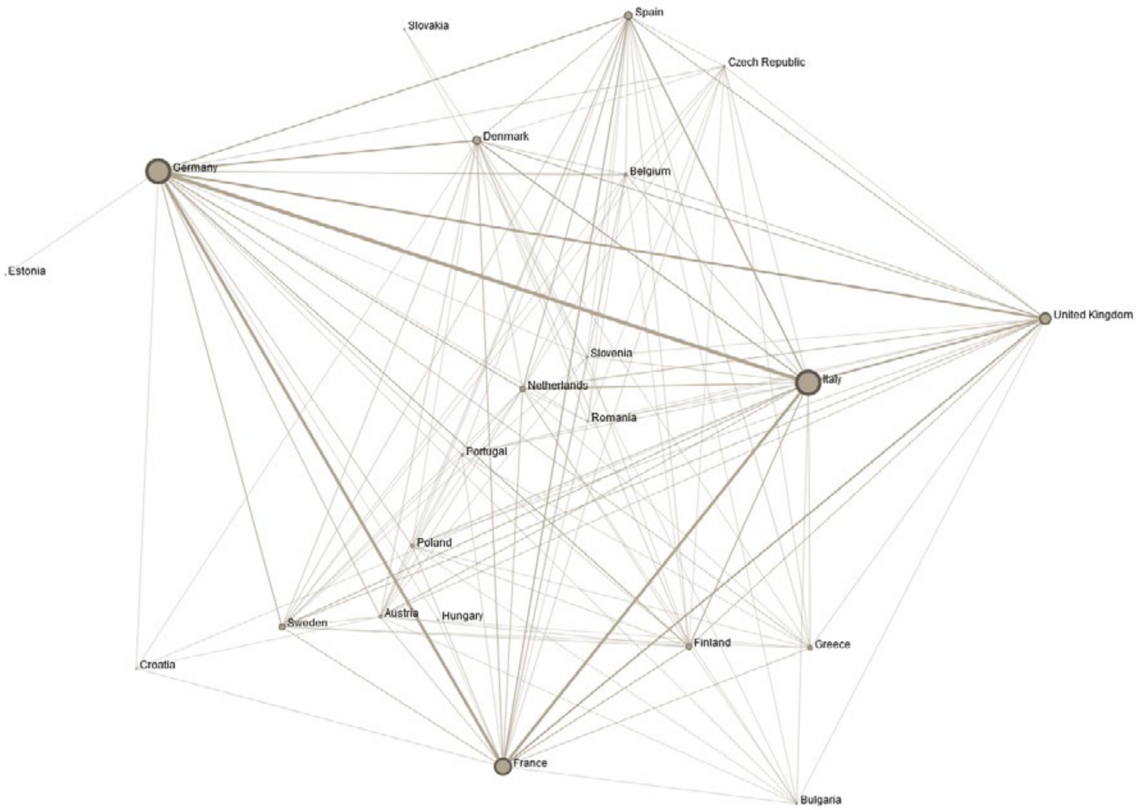
Figure 2: Number of FCH 2 JU-supported projects and annual budget calls 2008-2017.



* Projects included in the Programme Review 2018 covering calls 2008-2017/Projects signed on 1/9/2019.

Tools to understand collaborations are being developed. Tools for Innovation Monitoring (TIM) gathers data on three types of document: scientific publications, patents and EU granted projects. The JRC has developed a version for FCH 2 JU, which aims to monitor and analyse thematic or technological areas, tracking current and emerging technologies. An example of the data that can be visualised in TIM is given in Figure 3. The size of the nodes represents the number of entries associated with a European country; the weight of the connecting lines represents the number of common, co-authored entries between two countries.

Figure 3: TIM visualisation of output from FCH 2 JU beneficiaries and collaborations grouped according to EU countries[8].



The direction of the programme is guided by the Multi-Annual Implementation Plan for 2008-2013 under FP7 and Multi-Annual Work Plan (MAWP) for 2014-2020 under Horizon 2020 (H2020). These specify targets for FCH technologies in Europe in the form of key performance indicators (KPIs) for cost, durability and performance. The MAWP targets were revised and updated in 2018[9]. Project-specific targets presented in the yearly call topics were also considered. The progress of the programme is judged by progress towards achieving all these targets; for the current review, the relevant ones are the international state-of-the-art (SoA) of 2017 and the targets for 2020.

The FCH 2 JU supports the deployment of hydrogen technologies via project-funding calls each year and other networking and dissemination initiatives. In 2017 the FCH 2 JU launched an initiative supporting regions and cities to reduce their emissions and realise a green energy transition by deploying hydrogen technologies[10]; 92 regions and cities participated. Financing these investments will amount to approximately EUR 1.8 billion over the next five years. Several studies surveying a broad European context and a collection of success stories have been published and are updated periodically[11].

8. Extracted from the version of TIM adapted by the JRC for the FCH 2 JU. For more information see here: https://www.fch.europa.eu/page/tools-innovation-monitoring-tim
9. https://www.fch.europa.eu/sites/default/files/MAWP%20final%20version_endorsed%20GB%2015062018%20%28ID%203712421%29.pdf
10. https://www.fch.europa.eu/publications/fuel-cells-and-hydrogen-green-energy-european-cities-and-regions
11. https://www.fch.europa.eu/publications/fch-ju-success-stories

1.3. PURPOSE AND SCOPE OF PROGRAMME REVIEW 2018

The purpose of the Programme Review is to ensure the FCH 2 JU programme is aligned with the strategy and objectives set out in the founding Council Regulation (EU) No 559/2014[12] and the MAWP and Annual Work Plan (AWP). The 2018 review includes all projects that were ongoing[13] for any time in April-October of 2017. It covers 87 projects, of which 58 began under FP7 and 29 under H2020. Of these, 16 had been running for 18 months or less, 69 were reviewed for the 2017 report, and 18 are reviewed for the first time this year. Projects have been assigned to six review panels linked with the two main pillars, Transport and Energy, and cross-cutting activities relevant to both. The panels are listed in Table 1.

Table 1: Panels for the 2018 review

PILLAR/ACTIVITY	PANEL NAMES	TOPICS
Transport	1 - Trials and Deployment of Fuel Cell Applications	Projects targeting the demonstration and PoC of FCH applications in the Transport pillar
	2 - Next Generation of Products	Basic and applied research projects tackling subjects related to the Transport pillar
Energy	3 - Trials and Deployment of Fuel Cell Applications	Projects targeting the demonstration and PoC of FCH stationary heat and power applications in the Energy pillar
	4 - Next Generation of Products	Basic and applied research projects related to FCH stationary heat and power applications
	5 - Hydrogen for Sectorial Integration	All projects addressing hydrogen production, distribution and storage issues
Cross-cutting	6 - Support for Market Uptake	Projects addressing cross-cutting issues

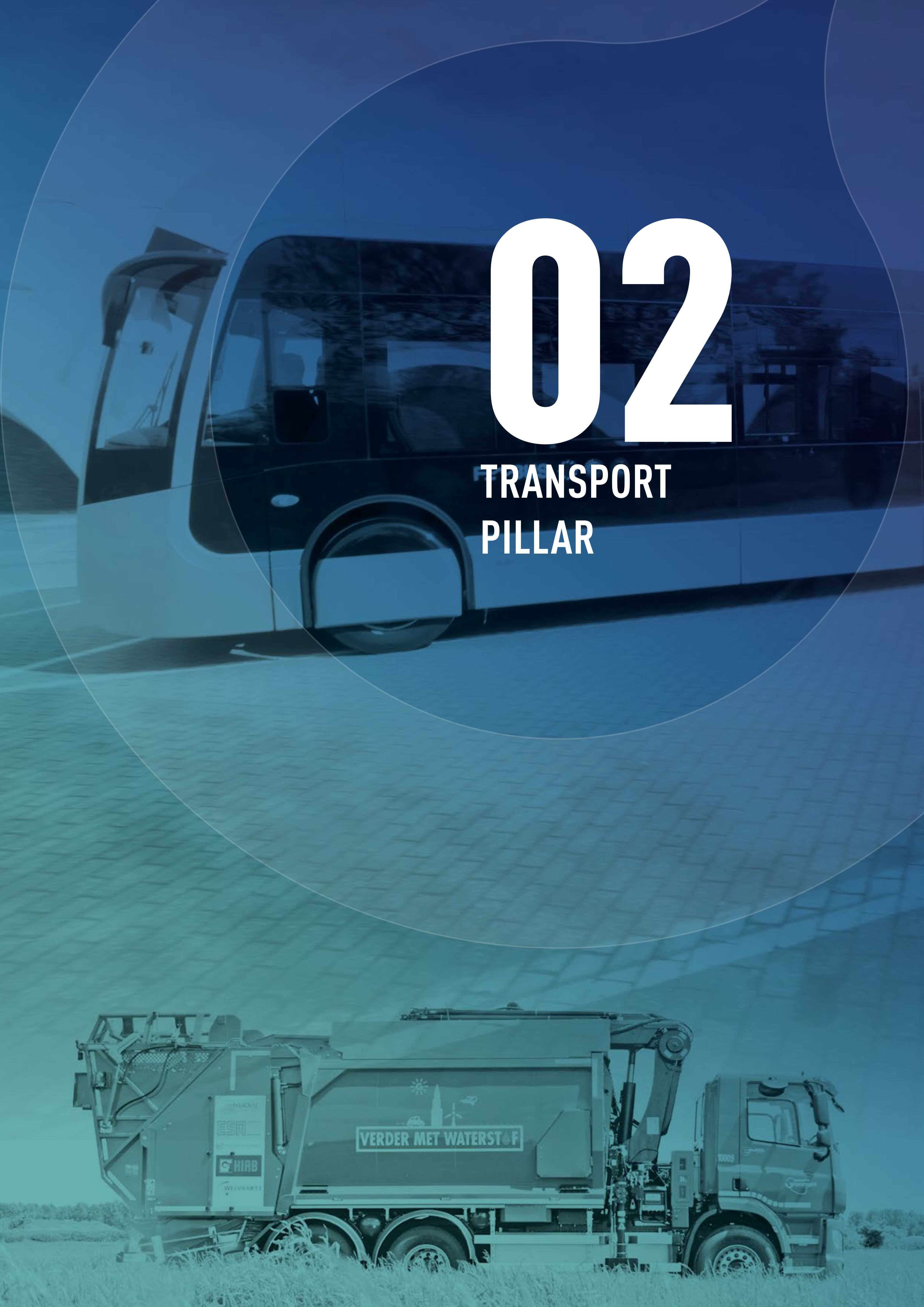
1.4. PRESENTATION OF THE REVIEW FINDINGS

The 2018 review pays particular attention to the added value, effectiveness and techno-economic efficiency of FCH 2 JU activities. Recommendations covering these aspects are formulated to better meet the overall FCH 2 JU programme objectives. This report summarises the assessment of the projects in the panels listed in Table 1. For each panel, because of the wide range in scope, activities and applications of the projects, those covering similar or related topics were attributed to a number of focus areas. The assessment was performed for each focus area. This document provides qualitative observations regarding the major accomplishments of the projects and any difficulties they encountered. The six indicators and their relative weights in the total score are:

- target achievement (23 %)
- project impact (23 %)
- benchmarking against international SoA (23 %)
- exploitation plans and intellectual property (15 %)
- interactions with other projects, sectorial organisations and initiatives (8 %)
- dissemination efforts (8 %)

A weighted sum for each of the six indicators was used to obtain an overall score and a quantitative evaluation. Each review also identifies the strengths of the panel and areas that would benefit from additional focus, and proposes follow-up actions. Some do not differ substantially from those of previous years, but the FCH 2 JU has shown progress in respect to several of them.

12. OJ L 169, 7.6.2014, p. 108-129
13. 'Ongoing' means between project start date and project end date.



02
TRANSPORT PILLAR

2.1. OBJECTIVES

FCH technologies play an important role in reducing emissions, including GHG and local emissions such as SOx, NOx and particulate matter, as well as noise from transport activities. The use of 'green' hydrogen significantly reduces carbon emissions. FCH technologies also contribute to enhanced energy security through higher conversion efficiencies and reduce dependence on fuel imports.

The aim of the activities under the Transport pillar is to accelerate commercialisation of FCH technologies in transport through a programme including demonstration and research projects. The goal is to reduce FC system costs for transport applications, increase their lifetime and reduce the use of critical raw materials such as platinum group metals (PGM).

2.2. BUDGET

To date (project calls from 2008 to 2017), 60 projects in the Transport pillar have received financial contributions from the FCH 2 JU totalling approximately EUR 388 million. The distribution of projects in the two main activity areas is shown in Table 2.

Table 2: FCH 2 JU financial contribution for the two main areas in the Transport pillar

Trials and Deployment of Fuel Cell Application – Transport	**€267.74 million**
Next Generation of Products – Transport	**€120.70 million**
Total	**€388.44 million**

2.3. PANEL 1 – TRIALS AND DEPLOYMENT OF FUEL CELL APPLICATION – TRANSPORT

The focus of the demonstration actions in this panel is to validate technologies, to prove technology readiness, reliability, robustness, fuel efficiency and sustainability. Transportation demonstration actions should also strengthen customer acceptance and ease of use and enable full commercialisation by identifying best business cases. This has historically been performed for road transport activities. However, a study on the use of FCH in the railway environment was commissioned in 2019[14].

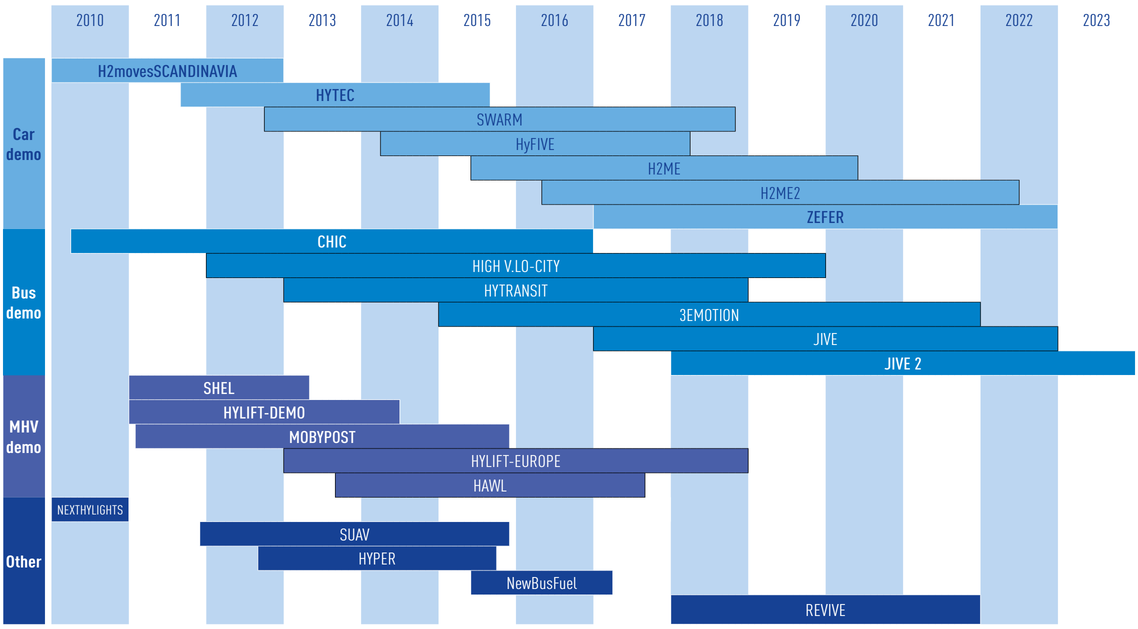
Demonstration projects focus on the following areas:

- Cars and related refuelling infrastructure
- Buses and related refuelling infrastructure
- Material handling vehicles (MHVs)

The timeline for the FCH 2 JU programme portfolio of transport demonstration projects and their distribution across the above three focus areas is shown in Figure 4. The present review covers the 10 projects highlighted in black.

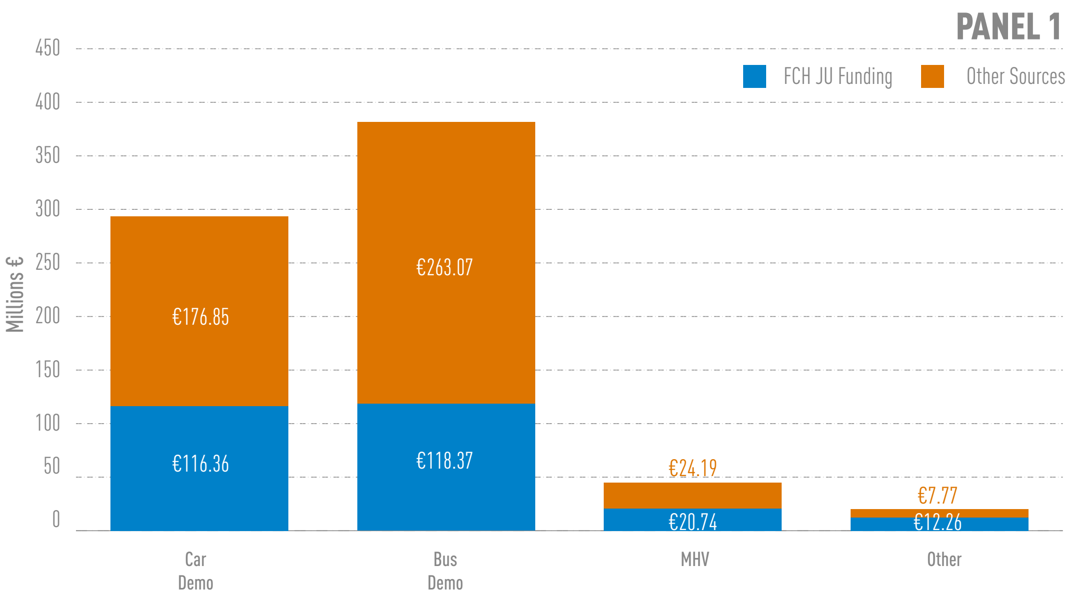
14. https://www.fch.europa.eu/news/fuel-cell-railway-fch-ju-shift2rail-ju-launch-new-study

Figure 4: Dates of Trials and Deployment of Fuel Cell Application in the Transport pillar included in the 2018 review. Projects highlighted have been considered within PRD 2018



Following the calls between 2008 and 2017, the FCH 2 JU supported 23 projects[15] relevant to this panel with a total FCH 2 JU contribution of EUR 267.74 million and a contribution from partners of EUR 471.9 million[16]. The distribution of total budgets is shown in Figure 5.

Figure 5: Funding for Panel 1 (Trials and Deployment of Fuel Cell Application – Transport) from the start of the multi-annual programme up to and including the 2017 calls.

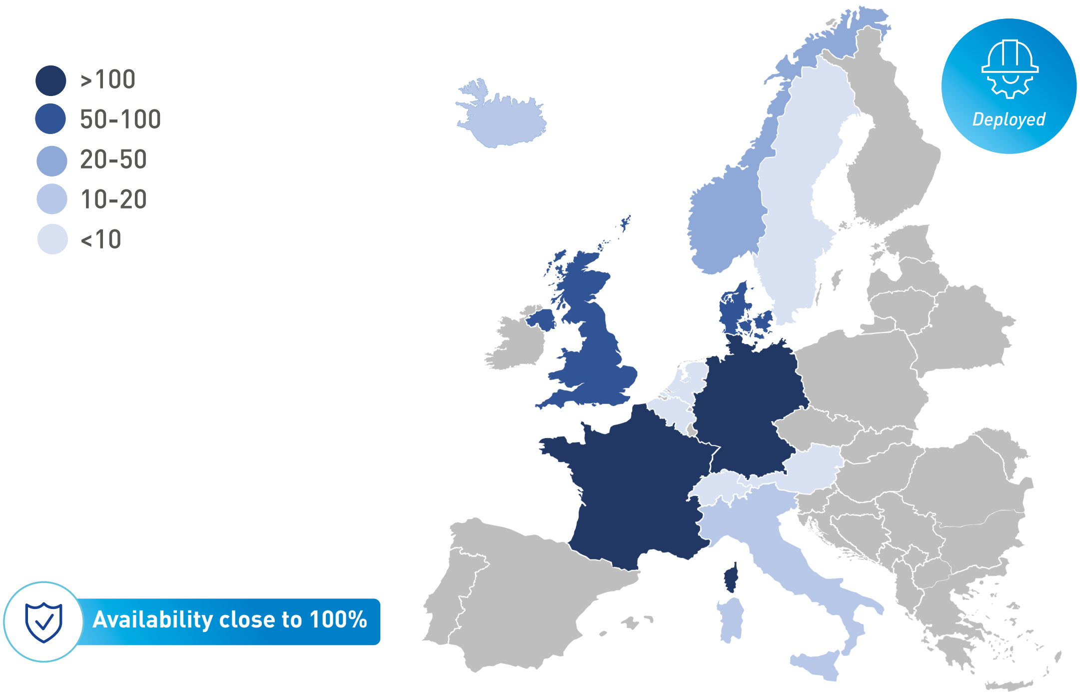


15. Projects associated with APU development have been moved to Panel 2 in this year's report.
16. These figures include the overarching project H2ME2, which draws EUR 8 million (of total EUR 35 million) from the Energy pillar.

The projects in the focus area car demo are HyFIVE, SWARM, H2ME and H2ME2. H2ME and H2ME2 have the same objective – the deployment of hydrogen cars and refuelling infrastructure across Europe. H2ME focuses on car original equipment manufacturers (OEM) whilst H2ME2 focuses on end-users. Additionally, H2ME2 has a strong emphasis on grid-balancing activities using on-site electrolysers. If not explicitly labelled as H2ME or H2ME2, this report refers to both projects as the H2ME initiative.

Different vehicle types are being deployed in nine EU Member States, Norway and Iceland, as shown in Figure 6, ranging from private cars to lightweight small vehicles specifically designed for city and regional transport.

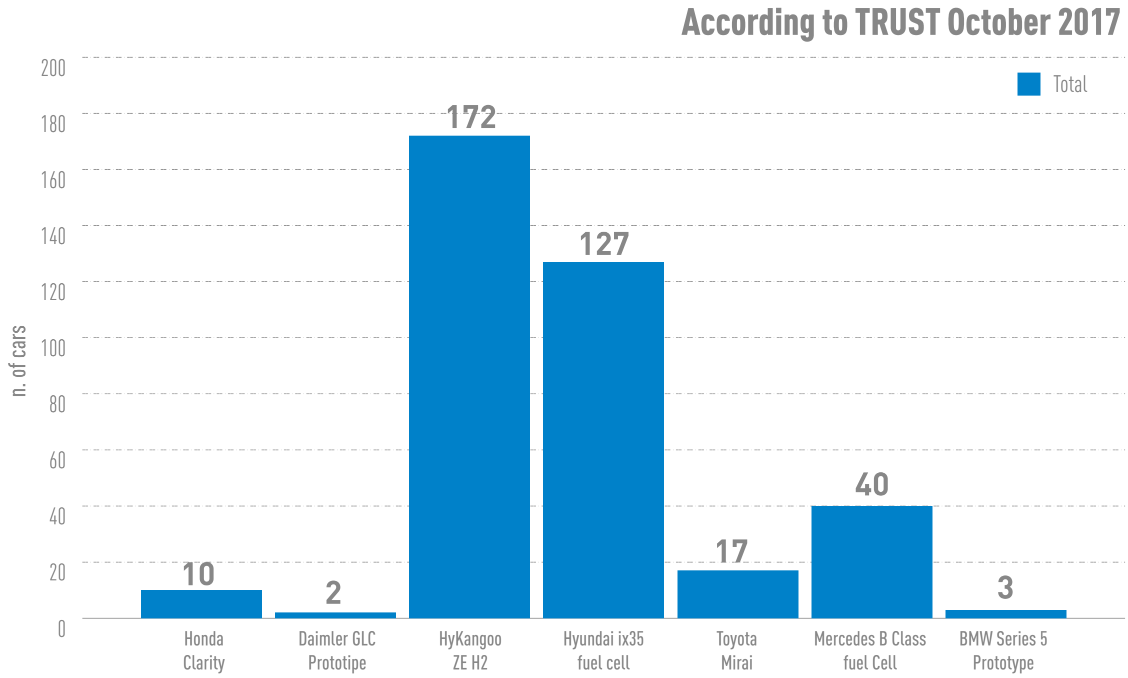
Figure 6: Distribution of FC electric vehicles deployed by FCH 2 JU demonstration projects.



Demo activities involving cars include more than 1 900 light-duty vehicles, of which more than 630 are in operation (the remainder are planned within the running projects). In total, 381 cars reported data in Technology Reporting Using Structured Templates (TRUST) and have accumulated a total of almost 3.8 million km driven.

From May 2016 to May 2017, 100 new vehicles were deployed within H2ME and 113 within H2ME2, while SWARM has prepared new hybridised hydrogen-electric vehicles for trials, including three next-generation Riversimple cars, three Microcab and two prototype e-mobile Elano microcars. HyFIVE continued the demonstration activities of 153 vehicles and was completed in 2018. The distribution of models deployed is presented in Figure 7.

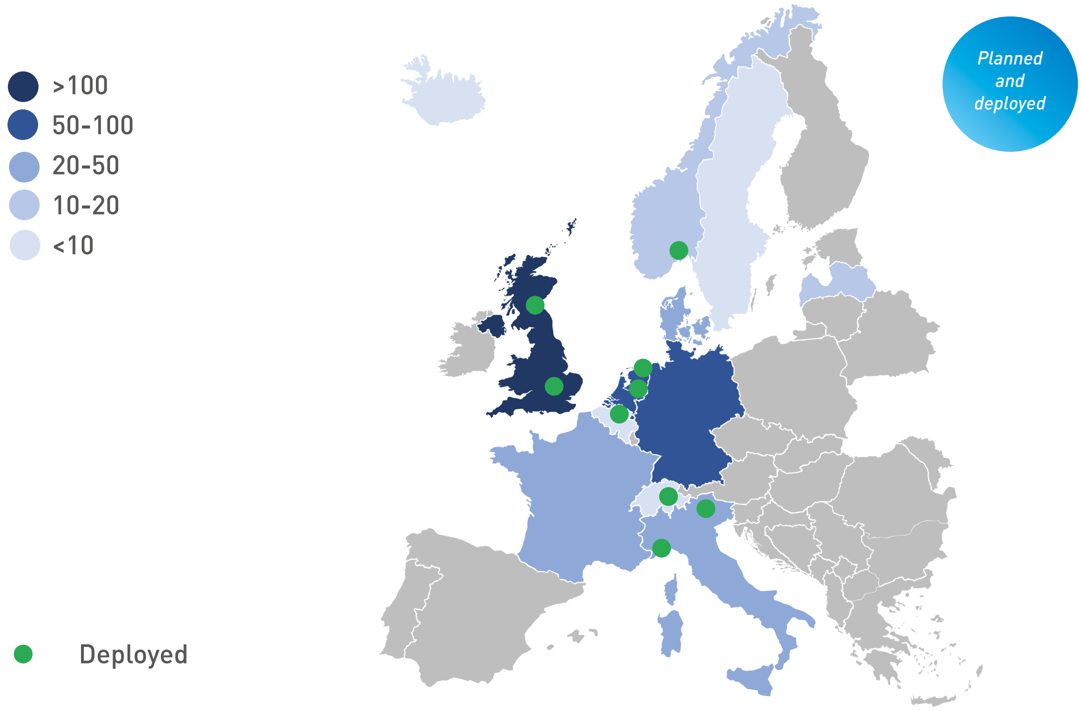
Figure 7: Total number of cars and prototypes operating in 2017 (grouped by model; according to data available in TRUST[17]).



In 2017, at least 1.83 million km were driven and more than 23 200 kg of hydrogen was consumed (average fuel consumption of 1.36 kg per 100 km[18]; this is above the expected consumption for SoA 2017 and MAWP 2020 targets). Average vehicle availability reached 99.3 % in 2017. The expected MAWP 2020 targets for availability (98 %) and FC system durability (5 000 h) have been reached[19]. Car prices are not expected to be significantly impacted by the cost of the FC, due to the current premium nature of FC electric vehicles. If, however, FC vehicles on the market begin to cover more popular car segments, the relative impact of FC on price is expected to be higher. The distribution of planned and deployed hydrogen refuelling stations (HRS) is shown in Figure 8.

17. Daimler GLC and BMW Series S are prototypes.
18. Average fuel consumption was calculated by combining reported driving ranges and declared fuel consumptions. Some projects reported only one of the parameters and were thus excluded from calculations.
19. For projects reporting these data.

Figure 8: Distribution of hydrogen refuelling stations co-funded by FCH 2 JU.



The geographical deployment of HRS is expanding and aims to link early demo sites. In densely populated areas, the concentration of several **HRS** supports the emergence of and allows for the flexible service of taxi fleet or private car-hire systems. The planned total number of HRS under the Transport Demo panel is 99, of which 48 (28 cars, 11 buses, 9 MHVs) are already deployed. Twenty HRS for cars dispense hydrogen at 70 MPa; 11 also have a 35 MPa dispenser. The European HRS availability system (https://h2-map.eu/) is sponsored by the FCH 2 JU and provides information on the live status of each HRS.

Legally, to properly bill the quantities of hydrogen delivered by an HRS, measurements have to be performed with a prescribed accuracy, but metrology is currently a bottleneck. In 2018, the first deliverable of an ad hoc study, 'Proposition of a testing protocol for certification of existing and future HRS – development of a metering protocol for hydrogen refuelling stations' (HRS), was published[20]. The objective of this study is to define, in agreement with European national metrological institutes, a structured approach for enabling the certification of metering systems for HRS in Europe. The test protocol is currently being trialled at several FCH 2 JU HRS. For more details, see section 7.

To date, the FCH 2 JU-backed HRS network for cars covers 11 countries, and in 2017 delivered 46 738 kg[21] of hydrogen in 8 993 refuelling operations. The average HRS availability was 96 %, compared to 95 % in the previous year. Most of these installations meet the MAWP 2020 targets for station capital up-front expenditure (CAPEX) of EUR 1 million-EUR 2.5 million (the range refers to a minimum of 200 kg/day and a maximum of 1 000 kg/day).

However, the hydrogen MAWP 2020 cost targets are not yet being consistently achieved, due largely to electricity price, in the case of hydrogen produced by electrolysis, or distance to the hydrogen production sites. Car demo projects report the price of hydrogen at the pump ranging from EUR 7 to EUR 11.50/kg, with EUR 10/kg an average value, depending on the start date of the project and

20. https://www.fch.europa.eu/publications/proposition-testing-protocol-certification-existing-and-future-hrs

21. This number does not match the 10 200 kg of hydrogen reported above for cars, because some FCH 2 JU-backed HRS are open to the public and not restricted to FCH 2 JU-backed projects.

the hydrogen production method employed. The car demo projects report that 85 % of dispensed hydrogen based on mass was produced using electricity certified as 'green'.

A major asset of recent projects is that increased attention is being paid to demonstrating the benefits of electrolytic hydrogen production at the refuelling station with regards to balancing the electricity grid. The associated revenue generation from providing energy services by aggregated electrolyser-HRS systems at the MW scale may contribute to a future reduction in the cost of hydrogen at the pump.

In the 15 Member States that have chosen hydrogen to meet the requirements of the Directive 2014/94/EU for alternative fuel infrastructure, an HRS network is being created in large urban conurbations and along Trans-European Transport Network (TEN-T) corridors. The FCH 2 JU transport demonstration projects complement, to a certain extent, Member State activities towards the deployment of hydrogen infrastructure. There is a degree of alignment in the actions of the FCH 2 JU and the TEN-T Connecting Europe Facility (CEF). Germany is a positive example; there is full alignment, with one clear strategy on how to effectively exploit HRS presence on its territory, by using complementarity between TENT-T CEF and FCH 2 JU actions. H2ME and H2ME2 projects should be used as forums giving stakeholders input towards strategic planning for European hydrogen mobility.

As one of the main objectives of demonstration projects is increasing awareness among the public authorities and other stakeholders, attention should be paid to the scope, depth and quality of information disseminated. Public platforms providing information pertinent for both the general public and stakeholders should be established. This has been performed for the bus demos but should also be applied to all car demos, covering vehicle and HRS deployment numbers, achievements and lessons learned. This may also facilitate the transfer of information and experience for educational purposes. It would be particularly interesting to create a network of local authorities permitting HRS that through exchange of experiences and lessons learned could facilitate the establishment of new HRS and lay the foundations for a harmonised EU HRS permitting process[22].

Active exploitation of knowledge and experience acquired from the demos through dissemination to and training of first responders warrants additional efforts.

The projects High V.LO City, 3EMotion, HyTransit and JIVE were considered within the 2018 review of **bus** demos. Bus demonstrations financed with FCH 2 JU grants as of 2018 concerned 45 vehicles in 10 cities[23]. These demonstrations are operating with a technology that is now close to commercial reality, at technology readiness level (TRL) 8.

European FCH bus deployment can be considered SoA and appears to have progressed. The success of bus demo projects is supported by the fact that bus operators from new cities have joined the projects. This shows a growing involvement of regions and a steady increase in financial contribution from other sources. However, bus demos are afflicted by delays and issues related to permits (in particular when joint procurements across different regions are involved) and the supply chain of spare parts. Some of these difficulties have been addressed by the FCH 2 JU-funded study Strategies for Joint Procurement of Fuel Cell Buses. The study outlined the requirements of public transport authorities/operators for different stages of maturity that would allow FC bus manufacturers to realise the necessary investment in production lines. In 2017 and 2018, two European bus OEMs entered the FC bus market with new designs: WrightBus with the first double-decker and Safra with 9-12 m midibuses.

22. There are already some positive initiatives in this respect such as those of H2ME (http://www.element-energy.co.uk/wordpress/wp-content/uploads/2015/07/Installing-accessible-HRS-best-practice-guide_July-2015_FV.pdf) and HyLAW (https://www.hylaw.eu/).

23. Excluding five deployed buses that have been discontinued.

Under the 42 bus demonstrations reported in TRUST in 2016 and 2017, a total distance of more than 6 million km has been accumulated since the FCH 2 JU started. From 2016 and 2017 data on FCH 2 JU-backed bus demos, more than 257 500 kg of hydrogen has been consumed. In 2016, the average fuel consumption was reported to be 9 kg hydrogen per 100 km. In 2017, TRUST data reports an average of 10.6 kg hydrogen per 100 km (the values are 9-14.8 kg per 100 km). Fuel consumption varies significantly and is dependent on geographical and seasonal factors. The 2020 MAWP target of an average fuel consumption of 8 kg/100 km has not been achieved. The bus demo projects report that 88 % of dispensed hydrogen was produced using electricity certified as 'green'.

The 2017 SoA values for FC system lifetime, system cost and vehicle cost based on procurement prices have all been met; those for yearly operating costs (EUR 16 000/kW) are still to be achieved. Availability results show remarkable progress compared to 2016, reaching 87.8%, close to the 2020 MAWP targets of 90%. FCH 2 JU backed the installation of HRS in 10 European cities, reaching an average availability of 97% since the start of operations.

Current bus demos have provided further positive evidence on the performance and functionality of FCH buses and refuelling infrastructure, reducing barriers for their commercialisation. Operational experience has been acquired with different bus drivetrains and means of hydrogen production. Availability and cost of FCH buses seem to have profited from the experience of former projects and are improving. JIVE and JIVE2 will increase the number of new FCH buses, adding 291, and will take over fleets from former demo projects.

MHV projects HyLIFT-EUROPE and HAWL have been evaluated as part of the 2018 programme review. Both finished at the end of 2018. These two demo projects managed a fleet of more than 200 MHVs across three sites in 2018. At present, the FCH 2 JU has been the main driving force behind MHV deployment in Europe.

These vehicles are technically mature enough for commercialisation and some European MHV manufacturers are already offering FCH MHVs for the European market. Demo activities accumulated more than 600 000 h of operation with about 260 000 h in 2017 alone. In 2017, 87 300 refuelling operations were performed. The 2020 MAWP targets for mean time between failures (750 h) and availability (98 %) have been achieved and even surpassed. In at least one case, the target of 20 000 h for the lifetime of the MHV has been demonstrated. The on-board hydrogen storage cost (EUR 1 000/kg hydrogen), FC efficiency (50 %) and FC system cost (EUR 1 500/kW at 10 kW scale) targets remain to be proven. The three HRS that have reported information have reached availability levels higher than 98 %.

In some cases, FCH 2 JU initial investments were developed by a consortium through regional funds such as the Interreg project Waterstofregio. Here, former DON QUICHOTE partners have deployed 75 forklifts in a distribution centre belonging to a retail corporation in Belgium. A larger European coordination strategy between funding agents and rethinking the funding strategy for FCH MHV deployment could benefit future deployment.

Project feedback should be analysed and acted upon. Deployment still requires financial support and it seems unlikely that broad commercialisation will be achieved in the near future under current support mechanisms, despite the attainment of technical performance targets and the demonstrated viability of several business cases. Several non-technological factors may explain the difficulties encountered by demo projects in the EU[24]. A support mechanism such as tax credits could be more effective than financing further demo projects.

Based on the demo findings, a number of FC systems have been certified for use in Europe, and satisfactory system performance of FC-based MHVs with hydrogen refuelling has been confirmed

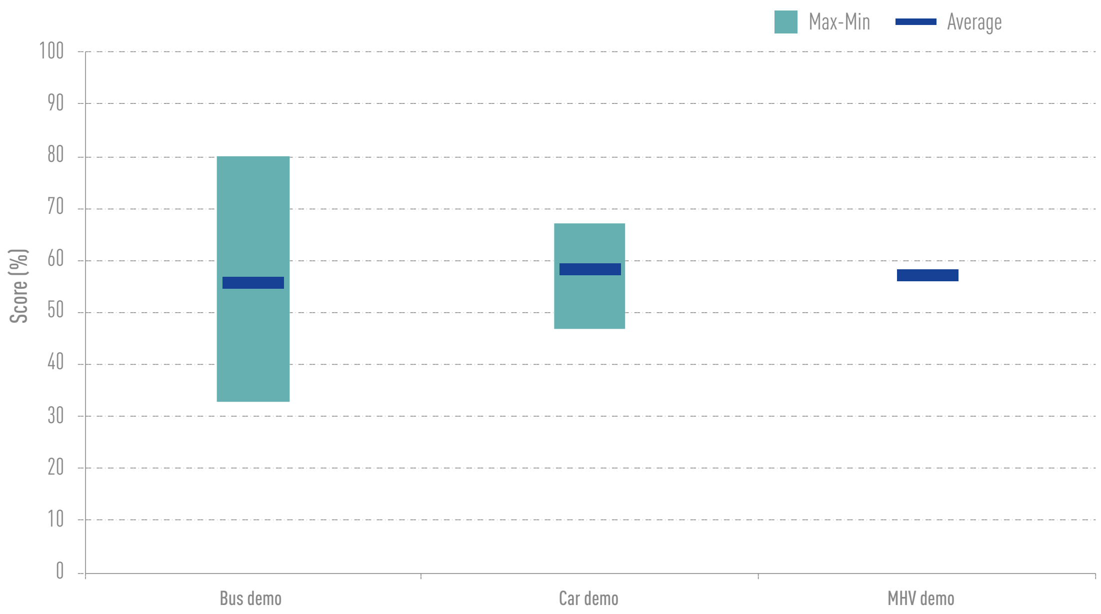
24. See the detailed analysis in the public HAWL deliverable 7.3

for indoor applications. Thanks to the two demos, a national French regulation for hydrogen in warehouse applications has been established, as well as a best practice document for obtaining approval when installing airside HRS in airports.

2.3.1. PANEL 1 – SUMMARY

The overall assessment of Panel 1 projects is shown in Figure 9. The figure shows a wide spread in the performance of bus demo projects, including one very well-performing project and at least one that is clearly lagging behind. For the other focus areas, the spread is much less significant. There are various reasons for differences in project performance, although approval processes (strongly dependent on regional and local administrations), procurement and supply chain issues are critical.

Figure 9: Maximum, minimum and average scores for each focus area of Panel 1. For focus areas with less than three projects, only the average is given.



Strengths

- Partners in demonstration projects show a significant commitment to FCH technology and clear interest in its commercialisation.
- Some projects stand out for their relationships with national or regional programmes.
- Training of bus drivers and repair and maintenance technicians is consistent.
- Often experiences are shared between projects and considered when setting up additional demos. This should be continued and strengthened.

Additional focus needed

- The regional dimension of coach demonstration projects, used for local and intercity passenger transport (as foreseen in HyTRANSIT), should be strengthened.
- Security in the supply of spare parts throughout the project should be ensured.

- The technological challenge is increasingly dependent on control and automation software. Further analysis of software issues causing HRS downtime is advised.
- Assessment of distribution and storage for large hydrogen volumes is necessary.

Follow-up actions[25]

- The Member States that have included hydrogen in their national policy framework should enhance participation in demo projects. Awareness of neighbouring countries that have not considered hydrogen should be a focus for future actions.
- Use the operational experience arising from transport demo projects to update safety evaluations: lift safety-related restrictions where this is justified by evidence.
- Any future MHV demo project should have an established portfolio of customers before kick-off, so that delays are minimised.
- The assessment of the time required to obtain the relevant permit and construct an HRS should become a future performance indicator.
- Lessons from car demos and related documents produced by consortia should be gathered in a single repository and promoted. This should be strengthened for buses.
- The Well to Wheel study by HyFIVE should be the cornerstone of a database of FC electric vehicle emissions and be updated with results of future studies from other demo projects.

2.4. PANEL 2 – NEXT GENERATION OF PRODUCTS – TRANSPORT

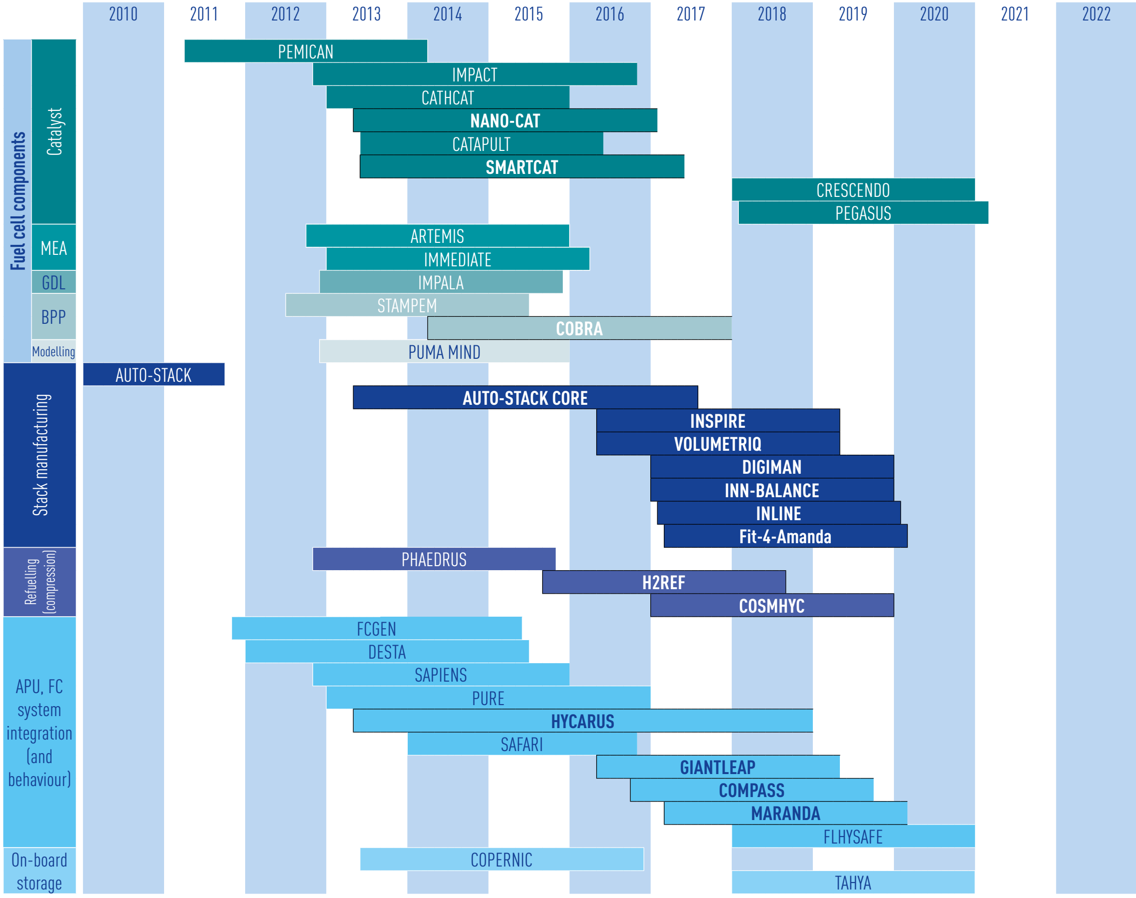
R&I projects focus on delivering better-performing FCs for transport and improved HRS systems, while also lowering costs. The project portfolio of transportation R&I activities covers the following research areas:

- Membrane electrode assemblies (MEA) – activities to develop and improve FC MEAs including gas diffusion layers for transportation.
- Catalysts – development of higher-performance, low-cost catalysts; reduction in catalyst loadings.
- Bipolar plates – development of materials for better performance at reduced cost.
- Design, manufacturing and process development.
- Advanced refuelling – projects to develop more cost-effective and efficient hydrogen refuelling technologies, auxiliary power units (APUs), FC system integration and diagnostics.

The 2018 Review covers 16 projects and their distribution is shown in Figure 10.

25. For follow-up actions addressing findings relevant to 2017 see the Programme Review Report 2017

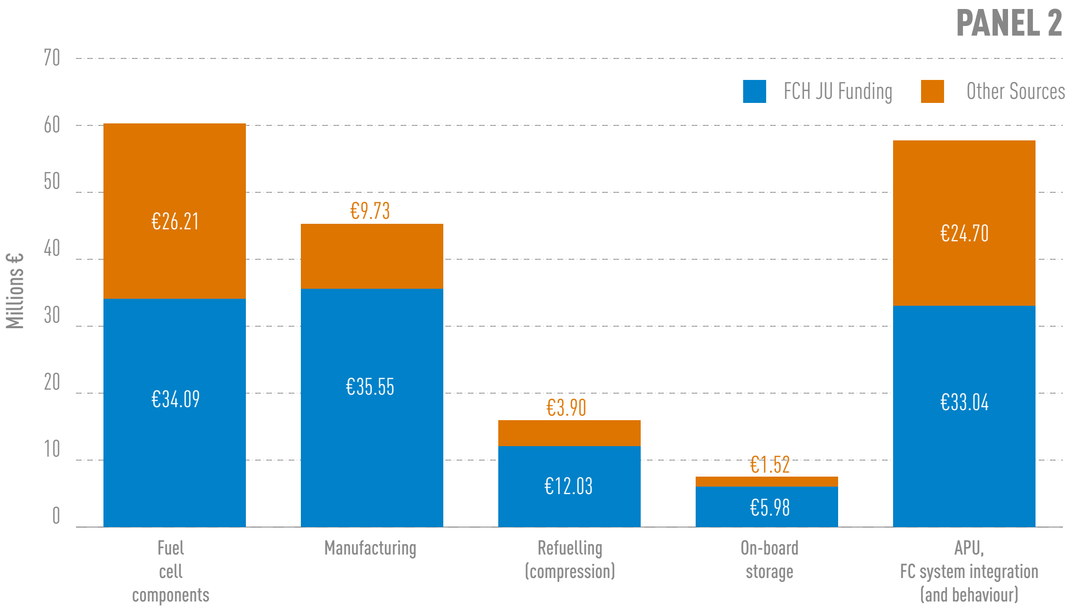
Figure 10: Date ranges of Next Generation of Products projects within the Transport pillar in the 2018 review. Projects highlighted in black are considered for PRD 2018.



From calls between 2008 and 2017, the FCH 2 JU supported 37 projects relevant to this panel[26] with a total FCH 2 JU contribution of EUR 120.7 million and a partner contribution of EUR 66.09 million. Total budget distribution over the five focus areas is shown in Figure 11.

26. Projects associated with APU development have been moved to Panel 2 in this year's report.

Figure 11: Funding for Panel 2 (Next Generation of Products – Transport) from the start of the multi-annual programme up to and including the 2017 calls.



The review for the focus area **FC components: Catalyst and bipolar plates** covers the projects Nano-CAT, SMARTCat and COBRA. Their goals are similar, namely to develop higher-performance materials i.e. MEAs (Nano-CAT), catalysts (SMARTCat) and bipolar plates (COBRA). The main aim is to decrease PGM utilisation (mainly platinum) and demonstrate reduced degradation and increased durability. The reduction in precious metal use has been especially effective for COBRA. Since metallic bipolar plates are coated, usually with gold, choosing less expensive titanium/niobium-based carbide and nitride coatings has led to a significant cost reduction, estimated at about 85 %.

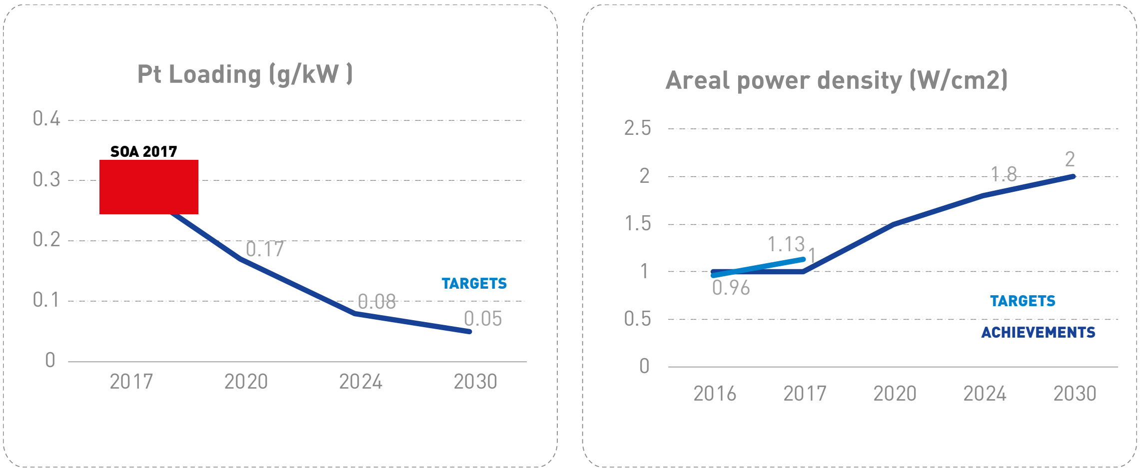
Generally, the three projects have made progress at the individual component level but not all met their targets. The achievements should be assessed under agreed reference conditions, using harmonised testing protocols and test methods. A performance assessment of the developed components under agreed reference conditions against set targets should take place independently from individual project review cycles.

The review for the focus area **manufacturing** covers the projects Auto-Stack Core (finished), DIGIMAN, Fit-4-AMandA, INLINE, INN-BALANCE, INSPIRE and VOLUMETRIQ. These projects aim to deliver mature stack components and production lines able to meet automotive performance specifications in large volume production along with innovative quality control techniques.

Several of these consortia build on experience from earlier projects in the FC components focus area. In particular, Auto-Stack Core, INSPIRE and VOLUMETRIQ established stack hardware platforms for use in automotive applications; however, their results have also been selected as a starting point for other industrial applications (e.g. AutoRe).

The projects included scale-up using realistic automotive cell and stack testing and produced FC stacks (rated capacities of 96 kW (Auto-Stack Core), 120 kW (VOLUMETRIQ), 140 kW (INSPIRE)) meeting almost all the 2017 SoA KPIs from the MAWP. In particular, the best-performing projects achieved an areal power density of 1.13 W/cm2 and a volumetric power density of 4 kW/l. Despite not being the prime objective for projects in the manufacturing portfolio, reductions in PGM loadings have also been reported, and in the last year a combined anode and cathode loading of 0.35 g/kW or less was reported (see Figure 12).

Figure 12: Targets and achievements for platinum loadings and areal power density. These two KPIs can be combined to obtain areal platinum loadings.



The success of these automotive projects also stems from the commitment of the automotive OEMs involved. It also relies on a well-established stepwise approach for R&D cycles in the automotive industry. This is exemplified by Auto-Stack Core. The progressive focus shift from stack definition and optimisation to manufacturing in a sequence of linked projects proved especially effective. This suggests continuing this approach for FCH 2 JU-funded projects in this focus area and extending the method to other focus areas.

DIGIMAN, Fit-4-AMandA, INLINE and INN-BALANCE started in 2017 and appear to be on track but supply of components and delays in obtaining a final design for crucial milestones are hampering progress. If successful, these actions will increase the quality, flexibility and speed of the process and decrease cost, while reducing the environmental impact of manufacturing stacks and components. Quality assurance and quality control activities could be key enablers for market growth and the establishment of an effective manufacturing chain.

The 2018 review for the focus area **refuelling (compression)** covers the projects COSMHYC and H2REF, both dedicated to advancing the technology for hydrogen compression at HRS. The two projects focused on building and testing novel prototype compressors. COSMHYC is developing a hybrid system combining a metal hydride compressor and a mechanical diaphragm compressor, while H2REF is developing a hydraulics-based compression and buffering system. Both have high potential to improve the techno-economics for compression and hence for HRS, for which the compressor is one of the critical components and main sources of station downtime. Moreover, the compressor developed by COSMHYC could have potential for use in decentralised hydrogen storage facilities.

Interaction with projects that demonstrate HRS is a good practice, and COSMHYC is benefiting from the experience gained in H2ME to improve its prototype design. The operation of the developed prototype compressors should demonstrate reliability. The COSMHYC consortium is pursuing design technical specifications for energy consumption of less than 6 kWh/kg H2.

The focus area **APU, FC system integration (and behaviour)** covers the projects HYCARUS, MARANDA, COMPASS and GiantLeap (n.b. COMPASS has been terminated and will not be discussed). The commitment by industrial players in the aviation and maritime sectors in HYCARUS and MARANDA is a good sign that FCH technologies could play a role in power generation for these modes of transport.

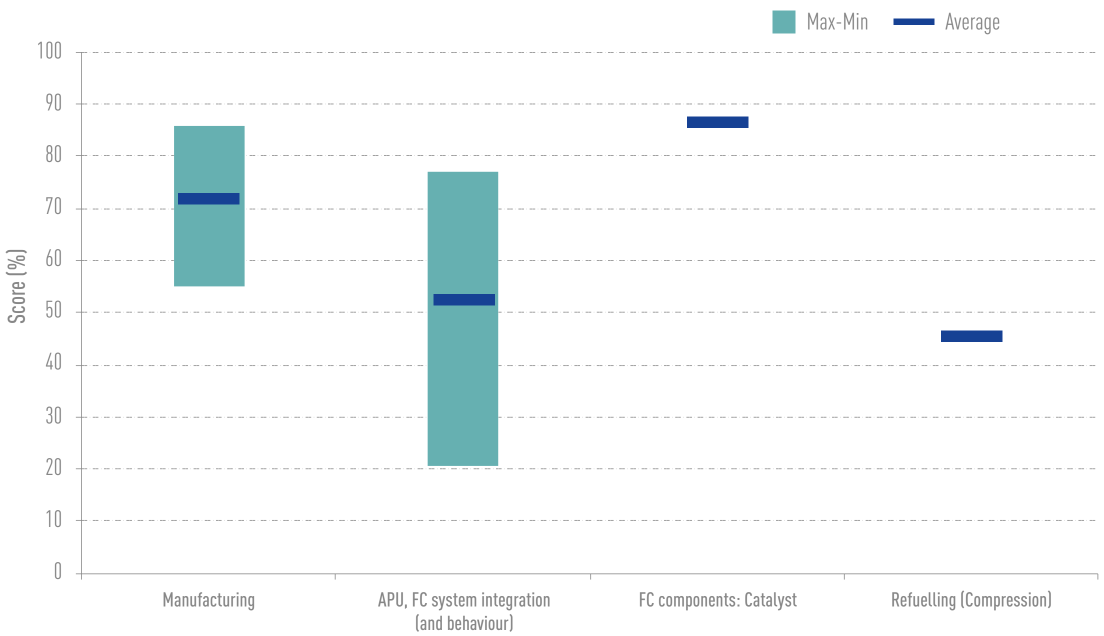
MARANDA is developing components for FC systems in maritime environments of high humidity and salinity. Safety is a major concern; the project identified gaps in regulations, codes and standards (RCS), which could act as a bottleneck for the implementation of hydrogen technologies in the maritime sector.

Aviation auxiliary power unit (APU) development performed by HYCARUS has achieved a final prototype, despite some technical shortcomings with respect to the project's initial targets. On-board diagnostics such as those developed by GiantLeap in particular will be an important aspect if FC technologies are to be successful in the transport sector.

2.4.1. PANEL 2 – SUMMARY

This section presents assessment results of projects based on the scores for the review categories with the overall assessment shown in Figure 13. The manufacturing focus area is composed of relatively recent projects offering promising opportunities. Scores in the APU focus area have a significant spread, highlighting the varying quality of results. Actions focused on the development of catalysts have been quite successful.

Figure 13: Maximum, minimum and average scores for focus areas of Panel 2. For focus areas with fewer than three projects, only the average is given.



Strengths

- A number of consortia combine an effective balance of required competences, knowledge, skills and infrastructures among project partners.
- Projects constructively contributed to ongoing efforts on harmonised testing protocols and procedures. They are committed to applying them in testing.

Additional focus needed

- Future maritime, aviation and rail transport FCH 2 JU actions could also consider the development of solid oxide fuel cells (SOFC) and high-temperature (HT) proton exchange membrane fuel cells (PEMFC), significant reduction of PGM in PEMFC catalysts, to make cost-effective and affordable automotive PEMFC a feasible alternative transport option for mass adoption worldwide.

- The data generated should be as comprehensive as possible, publicly available and accessible as an input for life-cycle assessment (LCA) and programme monitoring.
- Use system modelling analysis to extrapolate from existing R&I activities to new transport modes.

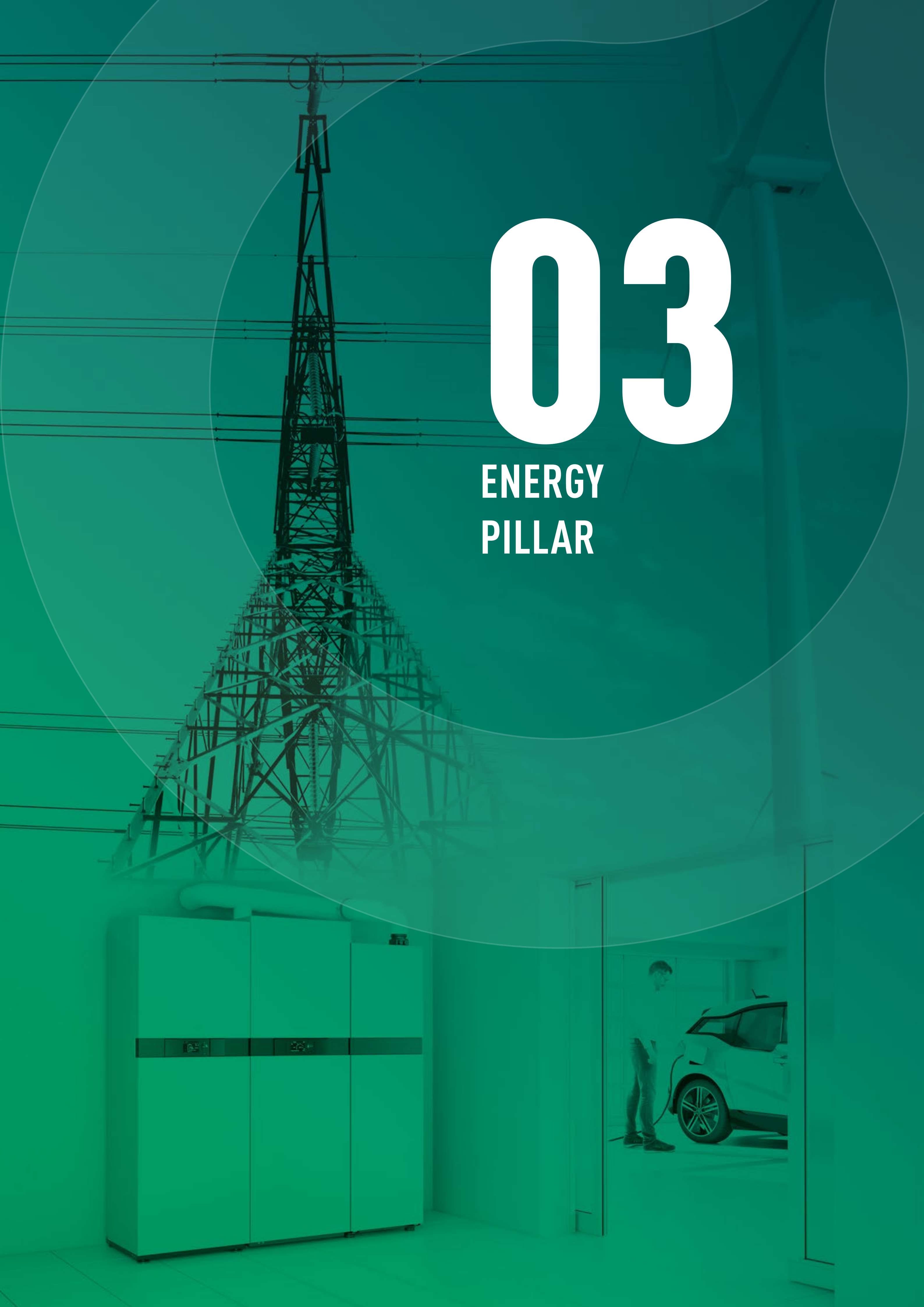
Follow-up actions[27]

- Projects could disseminate results outside the hydrogen technologies community.
- Synergies between manufacturing projects and other research projects should be exploited wherever possible.
- Explore establishing common product design for modular FCs, flexible enough to include all modes of surface transport and open to all supply chain actors.
- Consider the expected evolution of heavy-duty propulsion.
- Field test activities largely depend on approval from different authorities, which is not always straightforward.
- Survey thoroughly with expertise from CleanSky[28] the prospect of using FCs in aeronautics, considering requirements in the heavily regulated aviation sector.

27. For follow-up actions addressing findings relevant to 2017 see the Programme Review Report 2017
28. http://www.cleansky.eu/

03

ENERGY PILLAR



3.1. OBJECTIVES

The objective of the Energy pillar is to accelerate the commercialisation of FCH technologies for stationary FCs and for the production of green or low-carbon hydrogen as an energy vector in Europe. Activities in this pillar aim to increase the efficiency and durability of FCs and electrolysers for sustainable power and hydrogen production, while reducing costs. The FCH JU programme supports activities in three main areas:

- Stationary FC (power and heat) demonstrations and PoC activities to prove technology capability and readiness.
- Stationary FC (power and heat) R&I for improving performance, durability and cost.
- Hydrogen production pathways from renewable sources; handling, distribution and storage technologies enabling hydrogen to become a major energy vector for Europe.

3.2. BUDGET

To date (project calls from 2008 to 2017), 130 projects have received financial contributions from the FCH 2 JU totalling more than EUR 408 million across several types of technologies. The distribution of projects is shown in Table 3.

Table 3: FCH 2 JU financial contribution for three main activity areas in the Energy pillar

Trials and Deployment of Fuel Cell Applications	**€157.03 million**
Next Generation of Products	**€105.84 million**
Hydrogen for Sectorial Integration	**€145.28 million**
Total	€408.15 million

3.3. PANEL 3 – TRIALS AND DEPLOYMENT OF FUEL CELL APPLICATION – ENERGY

Stationary FC systems for power and combined heat and power (CHP) generation for distributed and mid-sized installations and centralised (large-scale installations) and for provision of back-up power need sustained innovation to reduce investment and operational costs while improving durability. Focus areas for this review are defined as:

- Demo projects aimed at establishing operational performance capabilities, proving readiness to potential end users and developing knowledge in installing, operating and maintaining units in real applications. These fall into three areas: micro (μ-CHP) for domestic and small commercial buildings, mid-size installations for larger commercial buildings and service sectors, and large installations, mainly for industry.
- PoC projects to test and validate whole-system concepts, usually around TRL 4-6, for all types of applications. There are also projects aimed at improving performance, reliability, durability and cost of balance of plant (BoP) components for the FC systems, alongside control sub-systems. These are clustered into two focus areas around off-grid/back-up applications or mid-size FC for a variety of applications.

The 2018 Review covers 13 projects and their distribution is shown in Figure 14.

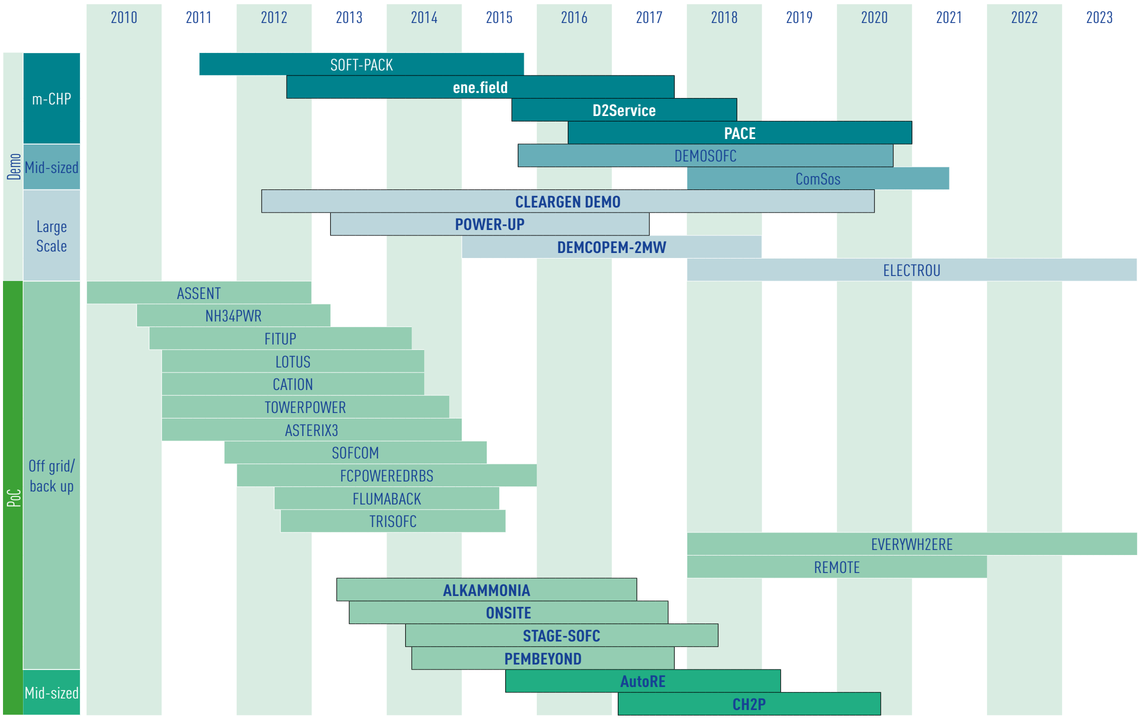


Figure 14: Date ranges of Trials and Deployment of Fuel Cell Application projects in the Energy pillar. Projects in bold are included in PRD 2018.

Following the calls between 2008 and 2017, the FCH 2 JU supported 29 projects in this panel with a total FCH 2 JU contribution of EUR 157.03 million and a partner contribution of EUR 163.1 million. Figure 15 shows historic budget distribution over the five focus areas.

Figure 16 shows the cumulative project contributions to various FC technologies from 2010. On average, funding has been more or less equally split between SOFC and PEMFC, with slightly more for the latter. From 2013, other FC technologies have also been funded.

Figure 15: Funding for Panel 3 (Trials and Deployment of Fuel Cell Application – Energy) from the start of the multi-annual programme up to and including the 2017 calls.

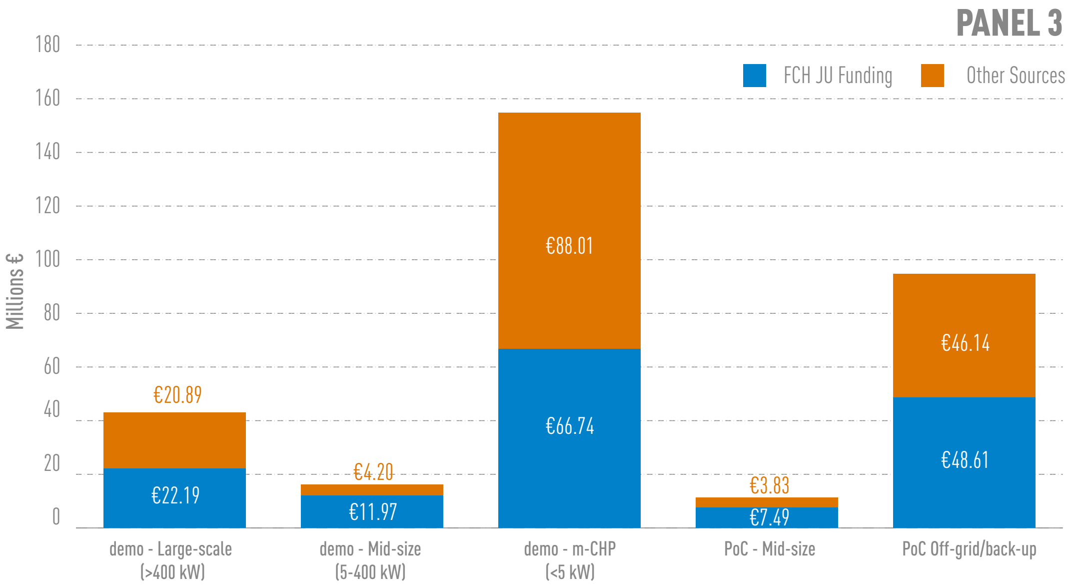
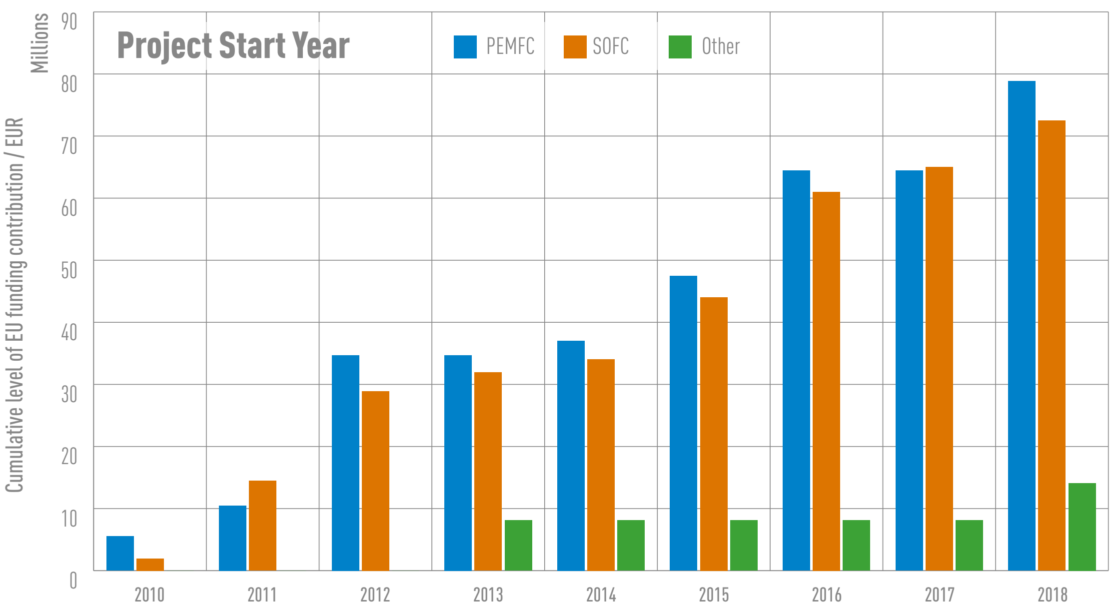


Figure 16: Cumulative level of the EU funding contribution for Panel 3 projects: funding shown per FC technology used.

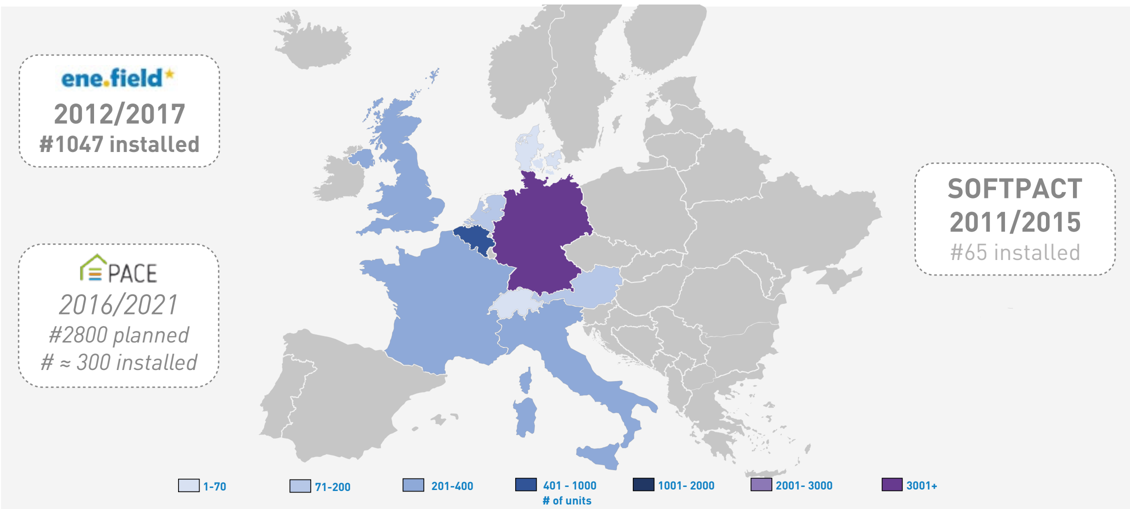


FCs have great potential for providing heat and power in domestic and small commercial buildings due to their high total and electrical efficiencies and their ability to run on conventional heating fuels. Technology leaders are approaching wide commercialisation following extensive field trials. However, with several thousand units of installed **FC μ-CHP systems** (Figure 17), Europe lags behind Japan, which has deployed more than 260 000 units. This is the subject of the focus area μ-CHP demo (< 5 kWe).

The project ene.field has installed 1 047 (604 SOFC, 443 PEM)[29] units from 10 suppliers in several European countries. PACE, which builds on ene.field, plans to move towards mass-market commercialisation with 2 800 FC μ-CHP units expected to be deployed by the end of the project and 10 000 installations a year after 2022. It is Europe's largest deployment of FC μ-CHP and has allowed manufacturers to reduce costs and build markets. Nevertheless, higher deployment volumes are required to further drive down FC and installation costs.

PACE aims to reach TRL 9 while reducing the price of new units by more than 30 %, and extending stack lifetime to over 10 years. It also plans to demonstrate the potential benefits to the electricity grid when many μ-CHP units are combined in a virtual power plant.

Figure 17: Deployed and planned FC μ-CHP installations across the EU.

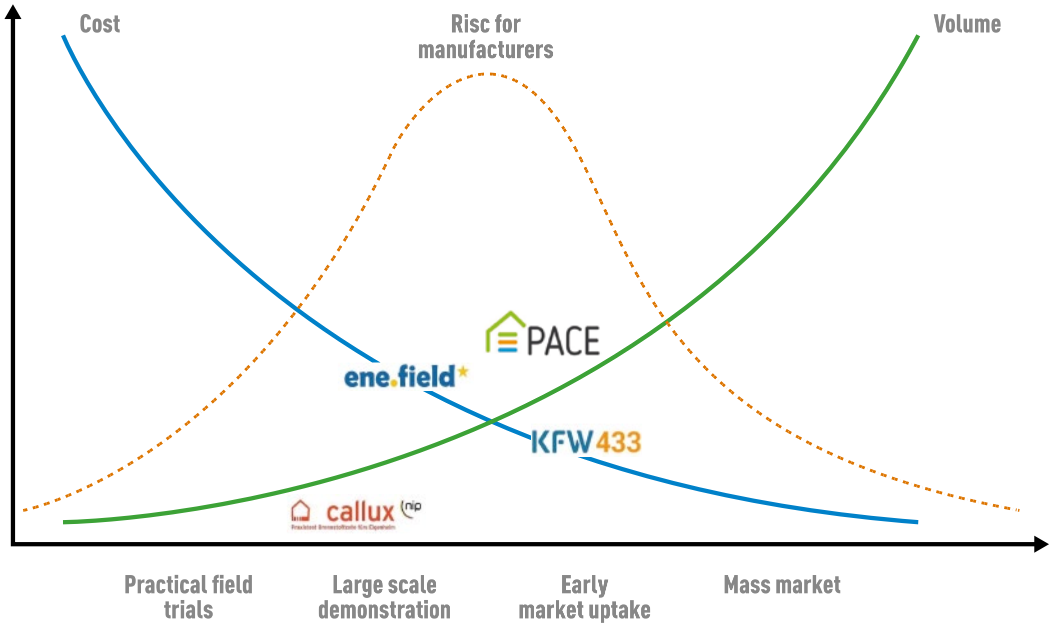


Reported average availability is below 97 %, though some units are reporting higher values. Reported lifetime, durability of key components (stacks) and efficiency (both electrical and thermal) are on average in line with the expected SoA references for 2017, and in some cases for MAWP 2020 targets. This data explains why current actions focus on developing the next generation of units and increasing the manufacturing and deployment volumes as a means to reduce costs (see Figure 18). During the transition from technological development to market phase, it is necessary to test different business models and to identify the best possible financing and lease models for providing energy services.

The D2Service project aims to improve serviceability of FC μ-CHP and back-up power systems by optimising design, installation and maintenance procedures for both SOFC- and PEMFC-based units. The project identified and prioritised actions aimed at increasing durability and simplifying the replacement procedure of components during maintenance.

29. Figures based on Q1 2019 data

Figure 18: Technology readiness and market uptake for μ-CHP systems in the EU.



Despite installing a significant number of μ-CHP systems, the market might still not be ready for full commercial uptake and the technology may require further targeted support. This may be due to high CAPEX of the systems requiring incentives for deployment, or regulatory issues. In Europe, deployment possibilities are expected to increase with the progressive lowering of μ-CHP system costs, driven down by a market volume increase. Reduced costs and higher market penetration should trigger a progressive reduction in the need for subsidies to aid deployment and stabilise demand.

Within the focus area **mid-size demo** (5-400 kWe), the DEMOSOFC project aims to show the advantages of a commercial-size SOFC-based CHP system in an industrial environment. The planned 175 kWe system is being installed in a waste water treatment plant in Italy and is expected to supply approximately 30 % of the site's electrical consumption and almost 100 % of the thermal requirement. By the end of 2017, the first of three 60 kWe SOFC modules was installed[30], and 2 500 h of operation were completed, confirming a high electrical efficiency of 50-55 % lower heating value (LHV), meeting the efficiency SoA figures for 2017. Lessons learned from this project have informed the design of the next generation of units developed under the R&I project INNOSOFC.

Under the focus area **large-scale FC installation** (> 400 kWe), the CLEARgen Demo project targets the field demonstration of a 1 MWe PEMFC system, based on development and optimisation of an existing PEMFC system. The selected demo site on Martinique is being prepared to exploit by-product hydrogen from a refinery plant.

DEMCOPEM-2MW aims to demonstrate a CHP PEM FC power plant (2 MWe and 1.5 MWth[31]) integrated into a chlor-alkali production plant. It pays special attention to the lifetime of the FCs and to lowering manufacturing costs in order to reduce the integrated plant's maintenance costs. China, which houses 50 % of the world's chlor-alkali production, has been selected as a demonstration site. The PEM system has been installed and has been working for 11 240 h, with an electric efficiency of 55 % LHV. The plant produced more than 13 GWh of electricity and provided

30. At the time of publishing, the second module is expected to have been installed.

31. Though conceptually foreseen, there is no plan to integrate the heat in the industrial system.

more than 7 GWh of thermal energy at ~65 °C. Plant average availability reached 95 % by the end of 2017. The project claims excellent flexibility in terms of part-load, standby operation and on-off control for plant operation. The capital and operating costs related to a possible roll-out phase are estimated at EUR 3 200/kW; if confirmed, this would be in line with the expected MAWP targets for 2020.

In POWER-UP, a plant of just above 200 kWel was realised and operated in an industrial environment, with the electricity exported to the local medium-voltage grid. The introduction of automation and modern manufacturing techniques enabled the scale-up of FC production while maintaining high quality, reproducibility and performance. The project has delivered the first large-scale alkaline fuel plant in the world in an industrial setting. Positive experience was acquired regarding stack and BoP, supply chain management and manufacturing. A number of patents have been generated.

Some projects under this focus area have reported lifetimes of 15 years, in line with SoA figures for 2017. Efficiency targets have been achieved and reported CAPEX values are in line with SoA figures for 2017. Performance in terms of FC reliability is still to be evaluated. Despite technical shortcomings, the potential impact of these projects is deemed high.

The focus area **PoC – off-grid/back-up** applications gathers projects focused on developing solutions for off-grid applications, targeting both back-up power and CHP.

The ALKAMMONIA project (finished) aimed to develop a prototype of a small-scale power system for remote applications. It integrates two main components: a fuel delivery system producing hydrogen from ammonia and an alkaline FC system. The subsystems were tested and integrated into a prototype. The project experienced delays.

The objective of ONSITE (finished) was to develop and operate a PoC SOFC/sodium-nickel-chloride battery hybrid system generating 10 kW of power. Together, the thermally integrated SOFC and the battery provided power following the varying demand of a medium-size telecom station. Waste heat was used for both heating and cooling.

PEMBeyond (finished) aimed to develop a bioethanol-fuelled PEMFC-based system for back-up and off-grid applications. The system test after commissioning displayed fast degradation due to sulphur contamination in the fuel processor, but component tests were successful and hydrogen produced from the bioethanol was shown to function well with the FC system.

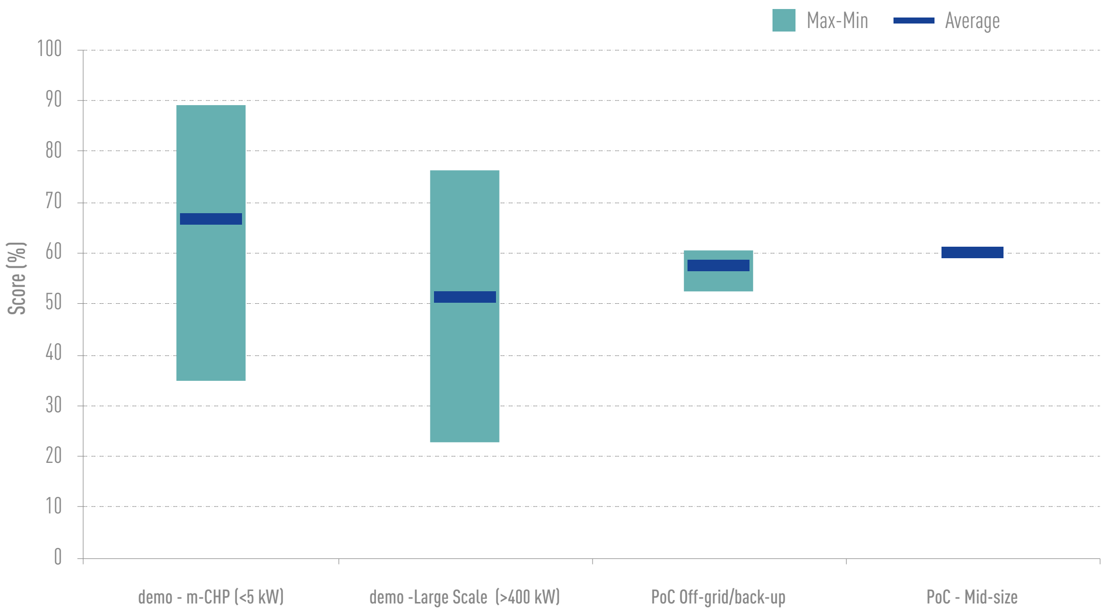
The aim of STAGE-SOFC (finished) was to develop a 5 kWel PoC SOFC system prototype for small-scale CHP and off-grid applications. It used catalytic partial oxidation with the high efficiencies of steam reforming in two adiabatically operated stages, with a staged cathode air supply allowing it to operate without a costly heat exchanger. The first prototype met targets for electrical power (> 5 kW AC) and electrical efficiency (> 45 %) without laborious water handling. The final PoC system testing was not concluded as planned.

Within the focus area **PoC of mid-size CHP**, the project AUTORE (closed) targeted the PoC for an automotive derivative FC system (50-100 kWel) for CHP in commercial and industrial buildings. Component testing is complete and the field test site has been partially commissioned. CH2P focuses on flexible co-generation of heat, power and hydrogen for distributed production in HRS. High conversion efficiency (up to 75 %, based on the energy content of the input gas and of the produced hydrogen, with the output power) and a low cost for hydrogen (< EUR 4.5/kg) are expected. The project will pilot test a system in a real-world scenario with a full capacity of 100 kg/day and 125 kW.

3.3.1. PANEL 3 – SUMMARY

This section presents assessment of projects in the panel focus areas based on the scores for review categories with the overall assessment shown in Figure 19. There is a large difference between the performance of individual µ-CHP demo projects. A similar situation is seen for industrial-size demos, but with a lower average performance. For the PoC off-grid/back-up projects, the spread is very small with an average between that of the first two categories. The last focus area was represented by only two projects, hence only the average is provided.

Figure 19: Maximum, minimum and average scores for relevant focus area of Panel 3. For focus areas with fewer than three projects, only the average is given.



Strengths

For µ-CHP applications

- The average reported lifetime has significantly increased since the last review (2017), approaching the MAWP 2020 target.
- Capital costs have decreased and cost reductions are now expected to drive more significant market penetration for µ-CHP applications.
- Established EU heating companies include FCs in their product portfolio.
- European leadership on solid oxide FC µ-CHP is triggering knowledge transfer for solid oxide electrolyser co-generation SOFC technology development.

For mid-size applications

- The MAWP KPIs 2020 for electrical and thermal efficiencies have been met. Some other KPIs, e.g. durability, are improving.
- Positive synergies between the two markets of automotive FC and CHP generation for stationary applications have been exploited.

For large-scale applications

- Deployment potential in product markets outside Europe has been demonstrated.
- Experience gained in the demo projects of large-scale FCs for stationary applications has the potential to support emerging FC applications for the maritime sector.

Additional focus needed

- Expand the duration of validation testing.
- Investigate factors defining technology deployment outside the EU to increase volumes and establish sustainable business cases.
- Address realistic challenging operation conditions for SOFC in real power scenarios.
- Continuous system and component development is needed to reduce CAPEX and running costs in order to achieve viable European business cases. Another focus for technical development should be increasing durability and availability.
- Explore spin-offs from projects on industrial FC applications in power-to-gas solutions.
- Attention should be given to methods for eliminating contaminants or increasing stack resistance, while bearing in mind the need for cost-effective BoP subsystems.

Follow-up actions[32]

- Activities in this respect should be strengthened and continued.
- Exploit the data from projects, including after their completion.
- For projects dealing with demo activities, exploitation plans need improvement regardless of the technology considered (PEMFC or SOFC). Market penetration for both HT and low temperature (LT) FC solutions should be considered a priority, and barriers to circulation of information should be removed wherever possible.
- Eastern Europe should be considered for future projects.
- Identify and map geographical areas and industrial applications of highest potential benefit for FC power generation or CHP system use.

3.4. PANEL 4 – NEXT GENERATION OF PRODUCTS – ENERGY

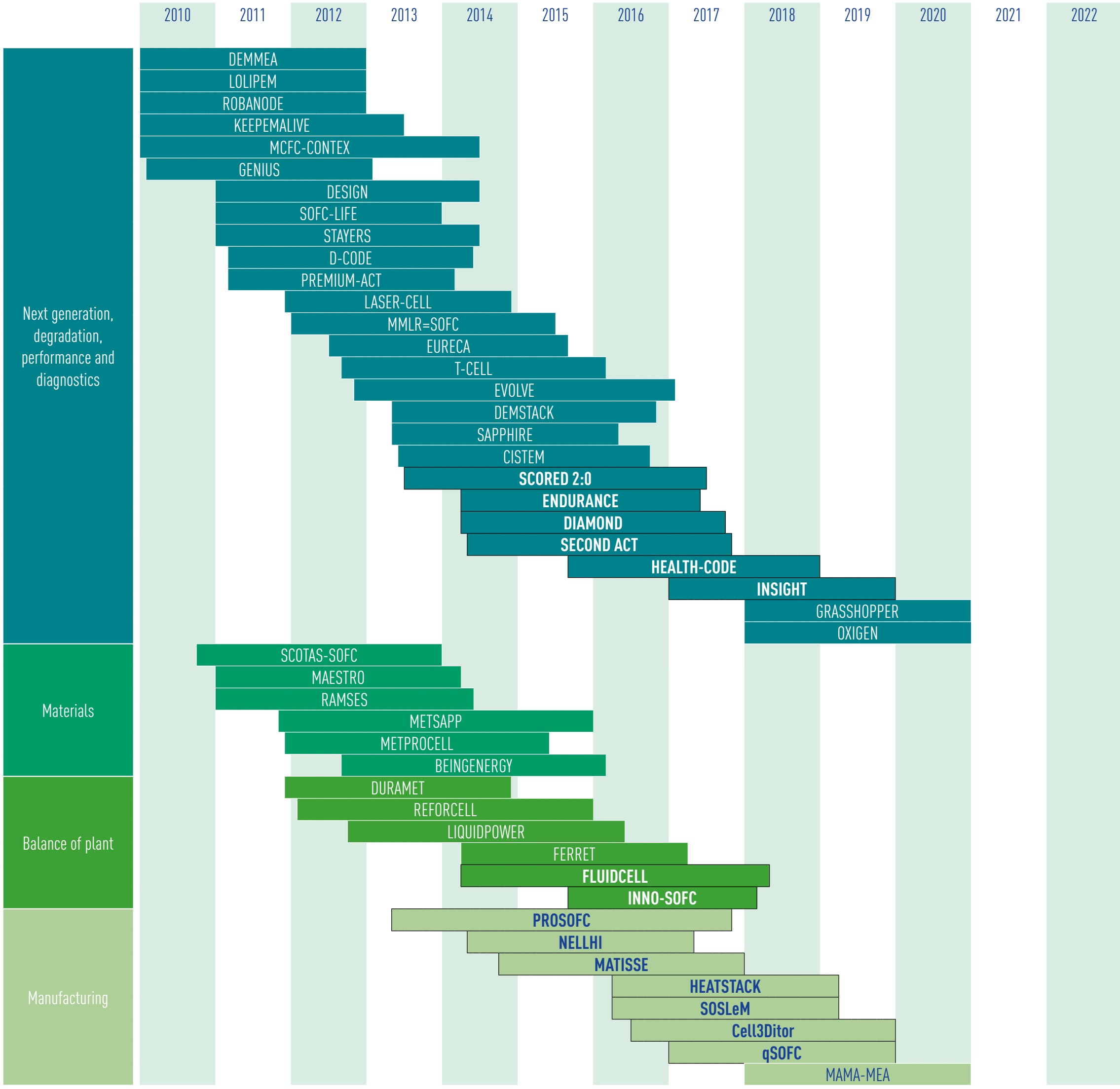
The projects included in the research portfolio for energy stationary applications were grouped into three focus areas:

- Next generation, degradation, performance and diagnostics, with six projects
- Manufacturing, with seven projects
- Balance of plant, with two projects

Of the 15 projects under review, 10 focus on SOFC. The FCH 2 JU programme portfolio of research projects on stationary FCs is shown in Figure 20. All projects in the Materials focus area were completed before this review.

32. For follow-up actions addressing findings relevant to 2017 see the Programme Review Report 2017

Figure 20: Date ranges of Next Generation of Products projects in the Energy pillar. Projects in bold are included in PRD 2018.



Following the calls between 2008 and 2017, the FCH 2 JU supported 47 projects relevant to this panel with a total FCH 2 JU contribution of EUR 105.84 million and a contribution from partners of EUR 76.7 million. The distribution of total budgets over the four focus areas is shown in Figure 21. Figure 22 shows the cumulative funding contribution for different technologies from 2010. It can be seen that, prior to 2014, funding for SOFC was slightly higher than for PEMFC, but markedly surpassed PEMFC funding after 2016.

Figure 21: Funding for Panel 4 (Next Generation of Products – Energy) from the start of the multi-annual programme up to and including the 2017 calls.

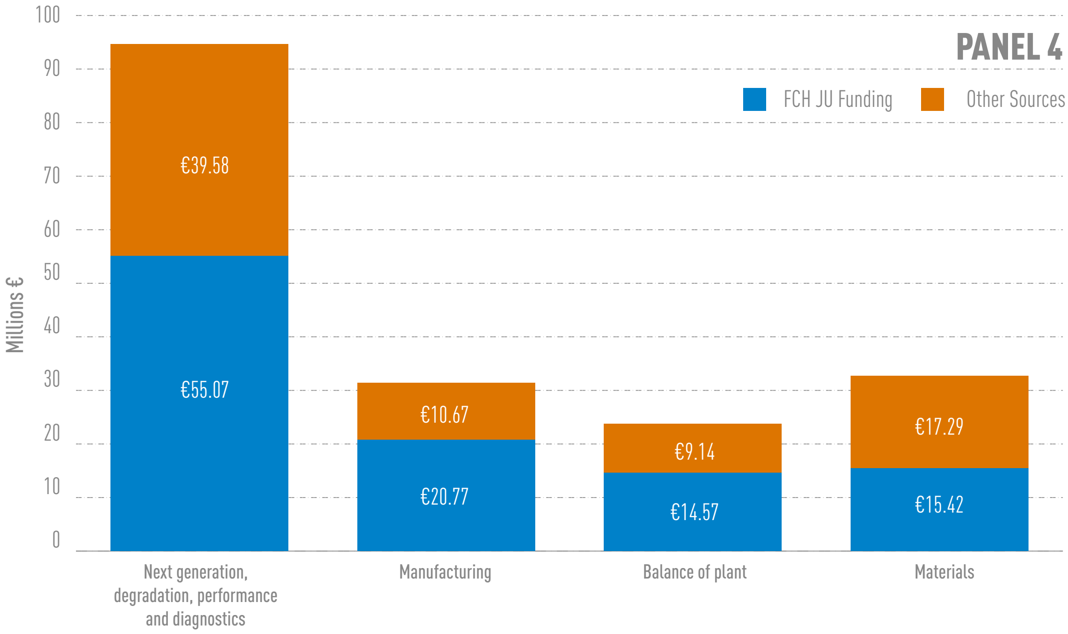
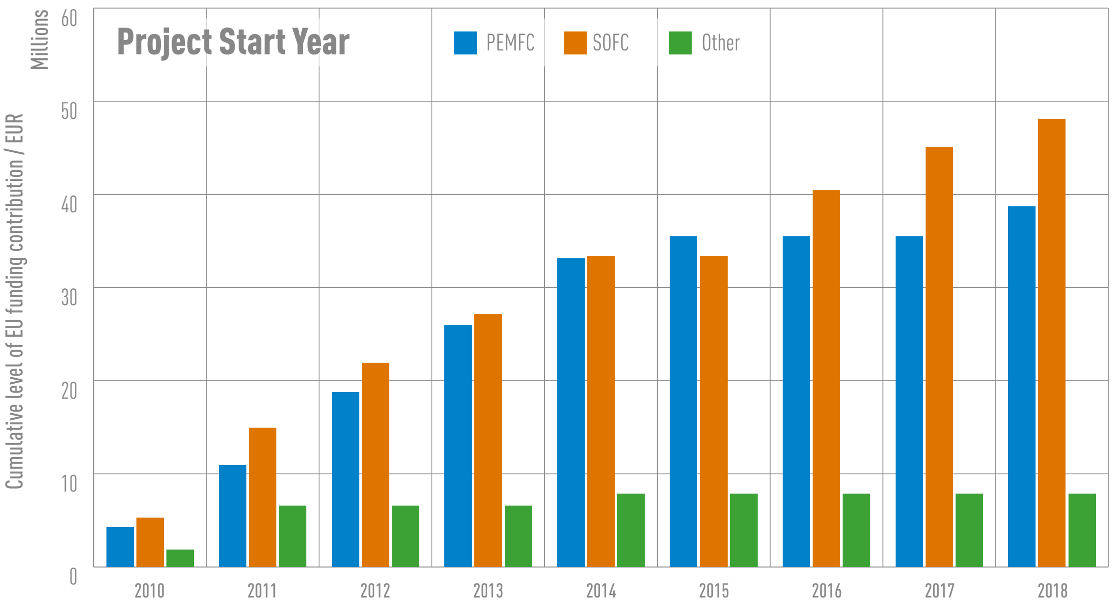


Figure 22: Cumulative EU funding contribution for Panel 4 projects per FC technology used.



Key achievements in the focus area **next generation, degradation, performance and diagnostics** include an enhanced understanding of degradation and the development of mitigation measures for improved sealants, coatings and textured electrodes. Mature embedded monitoring tools and developed accelerated stress testing protocols will help increase the life of both PEMFC and SOFC technologies. It would also benefit other demonstration projects to facilitate the wider use of these mature monitoring and diagnostic tools. Their application for transport systems should also be investigated. In the long term, use of these tools should reveal with certainty the major sources of and reasons for lack of system availability and component failure attributable to stack or BoP components.

Significant effort has been dedicated to achieving one of the key MAWP objectives – prolonged system lifetime of FCs – through the development of better-performing stacks and monitoring of stack life, which can help to identify failure mechanisms. Many of the reported degradation rates (< 1.2 %/1 000 hours on average) and figures of stack life (e.g. 40 000 h durability) exceed targeted values.

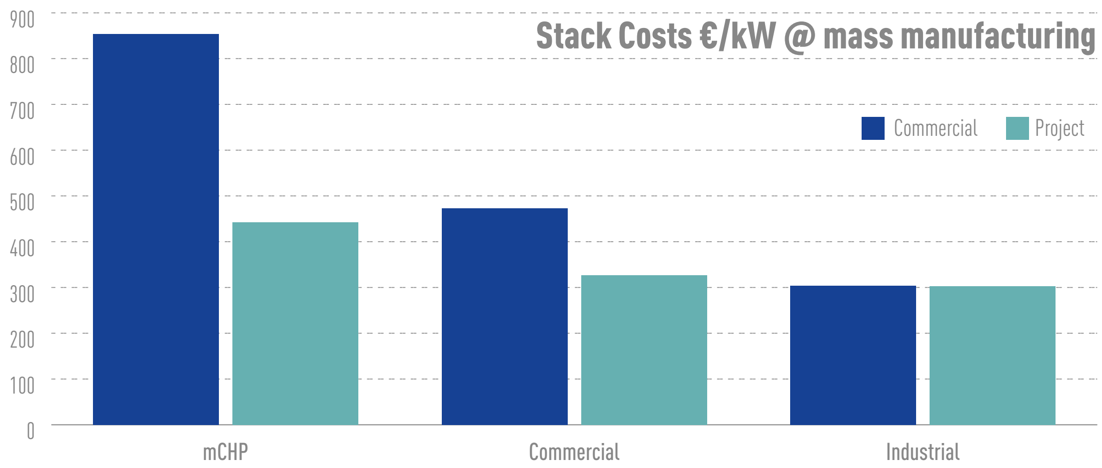
The reviewed projects benefited from outcomes of past projects through the presence of one or more project participants including industry in former consortia. Projects communicate their respective successes through common dissemination channels.

In the focus area **manufacturing**, all but one project (MATISSE, focusing on PEMFC) investigate SOFC manufacturing options. Each consortium has used varying approaches to improve SOFC stack manufacturability. Strategies for reducing cost, the use of critical raw materials and the production of pollutants have been implemented, mostly without affecting durability. Cost projections (especially for smaller FC applications such as μ-CHP) highlight the potential savings offered by scaling up manufacturing volumes (see Figure 23).

Novel manufacturing techniques and production chains, with increased automation and better cost estimation, have contributed to achieving the expected outcomes. The well-developed production chains positively affected the production process, cell efficiency and durability. Stack degradation also depends on the manufacturing process. In this respect, projects have progressed in addressing durability issues related to manufacturing.

The reported electrical efficiency for SOFC has reached a maximum (LHV) 74 %el (average 66 %el) at stack level. It is also likely to surpass the expected total system efficiency target of 57 %. With hydrogen, fuel use rates have reached values of up to 91 %. In general, cost reductions for SOFCs have been achieved through developing manufacturing methods, enabling projected stack costs as low as EUR 1 000/kW at mass production. For PEMFCs, platinum loadings have significantly decreased, with reports of up to 15 % platinum reduction compared to 2016. Durability seems to be the main challenge, despite some positive results.

Figure 23: Projected cost reductions for different stationary PEMFC options.



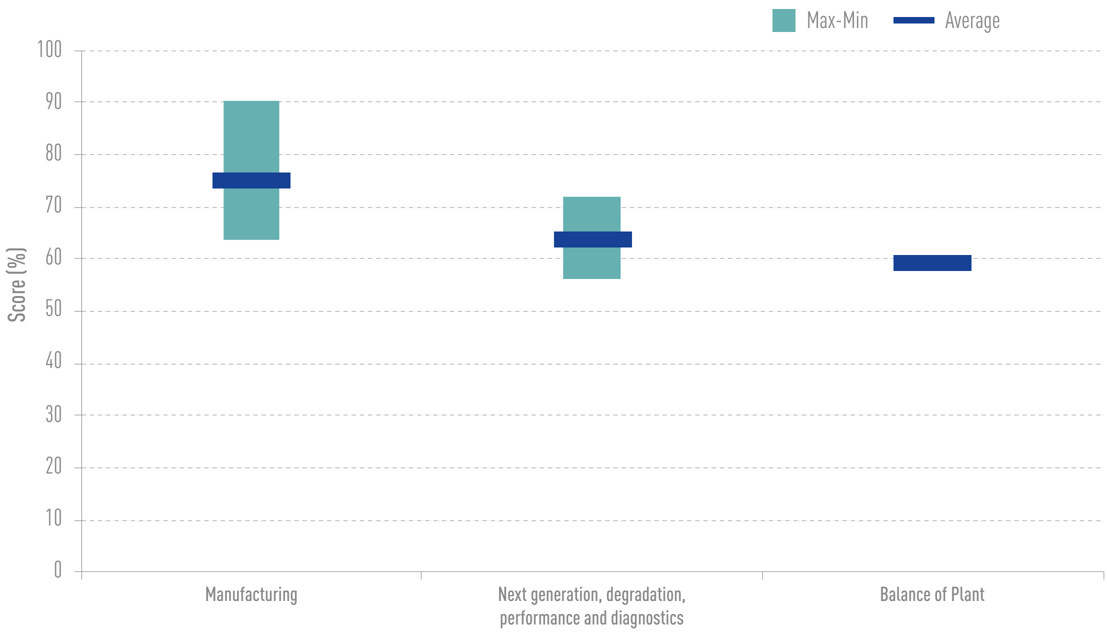
Within the focus area **balance of plant**, FLUIDCELL aims to develop new solutions for CHP units by coupling them with purpose-built bioethanol reformers. The project achieved several of its objectives, though not all. An overall TRL 5 was reached on all the technological components developed by the project. Market reach appears to be closer for the catalysts and membranes developed.

The goal of INNO-SOFC was to develop and demonstrate a 50 kW SOFC system based on an all-European value chain. It worked with other FCH 2 JU activities, adopted the stack developed by NELLHI and exchanged information with other consortia (notably SOFC and DEMOSOFC). The main achievements are 30 000 h of lifetime, 60 % electrical efficiency (74 % total stack efficiency), 4 000 EUR/kW system cost and reduced system complexity. The system design phase has delayed the project, and the robustness of single cells needed improvement. Nevertheless, results have been positive; in 2019, it is expected that two systems will be delivered to a Finnish industrial customer for use in a smart-grid system.

3.4.1. PANEL 4 – SUMMARY

Figure 24 shows the assessment of projects in Panel 4. The projects obtained overall positive evaluations, with those in the focus area manufacturing showing especially promising results.

Figure 24: Maximum, minimum and average scores for the relevant focus area of Panel 4. For focus areas with fewer than three projects, only the average is given.



Strengths

- Between system and component design, model development and diagnostics, the panel is well balanced.
- Significant progress in advancing the general SoA for SOFC, improved understanding of degradation processes and availability of effective diagnostic tools was reported.
- Cross-fertilisation across panels is evident. Several developments from other FCH 2 JU projects were carried over in projects considered in this year's portfolio.
- Active participation of industry (including a high number of SMEs) has enabled effective market reach.
- Manufacturing focus in this year's project portfolio appears to be progressing.

Additional focus needed

- Particular attention should be given to integrating developed FC stacks with established, off-the-shelf BoP components.
- Despite advances, durability targets have not been fully proven for all system designs.
- Harsh operating conditions have been considered but more work could be devoted to the development of testing protocols.
- Project findings should be exploited for their contribution to cross-cutting aspects.

Follow-up actions[33]

- Continuing field tests initiated by old projects could be taken up by new projects. Valuable information is often lost in the pursuit of new designs.

3.5. PANEL 5 – HYDROGEN FOR SECTORIAL INTEGRATION

The projects in Panel 5 contribute to the techno-economic objectives of making hydrogen production from renewables competitive, demonstrating hydrogen as a medium for energy storage, and sector coupling. This part of the Energy pillar aims to reduce cost and improve efficiency of hydrogen production, with a focus on demonstrating high-capacity electrolysis. Green hydrogen production systems are being designed for integration in smart grids.

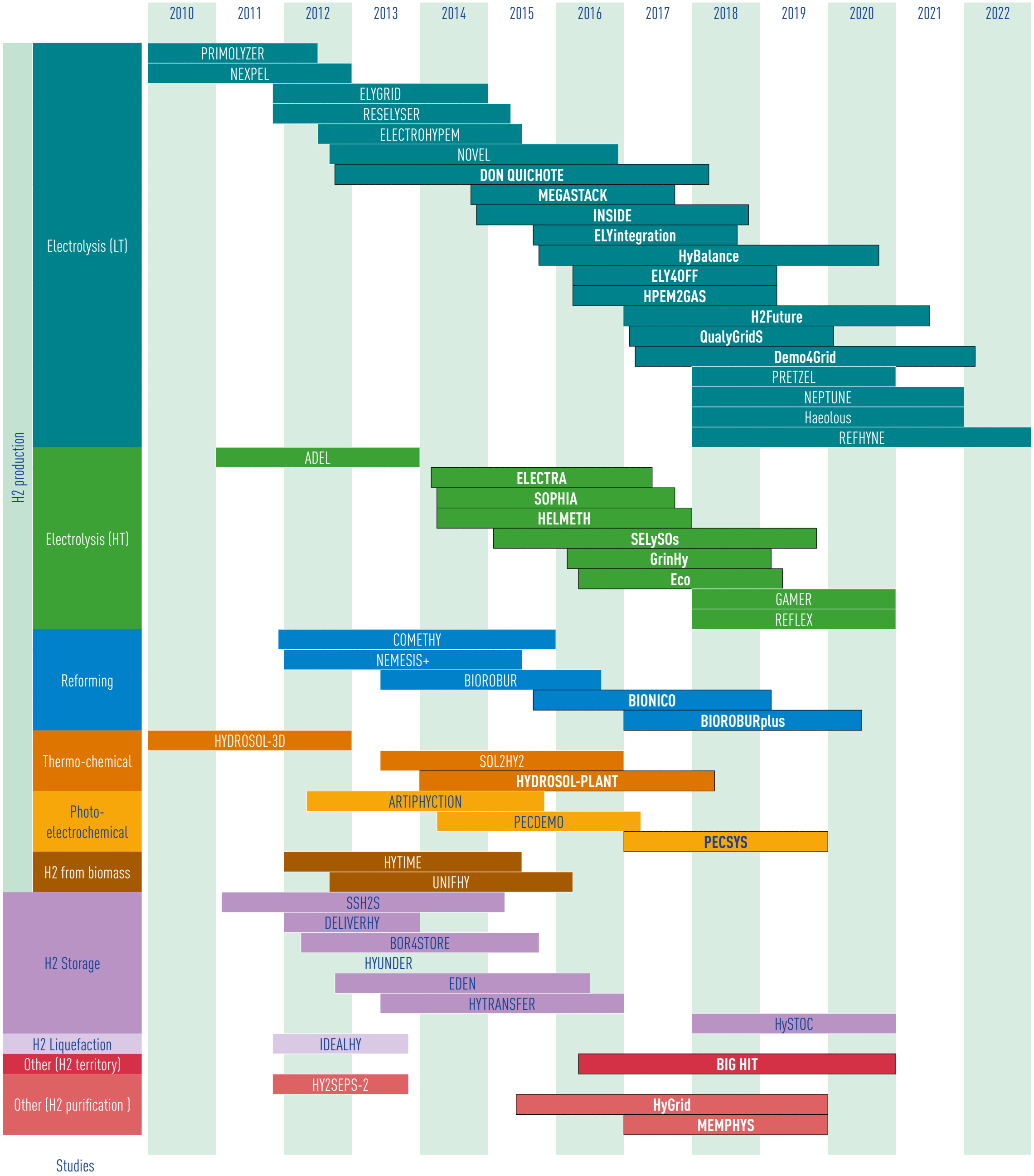
Panel 5 encompasses both research and demonstration projects on a wide range of topics. The technologies involved have different technology maturity and potential market size. Three main focus areas were defined for this year's review:

- Hydrogen production through electrolysis.
- Innovative reformers – reformer development for distributed hydrogen production from a number of feedstocks, including biogas and biodiesel.
- Innovative green hydrogen production methods for sustainable hydrogen production – development of hydrogen production technologies with long-term potential.

The remaining focus areas consist of hydrogen storage, separation and hydrogen territories. The present review covers the 24 projects highlighted in Figure 25. The FCH 2 JU portfolio of these 24 projects is shown in Figure 26. One third of these have ended and another third will end within the next year.

33. For follow-up actions addressing findings relevant to 2017, see the Programme Review Report 2017

Figure 25: Date ranges of Hydrogen for Sectorial Integration projects in the Energy pillar included in the 2018 review. Projects highlighted in black are considered for PRD 2018.



Following the calls between 2008 and 2017, the FCH 2 JU supported 54 projects relevant to this panel with a total FCH 2 JU contribution of EUR 145.28 million and a contribution from partners of EUR 63.73 million[34]. Figure 27 shows the cumulative contribution to projects on electrolyser technologies from 2010. The funding per MW of installed electrolyser capacity has decreased, as can be seen in Figure 28, which also shows the cumulative installed electrolyser capacity of the demonstration projects.

34. These figures include the overarching project BIG HIT, which draws EUR 5 million of FCH 2 JU funding split between the Energy (EUR 2.5 million) and Transport (EUR 2.5 million) pillars.

Figure 26: Funding for Panel 5 (Hydrogen for Sectorial Integration – Energy) from the start of the multi-annual programme up to and including the 2017 calls.

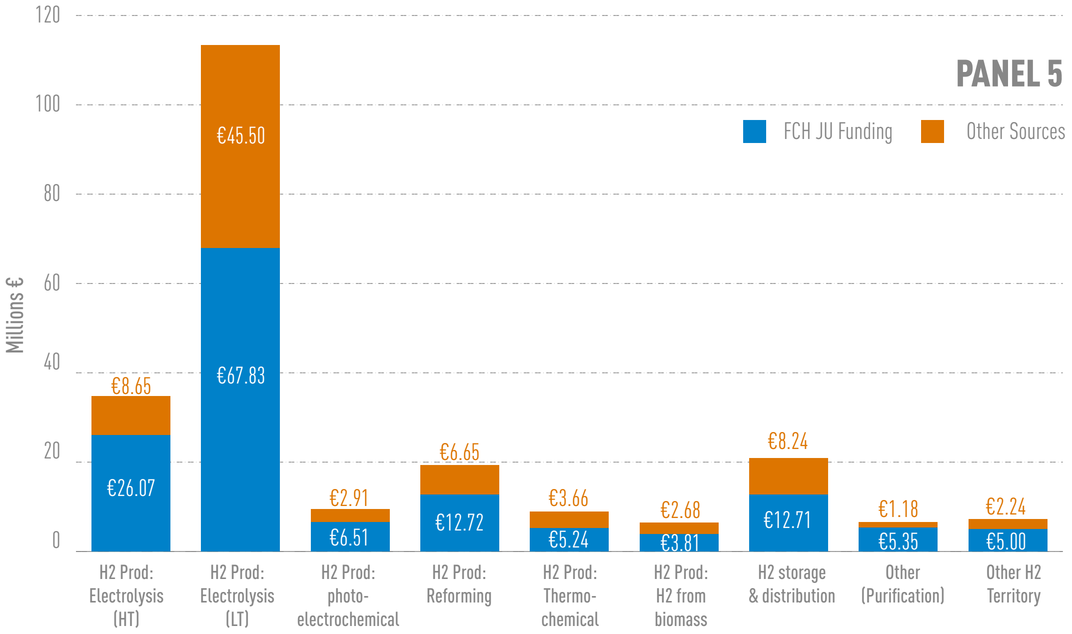


Figure 27: Cumulative EU funding contribution for electrolyser technology-related projects.

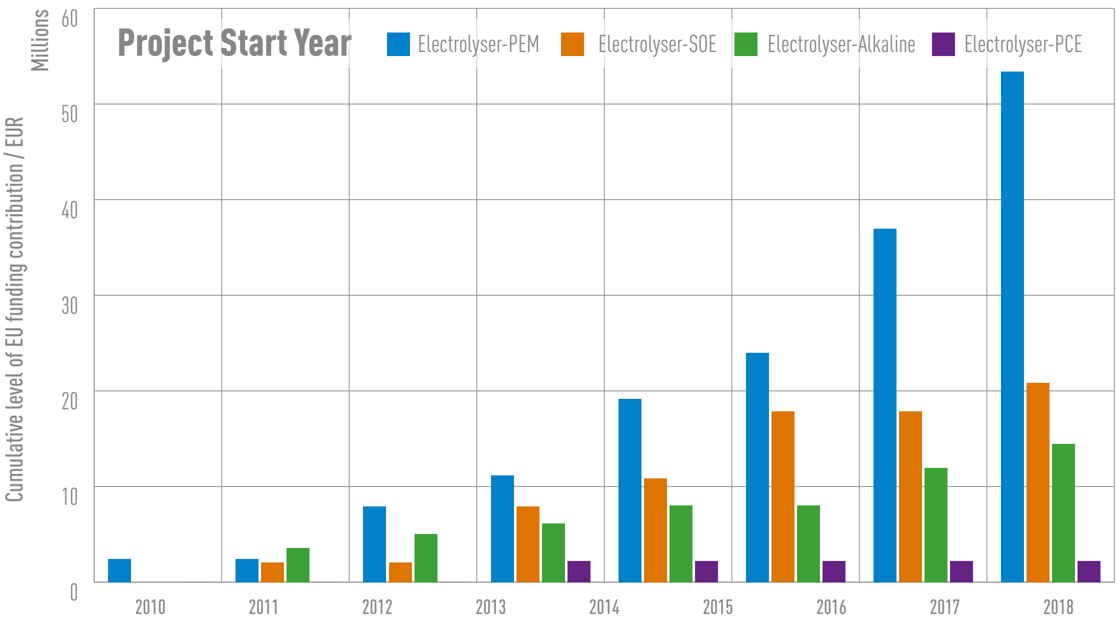
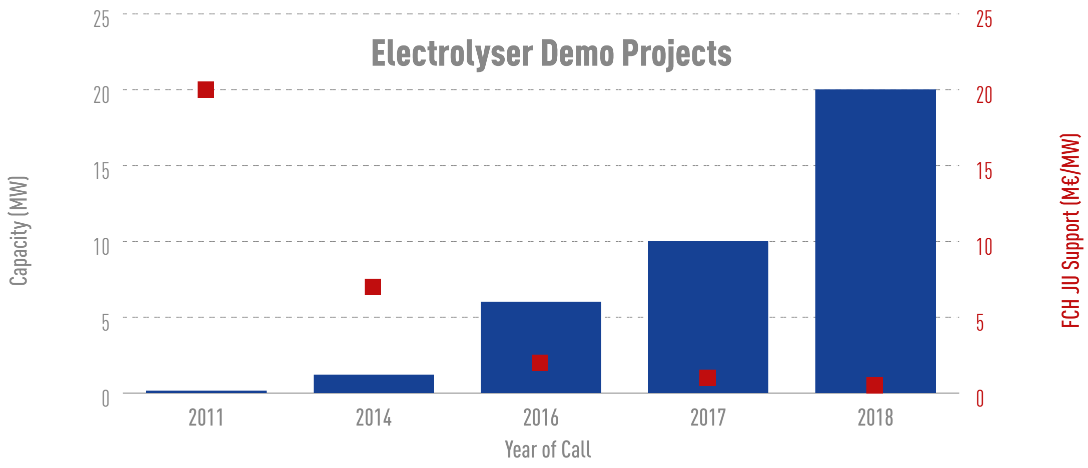


Figure 28: Installed capacity of electrolysers in MW and FCH 2 JU support per MW.



The focus area **LT electrolysis** consists of 10 projects: two on alkaline electrolysis, six on PEM electrolysis, one on grid services and one on monitoring/diagnostics. The FCH 2 JU has also supported the deployment of LT electrolysers for providing hydrogen for refuelling. In several projects in the Transport pillar (Panel 1), electrolysers are demonstrated as an on-site hydrogen generation system. Additionally, BIG HIT has deployed a 1 MW PEM electrolyser. Though considered in Panel 5, BIG HIT is classified as an overarching project. The electrolysers deployed in Transport pillar projects are evaluated in their respective panel and focus area.

For both alkaline and PEM electrolysis projects, the trend towards upscaling of the technology continues (see Figure 28). Technical progress has been made in the field of LT electrolysis, as PEM electrolysers have reached the 2020 MAWP energy consumption target of 55 kWh/kg H2 at rated power, at stack level. Electricity consumption of < 50[35] kWh/kg at cell and short stack level has been reported, a substantial improvement against the SoA. High current densities still pose a challenge in terms of degradation rate; however, a short stack tested at high current densities of 3 A/cm2 (at 1.8V) reached a value of 0.2 %/1 000 h, very close to the 2020 MAWP target of 0.19 % degradation per 1 000 h. Other notable achievements for PEM technology are a very small footprint of 10 m2/MW (beyond the 2030 MAWP target of 45 m2/MW) and a reduction of PGM use to approximately 3 mg/W while retaining reasonable performance (close to the 2020 MAWP target of 2.7 mg/W).

MEGASTACK sought to develop a suitable stack design for PEM electrolysers in the MW range. The aim was to reduce costs and increase current density. It also sought to contribute to understanding of the transport phenomena in the porous layers and flow fields as well as investigating processes causing cell degradation through experimental work and modelling.

Projects are increasingly studying applications with a potential business case, such as hydrogen for industrial applications and electricity grid services. Water electrolysers could play a role in the ancillary service market if they fulfil certain technical requirements. QUALYGRIDS supports these potential applications through developing standardised testing protocols for the provision of electricity grid services. HPEM2GAS and H2ME2 are also working on this. With support from partners of FCH 2 JU-funded projects (such as ELY4OFF, MEGASTACK, INSIDE and PRETZEL), JRC is drafting low-temperature electrolysis testing protocols for single cells and short stacks, as well as for system testing for grid-connected and off-grid applications. This will expand to high-temperature electrolysis (HTE) terminology and testing protocols in 2019. ELYNTEGRATION and QUALYGRIDS have performed a comprehensive mapping of technical requirements for the various services in Member States and identified promising markets.

35. 47 kWh/kg at 1A/cm2 @1.8V.

Improving the performance of PEM electrolysers for the provision of grid services is addressed by HPEM2GAS, which successfully targeted lowered energy consumption at high current densities, as well as reduced degradation at low PGM loading. The 180 kW prototype system developed is being validated in a field test. The hydrogen produced will be injected into the local gas grid and the project is looking into possible markets for the oxygen produced. ELYNTEGRATION addresses providing hydrogen for industry by testing a 250 kW prototype design for a single-stack, multi-MW, high-pressure, alkaline electrolyser. The project has assessed the market potential for industrial customers and has found ammonia production and the refining industry to be promising. It has also published an assessment of the regulatory framework regarding grid connection and grid services.

Pressurised alkaline electrolysis is also the focus of the DEMO4GRID project, which is demonstrating a 4 MW alkaline electrolyser that will be able to provide grid-balancing services with appropriate responsiveness. The electrolyser will be constructed at the site of a food provider in Austria. Additional activities include a thorough assessment of the sustainability of the process. A 6 MW PEM electrolyser will be deployed in a steel plant in Austria through the H2FUTURE project, which will also investigate the additional provision of grid services. The direct reduction of iron ore by hydrogen, combined with an electric arc furnace, has the potential to lower the environmental impact of steelmaking significantly. The 1.25 MW PEM electrolyser deployed as part of the HyBalance project in Denmark has been designed to provide electricity grid services and will make the hydrogen produced available to local industry, at high pressure, for mobility. The electrolyser will be operated by following electricity price signals, demonstrating the use of hydrogen in energy systems.

Other potential markets are explored by the ELY4OFF project, which is investigating various business cases including the provision of energy in isolated areas. The project is developing a 50 kW PEMWE autonomous off-grid electrolysis system linked to renewable energy sources. Finally, diagnosis and monitoring tools for LT electrolysers are being developed by the INSIDE project to optimise performance. In-situ diagnostic prototypes have been developed and operated, based on observation of the local current density distribution.

Under the focus area **high-temperature electrolysis**, solid oxide electrolyser technology, at least at stack level, already meets the MAWP 2030 targets for electricity consumption, with projects reaching values of 33-35.5 kWh/kg. The main research directions for ECO, ELECTRA, GRINHY, HELMETH, SOPHIA and SELYSOS, apart from addressing MAWP targets such as increased efficiency and lifetime, are co-electrolysis and reversible operation. The availability of solid oxide electrolyser cell (SOEC) stacks appears to have improved as well, with projects reporting no downtime at all. Advances have been made for capital costs at mass production level and the MAWP target for production loss rate < 1.9 %/1 000 h has been met. Though the CAPEX targets have not yet been achieved, promising cost projections for large-scale production (100 MW/annum) of 1 500 EUR/kW have been published. Reversible operation has been demonstrated, but further efforts are needed to improve the reversible efficiency. Co-electrolysis has been the focus of several projects, with promising early results regarding a conversion efficiency approaching 80 %.

SELYSOS focuses on understanding the degradation and lifetime of the SOEC electrodes. The project seeks to increase understanding of degradation, by developing theoretical models describing the degradation of the hydrogen electrode. Novel materials and components, in particular nickel-based and nickel-free electrodes, are being developed and tested.

Unlike water/steam electrolysis, proton ceramic electrolysis can produce dry hydrogen directly. Ceramic electrolysers are also well suited to high-pressure operation. The ELECTRA project has developed a tubular proton ceramic steam electrolyser, focusing on attaining stable steam electrodes, seals and interconnects. Key results include achieving a large cell area of 10 cm2, operation at 4 bar pressure, and 83 % higher heating value (HHV) efficiency.

Thermal integration of electrolysis with methanation can potentially achieve conversion efficiencies of > 80 %. HELMETH has developed a pressurised electrolyser combined with a CO_2-methanation module, achieving high gas conversion ratios. Further improvements are needed to reach the desired methanation efficiency of > 85 %. The environmental impact of the process was analysed and the use of non-fossil CO_2 sources is the more beneficial option. The potential sources of heat, which can be coupled to the solid oxygen electrolyser to improve efficiency, are often also sources of CO_2. Co-electrolysis has been explored by the project SOPHIA. A 3 kW pressurised HTE system coupled to a concentrated solar energy source was designed and tested. Electrode optimisation has led to a reduction of the operating temperature by 50-100 °C. The project will also try to implement direct internal methane formation inside the SOEC stack.

Using industrial waste heat, hydrogen can potentially be produced with less than 40 kWh/kg electricity, resulting in much lower costs. GRINHY is building and operating an HTE at a steel mill with an existing steam network, producing hydrogen at the required purity level. The objectives – an electrical system efficiency of > 80 % LHV, and testing performed at stack level of >10 000 h with a degradation rate of < 1 %/kg – have for the most part been achieved.

The focus area **reforming** covers biogas reforming, which has the potential to produce hydrogen at EUR 5/kg for decentralised applications. BIOROBUR, which has been succeeded by BIOROBURPLUS, had reached production costs close to this. Targeting TRL 6, BIOROBURPLUS will construct and test an oxidative steam reformer for the decentralised production of hydrogen with an efficiency of 81 % (HHV). If successful, it will meet the 2020 MAWP goal of 56 kWh/kg H2 from raw biogas.

The BIONICO project is also aiming at TRL 6 for a novel catalytic membrane reactor (CMR), which will be able to produce hydrogen from biogas in one step. The use of CMR is expected to increase the overall conversion efficiency to 72 % and decrease volumes and the need for auxiliary heat management units. This conversion efficiency meets the Annual Work Plan 2014 target.

The MAWP specifies 2020 targets for **HT water splitting** of system energy use of 100 kWh/kg H2, system capital costs of EUR 2 500/(kg/day), and a system lifetime of 2 years. Part of the focus area thermo-chemical hydrogen production, the HYDROSOL-PLANT project has demonstrated the production of hydrogen through thermo-chemical cycles. The project aimed at operating a 0.750 MWth scale plant for solar thermo-chemical hydrogen from water in a solar tower. The project has generated a large amount of know-how such as the manufacturing of materials for the reactor, and long-term testing over 1 000 h has been performed. This ambitious project is at the forefront of solar hydrogen production technology; however, not all targets could be reached.

There are two projects reviewed within the focus area **photo-electrochemical hydrogen production**. PECDEMO and PECSYS can be considered to be at the forefront of a highly challenging field. PECDEMO, building on the Nano-PEC project, developed a hybrid photo-electrochemical-photovoltaic tandem metal oxide/silicon-based device for light-driven water splitting. The project demonstrated solar-to-hydrogen efficiencies of 9.2 % (HHV) for a dual photo-anode. Stability of 1 000 h was shown for another type of photo-anode.

PECSYS is targeting the development of an integrated PV-electrochemical cell device enabling the potential increase in electrochemical efficiency of hydrogen production. The installation is to be demonstrated and validated for outdoor operation with a total module area of at least 10 m^2 at the end of the project. The project also seeks to reduce the amount of PGM used. PECSYS has achieved a 12.78 % solar-to-hydrogen efficiency in a lab-scale CIGS[36]-water splitting module using non-precious metal catalysts under alkaline conditions.

The focus area **other (hydrogen territory and purification)** reviewed three further projects. The first of its kind, the BIG HIT project is demonstrating replicable and integrated hydrogen energy solutions in an isolated territory. Hydrogen is seen as a solution to the wind curtailment problem

36. Photoactive material.

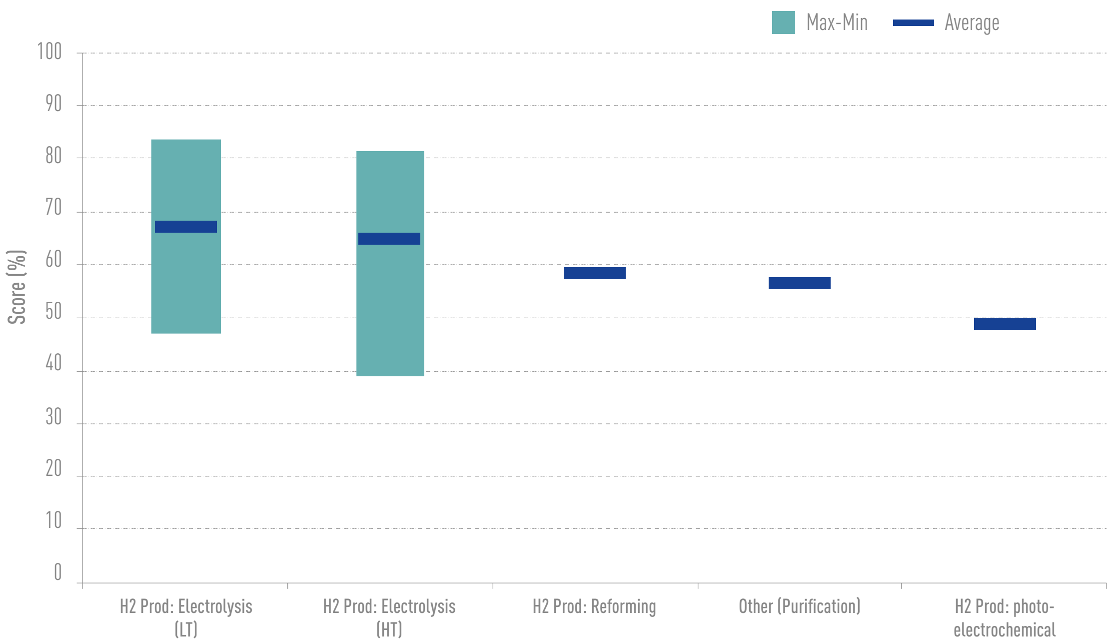
of the Orkney Islands, as it can be used in power, heat and transport applications. There have been issues related to the permitting of the hydrogen storage trailer. The project's objective is to store 970 kg of hydrogen, almost meeting the 2020 MAWP target of 1 000 kg. The field experience generated by BIG HIT with a hydrogen energy system in a remote and harsh environment will be useful for other projects.

HyGrid focuses on providing a means of transporting hydrogen produced from renewables by blending with natural gas and then separating it at the location where it is needed. Palladium- and carbon-based membranes for hydrogen recovery from low-concentration streams are being developed and tested. This appears to be the first effort to combine the three separation technologies: membrane module, electrochemical hydrogen separation compressor and temperature swing adsorption. MEMPHYS targets electrochemical hydrogen purification with the aim of a high contaminant tolerance at low system cost. It has achieved high hydrogen recovery rates at a low energy consumption of 3 kWh/kg H2 at cell level. With this concept, purification and compression can be achieved in one step.

3.5.1. PANEL 5 – SUMMARY

The overall assessment of the projects in panel 5 is shown in Figure 29. In addition to the average, the minimum and maximum ratings for the first two focus areas are shown. For the first two focus areas, only single projects have been assigned scores below 50 %.

Figure 29: Maximum, minimum and average scores for the relevant focus areas of Panel 5. For focus areas with fewer than three projects, only the average is given.



Strengths

- The trend towards upscaling for LT electrolysis is commendable, as is the investigation of business models. As seen in Figure 28, the installed capacity has been achieved with considerably lower FCH 2 JU support per MW in recent years.
- The involvement of industrial partners, as manufacturers or customers, is increasing.

- Large-scale demonstrations are furthering public acceptance and will trigger more commercial end-use interest in deploying renewable hydrogen production.
- Technical milestones have been met, in both LT and HT electrolyser efficiency.
- Europe is gaining a good position against international SoA in HTE and solar hydrogen production. There is the potential for HTE technology to play a major role in the production of hydrogen once upscaling to MW size is tackled.
- Several projects investigate sustainability aspects through LCA.
- There have been some cases of supplementary funding from national programmes.

Additional focus needed

- For LTE, the difference between stack and system efficiency is often high. The development of BoP components requires further attention.
- More effort should be placed on meeting the CAPEX targets for LTE and the hydrogen cost targets for the solar hydrogen production routes.
- In contrast to LTE, SOEC technology has no need for precious metal catalysts. However, SOECs are based on both heavy and light rare earth metals. The economic and ecological impact of rare earth elements should be taken into account.
- More general business models should be developed.
- For thermo-chemical hydrogen production, the hybrid-sulphur cycle might offer lower production costs than other routes. This option could be further investigated.
- Options that have not yet been tested on a large scale such as liquid hydrogen or chemical carriers should be carefully assessed against the technical KPIs expected.

Follow-up actions[37]

- For LTE, it should be assessed whether next-generation cell and stack development could be pursued in addition to demonstration activities.
- Focus should be on developing cost-effective manufacturing processes for LTE. Results of projects on fuel cell manufacturing should be exploited wherever possible.
- A more aggressive action on reducing PGMs and obtaining innovative catalysts should be considered
- Reduction in rare-earth metals use for high temperature electrolysis should also be the focus of future actions.
- Photoelectrochemical technology should be benchmarked against the combination of photovoltaics and electrolyser.
- Reflect on inclusion of reversible electrolysis more prominently in future portfolios.

37. For follow-up actions addressing findings relevant to 2017, see the Programme Review Report 2017

04

SUPPORT FOR MARKET UPTAKE (CROSS-CUTTING)

4.1. OBJECTIVES

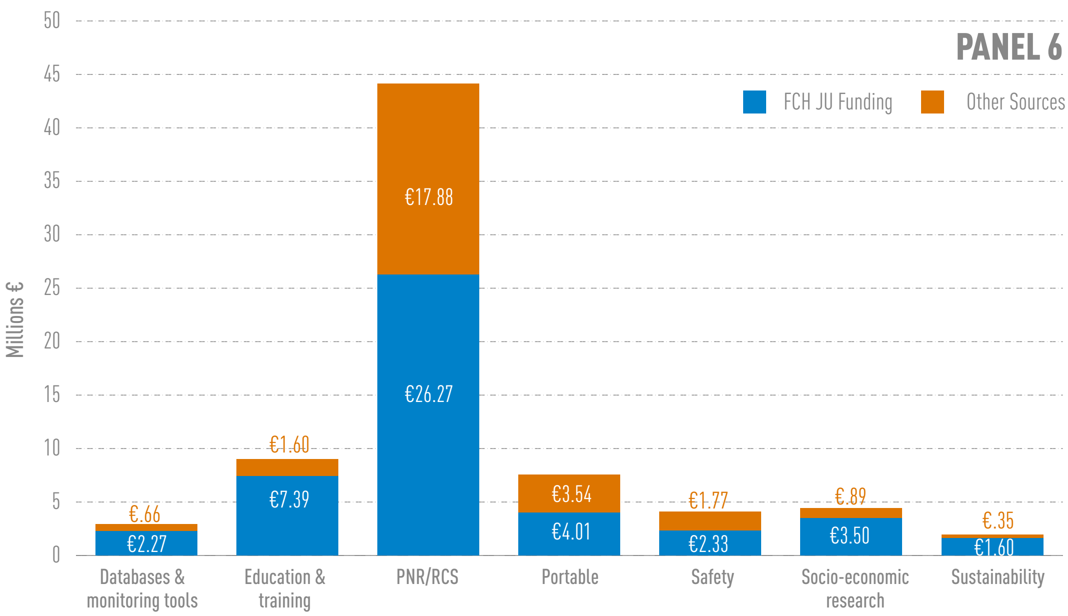
Cross-cutting projects constitute an essential part of the overall FCH 2 JU project portfolio since they address challenges common to the energy and transport pillars. Cross-cutting projects are intended to support market preparation and readiness by:

- Providing new knowledge to develop and improve regulations, codes and standards.
- Generating experimental data and validating modelling approaches to address safety of FCH technologies and applications.
- Preparing the European workforce; increasing public awareness and acceptance.
- Characterising and improving the environmental footprint of FCH technologies.

4.2. BUDGET

To date (project calls from 2008 to 2017), the FCH 2 JU has supported 37 projects in this panel with a contribution of EUR 47.40 million and a partner contribution of EUR 26.73 million. Total distribution of historical budgets over the seven focus areas[38] is shown in Figure 30.

Figure 30: Funding for Panel 6 (cross-cutting) from the start of the multi-annual programme up to and including the 2017 calls.



38. A detailed explanation of the cross-cutting focus areas will be presented in section 5.3.

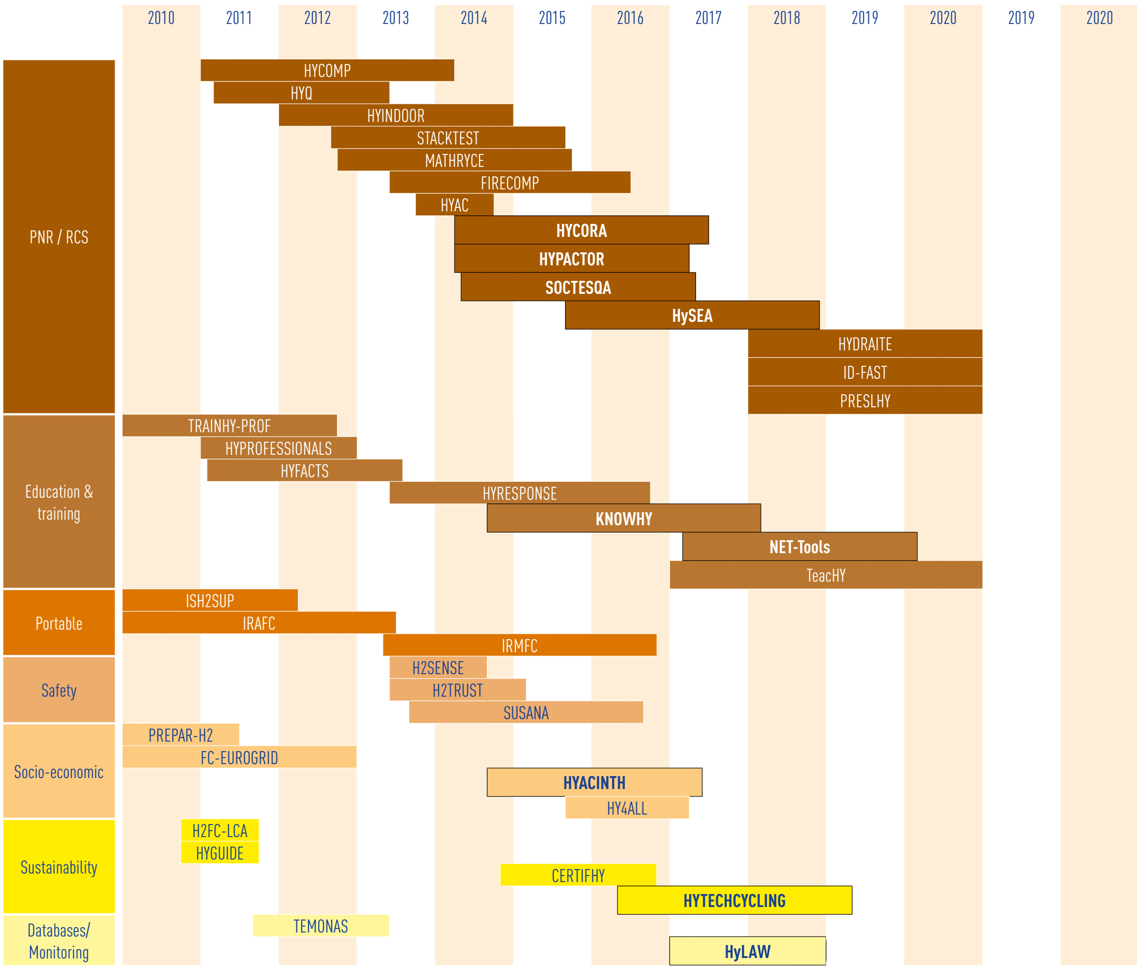
4.3. PANEL 6 – CROSS-CUTTING

The Panel 6 project portfolio supports a number of fields, with emphasis on the first three.

- Pre-normative research (PNR) and input into RCS: Research into aspects of FCH technologies of interest to the industry as a whole, with a view to gathering new knowledge to support the European FCH community and transferring the knowledge generated into standards and regulations.
- Safety aspects: Understanding safety issues associated with the deployment and adoption of FCH technologies. This is paramount for public acceptance of FCH technologies and provision of health and safety, and the emphasis is on public safety. This field is linked with the previous one, and with the databases mentioned below.
- Training and education: Actions to provide education and training for the FCH sector including scientists, engineers, technicians and decision-/ policy-makers outside the sector, as well as the education sector, certification bodies and first responders.
- Socio-economic research to assess the environmental and societal impact of FCH technologies in terms of GHG emissions, primary energy use and economic competitiveness; it also implies actions to increase social acceptance and awareness.
- Supporting the development of tools for the sustainability assessment of FCH technologies, e.g. LCA methods, and issues related to recycling and dismantling.
- Other activities including establishing databases for environmental, economic and socio-economic topics as part of knowledge management, and identifying and developing financial mechanisms to support market introduction.

The 2018 review covered the nine projects highlighted in black shown in Figure 31.

Figure 31: Date ranges of cross-cutting projects included in the 2018 review. Projects highlighted in black are considered for PRD 2018.



Within the focus area **PNR/RCS**, HyCoRA addresses a critical enabler for the whole hydrogen technology chain related to mobility, by focusing on a strategy for cost reduction of fuel quality assurance. The project has achieved considerable progress in defining credible potential cost reductions, in reviewing hydrogen impurity mapping, and in contributing to the development of improved analytical methods. It has also enabled the development of a European reference centre and successfully engaged with standardisation bodies.

Similarly, SOCTESQA has been able to develop, validate and submit to the relevant European and international standardisation bodies test procedures for performance characterisation of solid oxide cell/stack assembly. These procedures contribute to the achievement of an EU-wide uniform performance test scheme, completing similar work accomplished by project STACKTEST on PEM cell stacks from 2012-2015.

With the conclusion of project HYPACTOR, multiannual efforts involving several project activities aimed at better understanding the behaviour, safety and lifetime degradation of high-pressure on-board storage systems are ending. HYPACTOR investigated the response of on-board storage systems to external mechanical impacts, defining a correlation between impact and degradation and enabling progress in inspection and qualification procedures.

HySEA studies the behaviour of hydrogen releases in semi-confined spaces via full-scale field experiments and validated computer models. The understanding and control of associated phenomena is critical to the safe deployment of stationary hydrogen installations. The project has achieved an impressive collection of experimental evidence.

The FCH 2 JU Regulations, Codes and Standards Strategy Coordination Group (RCS SCG) has contributed to the multiannual strategy in this part of the programme by identifying and prioritising topics requiring further PNR. It has also provided a link between the PNR strategy and the standardisation and regulatory dimension.

In general, projects score well in terms of target achievement and project impact. They also show above-average performance for the dissemination indicator, because PNR results can be made public to a much greater extent than projects dedicated to product development. In this section the RCS SCG must be mentioned. As required in the MAWP, the overarching goal of this group is to set and implement a strategy enabling development and use of harmonised performance-based standards for FCH appliances and systems.

This year, two projects can be directly allocated to the focus area safety: HySEA and HYPACTOR. Other projects described in other focus areas are considered here too: KNOWHY and SOCTESQA. Safety-related findings from these projects feed directly into formulating safety requirements in standards and regulations under development. Table 4 specifies the contribution of these projects to safety assessment. Besides projects with an explicit safety dimension, additional progress is provided by demonstration projects, thanks to their rich field experience.

Table 4: Safety dimensions of Panel 6 projects.

Project	Focus area	Project contribution to safety assessment and progress
HYPACTOR	PNR/RCS	Better understanding of composite overwrapped pressure vessels for on-board storage under external mechanical impacts Input into standardisations for diagnostic tools and type approval testing
HySEA	PNR/RCS	Improving hydrogen safety for energy applications through PNR on vented deflagrations
SOCTESQA	PNR/RCS	Solid oxide cell and stack testing, safety and quality assurance. Among the testing protocols developed by the project, the first contains safety provisions
KNOWHY	Education	One of the training modules developed is dedicated to safety
NET-Tools	Education	Safety and PNR is an integral part of the e-laboratory
HyLAW	Databases	Safety is an important dimension of the regulatory/legal requirements

The description of this focus area would not be complete without mentioning the European Hydrogen Safety Panel, which formed in 2017 and agreed an overall strategy, modus operandi and annual plan (2018). Steered by the FCH 2 JU PO, it operates at programme level and will also engage with projects on safety (awareness, consultancy, assessment).

The focus area **education and training** is composed of KNOWHY and NET-Tools. KNOWHY, finished in 2017, developed training modules for technicians and other professional operators. With completion of this project, the focus area has produced a range of tools to educate all stakeholders in the value chain. A further dimension is tackled by NET-Tools, which started in 2017. It focuses on new e-education methods to enhance knowledge, productivity and competitiveness of those interested or involved in FCH technology deployment.

The focus area **sustainability** is composed of the project HYTECHCYCLING, which studies recycling, dismantling technologies and strategies. The project uses the LCA methodology and approaches defined in FC-HyGuide to investigate the role recycling can play in reducing CO_2 emissions and other environmental impacts. So far, a major achievement of HYTECHCYCLING, which concluded in 2019, has been identifying and classifying critical materials in FCs and water electrolysers and their flows in existing recycling and dismantling technologies.

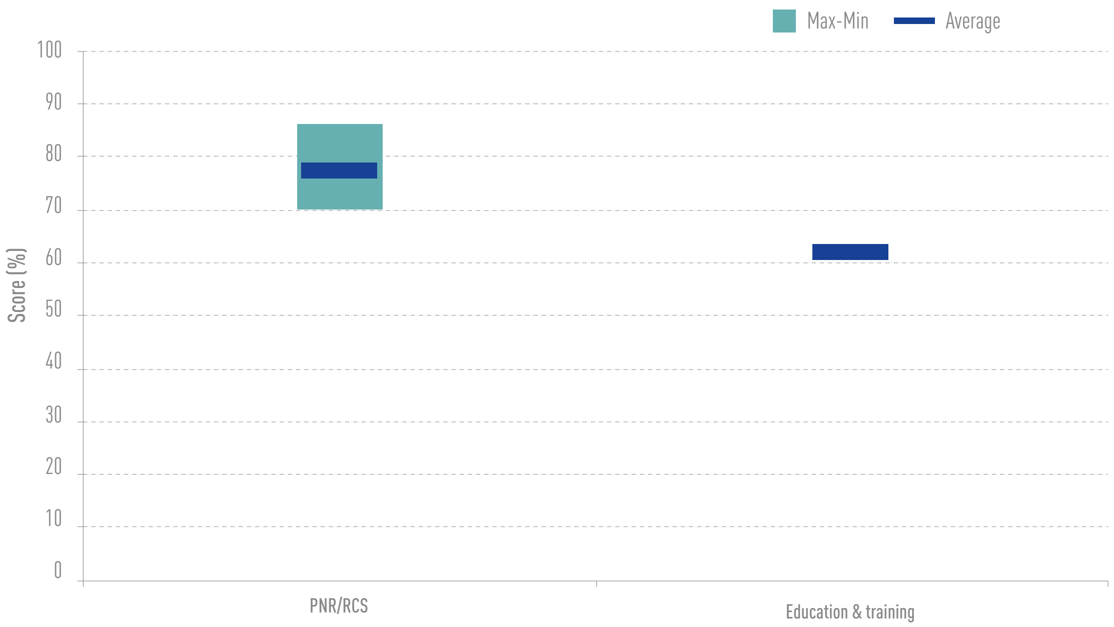
The focus area **socio-economic** contains only the project HYACINTH, which has analysed public awareness, concerns and acceptance levels for FCH technologies in the energy and transport sectors in selected Member States. It developed a public hydrogen technology acceptance database and issued recommendations to increase awareness and acceptance.

Under the focus area **databases**, HyLAW has analysed the laws applicable to FCH technology deployment at Member State level, mapping the legal framework and administrative processes. An interactive database allows for detailed assessment of the findings. The project's goal is to identify and rank related barriers. It is the first time such a complete analysis at Member State level has been carried out. The HIAD2.0 and HELLEN databases contain description and analysis of safety-related events along the FCH whole technology chains.

4.3.1. PANEL 6 – SUMMARY

The overall assessment of the projects reviewed in Panel 6 is shown in Figure 32. For more details on the methodology used, see Section 3. Figure 32 confirms the good to excellent performance of PNR projects in this panel, evident from the radar graph in Annex A.

Figure 32: Maximum, minimum and average scores for the relevant focus areas of Panel 6. For focus areas with fewer than three projects, only the average is given.



Strengths

- With predecessor projects, the PNR projects in this review have generated a comprehensive understanding of individual aspects of high-pressure storage systems and solid recommendations for present and future standardisation activities.
- The education projects completed a set of educational and training tools that has been made available to a broad range of users.
- The end of project HyLAW provides the first mapping and analysis of the legal and administrative barriers to technology deployment at EU Member State level.
- For the first time since the start of the FCH 2 JU programme, a project achieved the

systematic collection and analysis of the acceptance of FCH technologies throughout Europe, delivering a communication and management toolbox to assist future wide-scale technology deployment.

- The project HYTECHCYCLING is the first to address in a coordinated way the aspects of sustainability and the circular economy, classifying and linking energy and material flows of FCH technologies to the existing recycling and dismantling technologies.

Additional focus needed

- Demonstration projects in other panels are an opportunity for field validation of the RCS framework already in place. This experience could generate feedback for RCS improvement. However, proprietary information hinders the sharing of this data.
- After projects in the education and training focus area have finished, the process by which the tools are maintained and updated is not clear. Training modules in particular will need regular updates to account for technological progress.
- The first systematic European social acceptance analysis risks being an isolated exercise if no follow-up is ensured.

Follow-up actions[39]

- In 2018, the JRC mapped LCA achievements for all FCH 2 JU projects to address recommendations from 2017. In 2019, this report will be used as a basis for further discussions with experts, resulting in an LCA roadmap at programme level.
- Sustainability would profit from a coordinated platform at a programme level, to ensure these dimensions are integral parts of future projects.
- Maximise the impact of the achievements of HYACINTH on social acceptance dimensions of projects. These aspects should be integrated in future demo projects.

39. For follow-up actions addressing findings relevant to 2017, see the Programme Review Report 2017

05

PROJECT POSTERS

INDEX OF POSTERS

PANEL 1
TRIALS AND DEPLOYMENT OF FUEL CELL APPLICATIONS – TRANSPORT

H2ME
HYDROGEN MOBILITY EUROPE

Project ID:	671438
Call topic:	**FCH-01.7-2014** - Large scale demonstration of refuelling infrastructure for road vehicles
Project total costs:	**€ 62,305,033.3**
FCH JU max. Contribution:	**€ 32,000,000**
Project start - end:	01/06/2015 - 31/05/2020
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**www.h2me.eu**

BENEFICIARIES: AGA AB, AIR LIQUIDE ADVANCED BUSINESS, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, AREVA H2GEN, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, BOC LIMITED, CENEX - CENTRE OF EXCELLENCE FOR LOW CARBON AND FUEL CELL TECHNOLOGIES, COMMUNAUTE D'AGGLOMERATION SARREGUEMINES CONFLUENCES, DAIMLER AG, DANISH HYDROGEN FUEL AS, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, FALKENBERG ENERGI AB, H2 MOBILITY DEUTSCHLAND GMBH & CO KG, HONDA R&D EUROPE (DEUTSCHLAND) GMBH, HYOP AS, HYUNDAI MOTOR EUROPE GMBH, ICELANDIC NEW ENERGY LTD, INTELLIGENT ENERGY LIMITED, ITM POWER (TRADING) LIMITED, LINDE AG, LINDE GAS GMBH, McPhy Energy SA, NEL HYDROGEN AS, Nissan Motor Manufacturing (UK) Limited, NUCELLSYS GMBH, OMV REFINING & MARKETING GMBH, RENAULT SAS, SYMBIOFCELL SA, TOYOTA MOTOR EUROPE, WaterstofNet vzw.

PROJECT AND OBJECTIVES

Hydrogen Mobility Europe (H2ME) brings together Europe's four most ambitious national initiatives on hydrogen mobility (in Germany, Scandinavia, France and the UK). The project will expand their developing networks of Hydrogen Refuelling Station (HRS) (29 new stations will be deployed) and the fleets of FCEVs operating on Europe's roads (325 vehicles) creating both a physical and a strategic link between these four regions and three 'observer countries' (Austria, Belgium and the Netherlands), who will use the learnings produced by this project to develop their own strategies.

NON QUANTITATIVE OBJECTIVES

- Minimum of 100 FCEVs and 23 HRS
- Further activities for deployment of HRS and FCEVs after project
- HRS to be accessible for private users and integrated in petrol courts
- Ensure cross-fertilization of knowledge acquired in the project

PROGRESS & MAIN ACHIEVEMENTS

- Successful start of the demonstration: 220 vehicles and 6 HRS deployed to date (325 FCEVs and 29 HRS are planned by the end of the project)
- Project's HRSs achieved and demonstrate good level of availability: 97.5% (based on six stations and 5 operators)
- Fruitful cross-fertilization of knowledge acquired inside and outside of the project - including via a 300 people event in Brussels

FUTURE STEPS & PLANS

- All 29 HRS planned for the project expected to have been commissioned and be in operation
- All 325 vehicles planned for the project expected to be deployed including the first next generation Daimler GLC F-CELL
- Solid and growing basis of operational data from vehicles and stations and further fact based analysis on vehicles and HRS performances
- Further exploitation of results

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The development of a low cost FCEV will require many €100's millions of investment by OEMs, as well as some security of eventual sales volumes – an investment which is challenging when facing a) uncertainties about the customer response to the technology (many OEMs have been disappointed by the market response to battery vehicles), b) technological uncertainties about the eventual cost of the vehicles, and c) uncertainty that the HRS infrastructure will be in place. To overcome these problems, a series of national initiatives have been assembled to synchronise investments between OEM and HRS providers, pool risks and to attempt to cement a first mover advantage for early investors.

Increase the electrical efficiency and the durability of the different fuel cells

All stations will achieve a production-to-nozzle hydrogen production efficiency between 60% and 70% (depending on the method of production). Partners will aim for result in the upper-end of this range. All vehicles are designed to be operated for min. 6,000 h.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Fuel Cell Electric Vehicles					
TTW consumption NEDC (descriptive parameter)	%/100km	0.76	1.15	✓	Toyota Mirai in France and Germany
Availability	%	100	98	✓	Toyota Mirai in France and Germany
Hydrogen Refuelling Stations					
Availability	%	99.7	96	✓	HRS in Hovik (Norway)
Durability	years	5	5	✓	HRS in Hovik (Norway)
Lifetime	years	5	12	🛠	HRS in Hovik (Norway)
Durability	years	10	5	✓	HRS in Sandviken (Sweden)
CAPEX	Thousand EUR/(kg/day)	15.56	4-2.1	🛠	HRS in Hovik (Norway)
Lifetime	years	15	12	✓	HRS in Sandviken (Sweden)

*** As identified in MAWP Addendum 2018-2020, Target year 2020**

H2ME 2
HYDROGEN MOBILITY EUROPE 2

Hydrogen Mobility Europe


Project ID:	**700350**
Call topic:	**FCH-03.1-2015** - Large scale demonstration of Hydrogen Refuelling Stations and FCEV road vehicles - including buses and on site electrolysis
Project total costs:	**€ 104,112,613.33**
FCH JU max. Contribution:	**€ 34,999,548.5**
Project start - end:	01/05/2016 - 30/06/2022
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**www.h2me.eu**

BENEFICIARIES: AGA AB, AIR LIQUIDE ADVANCED BUSINESS, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, ALPHABET FUHRPARKMANAGEMENT GMBH, AREVA H2GEN, AUDI AKTIENGESELLSCHAFT, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, BRINTBRANCHEN, CENEX - CENTRE OF EXCELLENCE FOR LOW CARBON AND FUEL CELL TECHNOLOGIES, COMMUNAUTE URBAINE DU GRAND NANCY, COMPAGNIE NATIONALE DU RHONE SA, DAIMLER AG, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, GNVERT SAS, H2 MOBILITY DEUTSCHLAND GMBH & CO KG, HONDA R&D EUROPE (DEUTSCHLAND) GMBH, HYDROGENE DE FRANCE, HYOP AS, hySOLUTIONS GmbH, ICELANDIC NEW ENERGY LTD, INTELLIGENT ENERGY LIMITED, ISLENSKA VETNISFELAGID EHF, ITM POWER (TRADING) LIMITED, KOBENHAVNS KOMMUNE, LINDE GAS GMBH, MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, McPhy Energy SA, MINISTERIE VAN INFRASTRUCTUUR EN WATERSTAAT, NEL HYDROGEN AS, NEW NEL HYDROGEN AS, Nissan Motor Manufacturing (UK) Limited, NUCELLSYS GMBH, OPEN ENERGI LIMITED, RENAULT SAS, RENAULT TRUCKS SAS, SOCIETE D'ECONOMIE MIXTE DES TRANSPORTS EN COMMUN DE L'AGGLOMERATION NANTAISE (SEMITAN), SOCIETE DU TAXI ELECTRIQUE PARISIEN, STEDIN DIENSTEN BV, SYMBIOFCELL SA, TECH TRANSPORTS COMPAGNIE, THE UNIVERSITY OF MANCHESTER

PROJECT AND OBJECTIVES

H2ME 2 brings together actions in 8 countries in a 6-year collaboration to deploy over 1,100 vehicles and 20 new HRS and builds on activities conducted as part of the H2ME project.
The project will perform a large-scale market test of a large fleet of fuel cell electric vehicles operated in real-world customer applications across multiple European regions. In parallel, it will demonstrate that the hydrogen mobility sector can support the wider European energy system via electrolytic hydrogen production.

NON QUANTITATIVE OBJECTIVES

- Min of 200 fuel cell vehicles and 20 HRS
- Demonstration of electrolyser integrated HRS operating in grid balancing services
- Vehicles supplied from multiple OEMs, including cars and utility vehicles
- Ensure cross-fertilization of knowledge acquired in the project

PROGRESS & MAIN ACHIEVEMENTS

- Successful start of the demonstration: 113 vehicles and 3 HRS deployed to date (1100 FCEVs and 20 HRS are planned by the end of the project)
- Delivery of 50 FECVS in Paris for taxi fleet operation leading to growing interest for this and other sites for similar and more ambitious deployment
- Fruitful cross-fertilization of knowledge acquired inside and outside of the project - including via a 300 pp event in Brussels

FUTURE STEPS & PLANS

- All 20 HRS planned for the project expected to have been commissioned and be in operation
- Most of the 1100 vehicles planned for the project expected to be deployed
- Solid and growing basis of operational data from vehicles and stations and further fact based analysis on vehicles and HRS performances
- Further exploitation of results with key event during the European week if Cities and regions in Brussels

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The development of a low cost FCEV will require many €100's millions of investment by OEMs, as well as some security of eventual sales volumes – an investment which is challenging when facing a) uncertainties about the customer response to the technology (many OEMs have been disappointed by the market response to battery vehicles), b) technological uncertainties about the eventual cost of the vehicles, and c) uncertainty that the HRS infrastructure will be in place. To overcome these problems, the project is bringing together the key stakeholders in the H2 transport sector and is supporting these activities as well as allowing exchange of best practices between stakeholders and national initiatives.

Increase the electrical efficiency and the durability of the different fuel cells

The H2ME 2 project brings together the same alliance (now expanded to include the Netherlands), but with a focus beyond the deployment of stations alone, and instead working on three main pillars:

- Targeted interventions aimed at improving the performance of fuelling stations, through the deployment of new state of the art stations to support the roll-out plans in each market
- An increase in the scale of deployment of novel "second generation" FC vehicles across all initiatives
- Proving the value of electrolytic hydrogen production as a component of the overall European energy mix, particularly in facilitating the increased penetration of renewables.

All electrolysers will demonstrate an energy consumption lower than 60 kWh/kgH2 from the project start. All vehicles are designed to be operated for min. 6,000 h.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
TTW consumption NEDC (descriptive parameter)	kg/100 km	0.77	1.15	✓	Honda fleet (Denmark)
Yearly Maintenance Costs	EUR/km	0.037	0.03	but 2017 SoA achieved	Honda fleet (Denmark)
FC Durability	Hours	5000	5000	✓	Symbio fleet (Germany)
TTW consumption NEDC (descriptive parameter)	kg/100 km	0.95	1.15	✓	Hyundai fleet (France)
Availability	%	100	98	✓	Hyundai fleet (France)

* As identified in MAWP Addendum 2018-2020, Target year 2020

HAWL

HYDROGEN & WAREHOUSE LOGISTICS

HAWL

LARGE SCALE DEMONSTRATION OF SUBSTITUTION OF BATTERY ELECTRIC FORKLIFTS BY HYDROGEN FUEL CELL FORKLIFTS IN LOGISTICS WAREHOUSES

Project ID:	**325381**
Call topic:	**SP1-JTI-FCH.2012.4.1** - Demonstration of fuel cell powered material handling equipment vehicles including infrastructure
Project total costs:	**€ 9,018,435**
FCH JU max. Contribution:	**€ 4,278,555**
Project start - end:	01/09/2013 - 31/08/2017
Coordinator:	**AIR LIQUIDE ADVANCED BUSINESS, FR**
Website:	**https://hawlproject.eu/en**

BENEFICIARIES: AIR LIQUIDE ADVANCED TECHNOLOGIES SA, BT PRODUCTS AB, CESAB CARRELLI ELEVATORI SPA, CROWN GABELSTAPLER GMBH & CO KG, DIAGMA, FM France SAS, FM LOGISTIC CORPORATE, FM POLSKA SP ZOO, HYPULSION SAS, Toyota Material Handling Europe AB

PROJECT AND OBJECTIVES

The project aims at accelerating market penetration of fuel cell technologies in warehouses in Europe. 8 different fuel cells were developed and certified for use in Europe. Following a successful trial, 46 forklifts are now running at FM warehouse in Neuville aux Bois (France). Productivity is confirmed for a specific application. H2 solution brings flexibility for the operations, reduces risk and is preferred by users of the previous battery solution. A French regulation for warehouse H2 operations was published: this will reduce time for future deployment of H2 forklifts.

PROGRESS & MAIN ACHIEVEMENTS

- Deployment of 50 forklifts: the HAWL deployment becomes one of the main Hydrogen warehouse in Europe
- Publication of a French regulation for warehouse H2 applications which reduces permitting time and brings confidence to the logistic industry.

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

During the project, 8 types of forklifts were qualified for the European market. They can be used in any site in Europe

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
System Electrical efficiency, rated	%	45	50	🛠	Including forklift vehicles: Crown ESR, ToyotaRRE, ToyotaLPE in Neuville
Vehicle lifetime	Hours	87,600	20,000	✓	

* As identified in MAWP Addendum 2018-2020, Target year 2020

HYFIVE
HYDROGEN FOR INNOVATIVE VEHICLES

Project ID:	621219
Call topic:	**SP1-JTI-FCH.2013.1.1** - Large-scale demonstration of road vehicles and refuelling infrastructure VI
Project total costs:	**€ 39,060,997.33**
FCH JU max. Contribution:	**€ 17,970,566**
Project start - end:	01/04/2014 - 31/03/2018
Coordinator:	**GREATER LONDON AUTHORITY,UK**
Website:	**http://www.hyfive.eu/**

BENEFICIARIES: AIR PRODUCTS PLC, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, COPENHAGEN HYDROGEN NETWORK AS, DAIMLER AG, DANISH HYDROGEN FUEL AS, ELEMENT ENERGY LIMITED, Foreningen Hydrogen Link Danmark, HONDA R&D EUROPE (DEUTSCHLAND) GMBH, HYUNDAI MOTOR EUROPE GMBH, ISTITUTO PER INNOVAZIONI TECNOLOGICHE BOLZANO SCARL, ITM POWER (TRADING) LIMITED, LINDE AG, OMV REFINING & MARKETING GMBH, PARTNERSKAB FOR BRINT OG BRAENDSELS CELLER, THINKSTEP AG, TOYOTA MOTOR EUROPE.

PROJECT AND OBJECTIVES

HyFIVE is an ambitious flagship project that has committed four years to demonstrating the commercial viability of hydrogen vehicles and stations in Bolzano, Copenhagen, Innsbruck, London, Munich and Stuttgart.
HyFIVE has seen the delivery of six new refuelling stations, integrating an existing nine, with an initial plan to deliver 110 vehicles – this was revised to 185 in 2016. 154 vehicles were subsequently delivered by BMW, Daimler, Honda, Hyundai and Toyota therefore meeting our original objectives.

PROGRESS & MAIN ACHIEVEMENTS

- Deployed and operated six new state of the art hydrogen refuelling stations (compatible with the SAE J2601 and ISO standard)
- 154 FCEVs delivered and manufacturers involved have developed momentum behind the full commercial introduction of FCEVs around 2020
- Policy changes across Europe to commercialise the sector and prepare the market for high volumes of hydrogen vehicles and interoperable stations.

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Through the project's aim to deploy more than 100 FCEVs, the project enhanced the technical readiness of FCEVs for genuine commercial deployment in Europe, costs to consumers would be considered.

Increase the electrical efficiency and the durability of the different fuel cells

Improvements in Honda's Clarity Fuel Cell system, for example, has achieved an increase in maximum motor output to 130 kW and a power density of the fuel cell stack increased by 60% to 3.1 kW/L. The Clarity Fuel Cell is equipped with a high-pressure tank (70 MPa), increasing the mass of hydrogen that can be stored and extending the range of the vehicle compared to its predecessor FCX Clarity. Coupled with the efficient powertrain and reduced vehicle energy consumption, the Clarity Fuel Cell achieves a best in-class fuel cell vehicle range per full tank of over 700 km in the Japanese JC-08 cycle.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Around two thirds of the dispensed hydrogen were produced via electrolysis with electricity supplied by renewable energy, only 1 per cent was produced via electrolysis using electricity from fossil energy, and one third was produced from natural gas via steam reforming.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Fuel Cell Electric Vehicles					
TTW consumption NEDC (descriptive parameter)	kg/100 km	0.76-0.95	1.15	✓	Consumption range for Hyundai, Honda, Toyota in different countries
Hydrogen Refuelling Stations/Electrolyser					
Electrolyser Footprint	KW/m2	71.90	100	✓	London Teddington, Rainham and Cobham electrolyser
CAPEX for the HRS	Thousand EUR/(kg/day)	less than 1.7	4.-2.1	✓	Cobham HRS
Availability	%	up to ≈99	96	✓	Various HRS

* As identified in MAWP Addendum 2018-2020, Target year 2020

JIVE

JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE

Project ID:	735582
Call topic:	**FCH-01-9-2016** - Large Scale Validation of fuel cell bus fleets
Project total costs:	**€ 106,009,175.36**
FCH JU max. Contribution:	**€ 32,000,000**
Project start - end:	01/01/2017 - 31/12/2022
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**https://www.fuelcellbuses.eu/projects/jive**

BENEFICIARIES: ABERDEEN CITY COUNCIL*, BIRMINGHAM CITY COUNCIL, DUNDEE CITY COUNCIL, EE ENERGY ENGINEERS GMBH, ESWE VERKEHRSGESELLSCHAFT MBH, EUE APS, FONDAZIONE BRUNO KESSLER, HERNING KOMMUNE, HyCologne - Wasserstoff Region Rheinland e.V., HYDROGEN EUROPE, hySOLUTIONS GmbH, IN-DER-CITY-BUS GMBH, LONDON BUS SERVICES LIMITED, MAINZER VERKEHRSGESELLSCHAFT MBH, PLANET PLANUNGSGRUPPE ENERGIE UND TECHNIK GBR, REBELGROUP ADVISORY BV, REGIONALVERKEHR KOLN GMBH, RIGAS SATIKSME SIA, SASA SPA AG SOCIETA AUTOBUS SERVIZID'AREA SPA, SUEDTIROLER TRANSPORTSTRUKTUREN AG, THINKSTEP AG, TRENTINO TRASPORTI SPA, UNION INTERNATIONALE DES TRANSPORTS PUBLICS, VERKEHRS-VERBUND MAINZ-WIESBADEN GESELLSCHAFT MIT BESCHRANKTER HAFTUNG, WEST MIDLANDS TRAVEL LIMITED, WSW MOBIL GMBH

PROJECT AND OBJECTIVES

JIVE is an exciting project that promises to facilitate and expedite the full commercial viability of hydrogen fuel cell buses in Europe. Twenty-two project partners across seven member states are grouping together in three clusters to deploy 139 hydrogen fuel cell buses over six years in the largest project of its kind in Europe. Targets include the operation of 50% of the vehicles for at least 36 months of the project, HRS availability of near 100% and bus availability of 90%, with a requirement that buses cost no more than €650,000 each. The project is ongoing and experiencing delays.

NON QUANTITATIVE OBJECTIVES

- Lessons learnt from joint procurement
- Operators' guide to FCB deployment
- Lessons learnt in operator forum
- Collation of training materials
- Project and wider FCB dissemination and communication activities

PROGRESS & MAIN ACHIEVEMENTS

- The development of a procurement framework by Transport for London should make future FCB procurements an easier process, not just in the UK
- Transport providers have noticed that the demand for FC buses stimulated by the project has already brought about capex price reductions in FC buses

FUTURE STEPS & PLANS

- Despite delays, we plan for most buses to be on the road by October 2020
- The Zero Emission Bus Conference will be held in Cologne in November 2018
- A number of project deliverables associated with reports of lessons learnt and guidance for future procurements to be submitted by October 2020
- TfL framework for bus procurement is expected to be utilised by JIVE, JIVE 2 and future projects to speed up the bus ordering process

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Demand stimulation for fuel cell buses should help drive down the price of fuel cells for transport through economies of scale and other associated efficiency gains.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
HRS Availability of station (after teething period of max. six	%	HRSs not yet operational.	Target is 98% as a minimum with aspiration to achieve >99%	🛠	85 (2012)
Speed of dispensing	kg/min	HRSs not yet operational.	Target is > 3kg/min	🛠	N/A
Vehicle capex	EUR	So far all procurements have stuck to this requirement	625,000 (Project Target <650,000)	✓	850,000 (2014)

* As identified in MAWP Addendum 2018-2020, Target year 2020

HYLIFT-EUROPE

HYLIFT-EUROPE - LARGE SCALE DEMONSTRATION OF FUEL CELL POWERED MATERIAL HANDLING VEHICLES

Project ID:	303451
Call topic:	SP1-JTI-FCH.2011.4.1 - Demonstration of fuel cell-powered Material Handling vehicles including infrastructure
Project total costs:	€ 15,680,960.2
FCH JU max. Contribution:	€ 6,896,871
Project start - end:	01/01/2013 - 31/12/2018
Coordinator:	Ludwig-Boelkow-Systemtechnik GmbH, DE
Website:	http://www.hylift-europe.eu/

BENEFICIARIES: AIR LIQUIDE ADVANCED BUSINESS, AIR PRODUCTS GMBH, COPENHAGEN HYDROGEN NETWORK AS, DANTHERM POWER A.S, ELEMENT ENERGY LIMITED, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, H2 Logic A/S, HEATHROW AIRPORT LIMITED, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, MULAG FAHRZEUGWERK HEINZ WÖSSNER GMBH U. CO. KG, PRELOCENTRE, STILL GMBH

PROJECT AND OBJECTIVES

The aim of HyLIFT-EUROPE is to demonstrate more than 200 fuel cell materials handling vehicles and associated refuelling infrastructure at ≥ 2 sites across Europe (the initial plan foresaw 5-20 sites), making it the largest European trial of hydrogen fuel cell materials handling vehicles so far. This continues efforts of the previous FCH JU supported HyLIFT-DEMO project. In the HyLIFT-EUROPE project the partners demonstrate fuel cell systems in materials handling vehicles from the partner STILL and from non-participating OEMs.

NON QUANTITATIVE OBJECTIVES

- Validation of Total Cost of Ownership & path towards commercial target
- Plan and ensure initiation of supported market deployment beyond 2018
- Best practice guide for hydrogen refuelling station installations
- European dissemination and supporting of the European industry

PROGRESS & MAIN ACHIEVEMENTS

- Demonstration of about 200 hydrogen powered fuel cell materials handling vehicles and the corresponding hydrogen infrastructure at 2 sites
- Demonstration respectively real-world operation of indoor hydrogen refuelling stations including hydrogen supply at two European sites
- Development of a best practice guide for HRS installations and European dissemination and supporting of the European industry in this field.

FUTURE STEPS & PLANS

- Continuation of demo operations at both sites
- Improvement of vehicle performance
- Further increase of vehicle and HRS availability towards 100%
- Opening ceremony respectively dissemination activity in second half of 2018
- TCO and performance evaluation for both demonstration sites.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The deployment of ~200 fuel cell systems in materials handling vehicles constitutes the largest fleet of these vehicles in Europe and therefore contributes to economies of scale.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Forklifts in Prelocentre-System Electrical efficiency, rated	%	45	50	🛠	53 (2015)	HYLIFT-EU-ROPE - Class I forklifts in Prelocentre
Forklifts in Prelocentre-Vehicle lifetime	Hours	87,600	20,000	✓	N/A	

*** As identified in MAWP Addendum 2018-2020, Target year 2020**

HYTRANSIT
EUROPEAN HYDROGEN TRANSIT BUSES IN SCOTLAND

Project ID:	**303467**
Call topic:	**SP1-JTI-FCH.2011.1.1** - Large-scale demonstration of road vehicles and refuelling infrastructure IV
Project total costs:	**€ 17,769,854.34**
FCH JU max. Contribution:	**€ 6,999,999**
Project start - end:	01/01/2013 - 31/12/2018
Coordinator:	**BOC LIMITED, UK**
Website:	**http://aberdeeninvestlivevisit.co.uk/Invest/Aberdeens-Economy/City-Projects/H2-Aberdeen/Hydrogen-Bus/Hydrogen-Bus-Project.aspx**

BENEFICIARIES: ABERDEEN CITY COUNCIL*, DANTHERM POWER A.S, ELEMENT ENERGY LIMITED, HYDROGEN, FUEL CELLS AND ELECTRO-MOBILITY IN EUROPEAN REGIONS, PLANET PLANUNGSGRUPPE ENERGIE UND TECHNIK GBR, STAGECOACH BUS HOLDINGS LIMITED, VAN HOOL N.V.

PROJECT AND OBJECTIVES

The HyTransit project started in 2013 and will run through to the end of 2018. The project aims to contribute to the commercialization of hydrogen buses in Europe through the introduction of a fleet of six hybrid fuel cell buses and a hydrogen production and refuelling station in Aberdeen (Scotland).The main project objective is to demonstrate that a fuel cell bus is capable of meeting the everyday operational performance of an equivalent diesel bus on demanding inter-city routes in the UK.

NON QUANTITATIVE OBJECTIVES

- Safety issues report
- Project and wider FCB dissemination and communication activities
- Scottish hydrogen bus fleet case study
- Outreach to other European bus projects
- Strategy for continuing bus operation and HRS

PROGRESS & MAIN ACHIEVEMENTS

- 99.4% availability of the Kittybrewster HRS since the beginning of operation
- Nearly 1 million kilometres driven by the hybrid fuel cell buses
- 100 tons of CO2 saved in comparison to Euro VI buses

FUTURE STEPS & PLANS

- Consortium meeting to discuss the key lessons learnt from the project
- Complete, and finalize, the outstanding deliverables for the project in preparation for the project end in December 2018
- Finalize a strategy for the post-project operation of the buses and the HRS

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

HyTransit forms the backbone of the Aberdeen Hydrogen Bus Project, which together with four buses from the High V.LO-City project led to the deployment of Europe's largest fleet of hydrogen buses to date (JIVE and JIVE 2 projects).

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Fuel Cell Buses						
Availability of bus	%	77	95	🛠	69 (2012)	Buses in Aberdeen
TTW consumption SORT 1	kg/100 km	9.62	8	🛠	9 (2010)	
TTW consumption SORT 2	kg/100 km	9.07	8	🛠	9 (2010)	
Hydrogen Refuelling Station						
Fuel cell system durability	Hours	12,000	20,000	🛠	N/A	HRS in Aberdeen
Availability, in period 2017	%	98.6	96	✓	95 (2015)	

*** As identified in MAWP Addendum 2018-2020, Target year 2020**

SWARM

DEMONSTRATION OF SMALL 4-WHEEL FUEL CELL PASSENGER VEHICLE APPLICATIONS IN REGIONAL AND MUNICIPAL TRANSPORT

Project ID:	303485
Call topic:	SP1-JTI-FCH.2011.1.1 - Large-scale demonstration of road vehicles and refuelling infrastructure IV
Project total costs:	€ 15,294,319.66
FCH JU max. Contribution:	€ 6,712,985.6
Project start - end:	01/10/2012 - 31/10/2018
Coordinator:	ELEMENT ENERGY LIMITED, UK
Website:	http://www.swarm-project.eu/

BENEFICIARIES: AIR LIQUIDE ADVANCED TECHNOLOGIES SA, BIRMINGHAM CITY COUNCIL, COVENTRY UNIVERSITY ENTERPRISES LIMITED, DEUTSCHES FORSCHUNGSZENTRUM FUER KUENSTLICHE INTELLIGENZ GMBH, EWE-Forschungszentrum für Energietechnologie e. V., GESPA GMBH, H2O E-MOBILE GMBH, JADE HOCHSCHULE WILHELMSHAVEN/OLDENBURG/ELSFLETH, PLANET PLANUNGSGRUPPE ENERGIE UND TECHNIK GBR, RIVERSIMPLE ENGINEERING LIMITED, RIVERSIMPLE LLP, RIVERSIMPLE MOVEMENT LIMITED, SERVICE PUBLIC DE WALLONIE, THE UNIVERSITY OF BIRMINGHAM, TUV SUD AG, TUV SUD PRODUCT SERVICE GMBH, UNIVERSITAET BREMEN, UNIVERSITE DE LIEGE, UNIVERSITE LIBRE DE BRUXELLES

PROJECT AND OBJECTIVES

This project will establish a demonstration fleet of small passenger vehicles that builds on and expands existing hydrogen refuelling infrastructure. Three European regions will be participating in this effort: the UK (the Midlands and Wales), Belgium (the Brussels area and Wallonia), and North Rhine Westphalia Germany (Cologne/Weser Ems). Each of these regions will deploy a new hydrogen refuelling site to close the gaps in a continuous 'hydrogen highways' that leads from Scotland via the Midlands to London, connecting to Brussels and on to Cologne and Hamburg/Scandinavia/Berlin.

NON QUANTITATIVE OBJECTIVES

- Low cost small vehicles – the vehicles produced in this project will all have low volume production costs
- New regional hydrogen fuelling networks
- Strong representation of European SME's and European research institutions
- Demonstrate a complementary approach to hydrogen vehicle drive trains

PROGRESS & MAIN ACHIEVEMENTS

- Developement and operation for five Microcab Hydrogen Electric Vehicles (H2EVs) since 2015 alongside H2 refuelling in Coventry and Birmingham (UK)
- Preparation for trial of 20 cars and associated HRS in Abergavenny (UK) completed by Riversimple
- Air Liquide HRS in Brussels and Frechen (DE) built and respectively in operation since mid-2016 and mid-2018
- Developement

FUTURE STEPS & PLANS

- Delivery of 3 next gen H2EVs and 3 Left Hand Drive vehicles by Microcab
- Trial fully started in Abergavenny with 20 vehicles and associated refuelling station
- 2 prototypes Elano e-mobiles developed by Jade University
- All activities completed by October 2018

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

- Delivery and operation of a critical mass of passenger and delivery vehicles and infrastructure,
- Extensive performance monitoring via GMS/GPS protocols
- Development of commercialization and market entry strategies
- Enlargement and extension of existing hydrogen infrastructure by interlinking the (new) project sites with existing sites and projects in order to establish a chain of hydrogen refuelling stations from Scotland to North Scandinavia, and South & East Germany via London and Brussels
- Intensive liaison and interaction with existing demonstration projects,
- Hydrogen delivery at 10€/kg
- Implementation of cost reduction strategies for the second phase equipment,
- Low cost vehicles and standardized refuelling equipment for achievement of stringent cost reduction targets

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
CAPEX for the HRS	Thousand EUR/(kg/day)	16.5	4-2.1	🛠	Coventry HRS
Availability, in period 2017	%	97	96	✓	
Mean time between failures (MTBF)	days	5.16	2	✓	
Lifetime	years	10	12	🛠 SoA 2017 achieved	Birmingham HRS
Durability	years	5	5	✓	
Availability, in period	%	100	96	✓	
Availability, since start	%	70	96	✓	

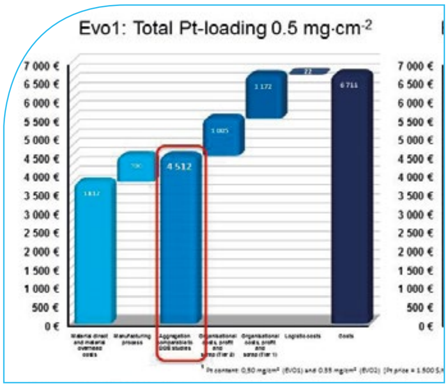
* As identified in MAWP Addendum 2018-2020, Target year 2020

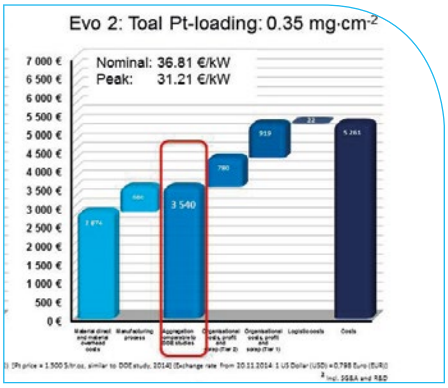
PANEL 2
NEXT GENERATION OF PRODUCTS – TRANSPORT

Auto-Stack CORE

AUTOMOTIVE FUEL CELL STACK CLUSTER INITIATIVE FOR EUROPE II

Project ID:	325335
Call topic:	SP1-JTI-FCH.2012.1.2 - Next Generation European Automotive Stack
Project total costs:	€ 14,673,625.27
FCH JU max. Contribution:	€ 7,757,273
Project start - end:	01/05/2013 - 31/07/2017
Coordinator:	ZENTRUM FUER SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG, BADEN-WUERTEMBERG, DE
Website:	www.autostack.zsw-bw.de/index.php?id=1&L=1





BENEFICIARIES: BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, BELENOS CLEAN POWER HOLDING AG, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, FREUDENBERG FCCT SE & CO. KG, FREUDENBERG VLIESSTOFFE KG, GREENERITY GMBH, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, PAUL SCHERRER INSTITUT, POWERCELL SWEDEN AB, REINZ-DICHTUNGS GMBH, SOLVICORE GMBH & CO KG, SWISS HYDROGEN SA, SYMBIOFCELL SA, VOLKSWAGEN AG, VOLVO TECHNOLOGY AB

PROJECT AND OBJECTIVES

¨AutoStack Core¨ establishes a coalition with the objective to develop best-of-its-class automotive stack hardware with superior power density and performance while meeting commercial target cost. The project consortium combines the collective expertise of automotive OEMs, component suppliers, system integrators and research institutes and thus removes critical disconnects between stakeholders. Within the project two stack evolutions were designed and tested. The second evolution achieved a peak power density of 4 kW/l. A third evolution was designed. The project finished July 31st 2017.

PROGRESS & MAIN ACHIEVEMENTS

- Peak power density under operating conditions agreed upon in DoW 4 kW/l
- Endurance testing for more than 3,000 h under dynamic load cycling
- Specific cost according to DoE model 36.81 €/kW

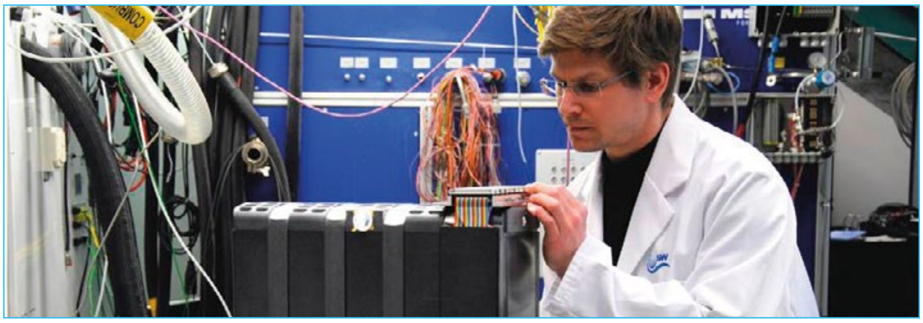
FUTURE STEPS & PLANS

- Project is finished
- The stack is offered as a prototype through Powercell and was selected as one stack to be used by Nikol-motors for truck application
- A German national follow-up project (AutoStack -Industry) in two phases involving 4 OEMs was started with a total budget of 60 M€

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

ReReduce the use of the EU defined 'Critical raw materials

Minimum Pt contents was found to 30 µgcm-2



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

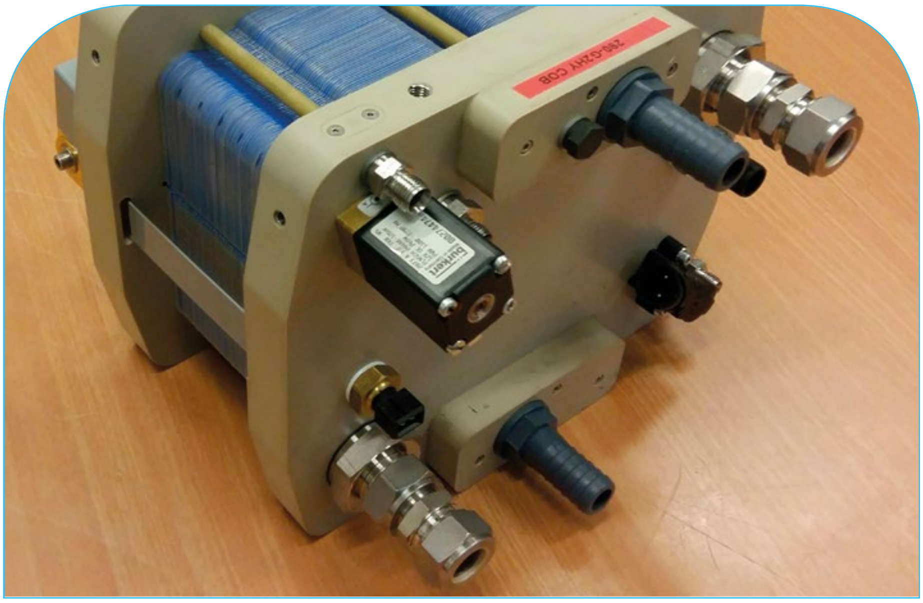
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA Year)	DESCRIPTION
Est. stack CAPEX (per kW) @ mass production	€/kW	36.81	50	✓ @ mass production	27.56 (2017)	Based on nominal power from a design specific cost study subcontracted to an independent party assuming a production level of 30 000 units per year using the boundary conditions of the DoE cost studies.
Areal power density	W/cm2	0.992	≈1	✓	N/A	Begin of life
Cell Volumetric power density	kW/l	4.05	2	✓	> 3.1 (2015)	Based on peak load under reference operating conditions as described in DoW

*As identified in AIP 2012, Target Year 2017

COBRA
COATINGS FOR BIPOLAR PLATES

Project ID:	621193
Call topic:	SP1-JTI-FCH.2013.1.2 - Research & Development on Bipolar Plates for PEM fuel cells
Project total costs:	€ 3,803,697.6
FCH JU max. Contribution:	€ 2,339,595
Project start - end:	01/04/2014- 31/12/2017
Coordinator:	COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.cobra-fuelcell.eu

BENEFICIARIES: BORIT NV, FUNDACION CIDETEC, IMPACT COATINGS AB, INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE LYON, SYMBIOFCELL SA



PROJECT AND OBJECTIVES

COBRA aims at developing and improving the PEMFC stack components and especially metallic bipolar plates. For automotive fuel cell stacks most of the OEMs have already chosen metallic bipolar plates as technological solutions for cost and process ability concerns. Thus, the COBRA focuses on two main topics to reach the performances, durability and cost objectives: the improvements of manufacturing process and the development of new coatings as alternative to expensive state-of-art gold coating. The project ended in December 2017.

NON QUANTITATIVE OBJECTIVES

PROGRESS & MAIN ACHIEVEMENTS

- Development of new coating for PEMFC bipolar plate (MaxPhase)
- Cost analysis of complete manufacturing process for COBRA technology
- Real field testing for a 5 kW COBRA stack in Hy-Kangoo vehicle (9300 kms)

FUTURE STEPS & PLANS

- Project is finished
- Long-term real field testing could be very useful to complete the project results (lack of time)

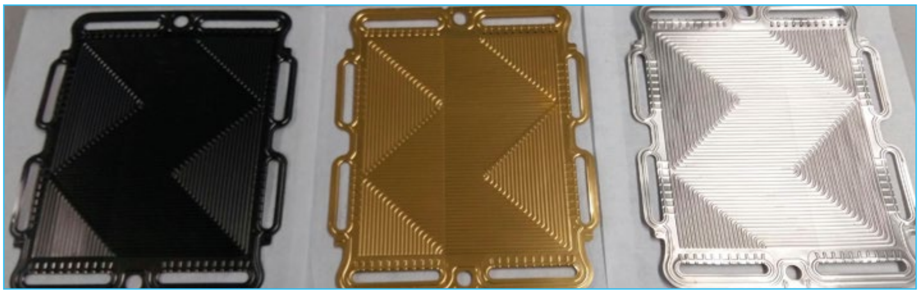
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Development of low cost manufacturing process and coating material for bipolar plate

Reduce the use of the EU defined 'Critical raw materials'

Replacement of gold coatings by low cost alternative solutions.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TAR-GET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA Year)	DESCRIPTION
Corrosion anode	µA/cm²	-0.1	<10	✓	0 (target : 1) (2020-DOE Target year)	Bipolar plate corrosion resistance
Corrosion cathode	µA/cm²	1.07	<10	✓	< 1 (target : <1) (2020-DOE Target year)	Bipolar plate corrosion resistance
Area specific resistance	mohm.cm²	5	<10	✓	6 (target : < 10) (2020-DOE Target year)	Bipolar plate specifications
Cost	euro/kW	9.8	2.5	🔧	7 (target : 3 for 500000 stack per year) (2020-DOE Target year)	Bipolar plate specifications
Rated stack total efficiency (LHV)	%	46	55	🔧	N/A	FC stack
Cell Volumetric power density	kW/l	1.5	7.3	🔧	N/A	FC stack

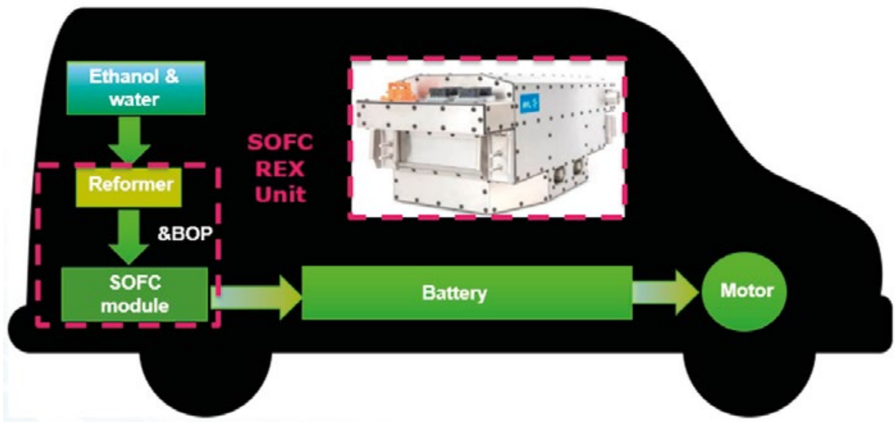
* As identified in MAWP Addendum 2018-2020 and AIPs 2012-2013, Target Years 2017-2020

COMPASS

COMPETITIVE AUXILIARY POWER UNITS FOR VEHICLES BASED ON METAL SUPPORTED STACK TECHNOLOGY

Project ID:	700200
Call topic:	FCH-01.5-2015 - Develop technologies for achieving competitive solutions for APU transport applications based on existing technology
Project total costs:	€ 3,920,302.5
FCH JU max. Contribution:	€ 3,920,302.5
Project start - end:	01/10/2016 - 30/09/2019
Coordinator:	AVL LIST GMBH, AT
Website:	www.h2020-compass.eu

BENEFICIARIES: FORSCHUNGSZENTRUM JULICH GMBH, Nissan Motor Manufacturing (UK) Limited, PLANSEE SE



PROJECT AND OBJECTIVES

This project is worldwide the first (publically known) approach to integrate SOFC based APUs (Auxiliary Power Units) into electrical powertrains. With this innovative approach, the attractiveness of Battery electric vehicles can be increased due to significant improvements in vehicle range and recharging times. Within the COMPASS project an advanced APU system will be developed, to convert chemical energy stored in a high energy density fuel tank (hydrocarbon, e.g. ethanol) into electricity, to recharge the vehicle HV battery for electrical driving.

PROGRESS & MAIN ACHIEVEMENTS

- Specification documents, DVP & APU to vehicle integration framework complete
- Advanced component for APU developed
- Advanced Simulation tool for Rapid starting developed

FUTURE STEPS & PLANS

A stack supplier and OEM partner are now actively recruited to join the consortium by AVL.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

A work package is devoted to this task.

Increase the electrical efficiency and the durability of the different fuel cells

A work package is devoted to this task.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Fuel Cell system durability	hours	5000	✓
Rated system total efficiency (LHV)	%	55	✓
APU CAPEX	€/kW	<2000	🛠
Est. APU CAPEX @ mass production	€/kW	<2000	✓ (projection)

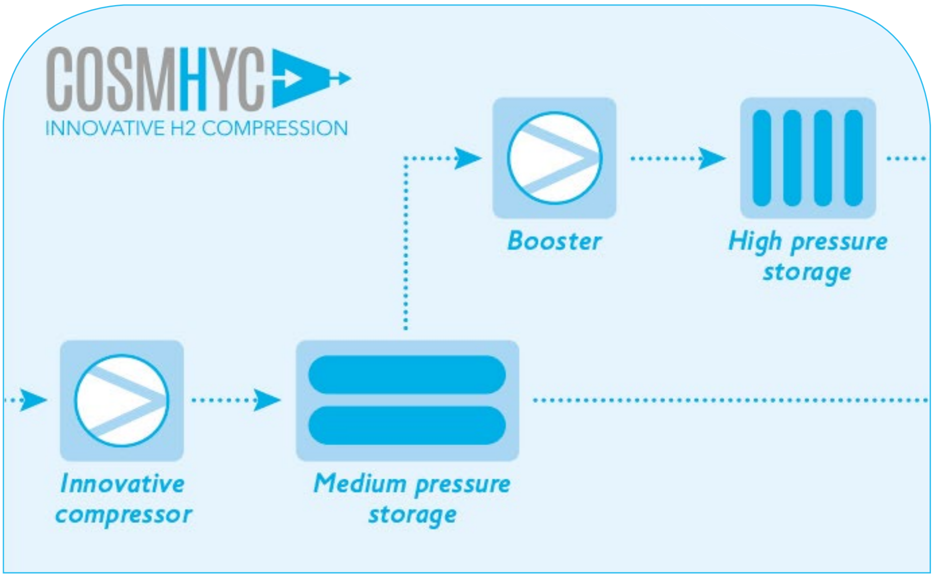
* As identified in MAWP Addendum 2018-2020 and AIPs/MAIPs, Target Years 2016-2020

COSMHYC

COMBINED HYBRID SOLUTION OF MULTIPLE HYDROGEN COMPRESSORS FOR DECENTRALISED ENERGY STORAGE AND REFUELLING STATIONS

Project ID:	736122
Call topic:	**FCH-01-8-2016** - Development of innovative hydrogen compressor technology for small scale decentralized applications for hydrogen refuelling or storage
Project total costs:	**€ 2,496,830**
FCH JU max. Contribution:	**€ 2,496,830**
Project start - end:	01/01/2017 - 30/09/2020
Coordinator:	**EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, DE**
Website:	**www.cosmhyc.eu**

BENEFICIARIES: Ludwig-Boelkow-Systemtechnik GmbH, MAHYTEC SARL, NEL HYDROGEN AS, STEINBEIS 2I GMBH, STEINBEIS INNOVATION GGMBH



PROJECT AND OBJECTIVES

COSMHYC develops and test a hybrid compression solution for hydrogen refuelling stations by combining an innovative compressor with a booster and optimizing both technologies for a compression from 1 to 1000bar. The objectives are to lower investment and operational costs, to reduce the noise level related to the booster, to increase the availability of stations, and thus to increase the efficiency of hydrogen delivery. MAHYTEC, EIFER and NEL are currently developing the compressors and focusing on the integration of both technologies, which will be tested in a comprehensive way.

NON QUANTITATIVE OBJECTIVES

- Modular and scalable
- Increase reliability
- Perform a cost of ownership assessment

PROGRESS & MAIN ACHIEVEMENTS

- Definition of technical requirements for the compression solution for selected applications (refuelling of FC cars, buses and trains...)
- Preliminary design of the innovative compressor along with the definition of the specification of the monitoring and control system
- Design of a mechanical compressor with major improvements in terms of efficiency and life time

FUTURE STEPS & PLANS

- Construction and tests of the mechanical compressor, integrating innovative features, advanced materials and noise reduction packaging
- Construction and tests of the innovative compressor along with safety analysis and pre-certification process
- Long-time testing of the COSMHYC compression solution as a virtual compressor following joint test programs and protocols
- Collection of operative and performance data and technical economic evaluation comparing processor concepts for selected applications
- Definition of a roadmap towards exploitation of the different compression solutions developed in COSMHYC for preparing their market deployment

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

- Possibility to use waste heat (no electricity consumption)
- Optimized compression system designed to minimize energy consumption below 6 kWh/kg
- Strong focus on technical-economic assessment

Reduce the use of the EU defined 'Critical raw materials'

- No platinum intrinsically
- No rare earths

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
Energy consumption	**kWh/kg**	**6**	**6**	✓	**3 (2017)**
Degradation	**%/9 months**	**5**	**10**	✓	**N/A**
Specific costs	**k€/kg*day**	**3.7**	**N/A**	🛠	**5-12**

*** Project's own objectives**

DIGIMAN

DIGITAL MATERIALS CHARACTERISATION PROOF-OF-PROCESS AUTO ASSEMBLY

Project ID:	736290
Call topic:	**FCH-01-1-2016** - Manufacturing technologies for PEMFC stack components and stacks
Project total costs:	€ 3,486,965
FCH JU max. Contribution:	€ 3,486,965
Project start - end:	01/01/2017 - 31/12/2019
Coordinator:	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.digiman.eu

BENEFICIARIES: FREUDENBERG PERFORMANCE MATERIALS SE & CO KG, INTELLIGENT ENERGY LIMITED, PRETEXO, THE UNIVERSITY OF WARWICK, TOYOTA MOTOR EUROPE

PROJECT AND OBJECTIVES

The project aims at advancing to MRL6 the critical steps of the PEM fuel cell assembly processes and in-line QC/end-of-line test and to demonstrate a route to automated volume process production capability within automotive best practices (cycle time optimization, cost reduction and quality control). The project will include digital codification of properties of GDL to establish yield impacting causes and effects relationships within the value chain (Industry 4.0 standards). The outcome will be a blueprint for beyond current state automotive PEM fuel cell manufacturing capability in Europe.

NON QUANTITATIVE OBJECTIVES

- Analyse the influence of GDL defects on performance
- Develop a scanning method for roll-stock GDL to identify defects
- On-line characterization of GDL properties
- Develop a Proof of Process and a blue print design for the stack automated manufacturing process

PROGRESS & MAIN ACHIEVEMENTS

- KPIs for i) fully automated stack assembly / test via automotive best practice and ii) stack performance at handover into an automotive production lin
- Proof-of-process demonstrator equipment for the uplifted cell assembly automation has been specified and designed (and is currently in manufacture)
- Deep characterization of GDL properties has enabled the development of meaningful automatic scanning techniques for digital QC and upstream/downstream

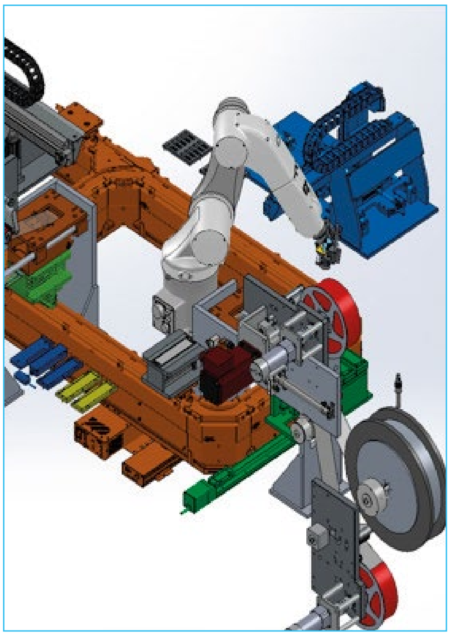
FUTURE STEPS & PLANS

- Finalize the validation of the Vision System for scanning roll-stock GDL
- Finalize the PoP and the blue print design
- Analyse the influence of some GDL defects on performance: propose a methodology to do so
- Virtual engineering and the development of the 'Digital Twin' plus a validation programme for stacks assembled via the PoP demonstrator

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The PoP of automated assembly of stack will allow the development of a Blueprint design for automated assembly of cells will reduce stack manufacture Capex and operational costs reducing cost.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET
Cycle time cell assembly	seconds	1st year project	<5
Component yield	%		>95
Material utilization	%		>99
Cost reduction (stack manufacturing)	%		>15
Increase AC64 stack process technology from TRL4 to TRL6	TRL		6

* Project's own objectives

Fit-4-AMandA

FUTURE EUROPEAN FUEL CELL TECHNOLOGY: FIT FOR AUTOMATIC MANUFACTURING AND ASSEMBLY

Project ID:	735606
Call topic:	FCH-01-1-2016 - Manufacturing technologies for PEMFC stack components and stacks
Project total costs:	€ 2,999,185
FCH JU max. Contribution:	€ 2,999,185
Project start - end:	01/03/2017- 29/02/2020
Coordinator:	UNIRESEARCH BV, NL
Website:	www.fit-4-amanda.eu

BENEFICIARIES: EWII FUEL CELLS A/S, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V., Proton Motor Fuel Cell GmbH, TECHNISCHE UNIVERSITAET CHEMNITZ, UPS EUROPE SA, USK KARL UTZ SONDERMASCHINEN GMBH

PROJECT AND OBJECTIVES

Fit-4-AMandA's ambition is to modify the current design of PEMFC stacks and stack components, and build an entirely new equipment facilitating automation of the stack assembly process (including inline non-destructive tests). Furthermore, it will demonstrate the resulting mass-produced stacks in real environment – by integration the output into a Light-Commercial-Vehicle. The project will offer the mass production machine innovative solutions, which effect process, product and tools with the objective to bring the MRL from 5 to 7.

NON QUANTITATIVE OBJECTIVES

- Development of fast inline non-destructive quality assurance (NDT-QA) test methods for automated production of MEAs and stack assembly
- FC Market study

PROGRESS & MAIN ACHIEVEMENTS

- Stack design optimized for automatic manufacturing: design, tolerances, material and surfaces; assembly drawings with the relevant parameters
- Design of machine system for automatic fuel cell stack assembling, consisting of mechanical design, pneumatic and electrical design and control system
- Fast in-line tests of fuel cell components and sub-assemblies, addressing integrity, quality, tightness and post-process control.

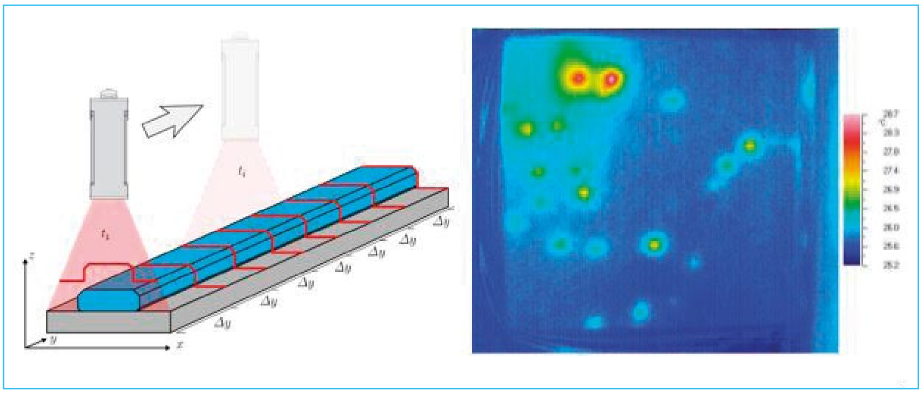
FUTURE STEPS & PLANS

- Develop a new bonding technique for the BPP to ensure it meets the technical and performance requirements
- Negotiate with suppliers to ensure that materials and equipment relevant for the building of the mass manufacturing machine is delivered on time
- Delays due to the procurement of materials and equipment. Come up with out of the box solutions to ensure that the project is completed on time
- To minimize delay, system can be equipped with a PM SoA stack first which can be replaced when the machine stack is available

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Develop a mass manufacturing machine that enables high volume production of fuel cell stacks in a cost effective way. Thus eventually lowering the production cost of fuel cell systems to be used in transport applications.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

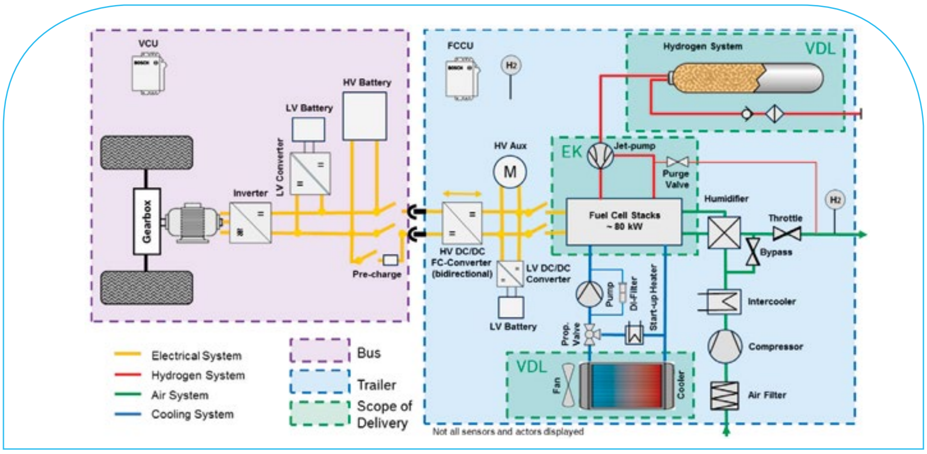
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack electrical efficiency (LHV) - observed	%	51	55	🛠
Cell Volumetric power density	kW/l	1.42	7.3	🛠

*** As identified in MAWP Addendum 2018-2020, Target Year 2020**

Giantleap

GIANTLEAP IMPROVES AUTOMATION OF NON-POLLUTING TRANSPORTATION WITH LIFETIME EXTENSION OF AUTOMOTIVE PEM FUEL CELLS

GIANTLEAP



Project ID:	700101
Call topic:	FCH-01.2-2015 - Diagnostics and control for increased fuel cell system lifetime in automotive applications
Project total costs:	€ 3,260,297.5
FCH JU max. Contribution:	€ 3,260,297.5
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	SINTEF AS, NO
Website:	www.giantleap.eu

BENEFICIARIES: BOSCH ENGINEERING GMBH, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, ELRINGKLINGER AG, INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L'AMENAGEMENT ET DES RESEAUX, STIFTELSEN SINTEF, SVEUCILISTE U SPLITU, FAKULTET ELEKTROTEHNIKE, STROJARSTVA I BRODOGRADNJE, UNIVERSITE DE FRANCHE-COMTE, VDL BUS & COACH BV, VDL BUS CHASSIS BV, VDL BUS ROESELARE, VDL ENABLING TRANSPORT SOLUTIONS BV

PROJECT AND OBJECTIVES

Giantleap aims to develop new diagnostic, prognostic and control approaches to improve the availability and reliability of fuel-cell electric buses (FCEBs). FCEB demonstrations have reported multiple issues, often not related to the fuel cells but more with the balance-of-plant (BoP), especially compressors. Giantleap shall demonstrate the operation of a FCEB system with new algorithms and analyse the produced data to validate the approach. To further increase reliability and availability, the FCEB is actually a battery bus with a detachable fuel-cell range extender.

NON QUANTITATIVE OBJECTIVES

- Flexible conversion of battery buses into hydrogen buses, flexibility for operators
- Better understanding of rejuvenation techniques in fuel cells
- Provide publicly available data for BoP

PROGRESS & MAIN ACHIEVEMENTS

- Development of relay-based, inexpensive sensing technique for low-frequency resistance in fuel cells
- Development of comprehensive prognostic software for fuel cells and balance-of-plant units in FC systems
- Development and testing of passive, highly reliable, stack-integrated hydrogen recirculation system.

FUTURE STEPS & PLANS

- Implementation of control & PHM system
- Demonstration activities
- Validation of approaches with experimental data
- Exploitation plan and business case for end users
- Public data collection

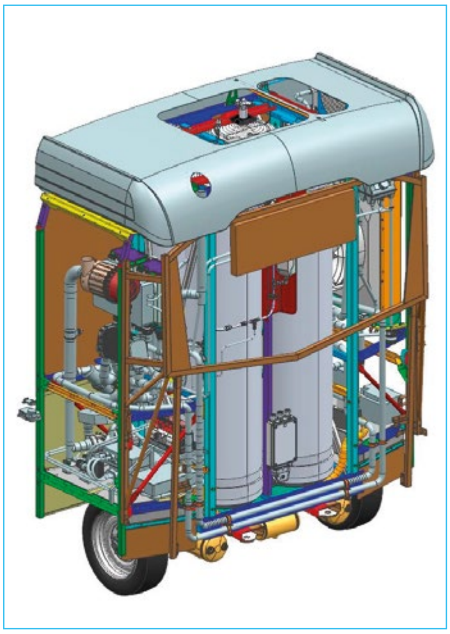
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Focus on increasing system and stack lifetimes, which directly contribute to a lower TCO.

Increase the electrical efficiency and the durability of the different fuel cells

Focus on increasing durability of fuel cells (also systems) with multiple innovative control and PHM approaches.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
FC Bus Cost	k€	565	625	✓	N/A	Estimate by VDL for production at scale
Availability	%	85	90	🔧	85 (2017)	Demonstration not started yet.
Stack lifetime for buses	hours	10,000	20,000	✓	25,000 (2017)	N/A

*As identified in MAWP Addendum 2018-2020, Target Year 2020

H2REF

DEVELOPMENT OF A COST EFFECTIVE AND RELIABLE HYDROGEN FUEL CELL VEHICLE REFUELLING SYSTEM

Project ID:	671463
Call topic:	**FCH-01.5-2014** - Development of cost effective and reliable hydrogen refuelling station components and systems for fuel cell vehicles applications
Project total costs:	€ 7,127,941.25
FCH JU max. Contribution:	€ 5,968,554
Project start - end:	01/09/2015- 31/05/2019
Coordinator:	CENTRE TECHNIQUE DES INDUSTRIES MECANIQUES, FR

BENEFICIARIES: H2NOVA, HASKEL EUROPE LTD, HASKEL FRANCE, HEXAGON RAUFOSS AS, LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH, THE CCS GLOBAL GROUP LIMITED, UNIVERSITE DE TECHNOLOGIE DE COMPIEGNE.

PROJECT AND OBJECTIVES

H2REF addresses compression and buffering of H2 for refuelling of 70 MPa vehicles and aims to bring a novel cost effective, high-performance, and reliable hydraulics-based system, from TRL 3 to 6. Following design of the process and of the core compression device, a full scale prototype compression and buffering module (CBM) was built in a test area. Following compression device testing, the full CBM including the number of compression devices for the complete compression and dispensing cycle will be tested in closed loop operation. The CBM will be interfaced with a vehicles dispenser for demo.

NON QUANTITATIVE OBJECTIVES

- Techno-economic analysis based on project results
- Have the technology covered by the RCS framework

PROGRESS & MAIN ACHIEVEMENTS

- CBM process developed, full scale prototype system built, and compression device hydraulic actuation successfully tested
- Suitable bladder material identified and accumulator developed and successfully qualified for functional testing in CBM
- New hydrogen test area set up within consortium partner (Haskel) premises for testing of system in hydrogen service

FUTURE STEPS & PLANS

- Functional testing of the bladder accumulator in hydrogen service
- Closed-loop functional testing of the CBM process with a complete set of accumulators
- Interfacing of CBM with a dispenser and demonstration of vehicle refuelling using this process

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

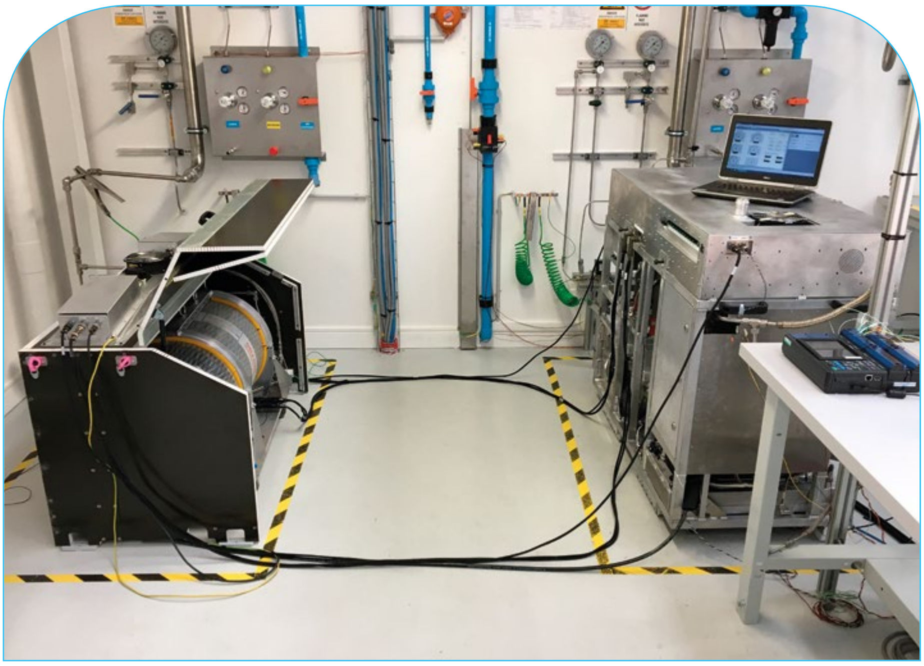
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
TRL	N/A	3.00	Bring from TRL3 to TRL6 a technical solution providing a step change	(due later) Through an extensive component and system testing programme
CBM manufacturing cost	K€	0.00	300 assuming 50 units/yr	(due later) Through the novel implementation of mature technologies (hydraulics and composite pressure vessels)
Throughput	kg/d	0.00	Throughput of 720 kg/d from 7 MPa with a pumping power of 75 kW	(due later) No long recharge of buffers needed, allowing a throughput of 30 kg/h 24h/d from 7 MPa with a pumping power of 75 kW
Average consumption	kWh/kg	0.00	1.5	(due later) Thanks to the conservation of source storage pressure

* As identified in AWP 2014 and Projects own objectives, Target Years 2018-2019

HYCARUS
HYDROGEN CELLS FOR AIRBORNE USAGE

Project ID:	325342
Call topic:	SP1-JTI-FCH.2012.1.6 - Fuel cell systems for airborne application
Project total costs:	€ 12,064,473.93
FCH JU max. Contribution:	€ 5,219,265
Project start - end:	01/05/2013 - 31/12/2018
Coordinator:	ZODIAC AEROTECHNICS SAS, FR
Website:	www.hycarus.eu

BENEFICIARIES: AIR LIQUIDE ADVANCED TECHNOLOGIES SA, ARTTIC, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DASSAULT AVIATION SA, DRIESSEN AEROSPACE CZ SRO, INSTITUTO NACIONAL DE TECNICA AEROESPACIAL, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, ZODIAC CABIN CONTROLS GMBH, Zodiac ECE



PROJECT AND OBJECTIVES

The main objective of HYCARUS is to develop a Generic Fuel Cell System (GFCS) in order to power non-essential aircraft applications such as a galley in a commercial aircraft or to be used as a secondary power sources on-board business jets. Demonstration of GFCS performances in relevant and representative cabin environment (TRL 6) will be achieved through flight tests on-board a Dassault Falcon aircraft. In addition, HYCARUS will assess how to valorise the by-products (especially heat and Oxygen Depleted Air - ODA) produced by the fuel cell system to increase its global efficiency.

PROGRESS & MAIN ACHIEVEMENTS

- All System verification tests completed including dysfunctional tests defined in accordance with the System Safety Analysis (SSA) made
- EMI qualification tests (D0160 Section19, 20, 21, 25) have been performed successfully on the Fuel Cell System
- Completion of the Fuel Cell system prototype which will be used for the Flight tests campaign

FUTURE STEPS & PLANS

- End of Qualification tests (Climatic and vibration tests) according to the D0160 standard at Fuel Cell system level
- Flight tests clearance (permit to fly)
- Flight tests campaign (3 flights are planned)

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The main objectives of HYCARUS is to develop a Generic Fuel Cell System (GFCS) in order to power non-essential aircraft applications such as a galley in a commercial aircraft or to be used as a secondary power sources on board business jets. Demonstration of GFCS performances in relevant and representative cabin environment (TRL 6) will be achieved through flight tests on-board a Dassault Falcon aircraft.

QUANTITATIVE TARGETS AND STATUS

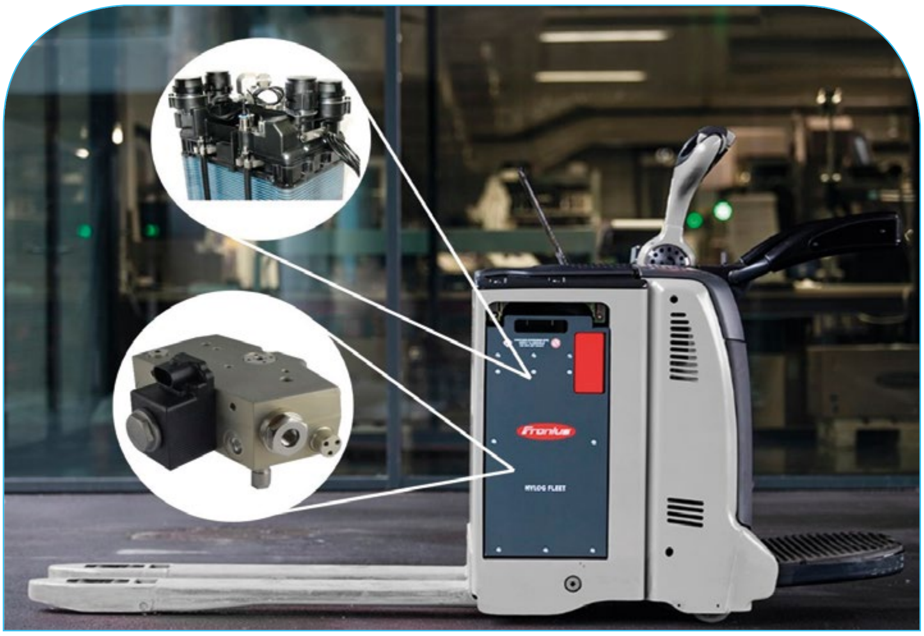
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/ project (SoA year)	DESCRIPTION
KPI - System total efficiency (LHV), observed	%	45	25	✓	55	Fuel cell system efficiency (LHV) at 25% of rated power: 55%
Durability	hours	[-]	3,500/10,000	🛠	N/A	N/A

* As identified in MAWP Addendum 2018-2020 and AIP 2012, Target Years 2018-2020

INLINE

DESIGN OF A FLEXIBLE, SCALABLE, HIGH QUALITY PRODUCTION LINE FOR PEMFC MANUFACTURING



Project ID:	735367
Call topic:	FCH-01-3-2016 - PEMFC System Manufacturing technologies and quality assurance
Project total costs:	€ 3,286,068.75
FCH JU max. Contribution:	€ 3,286,068.75
Project start - end:	01/02/2017 - 31/01/2020
Coordinator:	PROFACTOR GMBH, AT
Website:	http://inline-project.eu/

BENEFICIARIES: ELRINGKLINGER AG, FRONIUS INTERNATIONAL GMBH, Karlsruher Institut fuer Technologie, OMB SALERI SPA

PROJECT AND OBJECTIVES

The Project aims on a development of a design for a high qualitative manufacturing of Proton Exchange Membrane fuel cells. The objectives include the redesign of the media supply unit, the development of automated Quality inspection methods and the scalability of the manufacturing process. Currently the original manufacturing process has been successfully simulated, and the first Demonstrators for inline Quality Control are built up. Also some Engineering samples of the redesigned media supply unit and the new manufactured tank Valve are available.

PROGRESS & MAIN ACHIEVEMENTS

- Redesigned media supply unit
- Simulation of the full manufacturing process at it is currently run at Project Partners
- First Demonstrators of assisted assembly Station and inline quality Control

FUTURE STEPS & PLANS

- Manufacturing of each 10 Engineering samples of Media Supply Unit and Tank valve
- Manufacturing of 20 Hylog Fleet PEMFC Systems
- Fully operational assisted assembly station
- 2 functional non-destructive inline quality control methods
- Full Simulation of the new design of the manufacturing process

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The Addition of assisted assembly and automated inline Quality Control to reach Scalability in the production process will reduce production costs and lower cycle time and increase the quantity at the same time.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	TARGET YEAR	TARGET SOURCE
Project process: Production Rate	(stacks/yr)	100	100-50,000	✓	2016	AWP 2016
Rated FC system durability	hours	20,000	5000	✓	2020	MAWP Addendum 2018-2020
System availability	%	100	98	✓	2020	MAWP Addendum 2018-2020

* As identified in MAWP Addendum 2018-2020 and AWP 2016, Target Year 2020

INN-BALANCE

INNOVATIVE COST IMPROVEMENTS FOR BALANCE OF PLANT COMPONENTS OF AUTOMOTIVE PEMFC SYSTEMS

Project ID:	735969
Call topic:	**FCH-01-4-2016** - Development of Industrialization-ready PEMFC systems and system components
Project total costs:	€ 6,156,288.75
FCH JU max. Contribution:	€ 4,994,538.75
Project start - end:	01/01/2017- 31/12/2019
Coordinator:	FUNDACION AYESA, ES
Website:	www.innbalance-fch-project.eu

BENEFICIARIES: AVL LIST GMBH, Brose Fahrzeugteile GmbH & Co. Kommanditgesellschaft, Wurzburg, CELEROTON AG, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, Powercell Sweden AB, STEINBEIS 2I GMBH, STEINBEIS INNOVATION GGMBH, UNIVERSITAT POLITECNICA DE CATALUNYA, VOLVO PERSONVAGNAR AB

PROJECT AND OBJECTIVES

INN-BALANCE project aims to design, develop and test balance of plant components for automotive fuel cells in order to increase their efficiency and reliability and to reduce costs. Specifically, the main technical objectives are to improve and tailor development tools for design, modelling and testing innovative components in fuel cell based vehicles and to achieve high technology readiness levels (TRL7 or higher) in all the tackled developments. The project is currently in the middle of the execution and the BoP components are under development.

NON QUANTITATIVE OBJECTIVES

- Develop different types of system models
- Advanced supervisory control strategies
- Test the fuel cell system into a vehicle powertrain
- To develop a technology plan
- To elaborate an exploitation, communication and dissemination plan

PROGRESS & MAIN ACHIEVEMENTS

- Overall fuel cell system layout defined
- 100 kw fuel cell stack prototype already manufactured.
- Air turbo-compressor prototype sample A available in Celeroton´s facilities and under testing

FUTURE STEPS & PLANS

- On-board diagnostics software
- Anode module prototype
- Air turbo-compressor prototype sample B
- Cathode module prototype
- Thermal management prototype

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

One of the activities of the project is to develop a tool to optimize the design of the prototypes considering the impact on the mass production. To that end, the design of the components is not only focused on the performance but also on the manufacturing implications.

QUANTITATIVE TARGETS AND STATUS

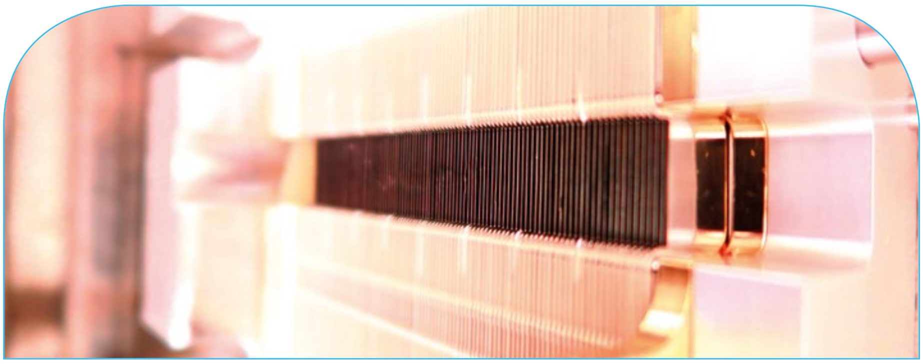
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Cold start	Celsius degree	Under development	-40	🔧	The temperature able to start up and shut down.
Air compressor power	kW	Under development	10-12	🔧	The power of the turbo compressor
Manufacturing cost of the air compressor	€/unit	Under development	250	🔧	The estimated manufacturing cost per unit at 50.000 units/year production
Manufacturing cost of the anode	€/unit	Under development	220	🔧	The estimated manufacturing cost per unit at 50.000 units/year production
Manufacturing cost of BoP	€/kW	Under development	100	🔧	The estimated manufacturing cost of BoP at 50.000 unit/year
Rated stack electrical efficiency (LHV)	%	53	> 55%	🔧	N/A
Areal power density	W/cm2	0.975	1.5	🔧	Maximum continuous, up to 1.2 possible for limited time

*As identified in MAWP Addendum 2018-2020, AIP 2012 and project's own objectives, Target Years 2019-2020

INSPIRE

INTEGRATION OF NOVEL STACK COMPONENTS FOR PERFORMANCE, IMPROVED DURABILITY AND LOWER COST



Project ID:	**700127**
Call topic:	**FCH-01.1-2015** - Low cost and durable PEMFCs for transport applications
Project total costs:	**€ 6,878,070.01**
FCH JU max. Contribution:	**€ 6,877,869.75**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**JOHNSON MATTHEY PLC, UK**
Website:	**www.inspire-fuelcell.eu**

BENEFICIARIES: ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, JOHNSON MATTHEY FUEL CELLS LIMITED, PRETEXO, REINZ-DICHTUNGS GMBH, SGL CARBON GMBH, TECHNISCHE UNIVERSITAET BERLIN, TECHNISCHE UNIVERSITAET MUENCHEN, Teknologian tutkimuskeskus VTT Oy, UNIVERSITE DE MONTPELLIER

PROJECT AND OBJECTIVES

The overall aim of INSPIRE is to develop and integrate together the most advanced MEA components (electro catalysts, membranes, gas diffusion layers and bipolar plates) into 3 generations of automotive stacks meeting a beginning-of-life power density of 1.5 W/cm2 at 0.6 V, durability of over 6,000 hours operation with less than 10% power degradation, and a stack assessment showing production costs below 50 €/kW for an annual production rate of 50,000 units. The first generation, 140kW, 395 cell stack is now in operation and 3 new catalysts meeting the 0.44 A/mgPt target have moved to scale-up.

NON QUANTITATIVE OBJECTIVES

- Scale-up best performing catalyst for stack MEAs
- Develop two new generations of BPP for automotive stacks
- Dissemination of project results

PROGRESS & MAIN ACHIEVEMENTS

- 4 new catalysts have met the project mass activity and stability requirements (>0.44 A/mg Pt), with 3 of those catalysts having now moved to scale-up
- The Milestone 2 target of 1.2 W/cm2 @ 0.6V was achieved with the GEN 1.0 MEA design in the INSPIRE GEN 1.0 hardware at BMW
- The 1st generation 395 cell stack has been manufactured and validated, demonstrating 140 kW, 2.8 kW/l with prototype housing, 5.4 kW/l without housing

FUTURE STEPS & PLANS

- Testing with the second generation (GEN 2.0) stack due to start June 2018; third generation (GEN 3.0) earmarked for February 2019
- 1.2 W/cm2 MEA mid-term performance achievement to be fully demonstrated in full stack; plus MEA development towards 1.5 W/cm2 target
- Following successful scale-up of the three new catalysts from WP3, further catalyst layer optimization will take place to be implemented in GEN 3.0
- New high performing, durable membrane to be scaled-up and implemented in GEN 3.0.
- Six-month project extension to be agreed by the beneficiaries and Grant Amendment request submitted

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Main project target to reduce production cost of overall stack to below 50€/kW.

Reduce the use of the EU defined 'Critical raw materials'

Project target is to reduce loading to 0.2 mgpt/cm2 and assess recycling potential.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
1.5 W/cm2 at 0.6V	W/cm2	1.14	1.5	🔧	Demonstrated in 395 cell stack
10% performance loss over 6,000 hours	%	N/A	10%	🔧	Not yet assessed
MA >0.6 A/mg	A/mg	0.6	0.6	✓	N/A
Loading <0.125 mg/cm2	Mg/cm2	0.3	0.12	🔧	GEN 2.0 design demonstrated in screener and large single cell at 0.25 mg/cm2 but not in stack.
50€/kW @ 50,000 units/year	€/kW	N/A	50	🔧	Not yet assessed
Areal power density	W/cm2	1.13	1.5	🔧 But SoA 2017 achieved	N/A
PGM catalyst loading - Anode	g/kW	0.073	0.17	🔧	N/A
PGM catalyst loading - Cathode	g/kW	0.244			

*As identified in MAWP Addendum 2018-2020 and AWP 2015, Target Year 2019-2020

MARANDA

MARINE APPLICATION OF A NEW FUEL CELL POWERTRAIN VALIDATED IN DEMANDING ARCTIC CONDITIONS

Project ID:	**735717**
Call topic:	**FCH-01-5-2016** - Develop new complementary technologies for achieving competitive solutions for Marine applications at an economic scale of implementation
Project total costs:	**€ 3,704,757.5**
FCH JU max. Contribution:	**€ 2,939,457.5**
Project start - end:	01/03/2017- 28/02/2021
Coordinator:	**Teknologian tutkimuskeskus VTT Oy, FI**
Website:	**www.vtt.fi/sites/maranda**

BENEFICIARIES: ABB OY, OMB SALERI SPA, PERSEE, Powercell Sweden AB, SUOMEN YMPARISTOKESKUS, SWISS HYDROGEN SA, VERTIGO GAMES BV

PROJECT AND OBJECTIVES

In MARANDA project an emission-free hydrogen fuelled PEMFC based hybrid powertrain systems (3 x 82.5 kW AC) are developed for marine applications and validated both in test benches and on board the research vessel Aranda, including full scale freeze start testing of the system. The project will increase the market potential of hydrogen fuel cells in marine sector. General business cases for different actors in the marine and harbour or fuel cell business will be created.

NON QUANTITATIVE OBJECTIVES

- The impact related to the development of RCS
- Fuel cell systems should be able to withstand the shocks, vibrations, saline environment and ship motions
- The evaluation of the economic and environmental impact for a prospective customer
- The formulation of an initial go-to market strategy with support from stakeholders.
- The mapping of opportunities for future demonstration 'innovation' actions.

PROGRESS & MAIN ACHIEVEMENTS

- Regulations, codes and standards for fuel cells in marine applications has been reviewed and gaps identified
- First 100 kW S3 stack has been assembled and delivered for the use in fuel cell system
- Environmental assessment of hydrogen for research vessel use has been completed

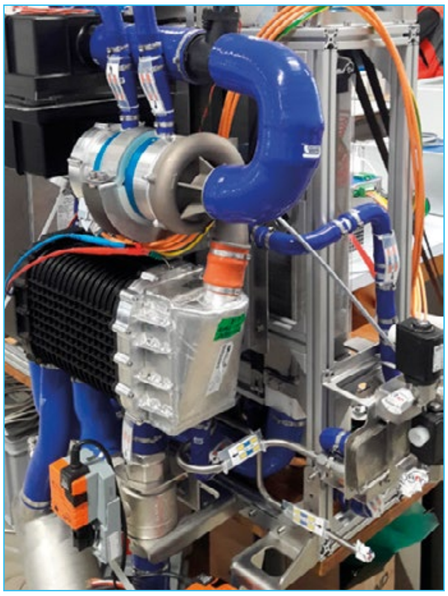
FUTURE STEPS & PLANS

- Commissioning of the first fuel cell system at durability test site (M19)
- Acceptance from Finnish Transport Safety Agency (Trafi) for the installation of FC system and hydrogen storage in Aranda (M22)
- Field trial start in target vessel (M27)
- 1st FC system complete 4380 testing (M36)
- Field trial start in target vessel completed (M45)

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

The experimental results of the project will help to understand the durability issues of fuel cells in marine applications.



QUANTITATIVE TARGETS AND STATUS

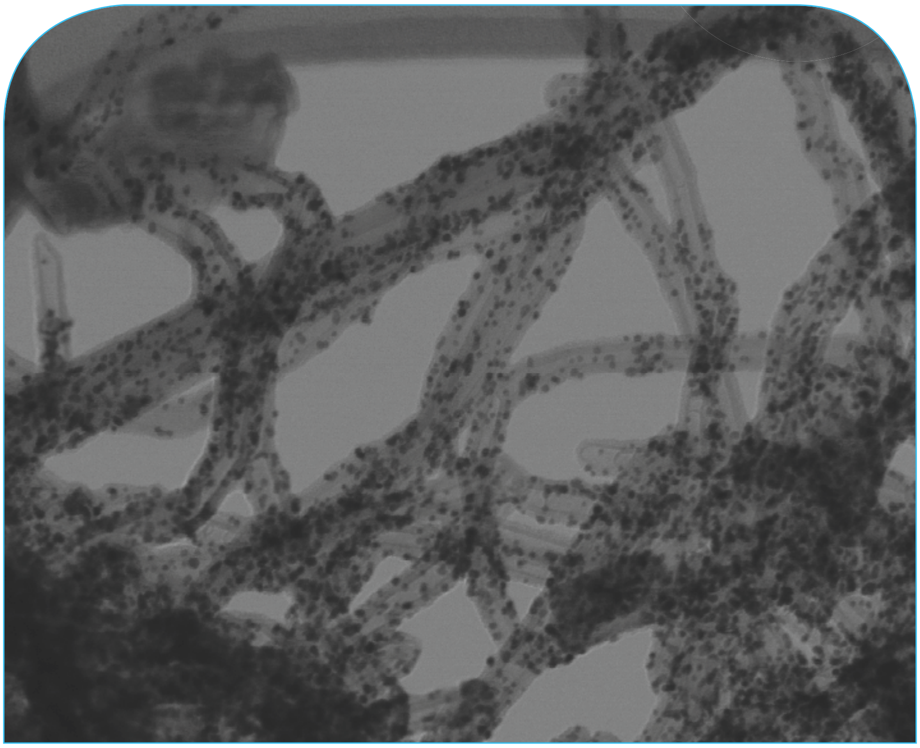
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Fuel cell system effect	kW	82.5	75	✓	Design value AC power
Freeze start capability	C	N/A	-35	🛠	To be tested
Rated system electrical efficiency (LHV)	%	48	42	✓	The fuel to electric efficiency (AC) objective in the project (BoL).
Rated stack durability	Hours	15,000	15,000	✓	Fuel cell system durability has been estimated to be the same as stack durability. Different BoP components will have different life-times.
FC system CAPEX	€/kW	4000	<6000	✓	Including hydrogen storage for 8 hours operation.

*As identified in AWP 2016, Target Year 2020-2021

Nano-CAT

DEVELOPMENT OF ADVANCED CATALYSTS FOR PEMFC AUTOMOTIVE APPLICATIONS



Project ID:	325239
Call topic:	**SP1-JTI-FCH.2012.1.5** - New catalyst structures and concepts for automotive PEMFCs
Project total costs:	€ 4,394,331
FCH JU max. Contribution:	€ 2,418,439
Project start - end:	01/05/2013 - 31/01/2017
Coordinator:	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.nanocat-project.eu

BENEFICIARIES: ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS – ARMINES, C-TECH INNOVATION LIMITED, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, FUNDACION TECNALIA RESEARCH & INNOVATION, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, NANOCYL SA, VOLVO TECHNOLOGY AB

PROJECT AND OBJECTIVES

The objectives of Nano-CAT were the synthesis on new catalyst concept to reduce the loading of platinum in PEMFC and increase durability. The consortium synthesized innovative support (highly resistance carbon nanotubes and metal oxide aerogel) and did there functionalization with platinum nanoparticles. Those new catalysts showed good performances and durability against commercial reference (Pt/C). Finally, those materials were integrated in full 25 cm2 MEA and advantages in some specific accelerated stressed tests.

NON QUANTITATIVE OBJECTIVES

- Contribution to testing protocol harmonization
- Contribution to determination of ageing mechanism

PROGRESS & MAIN ACHIEVEMENTS

- Functional of carbon nanotube as catalyst support for PEMFC and set up of the adapted catalyst deposition procedure
- Optimization of metal oxide aerogel as catalyst support for PEMFC: optimization of the porous structure, electrical conductivity and Pt deposition
- Low loaded MEA performance

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Reduction of Pt loading in electrodes. Development of robust support.

Increase the electrical efficiency and the durability of the different fuel cells

Development of new catalyst structure and support to stabilized active layer and catalytic activity.

Reduce the use of the EU defined 'Critical raw materials'

Reduction of Pt loading. Development of PGM free catalysts (both for anode and cathode).

QUANTITATIVE TARGETS AND STATUS

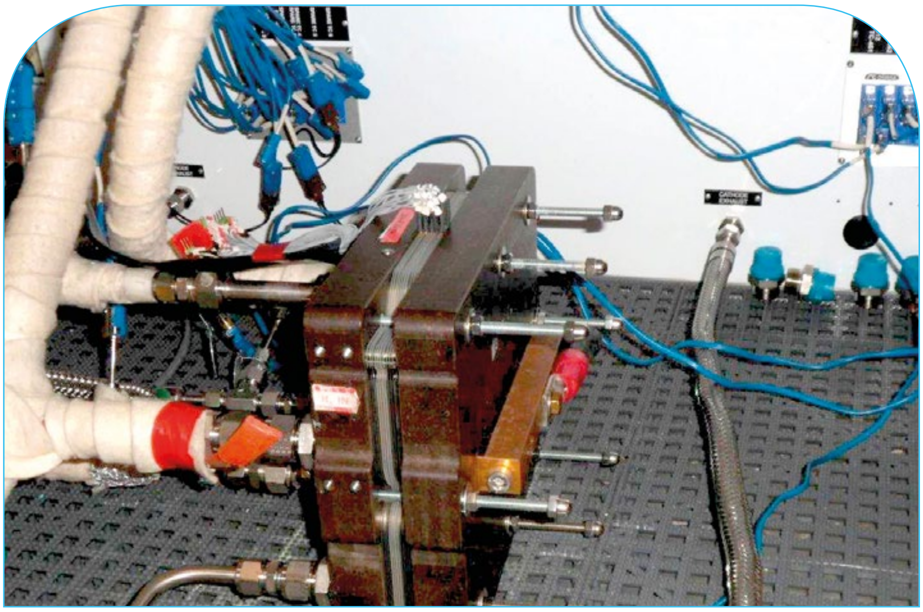
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
MEA power density	mW/cm2	1000	1000	✓
degradation, loss of performance	%	10	10	✓
catalyst stability-residual ECSA	%	100	70	✓
conductivity of metal oxyde aerogel	S/cm	0.95	0.4	✓

*As identified in AIP 2012 and project's own objectives, Target Year 2017

SMARTCat

SYSTEMATIC, MATERIAL-ORIENTED APPROACH USING RATIONAL DESIGN TO DEVELOP BREAK-THROUGH CATALYSTS FOR COMMERCIAL AUTOMOTIVE PEMFC STACKS



Project ID:	325327
Call topic:	**SP1-JTI-FCH.2012.1.5** - New catalyst structures and concepts for automotive PEMFCs
Project total costs:	€ 4,768,172.6
FCH JU max. Contribution:	€ 2,501,998
Project start - end:	01/06/2013 - 31/05/2017
Coordinator:	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, FR
Website:	www.smartcat.cnrs.fr

BENEFICIARIES: BASIC MEMBRANES BV, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, MXPOLYMERS BV, STIFTELSEN SINTEF

PROJECT AND OBJECTIVES

The present consortium will build a new concept of electrodes based on new catalyst design (ternary alloys/core shell clusters) deposited on a new high temperature operation efficient support. In order to enhance the fundamental understanding and determine the optimal composition and geometry of the clusters, advanced computational techniques will be used in direct combination with electrochemical analysis of the prepared catalysts. SMARTCat will thus enable to automate the MEA production and build efficient short-stack required for competitive automotive fuel cell operation.

NON QUANTITATIVE OBJECTIVES

- Stability of ternary PtMeAu/C catalysts upon potential cycling
- Atomic arrangement of ternary catalysts using Molecular Dynamics
- PhD candidate training

PROGRESS & MAIN ACHIEVEMENTS

- Development of ternary catalysts and supports with either higher activity or higher stability than Pt/C catalyst
- Stack 10 cells 220cm2 active area loaded with 0.18 mg/cm^2 Pt3NiAu 5Wcm-2 / 1.1 kW = performance of same stack loaded with 0.42 mg/cm^2 pure Pt
- Achievement of automated 70 MEA/day with membrane size = electrode size + 5%

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the use of the EU defined 'Critical raw materials'

Minimum Pt contents was found to 30 µgcm-2

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Stack availability	%	100	98	✓	N/A
Areal power density	W/cm2	0.137	1.5	🛠	
PGM catalyst loading - Anode	g/kW	0.015	0.17	✓	
PGM catalyst loading - Cathode		0.015			
Stack Durability	hours	5000	5000	✓	Estimated using PVD coating technology developed in SMART-Cat with 1W/cm2

*As identified in MAWP Addendum 2018-2020, Target Year 2020

VOLUMETRIQ

VOLUME MANUFACTURING OF PEM FC STACKS FOR TRANSPORTATION AND IN-LINE QUALITY ASSURANCE

Project ID:	671465
Call topic:	**FCH-01.2-2014** - Cell and stack components, stack and system manufacturing technologies and quality assurance
Project total costs:	**€ 4,988,450.25**
FCH JU max. Contribution:	**€ 4,961,950**
Project start - end:	01/09/2015 - 28/02/2019
Coordinator:	**CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR**
Website:	**www.volumetriq.eu**

BENEFICIARIES: BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, ELRINGKLINGER AG, INTELLIGENT ENERGY LIMITED, JOHNSON MATTHEY FUEL CELLS LIMITED, JOHNSON MATTHEY PLC, PRETEXO, SOLVAY SPECIALTY POLYMERS ITALY SPA, UNIVERSITE DE MONTPELLIER


Automated Stack Assembly Line (ASAL)

PROJECT AND OBJECTIVES

VOLUMETRIQ provides the entire European supply chain for an optimized stack design to enable validation of performance, lifetime and manufacturability, with analysis of each process capability and efficiency, including costs, while developing the appropriate quality assurance methodologies for at-scale fuel cell manufacturing. At M35 of the 42 month duration, VOLUMETRIQ currently achieves 2.2 A/cm2 at 0.6 V with project materials and hardware, and uses manufacturing and assembly processes compatible with high volume production.

PROGRESS & MAIN ACHIEVEMENTS

- Achieved 2.2 A/cm2 at 0.6 V in VOLUMETRIQ hardware
- Improved MEA assembly process leading to a cycle time reduction of ca. 72 %
- New membrane design with lower H2 crossover, improved mechanical properties, and similar/lower proton resistance than ePTFE-reinforced membranes

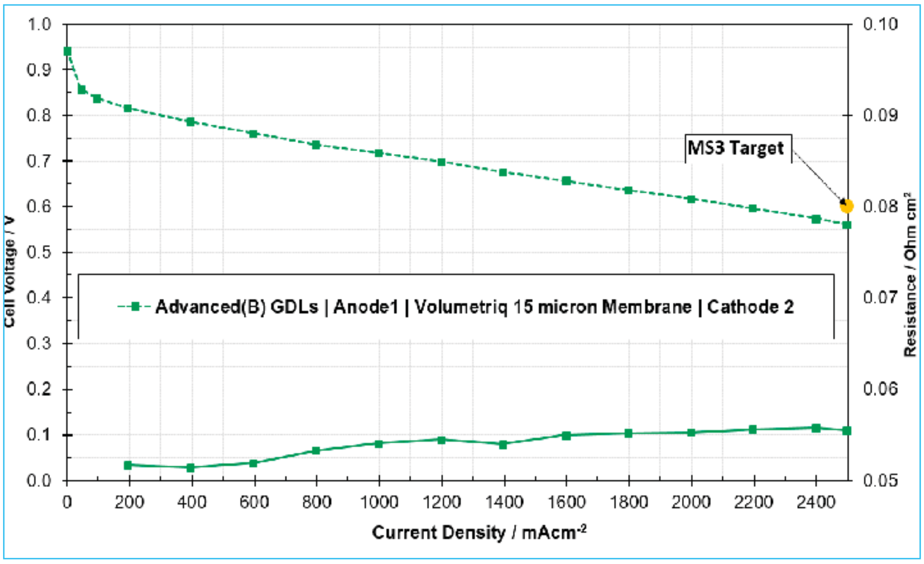
FUTURE STEPS & PLANS

- Manufacture of membrane with electro spun reinforcement
- Finalize tooling, BPP stamping and production
- CCM production for stack
- Stack test
- Costs analysis

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

.dvanced handling technologies for CCM processing, with potential cycle time reduction of ca. 61 % and increased yield.
Improvements on the MEA assembly process developed, leading to a cycle time reduction of ca. 72 %.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
stack volumetric power density	kW/l	4.1-5.01 kW/L (excluding housing) expected for NM12 stack	7.3	🔧	3.5 kW/L (2017)

*As identified in MAWP Addendum 2018-2020, Target Year 2020

PANEL 3 TRIALS AND DEPLOYMENT OF FUEL CELL APPLICATIONS – ENERGY

ALKAMMONIA

AMMONIA-FUELLED ALKALINE FUEL CELLS FOR REMOTE POWER APPLICATIONS

Project ID:	325343
Call topic:	**SP1-JTI-FCH.2012.3.5** - SP1-JTI-FCH.2012.3.5 - System level proof of concept for stationary power and CHP fuel cell systems at a representative scale
Project total costs:	€ 2,884,512.59
FCH JU max. Contribution:	€ 1,962,548.00
Project start - end:	01/05/2013- 30/06/2018
Coordinator:	AFC ENERGY PLC, UK
Website:	www.alkammonia.eu

BENEFICIARIES: ACTA SPA, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, FUEL CELL SYSTEMS LTD, PAUL SCHERRER INSTITUT, UNIVERSITAET DUISBURG-ESSEN, UPS SYSTEMS PLC, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH

PROJECT AND OBJECTIVES

In project ALKAMMONIA a proof-of-concept system designed to provide power in remote areas has been developed and is being tested, focusing on diesel generator displacement opportunities. The project integrates three innovative and proven technologies: a highly efficient and low-cost alkaline fuel cell system, plus a novel ammonia fuel system which consists of a fuel delivery system and a cracker system for generation of a hydrogen rich gas. The integrated system is being rigorously tested and the results will be shared with potential end-users.

NON QUANTITATIVE OBJECTIVES

- Achieve CE certification for cracker
- Assessment of system impacts

PROGRESS & MAIN ACHIEVEMENTS

- Successful short-term testing of the alkaline fuel cell Balance of Plant and stack
- Successful testing of the ammonia cracker and fuel delivery system
- Successful integration of sub-systems into the ALKAMMONIA system

FUTURE STEPS & PLANS

- Complete longevity testing for integrated ALKAMMONIA system, this involves a 1,000h test plus data analysis and forecasting.
- Life Cycle Analysis of integrated system and comparison with competing technologies for specific target applications.
- Close out the project, which includes documenting achievements per Consortium knowledge management guidelines and finalizing project report

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Stack development as part of this project has addressed both increased electrical efficiency and durability of alkaline fuel cells.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/ project (SoA Year)	SoA Source
Cracker efficiency (based on LHV)	%	90 % (thermal efficiency) (by feeding the cracker with gaseous ammonia and firing the system burner with LPG)	No comparable information about burner fired crackers is available.	The only available information in literature belongs to electrical heated small scale micro ammonia crackers, which are not applicable here.
Maintain high efficiency of current AFC stack	%	62%, based on electrochemical efficiency calculation, measured against the lower heating value (LHV) of hydrogen, using a technical grade H2 fuel supply for testing.	59%	After our literature survey, the only applicable SoA is based on POWER- UP, also utilising AFC Energy technology and based on a technical grade H2 fuel supply
Reduced AFC stack weight	kg	70kg, this is the stack weight, i.e. excluding the enclosure, based on a 2.5kWe stack BOM.	200kg, based on a 5kWe stack.	After our literature survey, the only applicable SoA is based on AFC Energy's State of the Art at the ALKAMMONIA project start.
Increased AFC stack durability	hours	≥6,300h, extrapolated from 2,000h of actual operation, using technical grade H2 fuel supply	N/A	After our literature survey, the only competing alkaline fuel cell manufacturer for this success criterion to AFC Energy are GENCELL, who have made no relevant information public, with inferences of perhaps 500h, not explicitly stated.
Reduced AFC stack leakage losses	%	<1%	<10%	After our literature survey, the only applicable SoA is based on AFC Energy's State of the Art at the ALKAMMONIA project start.

* Available data provided by the Project

AutoRE
AUTOMOTIVE DERIVATIVE ENERGY SYSTEM

Project ID:	671396
Call topic:	**FCH-02.5-2014** - Innovative fuel cell systems at intermediate power range for distributed combined heat and power generation
Project total costs:	€ 4,464,447.25
FCH JU max. Contribution:	€ 3,496,947.00
Project start - end:	01/08/2015 - 30/04/2019
Coordinator:	ALSTOM POWER LTD, UKE
Website:	www.autore-fch.com

BENEFICIARIES: DAIMLER AG, ELVIO ANONYMI ETAIREIA SYSTIMATON PARAGOGIS YDROGONOU KAI ENERGEIAS, GENERAL ELECTRIC (SWITZERLAND) GMBH, NUCELLSYS GMBH, STIFTELSEN SINTEF, SVEUCILISTE U SPLITU, FAKULTET ELEKTROTEHNIKE, STROJARSTVA I BRODOGRADNJE, UNIVERSITA DEGLI STUDI DELLA TUSCIA

PROJECT AND OBJECTIVES

The main objective is to create the foundations to commercialize a 50-100kWe automotive derivative fuel cell CHP system. The project is in its 3rd year, with key achievements including: automotive fuel cell is installed/commissioned, gas reformer is built and factory tested, significant modelling of the cycle has been completed, together with laboratory scale testing of fuel cell stack on reformate and the membrane to separate H2. Next steps are to deliver the reformer to the UK test site, complete site installation and carry-out the 3000h test programme.

NON QUANTITATIVE OBJECTIVES

- Support development of codes and standards for new technologies
- Constribute to decarburization of building/power sectors

PROGRESS & MAIN ACHIEVEMENTS

- The prototype CHP site has been prepared, fuel system installed and commissioned and gas reformer built and factory tested
- Testing of fuel cell short-stacks completed on reformate, together with testing of hydrogen separation membranes
- Modelling of the system has been completed showing reformer thermal integration improves overall performance

FUTURE STEPS & PLANS

- Deliver natural gas reformer to prototype site and complete system build and commissioning
- Complete 3000h system endurance test
- Complete system modelling activities including RAMS study
- Prepare business case for commercial system and disseminate project findings to key stakeholders

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

- Test of novel components e.g. hydrogen membrane to increase efficiency
- 3000h demonstration test to determine durability issues
- Cycle performance modelling to define optimum configuration

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

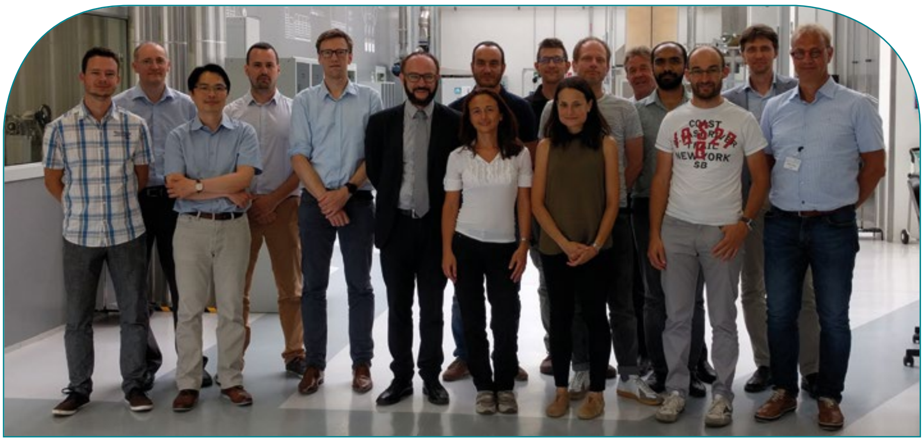
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA Year)
Rated system electrical efficiency (LHV)	%	👤	42-60	🔧	52%
Rated system thermal efficiency (LHV)	%	👤	24-42	✓	N/A
Lifetime of the fuel cell system	years	👤	8 - 20	✓	N/A
Stack durability	hours	👤	50,000	🔧	21,900
Reliability	hours	👤	30,000	🔧	N/A
Hydrogen tolerance	% (volume)	👤	100	🔧	N/A
CAPEX	EUR/kWe	👤	4,500 - 7,500	✓	2,400
Land use / footprint	m2/kW	0.02	0.08	✓	N/A

*As identified in MAWP Addendum 2018-2020, Target year 2020

CH2P

COGENERATION OF HYDROGEN AND POWER USING SOLID OXIDE BASED SYSTEM FED BY METHANE RICH GAS

Project ID:	735692
Call topic:	FCH-02-4-2016 - Co-generation of Hydrogen and Electricity with High-Temperature Fuel Cells (>50 kW) generation
Project total costs:	€ 6,868,158.75
FCH JU max. Contribution:	€ 3,999,896
Project start - end:	01/02/2017- 31/07/2020
Coordinator:	FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES
Website:	www.ch2p.eu



BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, HTceramix SA, HYGEAR BV, HyGear Fuel Cell Systems B.V., HYGEAR TECHNOLOGY AND SERVICES BV, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, SOLIDPOWER SPA, VERTECH GROUP

PROJECT AND OBJECTIVES

CH2P is a project focused on flexible cogeneration of hydrogen and power for the distributed production on hydrogen refuelling stations. It aims at reaching high conversion efficiency (up to 75%), low cost of hydrogen (<4.5 €/kg), production of hydrogen compliant with the use on onboard PEMFC considering hydrogen purity. The project will have pilot testing of 100 kg/day system in real environment. At the present, the project in the component validation phase, after full design, system modelling and definition of a final P & Id layout.

NON QUANTITATIVE OBJECTIVES

- Dynamic and flexible generation of hydrogen and power
- Use of low carbon gas mixtures
- LCA to assess for carbon emissions using different methane rich mixtures
- High Educational Vocational Training course on Energy and Environment

PROGRESS & MAIN ACHIEVEMENTS

- Finalized the PFD - process flow diagram. Finalized the engineering in a P&ID. This consolidation has been achieved through system modelling
- Finalized the technology application scenarios: technology scenarios has been consolidated considering six main use cases of the HRS
- Finalized the definition of the system requirements

FUTURE STEPS & PLANS

- Complete the validation of components: stack, stacks-tower, large stack (4 stacks for 25 kW), PSA, steam reformer burner, heat exchangers, compressor
- Final engineering of the gas upgrading system, of the downstream purification and compression, of the fuel conditioning and filtering
- Realization of a 20 kg/day prototype system and controls including testing and validation
- Realization of a 100 kg/day system with validation and pilot testing in real environment
- Design of a 200 or 400 kg/day system for real scale HRS

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

CH2P, by its innovative cost model, will realize a considerable reduction of hydrogen cost compared with the SoA, down to 4,5 €/kg.

Increase the electrical efficiency and the durability of the different fuel cells

Electric efficiency is expected to be up to 75% and average of 65%. The durability of the fuel cell is expected to be 5 years.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Hours of operation - cumulative	hours	3500	1000	✓	The cumulative hours of operation for the stack development and testing for the period exceed 3500 h.
Purity required for the fuel	%	99.999	99.9	✓	5N purity level, compliant with the use in the transport sector, for onboard PEMFC
Rated system lifetime	years	10	8 - 20	✓	Hydrogen production research (excl. electrolysis)
Rated stack durability	hours	40,000	50,000	🔧	Fuel cells research at system level

*As identified in AWP 2016 and MAWP Addendum 2018-2020, Target years 2019-2020

D2Service

DESIGN OF 2 TECHNOLOGIES AND APPLICATIONS TO SERVICE

Project ID:	**671473**
Call topic:	**FCH-02.9-2014** - Significant improvement of installation and service for fuel cell systems by Design-to-Service
Project total costs:	**€ 3,636,797.5**
FCH JU max. Contribution:	**€ 2,953,790.75**
Project start - end:	01/09/2015 - 30/11/2019
Coordinator:	**DLR-INSTITUT FUR VERNETZTE ENERGIESYSTEME EV, DE**
Website:	**www.project-D2Service.eu**

BENEFICIARIES: BALLARD POWER SYSTEMS EUROPE AS, BOSAL EMISSION CONTROL SYSTEMS NV, BRITISH GAS TRADING LIMITED, ENERGY PARTNER SRL, SOLIDPOWER SPA, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH

PROJECT AND OBJECTIVES

The D2Service project aims at improving the service ability and maintainability of fuel cell-based m-CHP and backup power systems. The relatively high complexity of these systems currently still requires specialized service personnel and non-standard components when the systems are maintained in regular intervals or repaired due to failures. Two different fuel cell technologies, LT-PEMFC and SOFC, are investigated. Improvements are developed on system design and component levels, as well as guidelines for easier service procedures and manuals are designed.

NON QUANTITATIVE OBJECTIVES

- Elaboration of guidelines for development of guidelines for easily understandable service manuals
- Life-time desulphurisation (type HDS)
- Water treatment optimization

PROGRESS & MAIN ACHIEVEMENTS

- Improved design of SOFC and PEM m-CHP units with respect to efficiency, serviceability, durability and cost reduction
- Suitable catalyst and absorber materials identified for 60,000h lifetime of hydrodesulphurisation component
- Identification and preparation of sites for field trial of improved units

FUTURE STEPS & PLANS

- Installation of units on field trial sites
- Laboratory evaluation of SOFC m-CHP unit
- Development and verification of guidelines for easy-to-understand graphical manuals

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Development of more durable and standardized components, such as desulphurisation, water treatment and connections.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Rated stack durability	hours	40,000	50,000	SoA 2017 achieved
Stack durability	hours	40,000	50,000	SoA 2017 achieved
FC system CAPEX	EUR/kW	28,376	10,000	
Est. FC system CAPEX @ mass production	EUR/kW	8,890	10,000	✓ projection achieved
Degradation rate in %/kh	%/kh	0.304	<0.25	
System availability	%	75	97	

*As identified in AWP 2016, 2017 and MAWP Addendum 2018-2020, Target years 2019-2020

DEMCOPEM-2MW

DEMONSTRATION OF A COMBINED HEAT AND POWER 2 MWE PEM FUEL CELL GENERATOR AND INTEGRATION INTO AN EXISTING CHLORINE PRODUCTION PLANT

Project ID:	**621256**
Call topic:	**SP1-JTI-FCH.2013.3.5** - Field demonstration of large scale stationary power and CHP fuel cell systems
Project total costs:	**€ 10,524,200.4**
FCH JU max. Contribution:	**€ 5,466,525**
Project start - end:	01/01/2015- 31/12/2018
Coordinator:	**AKZO NOBEL INDUSTRIAL CHEMICALS B.V., NL**
Website:	**www.demcopem-2mw.eu**

BENEFICIARIES: JOHNSON MATTHEY FUEL CELLS LIMITED, MTSA TECHNOPOWER BV, NEDSTACK FUEL CELL TECHNOLOGY BV, POLITECNICO DI MILANO

PROJECT AND OBJECTIVES

The aim of the project was to design, construct and demonstrate an economical combined heat and power PEM fuel cell power plant and integration into a chlor-alkali production plant. The project is currently in its last year (a total of 48 months are foreseen), the PEM system has been installed since September 2016 at the chlor-alkali plant in Yingkou, China. The planned capacity of 2MW has been already reached, even if some technical problems (related to air and hydrogen quality) have been encountered.

NON QUANTITATIVE OBJECTIVES

Trainings of system operators

PROGRESS & MAIN ACHIEVEMENTS

- 2MW system operative (heat recovery available)
- Modelling/Monitoring and operation possible in remote
- Reduce/minimize hydrogen waste in the chlor-alkali factory

FUTURE STEPS & PLANS

- Solving some of the technical issues registered (due to local conditions) such as stack decay (both reversible and irreversible)
- Ongoing analysis on how to reduce costs and contribute to the design of the second generation PEM plant
- Further the analysis of the operational hours and data is been carrying on

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Rated system electrical efficiency (LHV)	%	50	45	✓
Rated system thermal efficiency (LHV)	%	35	22-40	✓
Lifetime of the fuel cell system	years	10	25	⚒ SoA 2017 Achieved
Stack durability	hours	16,000	20,000-60,000	⚒
Reliability	hours	8,500	25,000	⚒
Availability	%	95	98	⚒
Operation of the System**	MW	2 MW	2 MW system operation	✓

*As identified in MAWP Addendum 2018-2020, Target year 2020
** Project's own objective

DEMOSOFC
FCH2-JU PROJECT

DEMOSOFC

DEMONSTRATION OF LARGE SOFC SYSTEM FED WITH BIOGAS FROM WWTP

Project ID:	**671470**
Call topic:	**FCH-02.11-2014** - Large scale fuel cell power plant demonstration in industrial/ commercial market segments
Project total costs:	**€ 5,905,336.25**
FCH JU max. Contribution:	**€ 4,492,561**
Project start - end:	01/09/2015 - 31/08/2020
Coordinator:	**POLITECNICO DI TORINO, IT**
Website:	**www.demosofc.eu**

BENEFICIARIES: CONVION OY, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, RISORSE IDRICHE S.P.A., Società Metropolitana Acque Torino S.p.A., Teknologian tutkimuskeskus VTT Oy

PROJECT AND OBJECTIVES

DEMOSOFC operates the largest industrial-size Soli Oxide Fuel Cell (SOFC) biogas-fed FC plant in Europe, in Torino (IT). Key advantages of the DEMOSOFC concept, compared to traditional engines, are very high electrical efficiency (50-55% vs 35-40%), zero emissions and modularity. The first of the 3 SOFC modules started its operation on October 30, 2017 and has now reached more than 2500 hours. Results confirmed the efficiency of the SOFC module (always higher than 50%, with peaks at 55-56%) and the zero emissions (NOx and S02 below detection limits). The next 2 SOFC modules are expected to enter in operation within 2018.

NON QUANTITATIVE OBJECTIVES

- Build technical knowledge, customer confidence, investor confidence
- Demonstrate high efficiency of SOFC-based CHP systems fed by biogas
- Compete FMEA of the DEMO
- Dissemination for public awareness

PROGRESS & MAIN ACHIEVEMENTS

- More than 2500 hours of operation, with efficiency of the SOFC module always higher than 50% (with peaks at 55-56%) and zero emissions to atmosphere
- Complete experience of detailed engineering, installation and management of a biogas-fed SOFC CHP system in an existing industrial context
- Complete experience of design, construction and management of the biogas clean-up module for SOFC targets (material selection, engineering, control)

FUTURE STEPS & PLANS

- WP3: Tests of automatic regulation of the complete DEMO (e.g. reduction in biogas production, island mode operation because of a grid failure, etc.)
- WP4: Maintenance during the DEMO operation (including stack replacement in first module); analysis of degradation processes in the whole plant
- WP5: monitoring and analysis of technical KPIs (related to energy and emissions); guidelines for the replication of safety analysis
- WP6: monitoring and analysis of economic KPIs; re-engineering of the complete balance of plant hosting the SOFC (for minimization of plant costs)
- WP7: increase of activities with EU-level associations/ groups e.g. European Biogas Association (EBA), Municipal Waste Europe, Association of cities

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Through the in-field test, monitoring and analysis of a SOFC module, allowing to understand where and how to improve the overall performance of the plant. Then, through a demonstration of the high achievements of the technology, increasing the interest of end users and the quantity of orders per year.

QUANTITATIVE TARGETS AND STATUS

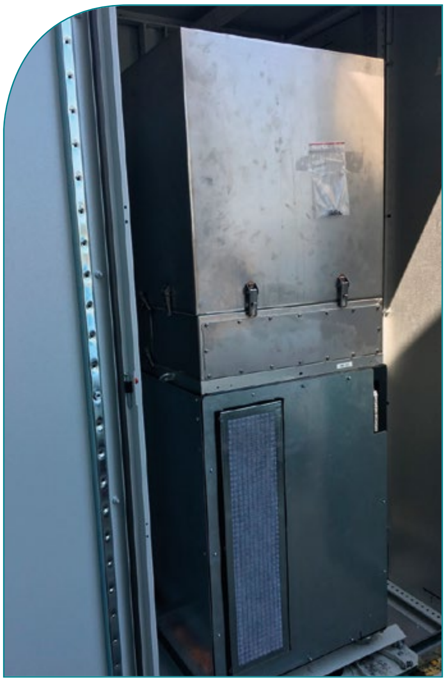
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Electrical efficiency	%	52	42-60	✓	41-55 (2020)	We do not have evidence of data from other similar plants if any (biogas-fed SOFC at industrial size) at the international level/ SoA based on MAW Addendum for medium sized applications
Thermal efficiency	%	30	24-42	✓	24-41 (2020)	

* As identified in MAWP Addendum 2018-2020, Target year 2020

ONSITE

OPERATION OF A NOVEL SOFC-BATTERY INTEGRATED HYBRID FOR TELECOMMUNICATION ENERGY SYSTEMS



Project ID:	**325325**
Call topic:	**SP1-JTI-FCH.2012.3.4** - Component and sub-system cost and reliability improvement for critical path items in stationary power and CHP fuel cell systems
Project total costs:	**€ 5,571,479.44**
FCH JU max. Contribution:	**€ 3,012,038**
Project start - end:	01/07/2013- 30/09/2017
Coordinator:	**CONSIGLIO NAZIONALE DELLE RICERCHE, IT**
Website:	**www.onsite-project.eu**

BENEFICIARIES: BONFIGLIOLI VECTRON GMBH, ERDLE ERICH KONRAD, ERICSSON TELECOMUNICAZIONI, FIAMM ENERGY STORAGE SOLUTIONS SRL, HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE, HTceramix SA, INSTYTUT ENERGETYKI

PROJECT AND OBJECTIVES

The ONSITE project aimed at developing a hybrid system using two innovative technologies: Solid Oxide. Fuel Cells (SOFC) and Sodium Nickel Chloride (SNC) batteries, capable of connecting production and storage devices on the one hand, and of managing and controlling the energy and its exchange with the power grid on the other hand.
Two prototypes of SOFC/SNC hybrid system have been realized and tested combining a 2.5 kW SOFC system, two SNC batteries and a bidirectional Power Conversion System showing a good electrical and thermal efficiency, 40% and 45% respectively.

PROGRESS & MAIN ACHIEVEMENTS

- SOFC systems, fed by natural gas, showing a good electrical and thermal efficiency, 40% and 45% respectively
- A prototype combining a 2.5 kW SOFC system, two SNC batteries and a bidirectional Power Conversion System able to generate both AC and DC micro grid
- Field test at a real Telecom Operator site

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

The project aimed at developing a hybrid FC system for stationary application. The developed SOFC generator reached 85% of total efficiency (40% electrical and 45% thermal).

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Rated Lifetime of the fuel cell system	years	10	8 - 20	✓	N/A	Stationary FC
FC system efficiency	%	40	42-60	🛠	52 (2017)	System
Land use / footprint	m2/kW	0.72	0.08	🛠	N/A	Stationary FC

*** As identified in MAWP Addendum 2018-2020, Target year 2020**

PACE

PATHWAY TO A COMPETITIVE EUROPEAN FC M-CHP MARKET

Project ID:	**700339**
Call topic:	**FCH-02.9-2015** - Large scale demonstration µCHP fuel cells
Project total costs:	**€ 83,765,010.07**
FCH JU max. Contribution:	**€ 33,932,752.75**
Project start - end:	01/06/2016 - 31/08/2021
Coordinator:	**THE EUROPEAN ASSOCIATION FOR THE PROMOTION OF COGENERATION VZW, BE**
Website:	**www.pace-energy.eu**

PROJECT AND OBJECTIVES

PACE is a major initiative aimed at ensuring the European m-CHP sector makes the next move to mass market commercialisation. The project will deploy a total of 2,800 new fuel cell m-CHP units with real customers and monitor them for an extended period. This will: Enable fuel cell m-CHP manufacturers to scale up production, using new series techniques, and increased automation. By 2020, five leading European manufacturers (Bosch, SOLIDpower, Viessmann, BDR Thermea and Sunfire) are expected to have installed capacity for production of over 1,000 units/year.

NON QUANTITATIVE OBJECTIVES

- Demonstrate in the field in the range of 2800 units
- Test and demonstration of remote control models with regards to grid stability support of Virtual Fuel Cell Power Plants as part of Europe's future renewable energy system
- Verification of heat and power contracting business models for applicable markets by the manufacturers present in the project
- Establish the basis and further develop, if possible, marketing and sales strategies of European m-CHP manufacturers

PROGRESS & MAIN ACHIEVEMENTS

- Fuel Cell micro-Cogeneration: Generating Sustainable Heat and Power for your Home - PACE kick-off event, 11 October 2017
- 942 units sold, 152 installed as of end May 2018
- Snapshot from PACE target markets - insights from Belgium, Italy, the Netherlands, and the United Kingdom available on project website

FUTURE STEPS & PLANS

- The majority of the 2800 units to be deployed in the project will be installed
- Solid and growing basis of operational data from m-CHP units with analysis and dissemination of project results
- EU & national political agendas - Put FC m-CHP on the EU agenda for new Commission (FC Declaration),
- EU Advocacy (2030 Framework) - Provide input on ongoing discussions (SRI, Electricity Market Design). Fix Energy Labelling methodology
- PACE technical workshop for policy-makers will be held on 09th October 2018, Brussels

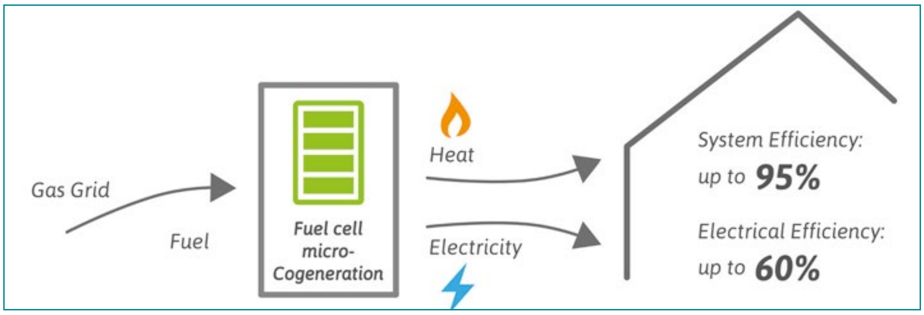
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

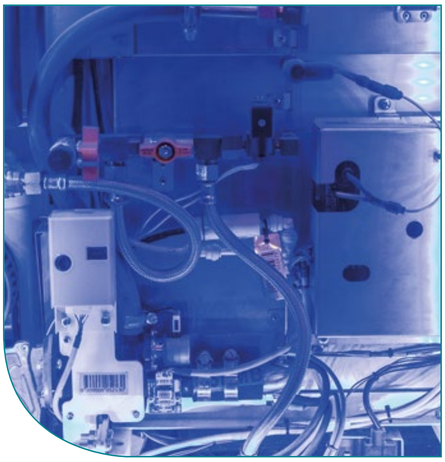
Increase the electrical efficiency and the durability of the different fuel cells

All manufacturers will develop next generation product designs with improved overall efficiencies (>90%) and/or electrical efficiencies (>50%), as well as aiming for 50% reduction in stack replacement or elimination of the need for stack replacement during a 10 year service plan.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The project will demonstrate the potential for FC m-CHP to offer real-world benefits to the grid through a large-scale demonstration involving virtual control of 25 units.

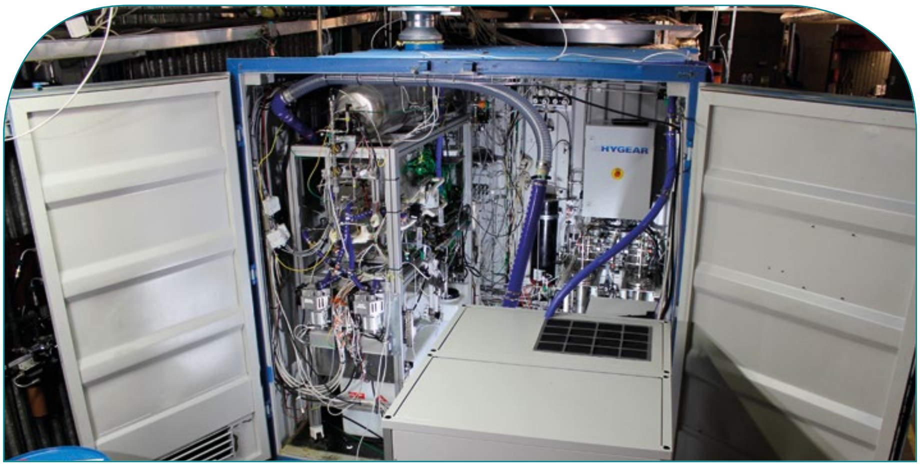




PEMBeyond

PEMBeyond

PEMFC SYSTEM AND LOW-GRADE BIOETHANOL PROCESSOR UNIT DEVELOPMENT FOR BACK-UP AND OFF-GRID POWER APPLICATIONS



Project ID:	621218
Call topic:	**SP1-JTI-FCH.2013.4.4** - Development of 1-30kW fuel cell systems and hydrogen supply for early market applications
Project total costs:	**€ 4,586,324.9**
FCH JU max. Contribution:	**€ 2,315,539**
Project start - end:	01/05/2014 - 31/12/2017
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.pembeyond.eu**

BENEFICIARIES: FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, GENPORT SRL - SPIN OFF DEL POLITECNICO DI MILANO, Powercell Sweden AB, TEKNOLOGIAN TUTKIMUSKESKUS VTT, UNIVERSIDADE DO PORTO

PROJECT AND OBJECTIVES

PEMBeyond project aims to develop a bioethanol fuelled integrated PEMFC based power system for back-up and off-grid applications. The work started from catalyst and adsorbent material development and continued in the design and manufacturing of subsystems. The subsystems were tested individually and then integrated together for a field trial. The system could not be fully demonstrated due to third party related Sulphur contamination in fuel processor, but the hydrogen produced from the bioethanol was shown to function well with the fuel cell system.

PROGRESS & MAIN ACHIEVEMENTS

- Steam reforming catalyst stability with crude bioethanol demonstrated with 1000 h laboratory run
- PSA product hydrogen CO level < 20 ppm reached with demo unit and < 0.2 in lab unit
- The in project developed S2 stack demonstrated for cold start-up capability from -25 °C

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources into while reducing operating and capital costs

The project demonstrated H2 production from crude bioethanol. Furthermore, a very effective PSA purification method was demonstrated, being capable of producing automotive grade fuels from very low quality synthesis gas streams.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The reformed ethanol fuel cell system was partially aimed for telecom and micro grid application, replacing existing diesel gensets, often combined with renewables.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Hydrogen tolerance of the Stationary Unit	%	100	100	✓	N/A
Rated system electrical efficiency (LHV)	%	48	45	✓	At 3 kW net operation point.
Lifetime of the fuel cell system	years	20	8 - 20	✓	Some of the blowers/pumps may need replacement depending on operating hours.
CAPEX	EUR/kW	3800	4,500 - 7,500 [or 2,500 (including H2 generator) (@ >500 units)]	🔧	N/A
Land use / footprint	m2/kW	0.1	0.08	🔧	N/A

*** As identified in AIP 2013, MAWP Addendum 2018-2020, Target years 2017- 2020**

POWER-UP

DEMONSTRATION OF 500 KWE ALKALINE FUEL CELL SYSTEM

Project ID:	325356
Call topic:	**SP1-JTI-FCH.2012.3.7** - Field demonstration of large scale stationary power and CHP fuel cell systems
Project total costs:	€ 13,654,855.67
FCH JU max. Contribution:	€ 6,137,565
Project start - end:	01/04/2013 - 30/06/2017
Coordinator:	AFC ENERGY PLC, UK
Website:	www.project-power-up.eu

BENEFICIARIES: AIR PRODUCTS PLC, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, G.B. INNOMECH LIMITED, PAUL SCHERRER INSTITUT, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH

PROJECT AND OBJECTIVES

In project POWER-UP, AFC Energy and the Consortium partners worked towards the demonstration of an alkaline fuel cell (AFC) system at Air Products industrial gas plant at Stade, Lower Saxony, Germany. This project is the world's first demonstration of a large-scale alkaline fuel cell system, intended to prove within four years that this laboratory-based prototype technology could be scaled up to a 240kWe industrial fuel cell system running on hydrogen available as a by-product of the chlor-alkali process.

NON QUANTITATIVE OBJECTIVES

Clear understanding of external impacts

PROGRESS & MAIN ACHIEVEMENTS

- The 240 kWe alkaline fuel cell demonstration plant in Germany has been constructed and commissioned successfully by AFC, a global first at this scale
- AFC Energy's fuel cell component manufacturing has been scaled up significantly, with 1.375% capacity improvement after yield
- Environmental 'footprint' and relevant socio-economic factors of the fuel cell system have been analyses and quantified by project partner PSI

FUTURE STEPS & PLANS

- Project is finished
- The Stade plant is still actively used as a demonstration facility for new alkaline fuel cell stack designs and balance of plant upgrades

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

For alkaline fuel cell technology, both the Balance of Plant and Stack efficiency and durability have increased remarkably during the project.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Lifetime of the fuel cell system	years	25	8-20	✓	N/A	Alkaline fuel cells allow cost-effective material and component selection with significant lifespan, due to the relatively low operating temperature and pressure
Conversion efficiency	%	62%, based on electrochemical efficiency calculation, measured against the lower heating value (LHV) of hydrogen	>85%	🛠	59% (2016)	N/A
Availability	%	>95% for specific runs'	97	✓ for specific runs'	90% (2013)	N/A

* As identified in MAWP Addendum 2018-2020, Target year 2020

STAGE-SOFC
INNOVATIVE SOFC SYSTEM LAYOUT FOR STATIONARY POWER

Project ID:	621213
Call topic:	**SP1-JTI-FCH.2013.3.4** - Proof of concept and validation of whole fuel cell systems for stationary power and CHP applications at a representative scale
Project total costs:	€ 3,921,223.1
FCH JU max. Contribution:	€ 2,165,724.6
Project start - end:	01/04/2014 - 30/04/2018
Coordinator:	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Website:	www.stage-sofc-project.eu

BENEFICIARIES: ICI CALDAIE SPA, LAPPEENRANNAN TEKNILLINEN YLIOPISTO, SUNFIRE GMBH, TEKNOLOGIAN TUTKIMUSKESKUS VTT, ZACHODNIOPOMORSKI UNIWERSYTET TECHNOLOGICZNY W SZCZECINIE

PROJECT AND OBJECTIVES

This project introduced a new SOFC-concept featuring the serial connection of an exothermal CPOx stage with an endothermic steam reforming stage. The project aimed at developing a proof-of-concept (PoC) system that achieves an electrical efficiency of at least 45 % and a thermal efficiency of over 85 %. The development of the PoC prototype consisted of two successive steps including the design and construction of two prototypes. Finally, the 2nd prototype was subjected to long-term testing.

PROGRESS & MAIN ACHIEVEMENTS

- The overall feasibility of the staged concept was verified
- Using an optimised system, AC net efficiency of 45 to 50 % can be achieved
- Through LCA studies verified that the concept provides a high CO2 emission reduction potential

FUTURE STEPS & PLANS

- Project is finished
- The problems encountered in the long term system will be corrected and the product developed to a commercial maturity

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

This target was one of the key issues of the project and it was clearly achieved.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Availability	%	99	97	✓
Rated system electrical efficiency (LHV)	%	45	42-60	✓
Rated system thermal efficiency (LHV)	%	40	24-42	✓
Lifetime of the fuel cell system	years	10	8 - 20	✓
Stack durability	khrs	20,000	50,000	🔧
Hydrogen tolerance	% (volume)	20	100	🔧
Land use / footprint	m2/kW	0.3	0.08	🔧

* As identified in MAWP Addendum 2018-2020, Target year 2020

CLEARgen Demo

THE INTEGRATION AND DEMONSTRATION OF LARGE STATIONARY FUEL CELL SYSTEMS FOR DISTRIBUTED GENERATION

Project ID:	303458
Call topic:	**SP1-JTI-FCH.2011.3.6** - Field demonstration of large stationary fuel cell systems for distributed generation and other relevant commercial or industrial applications
Project total costs:	**€ 10,343,142.6**
FCH JU max. Contribution:	**€ 4,590,095**
Project start - end:	01/05/2012- 30/09/2020
Coordinator:	**BALLARD POWER SYSTEMS EUROPE AS, DK**
Website:	**www.cleargen.eu**

BENEFICIARIES: AQUIPAC SAS, BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, HYDROGENE DE France, JEMA ENERGY SA, LINDE GAS MAGYARORSZAG ZARTKORUEN MUKODO RESZVENYTARSASAG, LOGAN ENERGY LIMITED

PROJECT AND OBJECTIVES

- The development and construction of a large scale fuel cell system for conversion of by-product hydrogen, purpose-built for the European market
- The validation of the technical and economic readiness of the fuel cell system power generation at the megawatt scale
- The field demonstration and deployment of fuel cell megawatt scale power system at a European chemical production plant. The project is in the phase of finalizing the host site preparation for installation and commissioning.

NON QUANTITATIVE OBJECTIVES

- Safety improvement
- Training

PROGRESS & MAIN ACHIEVEMENTS

- The planned studies (implementation, process, safety, civil work, steel structure, pipeline, instrumentation) were finalized
- The construction of the two 500 kW CLEARgen units and completion of FAT test were finalized
- The host site preparation is in progress

FUTURE STEPS & PLANS

- Installation and Commissioning: The preparation of installation phase is not yet advanced. Nevertheless, first discussions occur to plan the commission
- System Operation and Maintenance: This work package will begin together with the start of the fuel cell. System Monitoring Assessment and Knowledge Transfer: performance reports for 12,000 hours of operation from 2019 to 2020
- Midterm review, planned for October 2018
- Midterm conference, planned for March 2018

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

One of the objectives is to Demonstrate the commercial viability of fuel cells for use in distributed power generation and the benefits associated to the modularity that this technology and product offers.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Rated system electrical efficiency (LHV)	%	46.6	42-60	✓	The efficiency of the system is the average of 2 power banks. Efficiency of each power banks are respectively 46.4% and 46.8%.
Lifetime of the fuel cell system	years	15	8-20	✓	The PPA is planned on 15 years operation
Stack durability	hours	20,000	50,000	🛠	the aim is to reach 40 000 h of operation for a stack
Land use / footprint	m2/kW	0.278	0.08	🛠	The fuel cell system occupy 15.35m x 18.1m of land excluding purification system for hydrogen and transformer unit.

* As identified in MAWP Addendum 2018-2020, Target year 2020

ene.field

EUROPEAN-WIDE FIELD TRIALS FOR RESIDENTIAL FUEL CELL M-CHP

Project ID:	303462
Call topic:	**SP1-JTI-FCH.2011.3.7** - Field demonstration of small stationary fuel cell systems for residential and commercial applications
Project total costs:	**€ 54,542,494.38**
FCH JU max. Contribution:	**€ 25,907,168.77**
Project start - end:	01/09/2012 - 31/10/2017
Coordinator:	**THE EUROPEAN ASSOCIATION FOR THE PROMOTION OF COGENERATION VZW, BE**
Website:	**www.enefield.eu**

BENEFICIARIES: BALLARD POWER SYSTEMS EUROPE AS, BAXI INNOTECH GMBH, BOSCH THERMOTECHNIK GMBH, BRITISH GAS TRADING LIMITED, CERES POWER LIMITED, DANMARKS TEKNISKE UNIVERSITET, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, DOLOMITI ENERGIA SPA, DONG ENERGY OIL & GAS AS, DONG ENERGY WIND POWER HOLDING AS, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF-KIT EWIV, ELCORE GMBH, ELEMENT ENERGY LIMITED, ENGIE, GASWARME-INSTITUT ESSEN EV, HEXIS AG, HYDROGEN, FUEL CELLS AND ELECTRO-MOBILITY IN EUROPEAN REGIONS, IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, ITHO DAALDEROP GROUP BV, PARCO SCIENTIFICO E TECNOLOGICO PER L'AMBIENTE - ENVIRONMENT PARK SPA, POLITECNICO DI TORINO, RAZVOJNI CENTER ZA VODIKOVE TEHNOLOGIJE, Riesaer Brennstoffzellentechnik GmbH, SENERTEC KRAFT-WARME ENERGIESYSTEME GMBH, SOLIDPOWER SPA, THE ENERGY SAVING TRUST LTD BY GUARANTEE, VAILLANT GMBH, VIESSMANN WERKE GMBH & CO KG

PROJECT AND OBJECTIVES

Ene.field is the largest European demonstration of the latest home energy solution for private homes, fuel cell m-CHP. The project ran from 2012 to 2017 and during these five years it installed 1,046 Fuel Cell m-CHP systems across 10 key European countries and demonstrated more than 5.5 million hours of operation and 4.5 GWh of power produced. Outputs of the project include: detailed performance data, lifecycle cost and environmental assessments, market analysis, commercialization strategy.

NON QUANTITATIVE OBJECTIVES

- Provide an overview of the current regulations, codes and standards in Europe and at national level
- Carry out a comprehensive life cycle assessment (LCA)
- Determine a future commercialization strategy for the technology by reviewing cost and volume projections with the manufacturers and by exploring different routes to market assess the requirements for future policy or financial incentives

PROGRESS & MAIN ACHIEVEMENTS

- 1046 units have been installed FC m-CHP units have been installed under ene.field, which exceeds the original target of 1000
- A number of public reports (or reports with a public summary) have been produced with the findings of the project that are available on the website: enefield.eu
- FC m-CHP is ready for a large market penetration. In the best 6-month period, availability of the units to the end-user has been above 99%

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Real-life data from the field trial has shown electrical efficiencies in between 30 – 60%.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

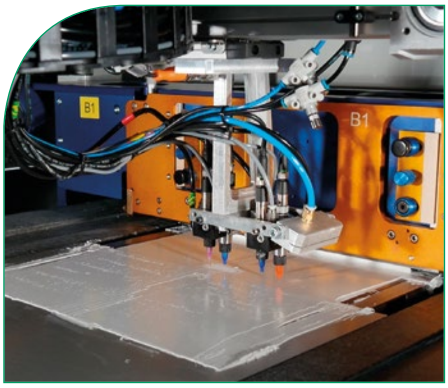
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Availability	%	Up to 100	97	✓
Operational and maintenance costs (OPEX)	EUR/kWh	Less than 0.02	0.05	✓
Lifetime of the m-CHP unit	years	10-15	13	✓
stack durability	hours	30,000- 80,000	50,000	✓
Hydrogen tolerance	%	Up to 100	100	✓

* As identified in MAWP Addendum 2018-2020, Target year 2020

PANEL 4
NEXT GENERATION OF PRODUCTS – ENERGY

Cell3Ditor

COST-EFFECTIVE AND FLEXIBLE 3D PRINTED SOFC STACKS FOR COMMERCIAL APPLICATIONS



Project ID:	700266
Call topic:	FCH-02.6-2015 - Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	€ 2,191,133.75
FCH JU max. Contribution:	€ 2,180,662.5
Project start - end:	01/07/2016- 31/12/2019
Coordinator:	FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES
Website:	www.cell3ditor.eu

BENEFICIARIES: 3DCERAM, DANMARKS TEKNISKE UNIVERSITET, FRANCISCO ALBERO SA, HyGear Fuel Cell Systems B.V., PROMETHEAN PARTICLES LTD, SAAN ENERGI AB, UNIVERSIDAD DE LA LAGUNA

PROJECT AND OBJECTIVES

The main goal of Cell3Ditor project is the development of a 3D printing technology for the industrial production of SOFC stacks. To achieve this, several intermediate steps have to be accomplished, including: formulation of printable inks and slurries of SOFC materials, development of a 3D printer for multi-material ceramics, fabrication of SOFC cell parts by 3D printing and two–step fabrication of joint-free 3D printed SOFC stack ready for integration in systems. Up to now, the project is matching the objectives with minor deviations due to the incorporation of a new fabrication technology.

NON QUANTITATIVE OBJECTIVES

- EHS issues due to utilization of nanometric raw materials
- Business plans looking for the commercialization of two outcomes of the project
- Dissemination in scientific, industrial and public forums
- Creation of an Industry Advisory Board focused on deployment and scalability of technology
- Evaluation of the investment and running costs of the technologies developed

PROGRESS & MAIN ACHIEVEMENTS

- Development of a multi-material ceramic 3D printing machine
- Formulation of printable inks and slurries of technical ceramic materials
- Fabrication of SOFC parts by 3D printing

FUTURE STEPS & PLANS

- Fabrication of complex design multi-material parts
- Fabrication of multi-material SOFC components
- Fabrication of SOFC stacks

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Although mainly thought for stationary applications, SOFC technology can be applied in transport sector as well. Actually, SOFC systems are the preferred solution for APUs in trucks and ships while Nissan has implemented a SOFC running on bioethanol. The technology developed in Cell3Ditor project presents a significant decrease of the CAPEX due to the elimination of fabrication stages and an increasing of the durability based on the removal of sealing.

Increase the electrical efficiency and the durability of the different fuel cells

The technology developed within Cell3Ditor project allow the fabrication of SOFC stacks without seals among the cells, decreasing one of the weakest points of such systems and increasing their durability.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

SOFC systems fabricated by Cell3Ditor technology could be used in electrolysis mode. Therefore, reduction of CAPEX expected due to the original manufacturing process can be easily extended.

Reduce the use of the EU defined 'Critical raw materials'

Cell3Ditor project is based on the manufacturing of SOFC stacks by additive manufacturing which implies a more efficient utilization of materials.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

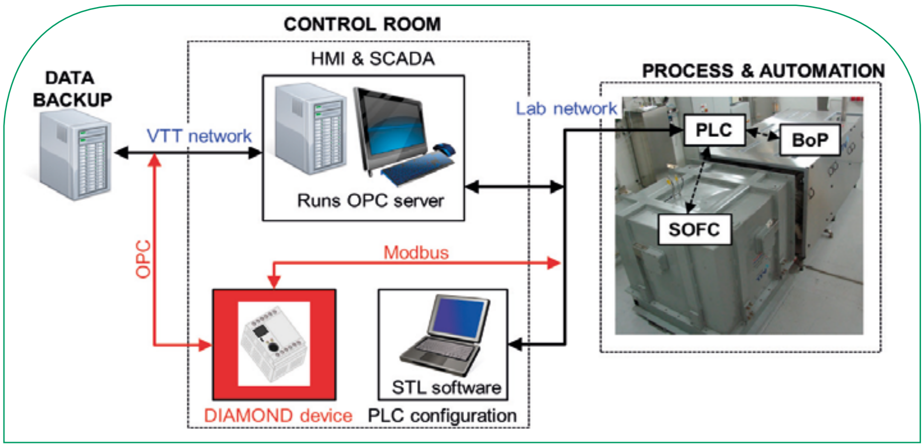
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project (SoA Year)	SoA YEAR	SoA Source
Stack weight	kg	6.7	3.5	2017	From experience in reference commercial stack: (SOFCMAN-ASC 60-cell Stack Module)
Stack volume	litters	1.8	1	2017	
Stack nominal capacity	kW	5	5	2014	Manufacturing cost analysis of 1 kW and 5 kW Solid Oxide Fuel Cell (SOFC) for auxiliary power applications, Battelle for the US Department of Energy (DOE Contract No. DE-EE0005250), February 2014
Active area per cell	cm2	100	200	2014	

* Available data provided by the Project

DIAMOND

DIAGNOSIS-AIDED CONTROL FOR SOFC POWER SYSTEMS

Project ID:	621208
Call topic:	SP1-JTI-FCH.2013.3.3 - Stationary Power and CHP Fuel Cell System Improvement Using Improved Balance of Plant Components/Sub-Systems and/or Advanced Control and Diagnostics Systems
Project total costs:	€ 3,613,489.6
FCH JU max. Contribution:	€ 2,101,808
Project start - end:	01/04/2014 - 30/09/2017
Coordinator:	HYGEAR B.V., NL
Website:	www.diamond-sofc-project.eu/about



BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, HTceramix SA, INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, INSTITUT JOZEF STEFAN, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

The DIAMOND project aimed at improving the performance of solid oxide fuel cells (SOFCs) for CHP applications by implementing innovative strategies for on-board diagnosis and control. Advanced monitoring models have been developed integrating diagnosis and control functions with the objective of having meaningful information on the actual state-of-the-health of the entire system. The new concepts have been validated using two different SOFC systems.

NON QUANTITATIVE OBJECTIVES

- Monitoring and diagnosis support the advanced control strategies to find the optimal values of the controller to be actuated on the system
- Diagnosis and control algorithms will be released for implementation into conventional hardware
- New diagnosis concepts will be introduced (e.g. backward residuals via inverse model)
- Improvement of the fault signature matrix will be achieved starting from the outcomes of the FCH-JU funded GENIUS and DESIGN projects
- Monitoring and diagnosis will support the control algorithms in adapting its parameters according to the actual system status reducing the risk of faults

PROGRESS & MAIN ACHIEVEMENTS

- Advanced control strategies to find the optimal operating point implemented and validated
- A procedure to estimate the remaining useful life has been developed and validated
- System models have been developed and validated

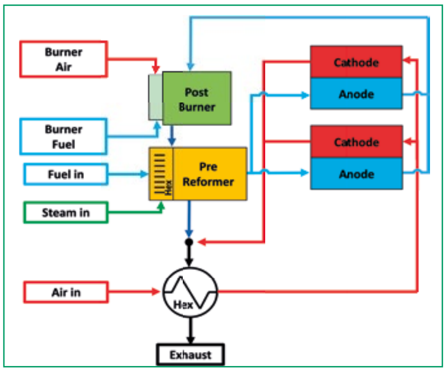
FUTURE STEPS & PLANS

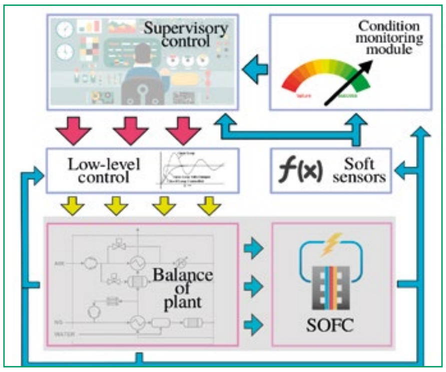
Project is finished

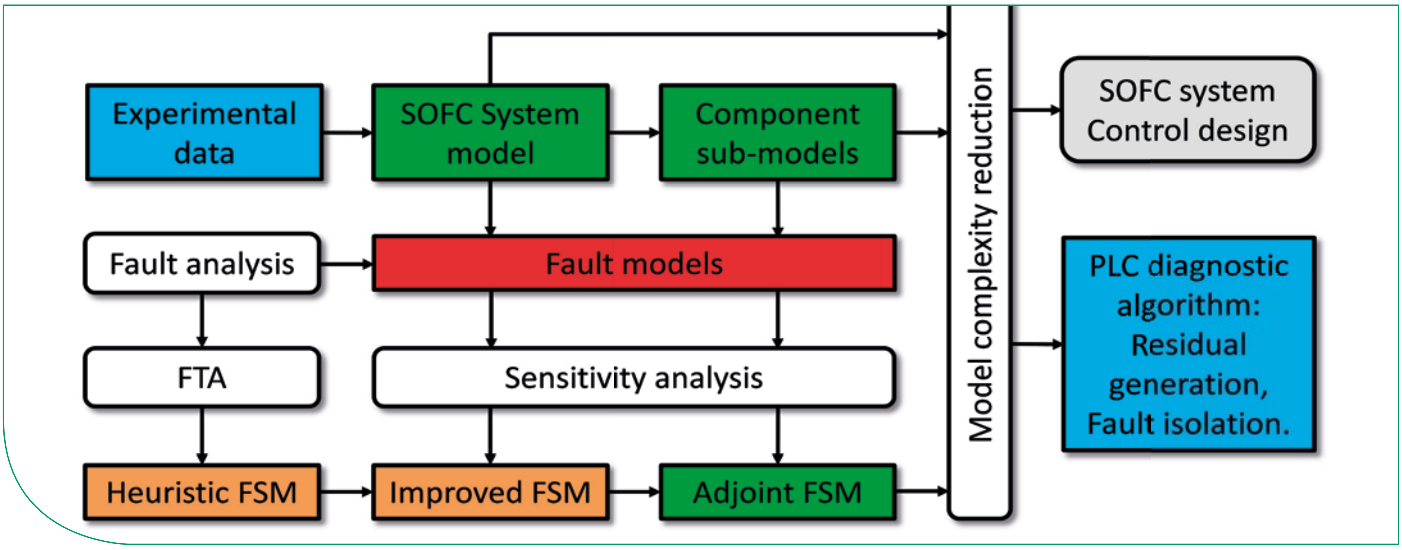
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Diagnostics and monitoring of systems will improve durability.



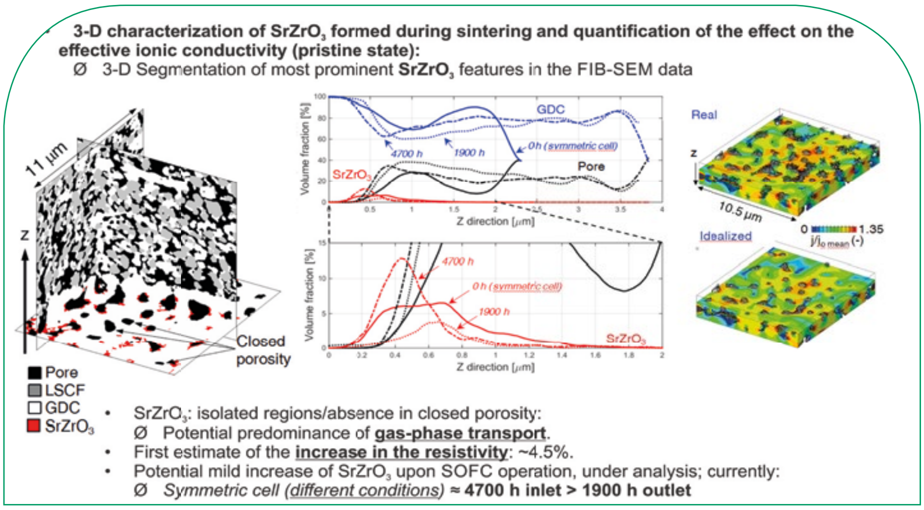




Endurance

ENHANCED DURABILITY MATERIALS FOR ADVANCED STACKS OF NEW SOLID OXIDE FUEL CELLS

Project ID:	**621207**
Call topic:	**SP1-JTI-FCH.2013.3.1** - Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
Project total costs:	**€ 4,256,293.61**
FCH JU max. Contribution:	**€ 2,556,232**
Project start - end:	01/04/2014 - 31/05/2017
Coordinator:	**UNIVERSITA DEGLI STUDI DI GENOVA, IT**
Website:	**www.durablepower.eu/index.php**



BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, HTceramix SA, INSTITUTE OF ELECTROCHEMISTRY AND ENERGY SYSTEMS, MARION TECHNOLOGIES S.A., SCHOTT AG, SOLIDPOWER SPA, UNIVERSITA DI PISA

PROJECT AND OBJECTIVES

The project ended up on May 2017. The main objectives of the project were:

- to contribute to the understanding of the degradation phenomena of the cells (SOFC) and of the stacking materials under operation in relationship with the steady state, the thermal cycles (up to 50), the idle to load cycles (up to 100)
- to refine the descriptive and predictive models at micro and macro level
- to introduce improvements at cella and stacking level in order to decrease the degradation rate

NON QUANTITATIVE OBJECTIVES

- D4.1: Handbook of testing procedures and protocols
- D8.1: Proceedings of the workshop « Degradation Mechanisms in Solid Oxide Cell and Systems »
- Serious Game « The lost colony »
- Public website

PROGRESS & MAIN ACHIEVEMENTS

- Degradation rate In Steam reforming Methane lower than 0.1% each 1000h (0.03%/1kh), achieved 100%
- Fully operating Joined thermomechanical and Electrochemical for micro and macro behaviours of SOFC stacks. Achievement 100%
- Idle to Load 100 cycles with contained losses (<4 mW/lcycle). Achievement 100%

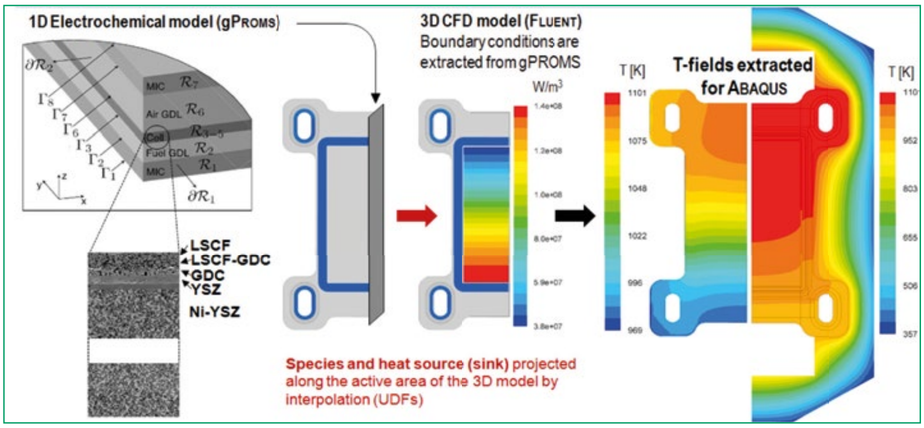
FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

The project contributed to lower the degradation rate in steady state and cycling conditions.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack durability	hours	50,000	50,000	✓
Stack availability	%	100	97	✓
Stack electrical efficiency (LHV) - observed	%	50	42-60	✓
Degradation rate	%/kh	0.2	<0.2	✓

* As identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020

FluidCELL

ADVANCED M-CHP FUEL CELL SYSTEM BASED ON A NOVEL BIO-ETHANOL FLUIDIZED BED MEMBRANE REFORMER

Project ID:	621196
Call topic:	**SP1-JTI-FCH.2013.3.4** - Proof of concept and validation of whole fuel cell systems for stationary power and CHP applications at a representative scale
Project total costs:	**€ 4,193,548.92**
FCH JU max. Contribution:	**€ 2,492,341**
Project start - end:	01/04/2014 - 31/07/2018
Coordinator:	**FUNDACION TECNALIA RESEARCH & INNOVATION, ES**
Website:	**www.fluidcell.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, HyGear B.V., ICI CALDAIE SPA, POLITECNICO DI MILANO, Quantis Sàrl, TECHNISCHE UNIVERSITEIT EINDHOVEN, UNIVERSIDADE DO PORTO, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

FluidCELL aims at developing an advanced m-CHP fuel cell system for decentralized off-grid applications. The new m-CHP will be based on a novel bio-ethanol fluidised bed catalytic membrane reformer working at low temperature (≤ 500ºC) and the most advance technology at the fuel cell level. Main progresses up to date:

- Catalyst & membranes for bio-ethanol reforming prototype developed
- Bioethanol fluidised bed membrane reformer validated at lab-scale & model validated
- Pilot scale reformer & fuel cell stack built & Factory Acceptance tests completed
- m-CHP system integrated

NON QUANTITATIVE OBJECTIVES

- Traineeships of UNISA students at TUE
- Catalysts characterization (UNISA and TUE)
- PEM manufacturing and characterization (CEA and POLIMI at CEA)
- Technical economic assessment and optimization of both reactors and complete system
- Life Cycle Analysis and safety Analysis

PROGRESS & MAIN ACHIEVEMENTS

- Bioethanol steam reforming in a membrane reactor under fluidization validated at lab-scale both experimentally and model
- Pilot scale ATR membrane reactor & fuel cell stack built and Factory Acceptance tests completed
- m-CHP system integrated

FUTURE STEPS & PLANS

- Modifying the pilot reactor working conditions to deliver a higher amount of H2 and purity (after the methanator)
- Proof of concept of the novel m-CHP system

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

FluidCELL is developing an advanced m-CHP fuel cell system for decentralized off-grid applications. The new m-CHP is based on a novel bio-ethanol fluidised bed catalytic membrane reformer working at low temperature (≤ 500ºC) for the production of H2 and the most advance technology at the fuel cell level.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

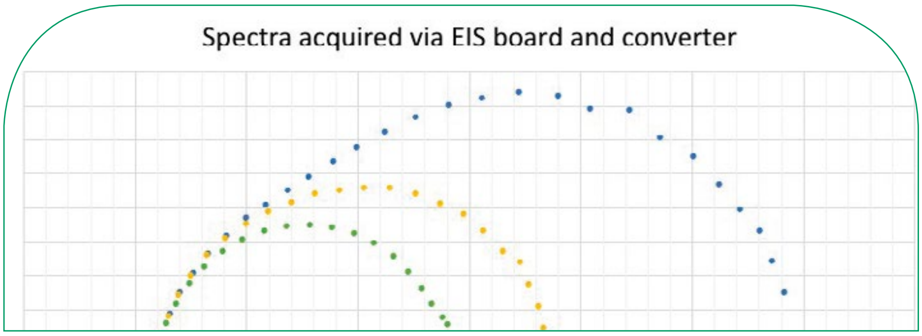
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project	SoA YEAR	SoA Source
Overall efficiency m-CHP unit	%	90 (Rated system total efficiency (LHV)	80	N.A.	Sidera30 by ICI Caldaie (http://www.icicaldaie.com/sidera-30.asp) Ethanol reformer and fuel cell by ZSW (https://www.zsw-bw.de/fileadmin/user_upload/PDFs/Aktuelles/2013/PDFs_Presseinformationen_Deutsch/ZSW_EtOHSystem_01.pdf).
Novel catalyst for bio-ethanol reforming with high durability	Highly-stable catalysts	Carbon formation rate (CFR) among the lowest found in the recent literature. Stable behaviour after 400 h of test with no further activity loss	Other studies were rarely focused on stability tests higher than 100 h. conversion until total deactivation of the catalyst	2015,2017 (long term stability)	C. Montero, A. Ochoa, P. Castaño, J. Bilbao, A.G. Gayubo, Monitoring NiO and coke evolution during the deactivation of a Ni/La2O3–ÐAl2O3 catalyst in ethanol steam reforming in a fluidized bed, Journal of Catalysis, 331 (2015) 181–192. V. Palma, C. Ruocco, E. Meloni, A. Ricca, Oxidative steam reforming of ethanol on mesoporous silica supported Pt-Ni/CeO2 catalysts, International Journal of Hydrogen Energy, 42 (2017) 1598-1608.
Development of long (>15 cm) and mechanically stronger H2 selective membranes & membrane production scale-up	cm	45 cm long membranes. 1 membrane per batch. But process optimized for having 4 membranes coated per day.	1 m long membranes (3 per batch)	-	ECN: http://www.hysep.com/ TECNALIA membranes have better properties than ECN membranes. ECN module is used for H2 separation, not for/as membrane reactor. J.L Viviente et al, Int. J. Hydrogen Energy 2017, 42, 13970-13987

* Available data provided by the Project

HEALTH-CODE

REAL OPERATION PEM FUEL CELLS HEALTH-STATE MONITORING AND DIAGNOSIS BASED ON DC-DC CONVERTER EMBEDDED EIS

Project ID:	**671486**
Call topic:	**FCH-02.3-2014** - Stationary fuel cell system diagnostics: development of online monitoring and diagnostics systems for reliable and durable fuel cell system operation
Project total costs:	**€ 2358736.25**
FCH JU max. Contribution:	**€ 2358736.25**
Project start - end:	01/09/2015 - 31/12/2018
Coordinator:	**UNIVERSITA DEGLI STUDI DI SALERNO, IT**
Website:	**www.pemfc.health-code.eu**



BENEFICIARIES: AALBORG UNIVERSITET, ABSISKEY, ABSISKEY CP, BALLARD POWER SYSTEMS EUROPE AS, BITRON SPA ,EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ELECTRO POWER SYSTEMS MANUFACTURINGSRL, EPS ELVI ENERGY S.R.L., TORINO E-DISTRICT CONSORZIO, UNIVERSITE DE FRANCHE-COMTE, UNIVERSITE DE TECHNOLOGIE DE BELFORT - MONTBELIARD

PROJECT AND OBJECTIVES

HEALTH-CODE aims at implementing an advanced monitoring and diagnostic tool for μ-CHP and backup PEMFC systems, to determine FC status (condition monitoring) and infer on residual useful lifetime. Five failure modes are detected: change in fuel composition; air and fuel starvation; sulphur poisoning; flooding and drying. The main objectives are: enhancement of EIS based diagnosis; development of monitoring and diagnostic tool for state-of-health assessment, fault detection and isolation and degradation level analysis; reduction of experimental campaign time and costs.

PROGRESS & MAIN ACHIEVEMENTS

- More than 2000 EIS spectra acquired on two different PEMFC technologies for either single cells or short/ full stacks, in nominal and faulty states
- EIS board correctly engineered & interfaced with LV & HV DC/DC converters. Converters suitably modified and adapted for EIS board interfacing and use
- Three diagnostic algorithms designed, tested offline and under implementation for validation. One active diagnosis approach tested as well

FUTURE STEPS & PLANS

- Integration of EIS board and DC/DC converter on PEMFC systems, for system testing in normal and faulty conditions
- Diagnostic methods benchmarking and overall evaluation assessment
- Diagnostic algorithms implementation on EIS board and online testing
- Completion of experimental activities still ongoing for lifetime extrapolation

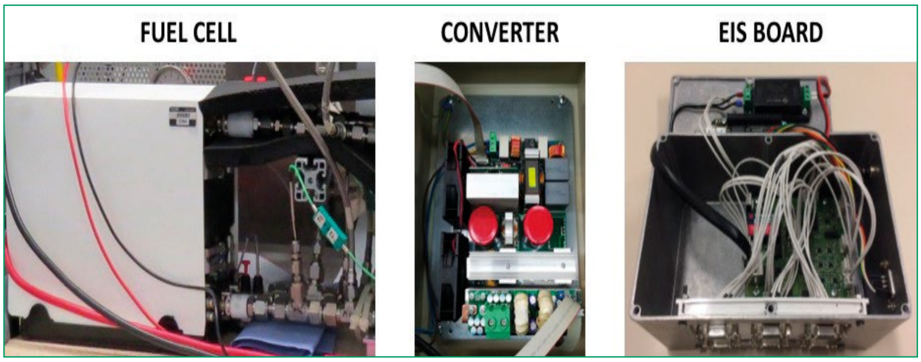
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The diagnostic algorithms can improve system state of health and lifetime, with a consequent reduction in maintenance costs. Moreover, the implementation of scaling-up approach can reduce testing time and costs.

Increase the electrical efficiency and the durability of the different fuel cells

The amount of detectable faulty states, coupled with the different types of diagnostic algorithms, can improve system efficiency, reliability and availability through advanced control techniques (not considered in HEALTHCODE).



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

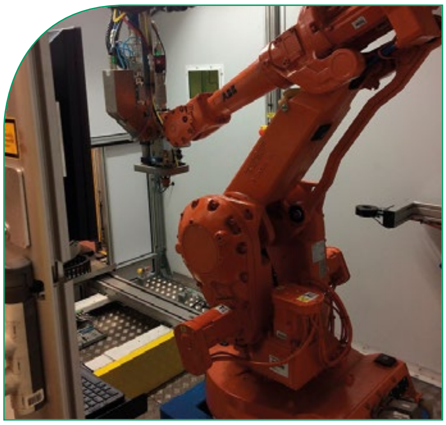
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
System electrical efficiency at start	%	50	36	✓	In nominal condition.
System electrical efficiency at end	%	40	36	✓	In nominal condition.
Diagnosis/monitoring tool availability	%	N/A	99	⚒	Not yet available / to verify with tests scheduled in 2018.
Predicted System durability	hours	15,000	20,000	⚒	5 years or 15000 hours or 1000 cycles.
System electrical efficiency at start	%	33.60	36	⚒	Value measured by notified body DGC.
Predicted System durability	hours	13,610	20,000	⚒	13610 MIN /40000 MAX. Highest number of operating hours on one system with same fuel processor and stack.

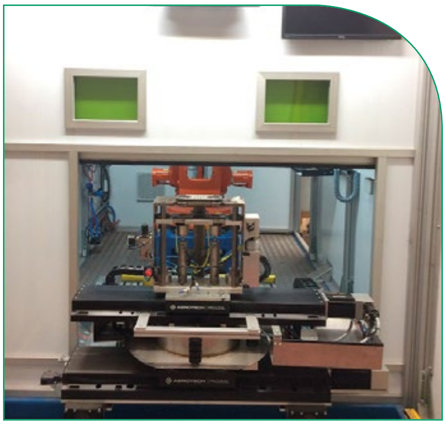
* As identified in MAWP 2014-2020

HEATSTACK

PRODUCTION READY HEAT EXCHANGERS AND FUEL CELL STACKS FOR FUEL CELL M-CHP

Project ID:	700564
Call topic:	**FCH-02.6-2015** - Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	€ 2,899,760
FCH JU max. Contribution:	€ 2,899,760
Project start - end:	01/04/2016 - 30/06/2019
Coordinator:	SENIOR UK LTD, UK
Website:	www.heatstack.eu/news-and-events/heatstack-production-ready-heat-exchangers-fuel-cell-stacks-fuel-cell-mchp





BENEFICIARIES: I.C.I CALDAIE SPA, PNO CONSULTANTS LIMITED, SENIOR FLEXONICS CZECH S.R.O., SUNFIRE GMBH, THE UNIVERSITY OF BIRMINGHAM, VAILLANT GMBH

PROJECT AND OBJECTIVES

The project focuses on the industrialisation of manufacturing the Cathode Air Preheater and Full Cell stack two realise a 50% cost saving once in volume production of these two most expensive components of micro-CHP systems. Currently system cost is the biggest hurdle to wide scale adoption of this technology in the domestic market. Research is also being undertaken into the benefits of using AluChrom in the CAPH to extend the longevity of the CAPH, further enhancing the overall lifetime cost of micro-CHP. Project currently at the start of the second half of a 37 month duration.

NON QUANTITATIVE OBJECTIVES

Change to MicroTIG welding from laser to reduce operator Health and Safety risk- but to overcome the material cracking and reduced precision.

PROGRESS & MAIN ACHIEVEMENTS

- Research results showing ax10 reduction of Cr evaporation using AluChrom318 in CAPH compared to the current standard of Inconel 625, SS309, Al SS309
- Redesigned CAPH which has proven to resist deformation when subjected to rigorous system level tests, suggesting component will last as long as stack
- Equipment in place and process validated for the automated welding of the cells and side plates off the CAPH, exceeding targeted process time reduction

FUTURE STEPS & PLANS

Transfer of CAPH automated production equipment to either new Welsh premises of Senior Olomouc facility.

- Completion of the stack glass sealing optimisation process by Sunfire, and implementation into their production line
- Sunfire to develop their first prototype system level units, first 5 then another 20. Over Q4 2019 Q1 & Q2 2020 they will manufacture 500 systems
- Integration of the Senior CAPH into ICICaldaie systems and testing to validate the cross system scale viability of the single design CAPH
- Delivery of techno-economic assessment of the improved processes compared to the pre-project approaches, and LCA analysis

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Although the project does not focus on efficiency or target durability, the focus on cost reduction of the two most expensive components will contribute to adoption of the technology in domestic homes.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Whilst not targeting efficiency of hydrogen production, the project does aim to half the production costs of microchip systems, so that if widely adopted these can contribute to electricity production at the point of use, reducing transmission losses, and create heat at the same time without the usual associated CO2 waste products, thus contributing to more efficient power generation and reduced environmental impact.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The project is focussed on the fuel source being natural gas. However this is used to produce hydrogen for the fuel cell by reducing the system cost and therefore facilitating mass market adoption, this can demonstrate large scale renewable sourced electricity production- for example if biogas is used in the network, and also enables domestic use of hydrogen as a heat and power source if hydrogen is successfully adopted into the grid.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
CAPH cost (sale) from 2000	%	Not able to confirm until high volume production of 10000pa has been realised	60	
CAPH manufacture time reduction from 8.83 hours	hours	The automated process and robotic laser welders are no in place- full cycle time yet to be tested but expected to be close to target	1.35	
Reduction of glass needed for Stack	%	Process still in development, but expected to realise this target	50	
Reduction of process time for glass sealant from 200 minutes	minutes	Process still in development, but expected to realise this target	100	
Electrical efficiency	%	34	55-60	
Durability	%	40,000	50,000	

* As identified in MAWP Addendum 2018-2020 and project's own objectives, Target years 2019- 2020

INNO-SOFC

DEVELOPMENT OF INNOVATIVE 50 KW SOFC SYSTEM AND RELATED VALUE CHAIN

Project ID:	**671403**
Call topic:	**FCH-02.5-2014** - Innovative fuel cell systems at intermediate power range for distributed combined heat and power generation
Project total costs:	**€ 3,998,081.25**
FCH JU max. Contribution:	**€ 3,998,081.25**
Project start - end:	01/09/2015 - 30/04/2019
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.innosofc.eu**

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, CONVION OY, Elcogen OY, ELRINGKLINGER AG, ENERGY MATTERS BV, FORSCHUNGSZENTRUM JULICH GMBH

PROJECT AND OBJECTIVES

INNO-SOFC project combines leading European SOFC technology companies and research centres to collaborate and form required phases in the SOFC value chain. Within this project a next generation 50 kW SOFC system together with its key components will be developed, manufactured, and validated. This system includes many significant improvements compared to current State of the Art, leading to 30,000 hours operating time, 4000 €/kW system costs, 60% electrical efficiency, and 85% total efficiency, which are required for large-scale commercialization of stationary fuel cells.

PROGRESS & MAIN ACHIEVEMENTS

- Conceptual design of the system finished
- Stack delivery for the system started
- Most promising end-users and applications identified and analysed.

FUTURE STEPS & PLANS

- Finish system detail design
- Manufacture stacks for the system
- System manufacturing and start-up

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

60% electrical efficiency and 85% total efficiency will be reached within this project in 50 kW power level which is a clear improvement over the SoA.

QUANTITATIVE TARGETS AND STATUS

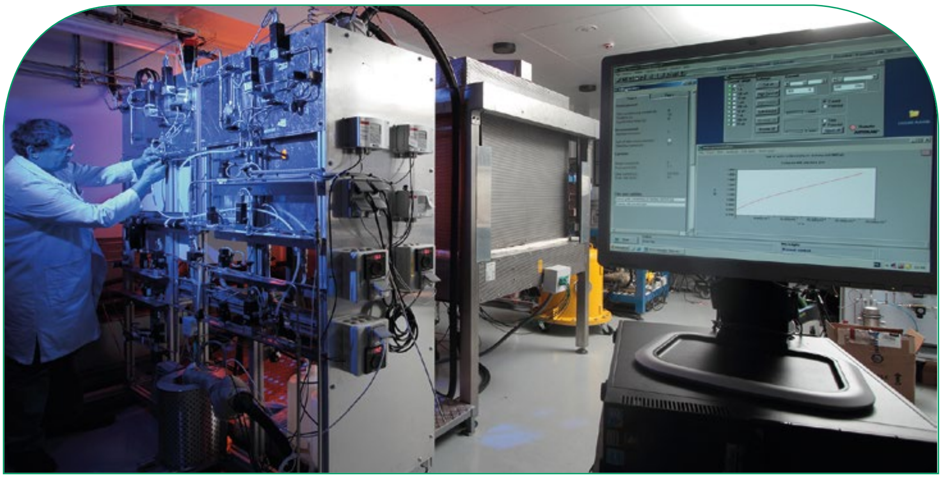
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Rated system electrical efficiency (LHV)	%	60	42-60	✓	60% -a small demo system (2009)	Stationary demo unit - LHV
Rated system thermal efficiency (LHV)	%	25	24-42	✓	N/A	Stationary demo unit - LHV
Lifetime of the fuel cell system	years	11.41	6 - 20	✓	N/A	Stationary demo unit
Stack durability	hours	30,000	50,000	Achieved SoA 2017	N/A	Stationary demo unit
Land use / footprint	m2/kW	0.1	0.08	Achieved SoA 2017	N/A	Stationary demo unit
Est. FC system CAPEX @ mass production	EUR/kW	4000	4,500 - 7,500	✓ projection has achieved	14,000 - real costs no mass production	FC system
BoP CAPEX @ mass production	EUR/kW	2000		✓ projection has achieved		FC system

* As identified in MAWP Addendum 2018-2020, Target year 2020

INSIGHT

IMPLEMENTATION IN REAL SOFC SYSTEMS OF MONITORING AND DIAGNOSTIC TOOLS USING SIGNAL ANALYSIS TO INCREASE THEIR LIFETIME



Project ID:	**735918**
Call topic:	**FCH-02-5-2016** - Advanced monitoring, diagnostics and lifetime estimation for stationary SOFC stacks and modules
Project total costs:	**€ 3,146,056.25**
FCH JU max. Contribution:	**€ 2,498,948.75**
Project start - end:	01/01/2017- 31/12/2019
Coordinator:	**COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.insight-project.eu**

BENEFICIARIES: ABSISKEY, ABSISKEY CP, AVL LIST GMBH, BITRON SPA, DANMARKS TEKNISKE UNIVERSITET, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, HTceramix SA, INSTITUT JOZEF STEFAN, SOLIDPOWER SPA, Teknologian tutkimuskeskus VTT Oy, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

The project aims at developing a Monitoring, Diagnostic and Lifetime Tool for SOFC stacks. Monitoring is based on 2 advanced techniques (EIS and THD) in addition to conventional stack signal. Durability tests with faults added on purpose generate the data required to develop and validate the algorithms. Fault mitigation logics will be developed to avoid stack failures and slow down their degradation. A specific low-cost hardware, consisting in a single board able to embed the tool will be developed and integrated into a commercial m-CHP, which will be tested on-field.

NON QUANTITATIVE OBJECTIVES

- Perform test with faults added on purpose
- Development of a monitoring, diagnostic and lifetime tool (MDLT)
- Implement the MDLT on a board

PROGRESS & MAIN ACHIEVEMENTS

- Definition and test of 3 faults considered as major for the SOFC stacks (high fuel utilisation, leakage and carbon deposition)
- Implementation of pseudo-random binary signal (PRBS) technique on short stack during testing
- First release of the board, so called "Bitron box"

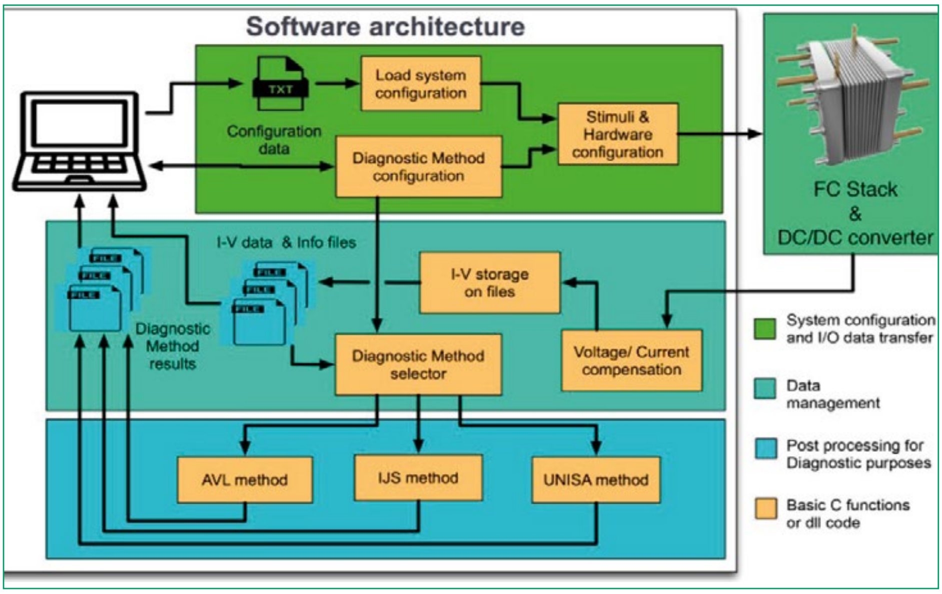
FUTURE STEPS & PLANS

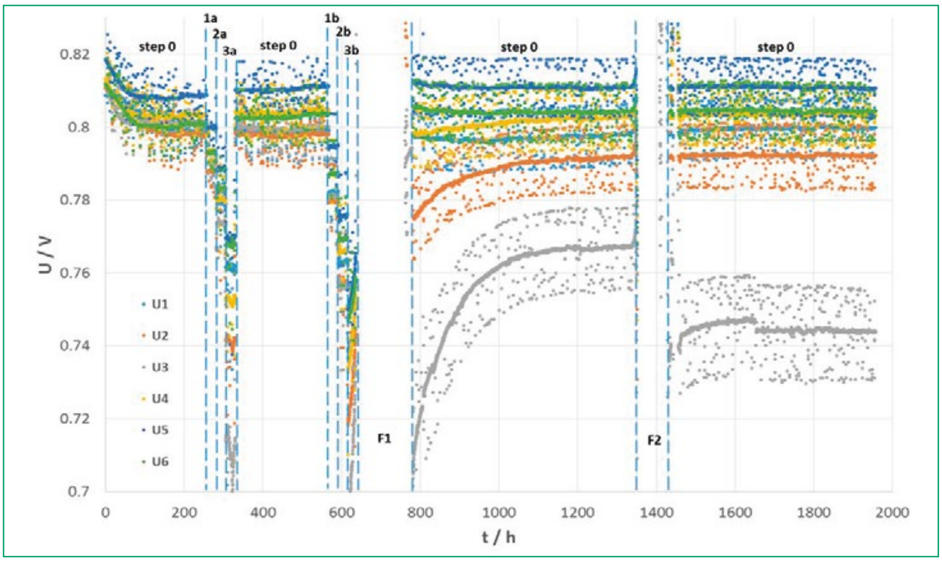
- Continuous interaction between WP2 testing and WP4/5 MDLT to provide data for the algorithms developments
- Completion of the testing campaign
- Completion of the board embedding the algorithms
- System integration of the board, lab test and subsequently on-field test on a m-CHP system

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Project targets a lifetime prolongation by 5% thanks to the MDLT tool embedding on the board included in the SOFC system Indeed, the combination of diagnostic algorithms and mitigations strategies will reduce the impact of faults and improve system reliability and availability.

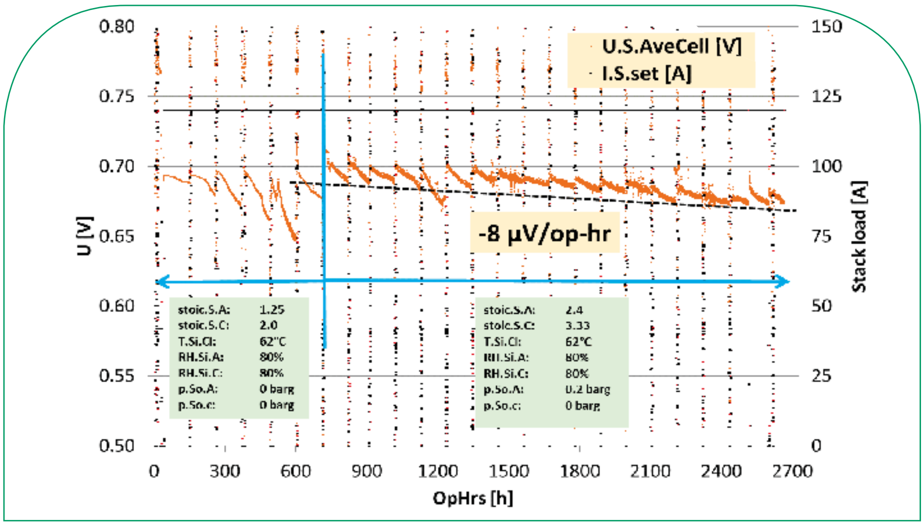




MATISSE

MANUFACTURING IMPROVED STACK WITH TEXTURED SURFACE ELECTRODES FOR STATIONARY AND CHP APPLICATIONS

Project ID:	621195
Call topic:	SP1-JTI-FCH.2013.3.2 - Improved cell and stack design and manufacturability for application-specific requirements for Stationary Fuel Cell power and CHP systems
Project total costs:	€ 3,192,819.8
FCH JU max. Contribution:	€ 1,684,717
Project start - end:	01/10/2014 - 31/12/2017
Coordinator:	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.matisse.zsw-bw.de/general-information.html



BENEFICIARIES: AREVA STOCKAGE D'ENERGIE SAS, INHOUSE ENGINEERING GMBH, NEDSTACK FUEL CELL TECHNOLOGY BV, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERGSTIFTUNG

PROJECT AND OBJECTIVES

MATISSE is targeting the delivery of PEMFC advanced cells and stacks for stationary applications. Three fuel cell designs are addressed for specific operation i.e. H2/02, H2/Air and reformate H2/Air. The methodology is based on the assessment of stacks with improved MEAs, including new compositions and processes developed to validate automated manufacturing. Performance, durability and heterogeneities of reference MEAs with homogeneous electrodes have been analysed before implementing MEAs with textured electrodes, allowing to modify the local operation and improve stacks behaviour.

NON QUANTITATIVE OBJECTIVES

- Validate automated manufacturing of MEAs for cost reduction
- Analysis of local operation for understanding and cells improvement
- Develop textured electrodes to improve MEA performance and robustness
- Validation of new electrodes under specific ageing conditions

PROGRESS & MAIN ACHIEVEMENTS

- Analysis of current distribution and improvement of cells performance by texturing the catalyst layers for 3 conditions (H2 or Reformate/Air, H2/O2)
- Validated transfer to a fully automated process (screen printing pilot line) for manufacturing large size electrodes of 3 different PEMFC designs
- Successful implementation of reference and textured MEAs showing targeted performance in all cases and expected durability under Reformate or H2/Air

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Development of electrodes improving stack operation for H2/O2, H2/Air, and Reformate/air.

QUANTITATIVE TARGETS AND STATUS

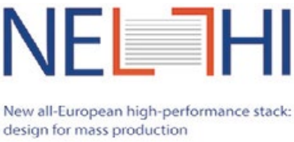
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project
Stack electrical efficiency (LHV) - observed	%	50	43-55	✓	N/A
Degradation rate	%/kh	0.7	< 0.25	🛠	N/A
Stack durability	hours	14,000	20,000	🛠	80,000
Stack availability	%	100	97	✓	N/A
Areal power density	%/kh	0.7	0.67	✓	N/A

* As identified in MAWP Addendum 2018-2020 and AWP 2017, Target years 2018- 2020

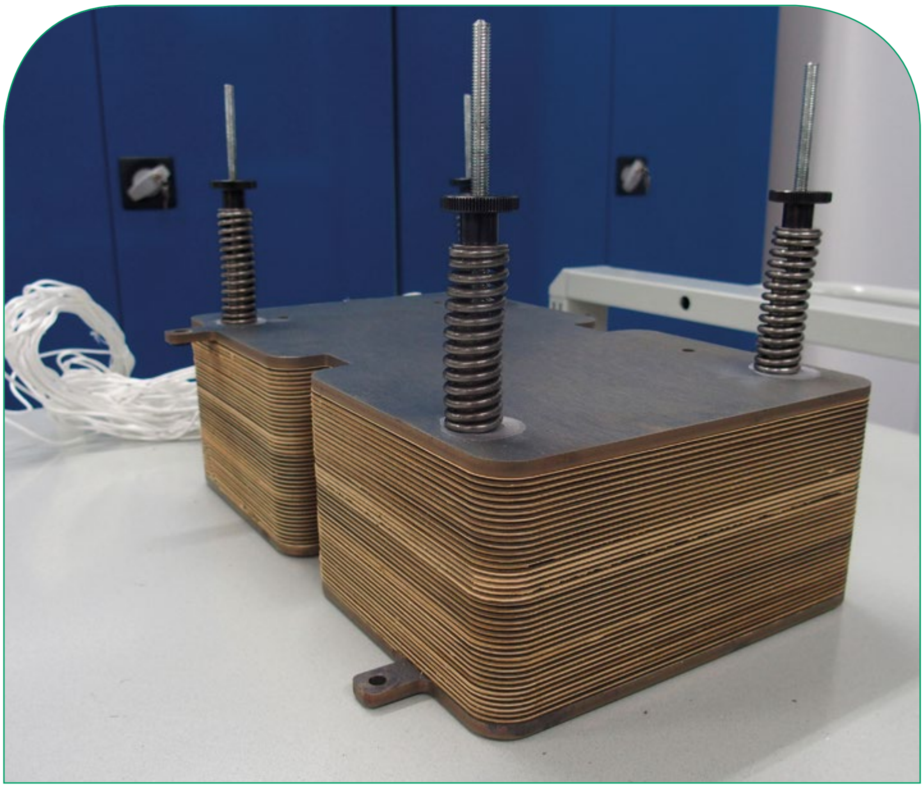
NELLHI

NEW ALL-EUROPEAN HIGH-PERFORMANCE STACK: DESIGN FOR MASS PRODUCTION



Project ID:	**621227**
Call topic:	**SP1-JTI-FCH.2013.3.2** - Improved cell and stack design and manufacturability for application-specific requirements for Stationary Fuel Cell power and CHP systems
Project total costs:	**€ 2,858,447.2**
FCH JU max. Contribution:	**€ 1,633,895**
Project start - end:	01/05/2014 - 30/04/2017
Coordinator:	**AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, IT**
Website:	**www.nellhi.eu**

BENEFICIARIES: AKTSIASELTS ELCOGEN, BORIT NV, CLAUSTHALER UMWELTTECHNIK INSTITUT GMBH, Elcogen OY, FLEXITALLIC LTD, SANDVIK MATERIALS TECHNOLOGY AB, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy



PROJECT AND OBJECTIVES

NELLHI combines European know-how in single cells, coatings, sealing, and stack design to produce a novel modular 1 kW SOFC stack at reduced temperature, of unprecedented performance. The stack has been developed over 3 successive generations according to system integrators' requirements guided by an industrial advisory group, achieving all objectives. The target application is stationary and residential combined heat and power production based on natural gas, and will form the basis for Elcogen's commercial stack technology as well as enforce market penetration for component manufacturers.

NON QUANTITATIVE OBJECTIVES

Improve capacity and maturity of all-European SOFC stack supply chain.

PROGRESS & MAIN ACHIEVEMENTS

- Record stack efficiency obtained: 74% electrical
- Very high single-pass fuel utilization achieved: 91% with hydrogen feed
- Very high yield rate of manufacturing process: 96% for cells, 97% for stacks

FUTURE STEPS & PLANS

Project finished. Outstanding objectives being dealt with in INNOSOFC and qSOFC projects.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Record single-pass stack efficiency was achieved and production costs were reduced. Durability was consolidated but can be further improved.

Reduce the use of the EU defined 'Critical raw materials'

The SOFC production process in NELLHI minimizes the use of critical raw materials.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Project process: Electrical efficiency	%	70	55-60	✓	60 (2013)	NELLHI - first generation FC stack
Project process: Electrical efficiency	%	74	55-60	✓		NELLHI - second generation FC stack
Durability	hours	20,000	50,000	🛠	40,000 (2016)	N/A

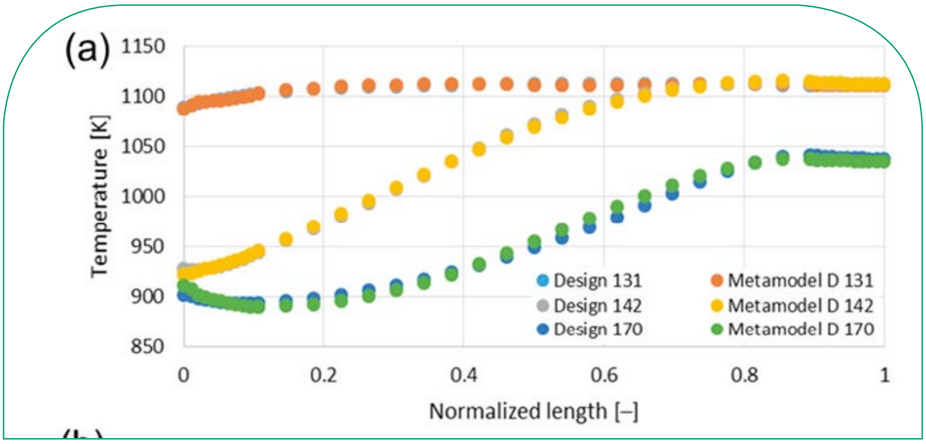
*As Identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020

PROSOFC

PRODUCTION AND RELIABILITY ORIENTED SOFC CELL AND STACK DESIGN

PROSOFC

Project ID:	**325278**
Call topic:	**SP1-JTI-FCH.2012.3.2** - Improved cell and stack design and manufacturability for application specific requirements
Project total costs:	**€ 7,331,214.71**
FCH JU max. Contribution:	**€ 3,011,000**
Project start - end:	01/05/2013 - 31/10/2017
Coordinator:	**AVL LIST GMBH, AT**
Website:	**www.prosofc-project.eu**



BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, DYNARDO AUSTRIA GMBH, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, FORSCHUNGSZENTRUM JULICH GMBH, HTceramix SA, IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, Karlsruher Institut fuer Technologie, TOPSOE FUEL CELL A/S

PROJECT AND OBJECTIVES

The PROSOFC project aims at improving the robustness, manufacturability, efficiency and cost of SOLIDpowers state-of-the-art SOFC stacks so as to reach market entry requirements. The key issues are the mechanical robustness of solid oxide fuel cells (SOFCs), and the delicate interplay between cell properties, stack design, and operating conditions of the SOFC stack. The project was finished in October 2017.

PROGRESS & MAIN ACHIEVEMENTS

- Material and electrochemical characterization to develop homogenized models to describe the properties used in multi physics modelling accomplished
- Multi-physics meta-models of stack to be utilized for automatic design variation and cost-based design optimization established
- Automated sensitivity analysis with the software tool optiSlang in combination with the design software tools (e.g. AVL FIRE, gProms) carried out

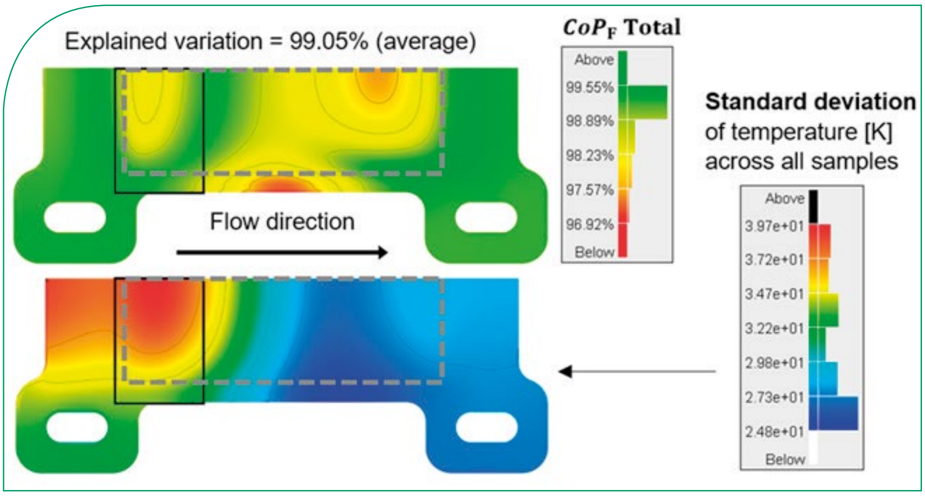
FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Robustness of stack could be improved by improved stack design



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
Stack electrical efficiency (LHV) - observed	%	62	55-60	✓	N/A
Electrical efficiency (SOFC system)	%	55	35-60	✓	52-60 (2017-2018)
Power density	W/cm2	0.3	N/A	🛠	0.22 (2017)

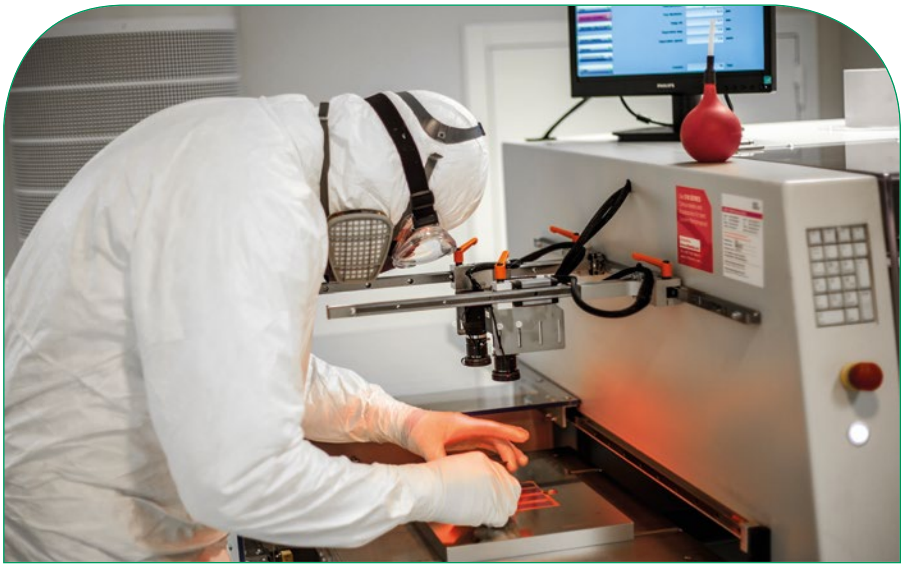
* As Identified in AWP 2017, Target year 2020

qSOFC

AUTOMATED MASS-MANUFACTURING AND QUALITY ASSURANCE OF SOLID OXIDE FUEL CELL STACKS

Project ID:	**735160**
Call topic:	**FCH-02-6-2016** -Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,110,015**
FCH JU max. Contribution:	**€ 2,110,015**
Project start - end:	01/02/2017 - 31/01/2020
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.qsofc.eu**

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, AKTSIASELTS ELCOGEN, Elcogen OY, ELRINGKLINGER AG, HAIKU TECH EUROPE BV, MUKO MASCHINENBAU GMBH, SANDVIK MATERIALS TECHNOLOGY AB



PROJECT AND OBJECTIVES

qSOFC project focuses on SOFC stack cost reduction and quality improvement by replacing manual labour in all key parts of the stack manufacturing process with automated manufacturing and quality control. This will lead to stack cost of 1000 €/kW and create a further cost reduction potential down to 500 €/kW at mass production (2000 MW/year).

PROGRESS & MAIN ACHIEVEMENTS

- First tests to detect defects in cell manufacturing using automated 3D machine vision inspection system have been successfully completed
- First results to streamline stack production show promising results
- Good results from cell manufacturing optimization for mass-production

FUTURE STEPS & PLANS

- Stack manufacturing (conditioning process) streamlined to reduce CAPEX and OPEX
- Cell manufacturing pastes and slurries modified to enable mass-manufacturing
- Validation of automated 3D machine vision inspection in cell production line
- Optimization of interconnect manufacturing using coated steel substrate
- Validation of the performance and durability of a stack manufactured using the developed mass-manufacturing methodology

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

qSOFC project introduces efficient quality assurance methods for the entire stack manufacturing value-chain thus reducing costs.

QUANTITATIVE TARGETS AND STATUS

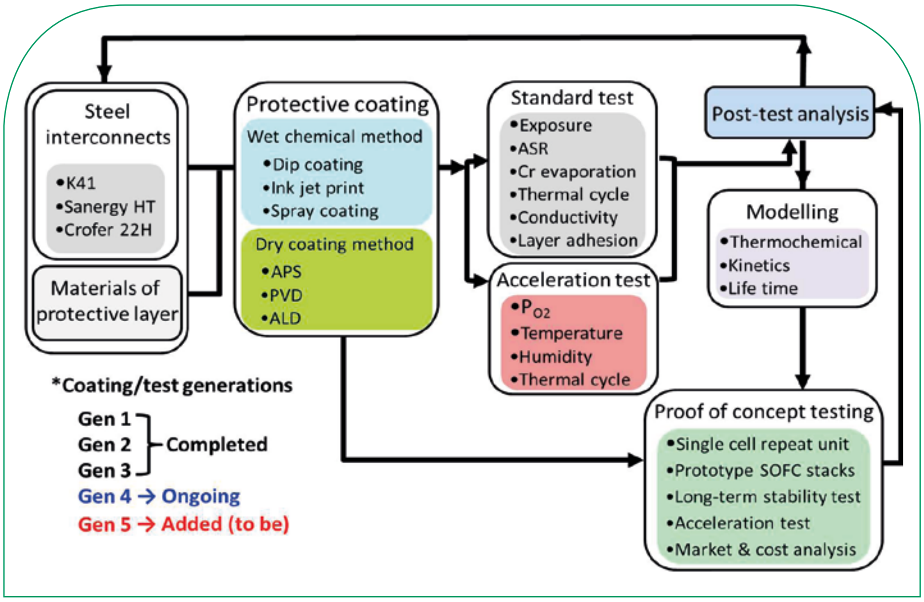
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
Reference & Project process: Electrical efficiency	%	74	55-60	✓	N/A
Reference process: Durability	hours	20,000	50,000	🛠	N/A
Reference process: Degradation rate	%/kh	1	<0.2	🛠	N/A
Stack manufacturing cost at 20 MW/a volume	€/kW	2000	<3000	✓	3000 (2017)

* As Identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020

SCoReD 2:0

STEEL COATINGS FOR REDUCING DEGRADATION IN SOFC



Project ID:	325331
Call topic:	**SP1-JTI-FCH.2012.3.4** -Component and sub-system cost and reliability improvement for critical path items in stationary power and CHP fuel cell systems
Project total costs:	€ 3,792,559.2
FCH JU max. Contribution:	€ 2,183,023
Project start - end:	01/07/2013 - 30/06/2017
Coordinator:	THE UNIVERSITY OF BIRMINGHAM, UK
Website:	www.birmingham.ac.uk/research/activity/scored/index.aspx

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, SOLIDPOWER SPA, Teer Coatings Limited, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, Turbocoating s.p.a.

PROJECT AND OBJECTIVES

Stainless steel interconnects in SOFC require protective coatings to subdue the formation of chromium hydroxide. The benchmark for such coatings is Sandvik Ce-Co PVD pre-coated steel sheet with an ASR of 5 mOhm cm2. SCORED 2:0 successfully attempted to find other coating materials and procedures that might be cheaper and just as effective as the Sandvik development. Two proof-of-concept stacks were tested for 10,000 hours to prove the effectiveness of the processes developed.

NON QUANTITATIVE OBJECTIVES

Cost reduction

PROGRESS & MAIN ACHIEVEMENTS

- The project delivered several materials/process combinations that deliver an ASR of 5 mOhm cm2 with low and very low chromium release rates
- The project developed a novel and to-date uncommon method of improving ASR and Cr release
- The project tested two stacks for 10,000+ hours to prove the effectiveness of the coatings developed

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Low-cost applications of protective layers will contribute to reducing cost; likewise longer lifetime will reduce TCO

Increase the electrical efficiency and the durability of the different fuel cells

Longer lifetime will reduce TCO

Reduce the use of the EU defined 'Critical raw materials'

Use of materials with no or less critical materials and lower cost

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

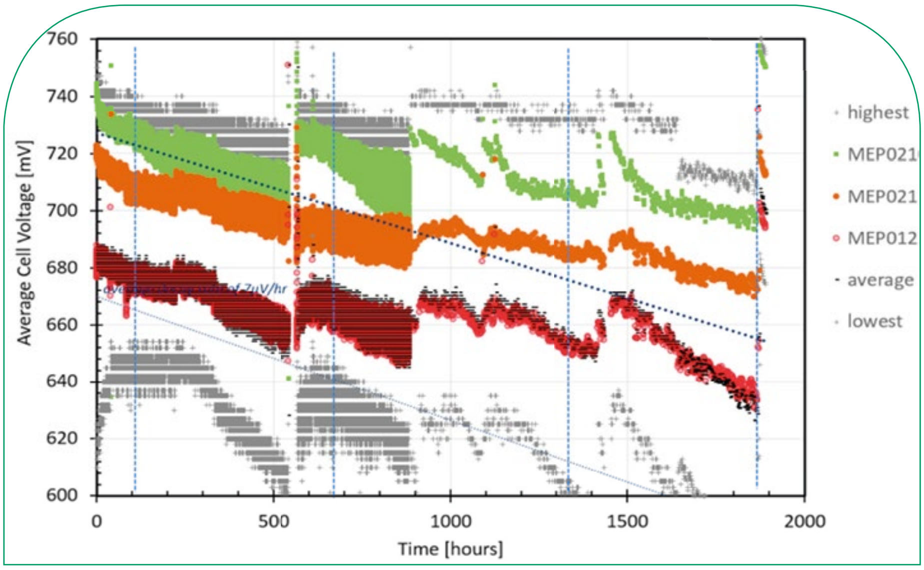
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack durability rated	hours	80,000	50,000	✓
Stack availability	%	100	97	✓
Degradation rate	%/kh	0.25	<0.2	🛠
Stack Durability	hours	80,000	50,000	✓

*As identified in MAWP Addendum 2018-2020, Target Year 2020

SECOND ACT

SIMULATION, STATISTICS AND EXPERIMENTS COUPLED TO DEVELOP OPTIMIZED AND DURABLE ÐCHP SYSTEMS USING ACCELERATED TESTS

Project ID:	621216
Call topic:	SP1-JTI-FCH.2013.3.1 -Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
Project total costs:	€ 4,700,436.57
FCH JU max. Contribution:	€ 2,523,254
Project start - end:	01/05/2014 - 31/10/2017
Coordinator:	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.second-act.eu



BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, SOLIDPOWER SPA, Teer Coatings Limited, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, Turbocoating s.p.a.

PROJECT AND OBJECTIVES

Second Act is focused on degradation understanding and proposal of modified stack components for improved durability of PEM fuel cell systems operating under Hydrogen, Reformate, or Direct Methanol. Modelling and experimental characterizations during or post-ageing allowed to identify mechanisms and causes for reversible or non-reversible losses mainly related to the catalysts. New cathode catalyst and catalyst layers made with various local compositions along the cells surface were implemented in cells or stacks and showed improved stability during long term or accelerated ageing tests

NON QUANTITATIVE OBJECTIVES

- Understanding of cell/stack degradation for H2 & Reformate PEMFC; DMFC
- Demonstrating improvements thanks to core components modifications
- Collection, production and analysis of ageing data (3 FC types)
- Quantification of mechanisms (exp and models) & verify of improvement)

PROGRESS & MAIN ACHIEVEMENTS

- Integration of a new cathode catalyst leading to reduced degradation rates for cells and stacks aged in the different conditions of the project
- Successful local data analyses and modelling of reversible and non-reversible degradation mechanisms allowing to define relevant mitigations methods
- Validation of non-homogeneous active layers mitigating local losses and improving DMFC or PEMFC stack performance stability in different conditions

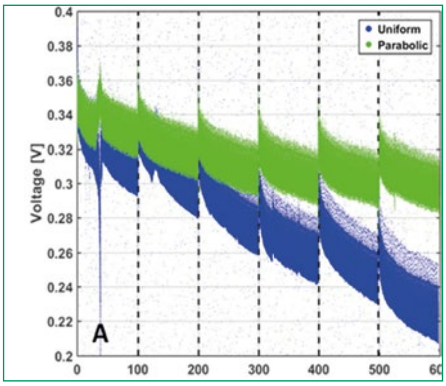
FUTURE STEPS & PLANS

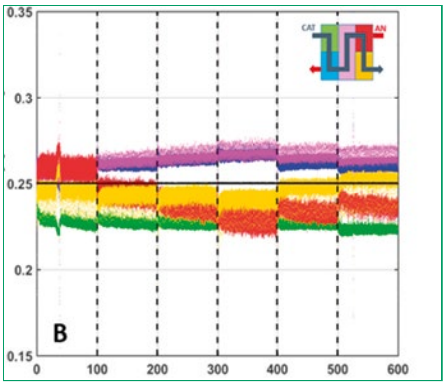
Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Increased of stack durability thanks to improved electrodes





QUANTITATIVE TARGETS AND STATUS

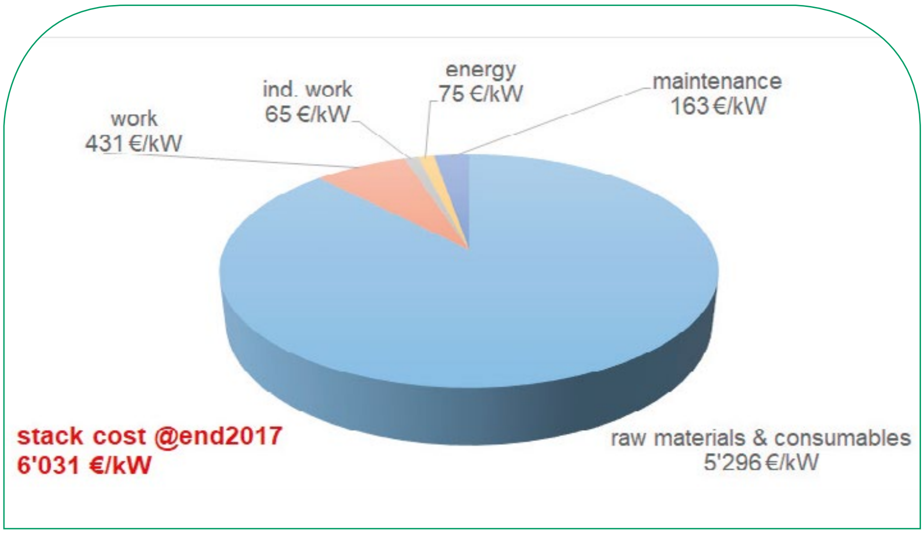
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Rated stack electrical efficiency (LHV)	%	50	42- 55	✓
Stack availability	%	100	97	✓
Degradation rate	%/kh	2	< 0.25	🔧

* As identified in MAWP 2014-2020, AWP 2016, 2017, Target years 2017-2020

SOSLeM
SOLID OXIDE STACK LEAN MANUFACTURING

Project ID:	**700667**
Call topic:	**FCH-02.6-2015** -Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,944,176.25**
FCH JU max. Contribution:	**€ 1,994,301.25**
Project start - end:	01/04/2016 - 31/03/2019
Coordinator:	**SOLIDPOWER SPA, IT**
Website:	**www.soslem.eu**



BENEFICIARIES: Athena S.p.a, AVL LIST GMBH, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, GREENLIGHT INNOVATION GMBH, HTceramix SA

PROJECT AND OBJECTIVES

Project aims at reducing manufacturing costs for SOFC stacks while making production more resource efficient and realizing environmental benefits. Significant results achieved are:

- Improvement of the manufacturing process of cassettes
- Definition of the implementation of optimized stack test system that will help stack preparation by advanced stack curing and conditioning
- Evaluation of alternative solutions for nickel removal from waste water
- Generation of environmental benefit and improved stack durability performances through alternative protective coating of cassettes

NON QUANTITATIVE OBJECTIVES

Enable environmental benefits.

PROGRESS & MAIN ACHIEVEMENTS

- Reduction of manufacturing costs for stack production
- Enable environmental benefits through removal of Co-based powder from cassettes manufacturing process
- Improvement of stack electrochemical performances

FUTURE STEPS & PLANS

- Implementation of new cassette design that will lead to a further decrease of capital costs
- Implementation of new stack design that will lead to a further decrease of capital costs
- Increase of productivity will lead to a better use of production resources

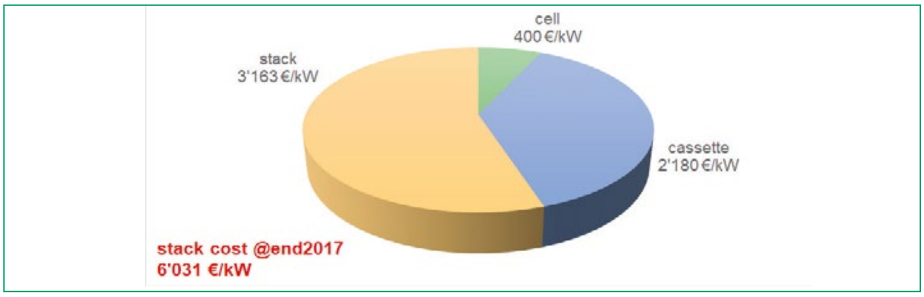
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

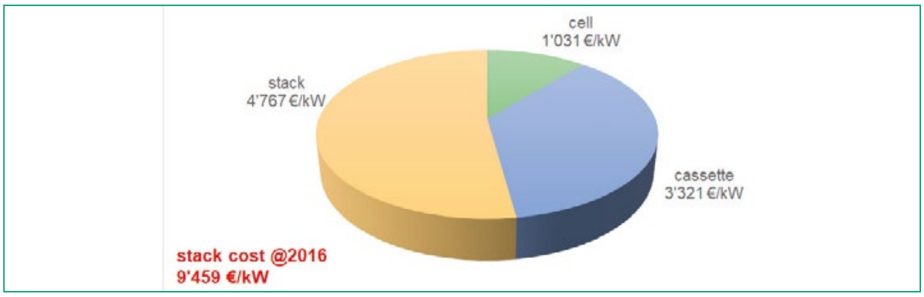
Reduce the production cost of fuel cell systems to be used in transport applications

Not to system to be used in transport applications, but stationary. Reduction of production cost of fuel cell system is the main purpose of project.

Reduce the use of the EU defined 'Critical raw materials'

Removal of Co-based powder from manufacturing process of cassettes and evaluation of on-site nickel removal system from waste water were done in the project.





QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack cost decrease	€/kW	3,428	≈ 3,500	✓

*Project's own objective

PANEL 5
HYDROGEN FOR SECTORIAL INTEGRATION

BIG HIT

BUILDING INNOVATIVE GREEN HYDROGEN SYSTEMS IN AN ISOLATED TERRITORY: A PILOT FOR EUROPE

Project ID:	**700092**
Call topic:	**FFCH-03.2-2015** - Hydrogen territories
Project total costs:	**€ 7,246,102.5**
FCH JU max. Contribution:	**€ 5,000,000**
Project start - end:	01/05/2016 - 30/04/2021
Coordinator:	**Fundacion Para El Desarrollo De Las Nuevas Tecnologias Del Hidrogeno En Aragon, ES**
Website:	**www.bighit.eu**

BENEFICIARIES: CALVERA MAQUINARIA E INSTALACIONES SL, COMMUNITY ENERGY SCOTLAND LIMITED, DANMARKS TEKNISKE UNIVERSITET, GIACOMINI SPA, ITM POWER (TRADING) LIMITED, MINISTRY FOR TRANSPORT, INFRASTRUCTURE AND CAPITAL, ORKNEY ISLANDS COUNCIL, SHAPINSAY DEVELOPMENT TRUST, SYMBIOFCELL SA, THE EUROPEAN MARINE ENERGY CENTRE LIMITED, THE SCOTTISH HYDROGEN AND FUEL CELL ASSOCIATION LTD

PROJECT AND OBJECTIVES

This 'Building Innovative Green Hydrogen Systems in an Isolated Territory' (BIG HIT) project is a major first step towards creating a genuine hydrogen territory in the Orkney Islands. The Islands have over 50 MW of installed wind, wave and tidal capacity generating over 46 GWhr per year of renewable power and has been a net exporter of electricity since 2013. Hydrogen is proposed as a solution to minimize the curtailment problems in Orkney, caused by the weak connection with the UK mainland. The hydrogen produced is used in thermal, power (cogeneration) and transport applications locally.

NON QUANTITATIVE OBJECTIVES

- Delivering the Local Authority's Orkney Hydrogen Economic Strategy
- Demonstrating replicable hydrogen economy solutions
- Bringing economic benefits to islands communities
- Improve local public acceptance of hydrogen
- Project Dissemination

PROGRESS & MAIN ACHIEVEMENTS

- HRS in Kirkwall have been already commissioned.
- Main project equipment already built: 5 H2 trailers (250kg H2 storage), H2 catalytic boiler (30 kW), 1 MW electrolyser; 5 H2 FC vans, 75 kW FC (cog)
- System design and detailed planning of sites already finished

FUTURE STEPS & PLANS

- All ground works complete and all equipment commissioned on site
- Data provision of the operation
- Business models, environmental and societal impact studies have been completed
- Exploitation and replicability studies completed and disseminated to the EU H2 community
- Conclusions and lessons learned to the 5 years project - recommendations

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

1,5 MW of PEME (2 units of 1MW and 0.5 MW) is directly coupled to 2 wind turbines (900 kW each) and a tidal facility (4MW) producing low price H2 and reducing the local curtailment of RES in the islands.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

BIG HIT is the first project using renewable hydrogen (produced by electrolysis using wind and tidal power curtailed) in 3 different local applications: heat, power and transport. BIG HIT aim to increase the energy efficiency in the islands using local renewable energies and hydrogen.

QUANTITATIVE TARGETS AND STATUS

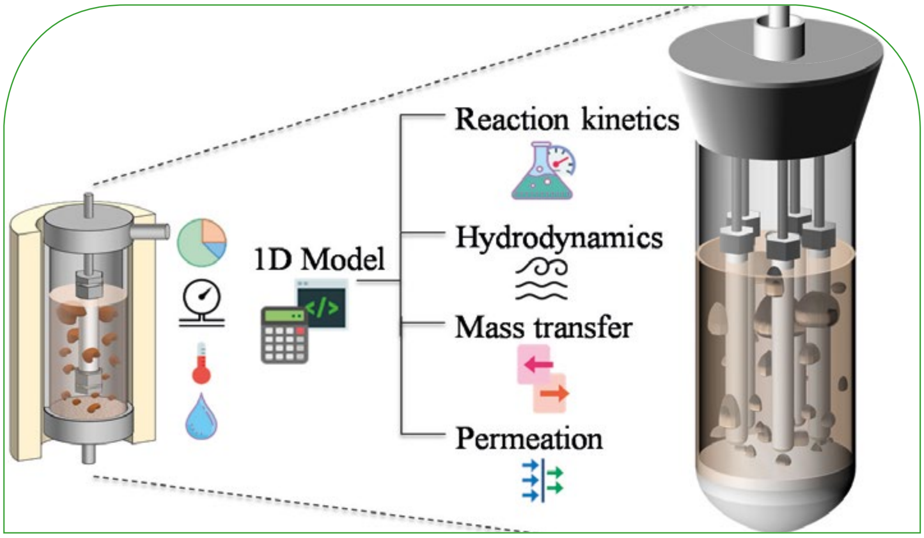
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
TTW consumption NEDC	kg/100 km	0.6	1.15	✓	Symbio FCEV
FC Durability	hours	5000	5000	✓	Symbio FCEV
Rated system electrical efficiency (LHV)	%	51	42-60	✓	
Rated system thermal efficiency (LHV	%	49	24-42	✓	Stationary Unit (cold ironing)
Stack durability	hours	10,000	50,000	🔧	

* As identified in MAWP Addendum 2018-2020, Target Year 2020

BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED HYDROGEN PRODUCTION



Project ID:	3396640
Call topic:	FCH-02.2-2014 - Decentralized hydrogen production from clean CO2-containing biogas
Project total costs:	€ 3,396,640
FCH JU max. Contribution:	€ 3,147,64
Project start - end:	01/09/2015 - 28/02/2019
Coordinator:	POLITECNICO DI MILANO, IT
Website:	www.bionicoproject.eu

BENEFICIARIES: ABENGOA HIDROGENO SA, ABENGOA RESEARCH SL, ENC ENERGY SGPS SA, ENC POWER LDA, FUNDACION TECNALIA RESEARCH & INNOVATION, I.C.I CALDAIE SPA, JOHNSON MATTHEY PLC, QUANTIS, RAUSCHERT KLOSTER VEILSDORF GMBH, TECHNISCHE UNIVERSITEIT EINDHOVEN

PROJECT AND OBJECTIVES

BIONICO will develop, build and demonstrate at a real biogas plant a novel fluidized catalytic membrane reactor, that allows biogas reforming and hydrogen separation in a single step, increasing overall efficiency (>70%) and decreasing volumes and auxiliary heat management units. Compared with any other membrane reactor project in the past, BIONICO will demonstrate the membrane reactor at a much larger scale, with more than 100 membranes implemented in a single fluidized bed membrane reactor, producing about 100 kg/day of H2. The membrane reactor is currently under construction.

PROGRESS & MAIN ACHIEVEMENTS

- Development + scale up of fluidizable reforming catalysts tolerant to a range of biogas compositions suitable for use in a membrane reforming reactor
- Development of Pd based membranes with ceramic finger-like supports with improved flux and selectivity, suitable for fluidized bed reactors
- Design of the catalytic membrane reactor implementing more than 100 membranes

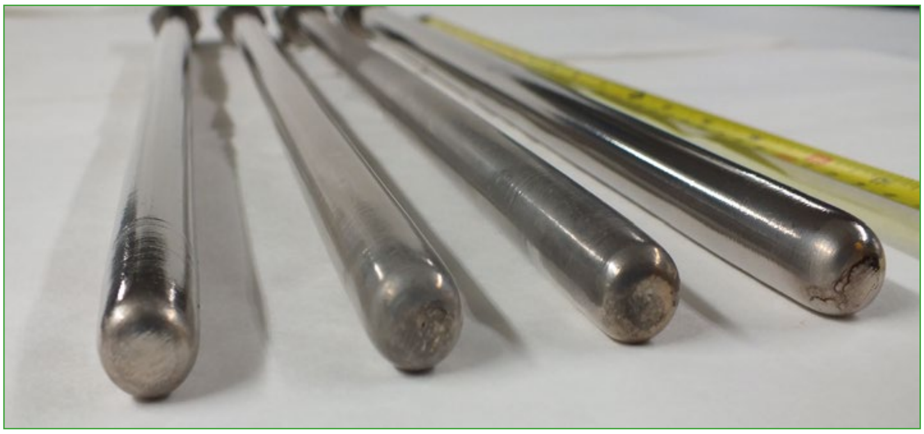
FUTURE STEPS & PLANS

- Assembly of the BIONICO reactor
- Assembly of the BIONICO system (reactor + Membranes + BOP)
- Test of the BIONICO system in the industrial facility of the manufacturer
- Shipping of the BIONICO system to the final installation site
- Installation, integration and testing of the BIONICO system in a real biogas plant

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

BIONICO aims at increasing the conversion efficiency from biogas to H2 thanks to process intensification using a fluidised bed catalytic membrane reactor. Hydrogen production and separation occur in a single reactor with advantages in terms of conversion efficiency (target efficiency >70%) and with reduced equipment and thus with reduced CAPEX.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

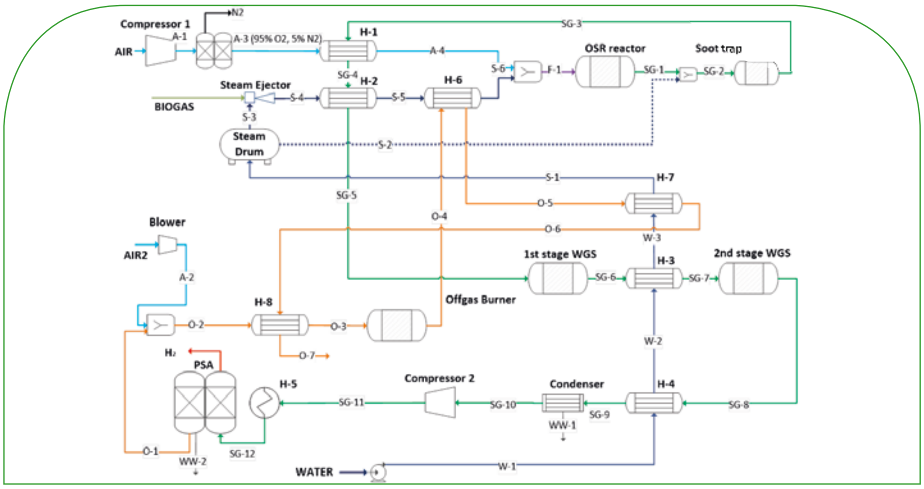
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA RESULT ACHIEVED TO DATE BY OTHER GROUP/PROJECT (SoA YEAR)
Overall Efficiency	%	71.5	72 (HHV)	✓	40-55 (2015)
Cost of Produced hydrogen	€/kg H2	4.8	N/A	🛠	7.2 (2015)

* As identified in AWP 2014, Target Years 2018-2019

BIOROBURplus

ADVANCED DIRECT BIOGAS FUEL PROCESSOR FOR ROBUST AND COST-EFFECTIVE DECENTRALISED HYDROGEN

Project ID:	**736272**
Call topic:	**FCH-02-2-2016** - Development of compact reformers for distributed bio-hydrogen production
Project total costs:	**€ 3,813,536.24**
FCH JU max. Contribution:	**€ 2,996,248.74**
Project start - end:	01/01/2017- 30/06/2020
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bioroburplus.org**



BENEFICIARIES: ACEA PINEROLESE INDUSTRIALE SPA, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, ENGICER SA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, HYSYTECH SRL, JOHNSON MATTHEY PLC, Karlsruher Institut fuer Technologie, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, SCUOLA UNIVERSITARIA PROFESSIONALEDELLA SVIZZERA ITALIANA, UAB MODERNIOS E-TECHNOLOGIJOS

PROJECT AND OBJECTIVES

The BioRoburplus project will develop a pre-commercial oxidative steam reformer (OSR) for sustainable and decentralized hydrogen production from biogas with no preliminary removal of CO_2. The TRL6 demo-plant will deliver at least 50 Nm3/h (107 kg/day) of H_2 at 99.9% purity and 1.5 bar with an energy efficiency conversion of 81% on a HHV basis. The ways to reach this objective are: i) high thermal integration, ii) PSA (pressure swing adsorption) off gas exploitation for reformer feed preheating, iii) power consumption minimization through CO_2 removal prior to the PSA.

NON QUANTITATIVE OBJECTIVES

- Development of a compact and cost-effective fuel processor for distributed H_2 production, easily scalable
- Dissemination and training activities
- LCA and Market penetration studies
- Manufacturing of support and catalyst coating process.
- Cross-cutting horizontal activities

PROGRESS & MAIN ACHIEVEMENTS

- Two OSR catalyst are being developed in parallel Powder scale results have shown good performances Innovative and suitable supports
- Technical and economical evaluation of different purification routes. Design of off-gas burner with integrated heat transfer system is in progress
- Preliminary LCA analysis study. Dissemination and training activities

FUTURE STEPS & PLANS

- Optimization of the catalyst coating process. Test of structured catalytic support on larger scale under more realistic conditions
- Optimization of the porous burner structure. Optimization of the PSA conditions
- CFD simulations results. To finish testing of the catalyst for WGS reactors
- LCA and PUEF draft versions to be performed. Dissemination and training activities

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The scientific and technological objectives of BioRoburplus clearly addresses this objective, since a complete fuel processor for simply-desulphurised biogas to hydrogen is developed at TRL 6 level, thereby even exceeding the requested TRL 5 owing to the availability in the partnership of a unique test site (ACEA). The Oxidative Steam Reforming technology based on catalysts supported on cellular ceramics, originally proposed and developed in the father project BioRobur, is here employed owing to several potential advantages compared to conventional steam reformer: lower tendency to promote coke formation; fast start-up and shutdown; compactness; easy control, etc.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA Year)
Nominal H2 production	Nm3/h	N/A (Phase of testing campaign to be started)		🔧	50 Nm3/h with an overall efficiency of the conversion of biogas to green hydrogen of 65%. (2016)
Overall plant efficiency	%	N/A (Phase of testing campaign to be started)	>80	🔧	Overall Plant efficiency of 65% for a processor with a a nominal production rate of 50 Nm3/h of hydrogn (2016)
Reformer outlet CO concentration	%	Process design and simulation confirm this values. Target achieved on lab-scale. To be demonstrated at the TRL6 level.	Below 8% on a dry-basis	✓	9.99 (2016)
Cost	€/kg	N/A (Demo-plant development on-going).	< 2	🔧	3 €/kg with an amortization time of 10 years (2016)
TRL	N/A	BioRoburplus plant under development. A dedicated TRL6 demo campaign will be performed.	TRL6 level	🔧	TRL5 (2016)
Start-up time after stand-by	min	N/A (Phase of testing campaign to be started)	<15 min.	🔧	Approx. 1 hour (2016)

*As identified in AWP 2016, Target years 2019- 2020

Demo4Grid

DEMONSTRATION OF 4MW PRESSURIZED ALKALINE ELECTROLYSER FOR GRID BALANCING SERVICES

Project ID:	736351
Call topic:	**FCH-02-7-2016** - Demonstration of large-scale rapid response electrolysis to provide grid balancing services and to supply hydrogen markets
Project total costs:	**€ 7,736,682.5**
FCH JU max. Contribution:	**€ 2,932,554.38**
Project start - end:	01/03/2017- 28/02/2022
Coordinator:	**DIADIKASIA BUSINESS CONSULTING SYMVOULOI EPICHEIRISEON AE, EL**
Website:	**www.demo4grid.eu**

BENEFICIARIES: FEN SUSTAIN SYSTEMS GMBH, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, IHT INDUSTRIE HAUTE TECHNOLOGIE SA, INSTRUMENTACION Y COMPONENTES SA, MPREIS WARENVERTRIEBS GMBH

PROJECT AND OBJECTIVES

Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE) designed for providing grid balancing services. The electrolysis plant will be installed in Völs near Innsbruck. As of 2019, the energy plant will be built and operated in the facilities of MPREIS.

PROGRESS & MAIN ACHIEVEMENTS

- Analysis of technical requirements & Analysis of RCS and safety assessment
- Engineering documents (Electrolyser and C&CS)
- Project website & dissemination tools

FUTURE STEPS & PLANS

- Construction of facilities and permits approval
- The engineering documents to implement the installation have been drafted by IHT and the final version will be executed after the HAZOP workshop
- Adapt the major changes on the Austrian power market and the regulatory energy market on Demo4Grid Business case by the end of 2018
- Demo site commissioning is staring in M2. A 6-month delay (maximum) might be due to the small delays on process design and the integration
- Demo site business operation is staring in M27 according to the initial plan

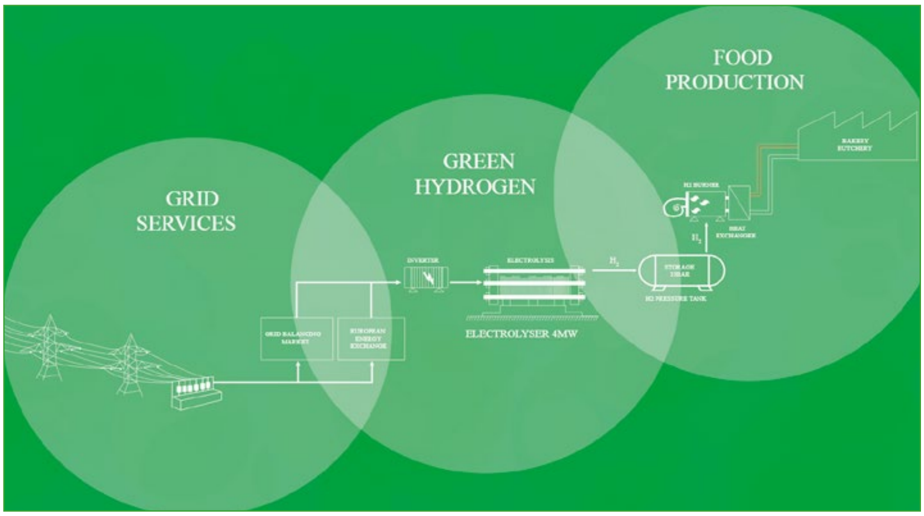
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

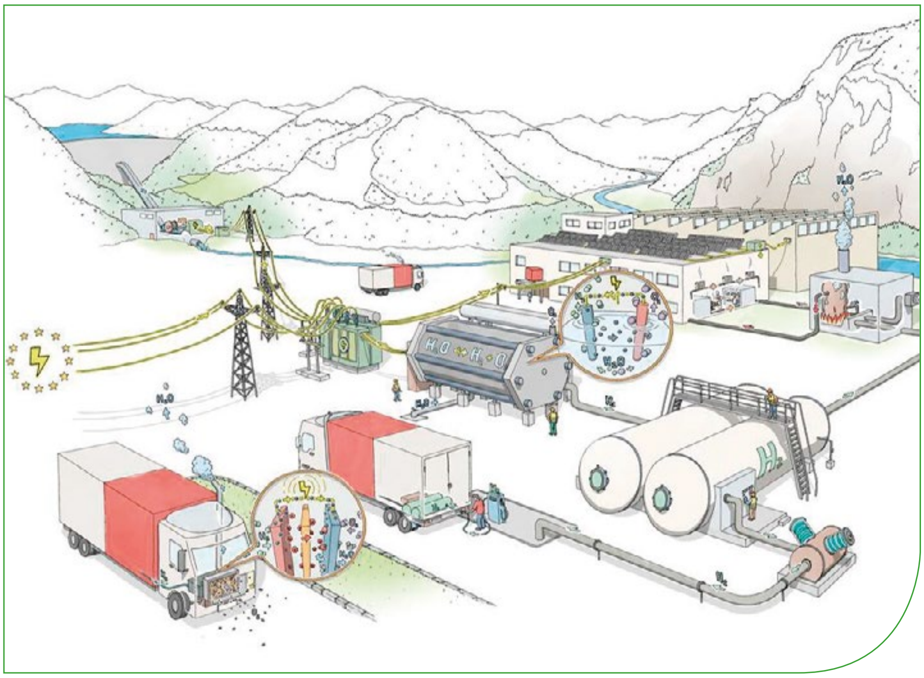
Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE). Demonstrate a PAE system efficiency of 52 kWh/kg H2 (@ 33 bar) in compliance with MAWP 2020 KP 1.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

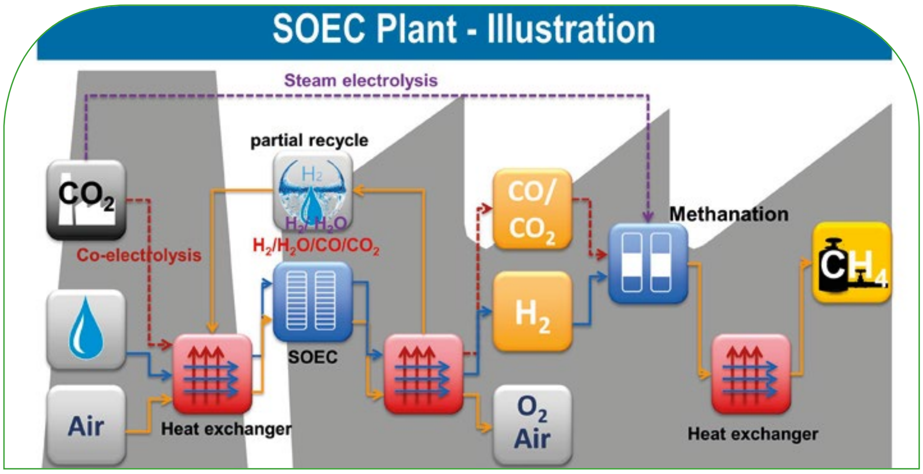
Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE) designed for providing grid balancing services. Demo4Grid will strive to demonstrate the appropriate levels of PAE responsiveness in terms of Time Response (i.e. Hot Start, Cold Start), Variable Loads and Ramp up/Ramp-down.





ECo

EFFICIENT CO-ELECTROLYSER FOR EFFICIENT RENEWABLE ENERGY STORAGE - ECO



Project ID:	**699892**
Call topic:	**FCH-02.3-2015** - Development of co-electrolysis using CO2 and water
Project total costs:	**€ 3,239,138.75**
FCH JU max. Contribution:	**€ 2,500,513.75**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**DANMARKS TEKNISKE UNIVERSITET, DK**
Website:	**www.eco-soec-project.eu**

BENEFICIARIES: BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ENAGAS, S.A., ENGIE, FUNDACIO INSTITUT DE RECERCA DE L´ENERGIA DE CATALUNYA, HTceramix SA, VDZ gGmbH

PROJECT AND OBJECTIVES

The overall goal of ECo is to develop and validate co-electrolysis of steam & CO2 via solid oxide electrolysis for conversion of renewable electricity into distributable and storable hydrocarbons. Improved SOECs were developed through electrode optimisation. Durability was studied under realistic co-SOEC operating conditions on cells and stacks to benchmark the technology. An SOEC plant was designed and the impact of operating parameters including internal methanation on methane production rate and system efficiency evaluated. Realistic cases were identified & the life cycles analysed.

NON QUANTITATIVE OBJECTIVES

- Understanding high pressure co-electrolysis durability
- Potential practical system-design case studies
- Economic analysis
- LCA

PROGRESS & MAIN ACHIEVEMENTS

- Successful improvement of SoA cells to allow for a lower operating temperature by 50-100 oC; durability studies under relevant conditions
- Environmental benefits shown through LCA of three cases integrating the Eco concept into biomass, biogas, and cement industries
- Co-SOEC plant designed including internal methanation; high pressure & co-electrolysis provide higher system efficiency & methan yield

FUTURE STEPS & PLANS

- Completing test matrix for SoA cells/stacks
- Complete integration of improved cells into stacks and performance/durability validation
- High pressure tests on cell, SRU, and system level for performance and durability
- Measurement of impurities in flue gas (CO2) and study of effect of selected ones on cell performance
- Economic analysis of co-SOEC integrated in plants

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

The project is related to electrolysis (not fuel cell) application. However, as current SOFCs and SOECs are similar - if not the same - the improvements achieved in the ECo project will most probably also have positive impact on their use in fuel cell mode.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The project concept is aimed at producing easily distributable and storable hydrocarbons. However, all improvements of the co-SOEC which produces hydrogen and CO, can be utilized for the hydrogen production through SOEC as well. Furthermore, the co-SOEC plant evaluation carried out in the project also considers the cases of steam SOEC vs. co-SOEC and gives thus output about how efficiency and cost situations can be improved, also for hydrogen production through SOEC.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

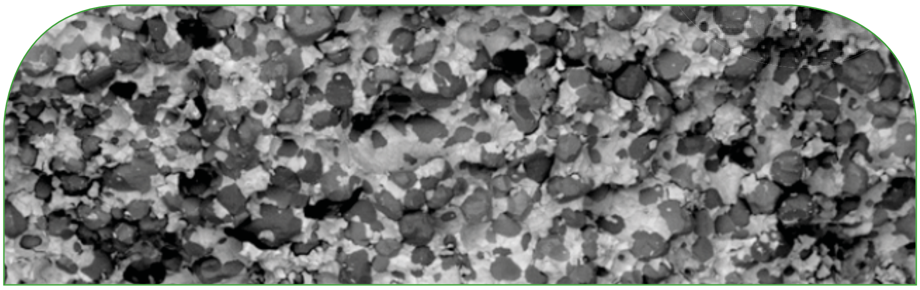
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Area specific resistance at 750 oC	Ohm cm2	0.2	0.2	✓	Two improved cell version developed in the project more with promising first results
Durability	%/1000 h	1	1.2	🛠	The improved cell promised smaller degradation rates, which will be studied in the coming project period
Co-electrolysis performance, temperature for -1.3 A/cm2 at 10 bar	oC	750	800-750	✓	More focus on high pressure tests in the coming project period
Stack: electrical efficiency degradation per 1000 h	%/kh	3	<1	🛠	Stack (1)
Stack: electrical efficiency degradation per 1000 h	%/kh	1.3	<1	🛠	Stack (2)
Stack: electrical efficiency degradation per 1000 h	%/kh	0.05	<1	✓	Stack (3)

*As identified in AWP 2016 and Project's own objectives, Target years 2019 - 2020

ELECTRA

HIGH TEMPERATURE ELECTROLYSER WITH NOVEL PROTON CERAMIC TUBULAR MODULES OF SUPERIOR EFFICIENCY, ROBUSTNESS, AND LIFETIME ECONOMY

Project ID:	**621244**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 4,007,084.6**
FCH JU max. Contribution:	**€ 2,240,552**
Project start - end:	03/03/2014 - 02/06/2017
Coordinator:	**UNIVERSITETET I OSLO, NO**
Website:	**www.mn.uio.no/smn/english/research/projects/chemistry/electra/index.html**



BENEFICIARIES: ABENGOA HIDROGENO SA, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, COORSTEK MEMBRANE SCIENCES AS, CRI EHF, MARION TECHNOLOGIES S.A., STIFTELSEN SINTEF

PROJECT AND OBJECTIVES

ELECTRA develops a tubular proton ceramic steam electrolyser based on BaZrO3 electrolyte, Ni-cermet hydrogen electrodes, and perovskite oxide steam electrodes. Utilisation of heat and steam to increase efficiency is modelled. Co-electrolysis of CO2 and steam is also investigated. Main research objectives are development of stable steam electrodes, and seals and interconnects for segmented-in-series tubes. The project aimed at demonstration of an 18-tube 1 kW module and ended medio 2017, having reached a majority of objectives except the test of the 1 kW module.

PROGRESS & MAIN ACHIEVEMENTS

- Stable steam electrodes for PCE with low polarisation resistance developed; LSM and LBGC
- Tubular segment run with high efficiency at 4 bar steam
- 1 kW multitubular module for individually monitorable and replaceable tubes designed and constructed

FUTURE STEPS & PLANS

Populating and testing the multitubular module.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

ELECTRA develops stationary steam electrolysers, suing renewable electricity and steam and heat from both combustion and renewable sources (e.g. geothermal and solar-thermal)

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/ project	SoA YEAR	SoA Source
Cell area	cm2	10	0.5	2015	E.g. Bi, L., Shafi, S. P. & Traversa, E. Y-doped BaZrO3 as a chemically stable electrolyte for proton-conducting solid oxide electrolysis cells (SOECs). Journal of Materials Chemistry A 3, 5815-5819, doi: 10.1039/C4TA07202B (2015). and Babiniec, S. M., Ricote, S. & Sullivan, N. P. Characterization of ionic transport through BaCe0.2 Zr0.7Y0.103-Đ membranes in galvanic and electrolytic operation. International Journal of Hydrogen Energy 40, 9278-9286, doi:https://doi.org/10.1016/j.ijhydene.2015.05.162 (2015)
Operated steam pressure	bar	4	1	2015	e.g. Babiniec, S. M., Ricote, S. & Sullivan, N. P. Characterization of ionic transport through BaCe0.2 Zr0.7Y0.103-Đ membranes in galvanic and electrolytic operation. International Journal of Hydrogen Energy 40, 9278-9286, doi: https://doi.org/10.1016/j.ijhydene.2015.05.162 (2015)
Efficiency	%	83 (MAWP 2020 Target achieved)	60	2012	E.g. Gan, Y. et al. Composite Oxygen Electrode Based on LSCM for Steam Electrolysis in a Proton Conducting Solid Oxide Electrolyser. Journal of The Electrochemical Society 159, F763-F767, doi:10.1149/2.018212jes (2012)
Faradaic efficiency	%	95	90	2015	E.g. Bi, L., Shafi, S. P. & Traversa, E. Y-doped BaZrO3 as a chemically stable electrolyte for proton-conducting solid oxide electrolysis cells (SOECs). Journal of Materials Chemistry A 3, 5815-5819, doi: 10.1039/C4TA07202B (2015)and Matsumoto, H., Sakai, T. & Okuyama, Y. in Pure and Applied Chemistry Vol. 85 427 (2012)
Steam electrode ASR	ohm cm2	0.2	0.2	2013	E.g. Strandbakke, R. et al. Gd- and Pr-based double perovskite cobaltites as oxygen electrodes for proton ceramic fuel cells and electrolyser cells. Solid State Ionics 278, 120-132, doi: http://dx.doi.org/10.1016/j.ssi.2015.05.014 (2015).and Li, S. & Xie, K. Composite Oxygen Electrode Based on LSCF and BSCF for Steam Electrolysis in a Proton-Conducting Solid Oxide Electrolyzer. Journal of The Electrochemical Society 160, F224-F233, doi:10.1149/2.027303jes (2013)

*** Available data provided by the project**

ELY4OFF

PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

Project ID:	700359
Call topic:	FCH-02.1-2015 - Improved electrolysis for Off-grid Hydrogen production
Project total costs:	€ 2,315,217.5
FCH JU max. Contribution:	€ 2,315,217
Project start - end:	01/04/2016- 31/03/2019
Coordinator:	FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES
Website:	www.eco-soec-project.eu

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, EPIC POWER CONVERTERS SL, INSTRUMENTACION Y COMPONENTES SA, ITM POWER (TRADING) LIMITED

PROJECT AND OBJECTIVES

The main goal of the ELY4OFF proposal is the development and demonstration of an autonomous off-grid electrolysis system (PEMWE, 50 kW) linked to renewable energy sources (solar PV), including the essential overarching communication and control system for optimising the overall efficiency when integrated in a real installation. Demonstrative period will take place in Huesca (Spain) and will last 8 months. The progress of the project (13 months of development by 1st May) follows the schedule foreseen.

NON QUANTITATIVE OBJECTIVES

- Development of an overarching control system
- Identification of eventual RCS barriers
- To explore potential uses of H2
- New business model

PROGRESS & MAIN ACHIEVEMENTS

- Steady-state testing of the membrane and stack components at large-scale has been completed
- An in depth assessment of the best options available for the DC/DC conversion linking the PV plant with the stack has been conducted
- One specific business case related to "electrification of isolated areas" has been evaluated through time-step simulations

FUTURE STEPS & PLANS

- Assembly, erection and commissioning scheduled between June and July 2018
- Demonstration period will last from August 2018 until March 2019
- LCA and cost assessment are being developed
- 2 additional business cases will be elaborated
- 3 Technical Workshops will be organized

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

This topic is addressed through 1) a direct DC/DC conversion between renewable source (PV) and the stack, and 2) a very efficient PEMWE.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	VALUE	TARGET	TARGET ACHIEVED?
Electrolyser Footprint	m2/MW	180.4	100	🔧
Estimated CAPEX of electrolyser @ 100MW annual production scale	EUR/(kg/d)	800	2,000	✔ projection
OPEX @ 10 years	EUR/(kg/d)/yr	350	41	🔧
Catalyst at the cathode	mg/W	0.6	1.4	🔧
Catalyst at the anode	mg/W	3		

*As identified in MAWP Addendum 2018-2020, Target year 2020

elyntegration

ELYntegration

GRID INTEGRATED MULTI MEGAWATT HIGH PRESSURE ALKALINE ELECTROLYSERS FOR ENERGY APPLICATIONS

Project ID:	**671458**
Call topic:	**FCH-02.8-2014** - Improvement of electrolyser design for grid integration
Project total costs:	**€ 3,301,391.25**
FCH JU max. Contribution:	**€ 1,861,309**
Project start - end:	01/09/2015- 31/08/2018
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.elyntegration.eu**

BENEFICIARIES: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V., IHT INDUSTRIE HAUTE TECHNOLOGIE SA, INSTRUMENTACION Y COMPONENTES SA, RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN, VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.

PROJECT AND OBJECTIVES

ELYntegration is focused in the design and engineering of a robust, flexible and cost competitive MW alkaline water electrolyser, capable of producing with a single stack up to 4.5 ton H2/day under highly dynamic power supplies, when high renewable energies shares are considered. The most attractive business models and the assessment on market potential have been implemented. Advanced new materials (membranes and electrodes) have been developed. A new membrane has been tested at pilot scale (500 mm) and durability investigated by ASTs under high dynamic profiles.

NON QUANTITATIVE OBJECTIVES

- Communication and control capabilities (C&CS)
- Regulatory framework and end-user requirements
- Business models
- Dissemination of results and exploitation

PROGRESS & MAIN ACHIEVEMENTS

- New advanced materials for AWE developed at pilot scale (420 mm): 2 new membranes and 1 electrode
- Degradation studies under high dynamic profiles carried out at pilot scale, for new advanced membrane (420 mm in size)
- Grid services protocols regarding potential business models defined. Tests to be performed at industrial scale.

FUTURE STEPS & PLANS

- Estimation of durability lifetime under high dynamic profiles finished (2 new membranes + 2 new electrodes)
- Demonstration of real stacks at industrial scale providing grid services (including new advanced membrane)
- Exploitation strategy defined and at least 4 scientific publications accepted
- Design of a MW alkaline water electrolyser, capable of producing with a single stack up to 4.5 t
- LCC assessment defined and including BOP cost optimization

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

LCC assessment, BOP cost optimization and development of new advanced materials for AWE are addressed.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Demonstration of real stacks providing grid services will be carried out.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET ACHIEVED?	SoA result achieved to date by other group/project
Reduction of CAPEX	M€/(t/d)	< 2.18		2.18 (2014)
Increase of stack size	kW	target for Project 9700 (to be reached)		5300 (2014)
Increase of stack capacity	t/d H2	target for Project 4.5 (to bwe reached)		1.62 (2014)
Efficiency degradation	% year	Not addressed at industrial scale		2 (2014)
Increase of output pressure	bar	30		30 (2014)

* As identified in MAWP Addendum 2018-2020, Target year 2020

GrInHy

GREEN INDUSTRIAL HYDROGEN VIA REVERSIBLE HIGH-TEMPERATURE ELECTROLYSIS

Project ID:	700300
Call topic:	**FCH-02.4-2015** - Proof of concept of HT electrolyser at a scale >70 kW
Project total costs:	€ 4,498,150
FCH JU max. Contribution:	€ 4,498,150
Project start - end:	01/03/2016 - 28/02/2019
Coordinator:	SALZGITTER MANNESMANN FORSCHUNG GMBH, DE
Website:	www.green-industrial-hydrogen.com/home

BENEFICIARIES: BOEING RESEARCH & TECHNOLOGY EUROPE S.L.U., EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, POLITECNICO DI TORINO, Salzgitter Flachstahl GmbH, SUNFIRE GMBH, Teknologian tutkimuskeskus VTT Oy, Ustav fyziky materialu, Akademie Ved Ceske republiky, v.v.i.

PROJECT AND OBJECTIVES

Central elements of the GrInHy project is the manufacturing and operation of the worldwide most powerful reversible high-temperature steam-electrolyser (HTE) at an integrated iron-and-steel works. The project objectives comprises the targeted electrical system efficiency of > 80 %LHV, the upscaling of the HTE towards a power input of 150 kW AC, the field operation of >7,000 h and degradation tests at stack level of >10,000 h with a degradation rate of <1 %/kh. Since its installation in June 2017, the system reached >5,000 h of operation while proving the reversibility and 3.8 H2 quality.

NON QUANTITATIVE OBJECTIVES

- Elaboration of an 'Exploitation Roadmap' for cost reducing measures
- Development of dependable system cost data
- Integration of a reversible operation mode (fuel cell mode)

PROGRESS & MAIN ACHIEVEMENTS

- Start of 7,000 h test operation running the system in various test sequences; more than 5,000 hours already reached
- Proof-of-concept of a continuous hydrogen production meeting the 3.8 quality
- Start of 10,000 h stack testing; more than 8,000 hours already reached

FUTURE STEPS & PLANS

- Completion of system test operation of at least 7,000 h
- Completion of stack testing of at least 10,000 h
- Proof of system robustness for continuous operation with optimized HPU components
- Joint workshop with other FCH2 JU projects about "Route to the Industrialisation of High-Temperature Electrolysis" in September 2018
- Completion of techno-economic studies and elaboration of exploitation and development Roadmap for the SOEC/RSOC towards a marketable product

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Due to a significant energy input in form of steam preferably from industrial waste heat, Steam Electrolysis (StE) achieves outstanding electrical efficiencies of more than 95 %HHV. By consuming less than 40 kWh_el per kilogram without the hydrogen processing (drying and compression), more than 20 % lower costs of operation are possible compared to low temperature electrolysis.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Electrical efficiency	%HHV	92	95	🛠	95	Efficiency of the RSOC unit including stacks and BoP components, excluding steam generation and compression
System capacity	kW_AC	154	150	✓	75	Rated AC power in electrolysis Mode. The corresponding power output in Fuel Cell mode is 30 kW_AC.
Lifetime	hours	5,000	7,000	🛠	20,000	Expected lifetime of the RSOC unit during test operation. However, the prototype uses a robust design and enhanced cell and stack technology to enable an even longer lifetime.
Lifetime	hours	8,000	10,000	🛠	20,000	Expected lifetime of separate stacks during stack testing in lab facilities.
Degradation	%/kh	0.8	1.00	✓	1.0	Voltage Degradation rate at constant temperature in electrolysis mode at 0.5 A/cm² compared to thermo-neutral voltage.
Estimated CAPEX of electrolyser @ 100MW annual production scale	EUR/(kg/d)	1500	4500	✓ Projection achieved	N/A	N/A
Electricity consumption @ nominal capacity	kWh/kg	42.7	40	✓	N/A	N/A

* As identified in MAWP Addendum 2018-2020, AWP 2015 and Project's own objective, Target years 2018-2020

H2Future

HYDROGEN MEETING FUTURE NEEDS OF LOW CARBON MANUFACTURING VALUE CHAINS

H2FUTURE
Green Hydrogen

Project ID:	**735503**
Call topic:	**FCH-02-7-2016** - Demonstration of large-scale rapid response electrolysis to provide grid balancing services and to supply hydrogen markets
Project total costs:	**€ 1,7823,264.13**
FCH JU max. Contribution:	**€ 11,997,820.01**
Project start - end:	01/01/2017 - 30/06/2021
Coordinator:	**VERBUND Solutions GmbH, AT**
Website:	**www.h2future-project.eu/technology**

BENEFICIARIES: AUSTRIAN POWER GRID AG, K1-MET GMBH, SIEMENS AKTIENGESELLSCHAFT, SIEMENS AKTIENGESELLSCHAFT OESTERREICH, STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND, VERBUND TRADING GMBH, VOESTALPINE STAHL GMBH

PROJECT AND OBJECTIVES

H2FUTURE is a European flagship project for the generation of green hydrogen from renewable electricity. Under the coordination of the utility VERBUND, the steel manufacturer voestalpine and Siemens, a technology provider, a large-scale 6 MW PEM electrolysis system will be installed and operated for green hydrogen production and grid services at the voestalpine Linz steel plant in Austria. Further partners are Austrian Power Grid, K1-MET and ECN part of TNO.

NON QUANTITATIVE OBJECTIVES

Industrial integration of green hydrogen production

PROGRESS & MAIN ACHIEVEMENTS

- Construction and operation permit obtained
- Detail engineering for 6MW PEM electrolyser plant performed
- KPIs for pilot tests and quasi-commercial operation defined

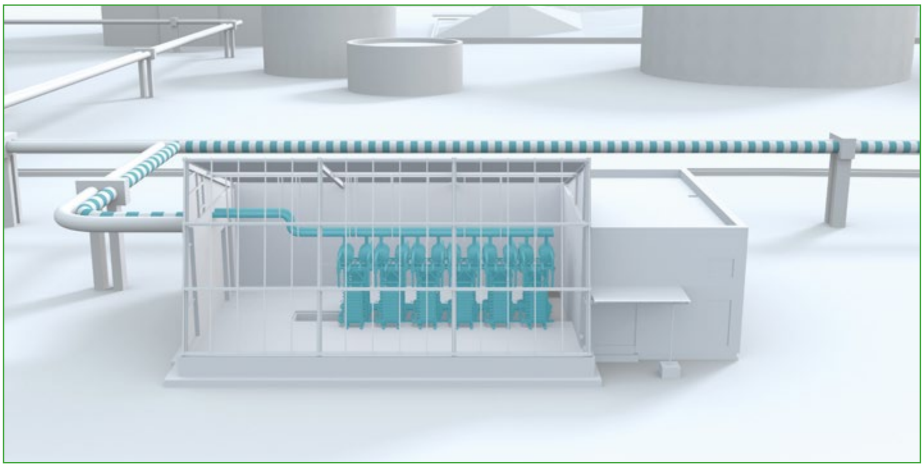
FUTURE STEPS & PLANS

- Commissioning at the beginning of 2019
- Pilot operation with various test scenarios in 2019
- Quasi commercial operation
- Operation for more than 5,000 hours as part of the project
- Accompanying analysis of roll-out and scale-up scenarios

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

H2FUTURE is currently the largest PEM electrolysis project which is in installation.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Electrolyser Footprint	m2/MW	10	100	✓

*** As identified in MAWP Addendum 2018-2020, AWP 2015 and Project's own objective, Target years 2018-2020**

HELMETH

INTEGRATED HIGH-TEMPERATURE ELECTROLYSIS AND METHANATION FOR EFFECTIVE POWER TO GAS CONVERSION

Project ID:	**621210**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 3,816,612.41**
FCH JU max. Contribution:	**€ 2,529,352**
Project start - end:	01/04/2014 - 31/12/2017
Coordinator:	**Karlsruher Institut fuer Technologie, DE**
Website:	**www.helmeth.eu**

BENEFICIARIES: DVGW DEUTSCHER VEREIN DES GAS- UND WASSERFACHES - TECHNISCH-WISSENSCHAFTLICHER VEREIN EV, ETHOSENERGY ITALIA SPA, European Research Institute of Catalysis A.I.S.B.L., NATIONAL TECHNICAL UNIVERSITY OF ATHENS – NTUA, POLITECNICO DI TORINO, SUNFIRE GMBH

PROJECT AND OBJECTIVES

The objective of the HELMETH project was the proof of concept of a highly efficient Power-to-Gas process by realizing the first prototype that combines a pressurized high temperature steam electrolysis with a CO2-methanation module. The project was completed at the end of 2017, demonstrating efficiencies of 76% on prototype scale and feasibility of efficiencies > 80% for large scale plants. Since the produced SNG was fully compatible with the existing natural gas grid (i.e. H2 <2 vol. %), practically no capacity limitation apply to store energy from fluctuating renewable energy sources.

NON QUANTITATIVE OBJECTIVES

- Manufacture of dedicated HTE cell and stacks for use in large systems
- Develop concepts of HTE for use with renewable energy production
- Develop concepts for pressurised electrolysis for more economical systems
- Test & evaluation of cells, stacks and systems under realistic cond

PROGRESS & MAIN ACHIEVEMENTS

- The main objective of the project to prove the feasibility of an integrated PtG process for highly efficient storage of renewable energy was achieved
- Efficiency of the integrated system of about 76 % (based on HHV) could be achieved. Efficiencies > 80% for scaled-up plants possible
- Further R&D work related to identified technical obstacles (i.e. steam mass flow control) is needed to reach higher Technology Readiness Levels

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The thermal integration of the exothermal CO2 methanation with the high temperature steam electrolyser enables much higher efficiencies (>80%) compared to the state-of-the-art utilizing low temperature electrolysis coupled to methanation.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The feasibility of a highly efficient Power-to-Substitute-Natural-Gas Process was demonstrated.

QUANTITATIVE TARGETS AND STATUS

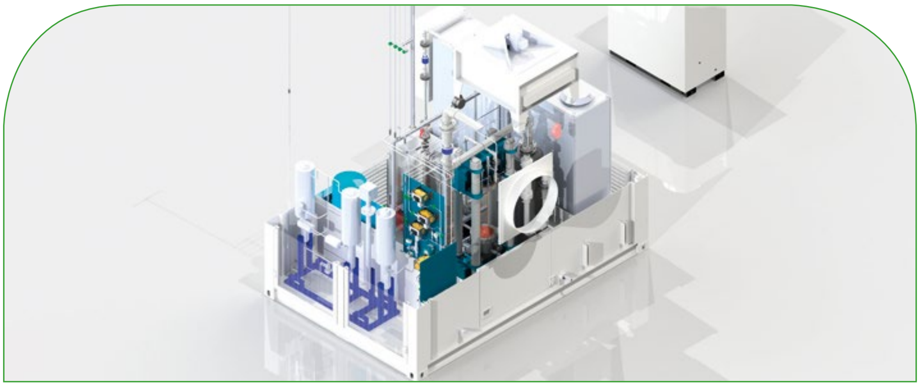
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/ project (SoA year)	DESCRIPTION
Current density at high-temperature (800-1000°C), pressurized cond.	A/cm²	1.0	1.0	✓	1.0 (2016)	1 A/cm² achieved with cell tests, 0.8 A/cm² at stack level
Degradation rates for short stacks	%/ 1000 h	0.43	0.5	✓	0.23 (2015)	Degradation rates < 0.5%/1000 h indirectly proven (linear extrapolation based on 320 h of tests + plausibility due to previous long term tests)
Conversion efficiencies from electricity to methane	%	76 (prototype) >80 (scale-up)	85	🔧	61.8 (2016)	Efficiency of the integrated system of about 76 %HHV based on measurements of the prototype could be achieved. Efficiencies > 80% for scaled-up plants possible
Stack electricity consumption for H2 production	kWh/kg	35.5	40	✓		Electrolyser research at stack level or lower & system level

*As identified in AWP 2013, Target year 2017

HPEM2GAS

HIGH PERFORMANCE PEM ELECTROLYZER FOR COST-EFFECTIVE GRID BALANCING APPLICATIONS



Project ID:	**700008**
Call topic:	**FCH-02.2-2015** - Improved electrolysis for Distributed Hydrogen production
Project total costs:	**€ 2,654,250**
FCH JU max. Contribution:	**€ 2,499,999**
Project start - end:	01/04/2016 - 31/03/2019
Coordinator:	**CONSIGLIO NAZIONALE DELLE RICERCHE, IT**
Website:	**www.hpem2gas.eu**

BENEFICIARIES: EWII FUEL CELLS A/S, HOCHSCHULE EMDEN/LEER, ITM POWER (TRADING) LIMITED, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, SOLVAY SPECIALTY POLYMERS ITALY SPA, STADTWERKE EMDEN GMBH, UNIRESEARCH BV

PROJECT AND OBJECTIVES

The HPEM2GAS project is developing a high performance PEM electrolysis technology optimised for grid management service (power-to-gas) through both stack and balance of plant innovations, culminating in a six-month field test of an advanced 180 kW (nominal) PEM electrolyser. The project will also contribute significantly to reducing the electrolyser CAPEX and OPEX costs. HPEM2GAS develops key technologies to bring innovative solutions from TRL 4 to 6 and will deliver a techno-economic analysis and an exploitation plan to bring the innovations to market.

NON QUANTITATIVE OBJECTIVES

- Readiness of field testing site
- Successful demonstration of the electrolysis system in grid balancing
- Final event/demonstration at the field test site

PROGRESS & MAIN ACHIEVEMENTS

- Achievement of operating current density for PEM electrolysis of 3 A/cm^2 at about 80% (HHV) efficiency
- Reduction of total noble metal catalyst loading per MEA to less than 0.5 mg /cm^2
- Development of advanced stack components and design (e.g. Aquivion membranes, stable nanostructured catalysts, advanced stack design)

FUTURE STEPS & PLANS

- New PEM electrolysis technology validated at 180 kW system level with nominal hydrogen production capacity > 80 kg H2/day
- Achieving efficiency better than 82% HHV H2 at system level
- Successful demonstration of the electrolysis system in grid balancing applications

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Efficiency better than 82% HHV H2 at 3 A cm-2 operating current density to reduce capital costs.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Demonstration of the advanced electrolysis system in grid balancing service through a field-testing campaign.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Membrane conductivity for large area membranes	S/cm	0.20	0.25	🔧	0.150 (2015)	Solvay Aquivion E98-09S membrane of 90 μm. Proton conductivity is >200 mS/cm-1 at T 80°C in presence of liquid water
Anode over potential vs. thermoneutral potential at 3 A cm-2 less than:	mV	200	200	✓	200 (2015)	IrRuOx solid solutions showed OER over potential of 153 mV, IR-free, at <80 °C and 3 A/cm2 with noble metal loading <0.4 mg/cm2 anode
Cathode over potential vs. , RHE at 3 A cm-2 less than:	mV	50	50	✓	100 (2015)	2 nm Pt/C catalysts showed HER over potential of 65 mV at 80 °C and 3 A/cm 2 with noble metal loading <0.1 mg/cm2
Current density at cell voltage <1.8 V under nominal operation	A/cm2	3	3	✓	N/A (2015)	3 A/cm 2 at 1.81-1.79 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm2
Maximum Performance at Ucell<2 V under transient operation	A/cm2	4.5	4.5	✓	2 (2015)	4.5 A/cm2 @1.92-1.96 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm2
Degradation in a 1000 h test	μV/h/cell	5	8	✓	10 (2015)	Degradation lower than 5 μV/h/cell in a 1000 h test in single cell at 3 A cm2
Gas cross over in terms of % H2 in the O2 stream (faradaic efficiency)	%	0.5	0.5	✓	1 (2015)	Achieved at nominal current density
Efficiency (HHV H2)	%	82	80	✓	77 (2015)	Voltage efficiency Achieved at cell and short stack level
Energy consumption	kWh/ kg H2	48	48	✓	52 (2015)	Achieved at cell and short stack level

***Project's own objective, Target year 2019**

HyBalance
HYBALANCE

Project ID:	671384
Call topic:	FCH-02.10-2014 - Demonstrating the feasibility of central large scale electrolysers in providing grid services and hydrogen distribution and supply to multiple high value markets
Project total costs:	€ 15,631,195.73
FCH JU max. Contribution:	€ 7,999,370.8
Project start - end:	01/10/2015 - 30/09/2020
Coordinator:	AIR LIQUIDE ADVANCED BUSINESS, FR
Website:	www.hybalance.eu

BENEFICIARIES: AIR LIQUIDE GLOBAL E&C SOLUTIONS FRANCE, CEMTEC FONDEN, COPENHAGEN HYDROGEN NETWORK AS, HYDROGENICS EUROPE NV, Ludwig-Boelkow-Systemtechnik GmbH, NEAS ENERGY AS

PROJECT AND OBJECTIVES

HyBalance is a project that demonstrates the use of hydrogen in energy systems. The hydrogen will be produced from water electrolysis, enabling the storage of cheap renewable electricity from wind turbines. It will thus help balance the grid, and the green hydrogen will be used for clean transportation and in the industrial sector. It will not only validate highly dynamic PEM electrolysis technology and innovative hydrogen delivery processes involved but also demonstrate these in a real industrial environment.

PROGRESS & MAIN ACHIEVEMENTS

Start-up of the hydrogen production plant

FUTURE STEPS & PLANS

- Nominal operation of the plant
- Hydrogen delivery to industry and transport market
- Demonstrate low electricity price with the help of grid balancing

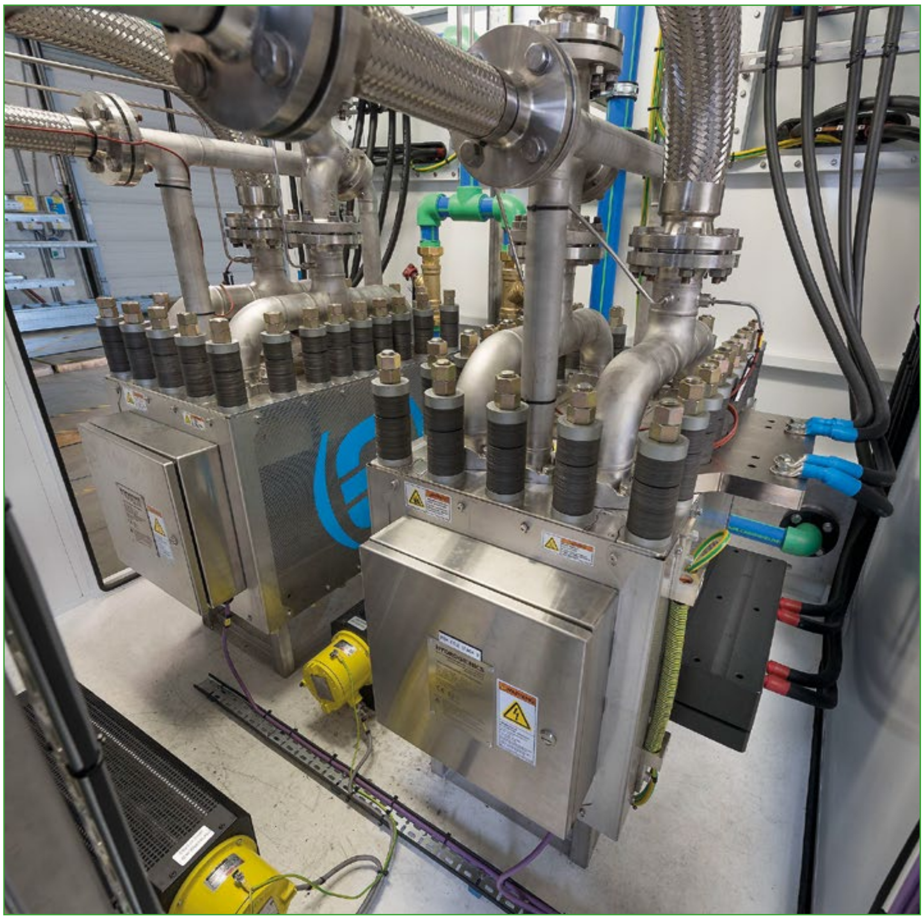
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

HyBalance is one step along the road to reduce electrolyser and system costs through upscaling and industrialization of power-to-hydrogen technology.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The operation of the plant is based on electricity spot price arbitration.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
KPI - Electrolyser Footprint	m2/MW	45	100	✓

*Project's own objective, Target year 2019

HYDROSOL-PLANT

THERMOCHEMICAL HYDROGEN PRODUCTION IN A SOLAR MONOLITHIC REACTOR: CONSTRUCTION AND OPERATION OF A 750 KWTH PLANT

Project ID:	**325361**
Call topic:	**SP1-JTI-FCH.2012.2.5** - Thermo-electrical-chemical processes with solar heat sources
Project total costs:	**€ 3,453,422.16**
FCH JU max. Contribution:	**€ 2,265,385**
Project start - end:	01/01/2014 - 30/04/2018
Coordinator:	**CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS, EL**
Website:	**www.hydrosol-plant.certh.gr**

BENEFICIARIES: CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ELLINIKA PETRELAIA AE, HyGear B.V.

PROJECT AND OBJECTIVES

Within the HYDROSOL-PLANT project (SP1-JTI-FCH.2012.2.5/ Contract No: 325361) the development and operation of a plant for solar thermoÐchemical hydrogen production from water is pursued. The main objectives of HYDROSOL-PLANT are to achieve a material life-time of more than 1000 operational hours and to construct a solar hydrogen production demo-plant in the 750 kWth range to verify the developed technology for solar thermochemical H20 splitting and demonstrate hydrogen production and storage on site at levels > 3kg/week.

NON QUANTITATIVE OBJECTIVES

- Modelling and simulation of the plant and of key components
- Field tests of prototype plant
- Development of real size components

PROGRESS & MAIN ACHIEVEMENTS

- Durability testing of structured redox material for over 1000 h of consecutive water splitting and thermal reduction
- Achieved hydrogen production exceeding 3kg/week at the laboratory scale
- Completed construction and integration of the 750kWth solar reactors and peripherals on the solar platform. The largest solar redox reactors to date

FUTURE STEPS & PLANS

- Project is finished
- Successful operation of the platform up to 1400C. Until the date of collection of these data, only thermal tests up to 900C were achieved.
- Successful operation of the platform in hydrogen production mode. Until the date of collection of these data only thermal tests were implemented.
- Minimization of consumption of N2 during the thermal reduction step
- Successful and efficient heat recovery

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Project activities contribute in the exploitation of entirely renewable sources for the production of hydrogen from water and solar energy.

Reduce the use of the EU defined 'Critical raw materials'

No critical raw materials are used in the process.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

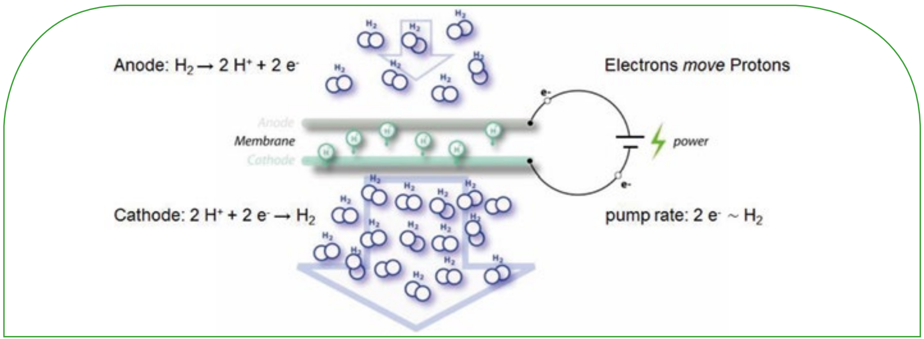
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/ project	SOA YEAR	SOA Source
Evaluation of material after multiple cyclic operation	hours	1000	283	2010	Chueh W.C., Falter C., Abbott M., Scipio D., Furler P., Haile S.M., Steinfeld A. (2010), Science, 330 (6012), pp. 1797–1801
H2 production	ml/g	7.35	4.6	2010	Chueh W.C., Falter C., Abbott M., Scipio D., Furler P., Haile S.M., Steinfeld A. (2010), Science, 330 (6012), pp. 1797–1801
Maximum H2 production rate	ml/min/g	0.45	0.1	2014	Kawakami S., Myojin T., Cho H.-S., Hatamachi T., Gokon N., Kodama T. (2014),Energy Procedia, 49, pp. 1980-1989
Solar hydrogen generator in a demonstration range @ 0.5-2 MW scale	kW	750	100	2006	HYDROSOL II Project ID: 20030 Funded under: FP6-SUSTDEV http://cordis.europa.eu/result/rcn/47004_en.html

* Available data provided by the project

HyGrid

FLEXIBLE HYBRID SEPARATION SYSTEM FOR H2 RECOVERY FROM NG GRIDS

Project ID:	**700355**
Call topic:	**FCH-02.5-2015** - Development of technology to separate hydrogen from low-concentration hydrogen streams
Project total costs:	**€ 2,847,710**
FCH JU max. Contribution:	**€ 2,527,710**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**TECHNISCHE UNIVERSITEIT EINDHOVEN, NL**
Website:	**www.hygrid-h2.eu/**



BENEFICIARIES: FUNDACION TECNALIA RESEARCH & INNOVATION, HYET HYDROGEN BV, HYGEAR BV, HyGear Fuel Cell Systems B.V., HYGEAR TECHNOLOGY AND SERVICES BV, NORTEGAS ENERGIA DISTRIBUCION SAU, QUANTIS, SAES GETTERS S.P.A.

PROJECT AND OBJECTIVES

The objective of the HyGrid project is to design, scale-up and demonstrate at industrially relevant conditions of a novel membrane based hybrid technology for the direct separation of hydrogen from natural gas grids. The focus of the project will be on the hydrogen separation through a combination of membranes, electrochemical separation and temperature swing adsorption to be able to decrease the total cost of hydrogen recovery. The project targets a pure hydrogen separation system with power and cost of < 5 kWh/kgH2 and < 1.5 €/kgH2, and a pilot designed for >25 kg/day of hydrogen production.

NON QUANTITATIVE OBJECTIVES

- Traineeships of students at TUE
- Membrane characterization (Tecnalia and TUE)
- Small scale EHP manufacturing and testing (HYET and TUE)

PROGRESS & MAIN ACHIEVEMENTS

- Palladium based membranes, carbon membranes and sealing for hydrogen separation with the recovery of hydrogen from low concentration streams developed
- A transient model for the TSA has been developed and the pilot scale TSA is now built
- A lab-scale EHP has been tested and used to validate the model and currently a pilot-scale EHP is under construction.

FUTURE STEPS & PLANS

- Simulate different configuration options to deliver a higher amount of H2 and purity within the target cost
- Proof of concept of the EHP system
- Technical economic assessment and optimization of the complete HyGrid system
- Finalize the delayed membrane module manufacturing
- Building the prototype of the HyGrid system

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Stack characterizations under selected conditions (i.e. fuel impurities, humidity, pressures, flowrates....) is useful to improve system management (positive impact at least on efficiency).

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

HyGrid technology could provide a means of transporting/storing the produced hydrogen from peak of renewable energy or any other means by blending it to the natural gas grid and then separate it using the HyGrid technology at different sites.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	TARGET	TARGET ACHIEVED	SoA result achieved to date by other group/ project	DESCRIPTION
Ideal selectivity	N/A	More than 10,000	✓	N/A	Development of ultra-thin Pd based membranes with selectivity (H2/CH4) ≥ 10.000 and H2 Permeance ≥ 10 x10E-7 mol m-2 s-1 Pa-1 calculated at ÐPH2 0.8 atm. Out of the tested membranes at the lab scale, few membranes achieved the specified targets
membrane H2 permeance	mol/ (m^2*s*Pa)	≥ 10 x10E-7		N/A	
Length of the membrane	cm	40-45 cm	✓	N/A	Development of long (40-45 cm) with membrane surface area of 1.26 m2 and mechanically stronger H2 selective membranes
Flow rate	Kg/day	25	🔧	N/A	A pilot scale membrane module for a hydrogen flow rate of more than 25 kg/day is under construction.
Recovery rate of H2	%	60	✓	30	Development of an electrochemical hydrogen separation compressor for low concentration stream (less than 3%) with recovery rate of 60%
Energy consump-tion	kWh/kgH2	4	✓	6	An electrochemical hydrogen separation compressor for low concentration stream with power consumption of lower than 5 kWh/kgH2 has been achieved
Cost	€/kgH2	less than 1.5	🔧	N/A	Manufacturing of a hybrid H2 separation, from a low hydrogen concentration stream of natural gas grid, prototype for 25 kg/day of H2 production. The preliminary cost analysis has been performed and the cost is a little bit more than what we anticipated at the beginning but further optimization in the configuration is now being carried out to fulfil the target
HRF (hydrogen recovery factor)	%	85	🔧	N/A	Overall hydrogen recovery factor of the HyGrid system
Purity	%	99.97	🔧	N/A	Overall purity of the separated hydrogen of the HyGrid system. The prototype has not yet been constructed

*Project's own objective (DoW), Target year 2019

INSIDE

IN-SITU DIAGNOSTICS IN WATER ELECTROLYZERS

Project ID:	**621237**
Call topic:	**SP1-JTI-FCH.2013.2.2** - Diagnosis and monitoring of electrolyser performance
Project total costs:	**€ 3,656,756.2**
FCH JU max. Contribution:	**€ 2,176,624.8**
Project start - end:	01/11/2014 - 31/10/2018
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE**
Website:	**www.inside-project.eu**

BENEFICIARIES: ACTA SPA, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, HELIOCENTRIS ITALY SRL, HOCHSCHULE ESSLINGEN, NEW NEL HYDROGEN AS

PROJECT AND OBJECTIVES

The development of diagnostics tools for three independent technologies for water electrolysis with individual properties is pursued: PEMWE, AWE, and AEMWE. The tool provides in-operando data from inside the electrolyser systems. It is based on an existing technology, which has been successfully used in the research on polymer electrolyte fuel cells. The aim is to use these diagnostics tools for online monitoring with the possibility for online adaptation of operational parameters, and for the prevention of hazardous operation modes while optimising the overall performance.

NON QUANTITATIVE OBJECTIVES

- Evaluation and verification of normal and accelerated test protocols
- Recommendation for improvements of water electrolysers

PROGRESS & MAIN ACHIEVEMENTS

- Prototype diagnostics hardware for PEMWE designed, manufactured, integrated and evaluated Enhancement in progress
- Prototype diagnostics hardware for AEMWE designed, manufactured, integrated and evaluated Enhancement in progress
- Prototype diagnostics hardware for AWE designed and manufactured. Integration and Evaluation pending

FUTURE STEPS & PLANS

- Evaluation of enhanced prototype for PEMWE
- Integration and Evaluation of prototype for AWE
- Evaluation of enhanced tools for AEMWE
- Evaluation of ASTs
- Public workshop on results and recommendations in Sept 2018

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Indirectly: Project outcomes (operando Monitoring and diagnostics) contribute to more targeted development and to intelligent Operation of Water electrolysers.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	TARGET ACHIEVED	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Diagnosis/monitoring tool availability	%	✔	2-dimensional current density monitoring was demonstrated in lab cell and industrial electrolyser /Current density monitoring was demonstrated in lab cell and industrial electrolyser (2015-2016)	Available for PEMWE electrolysis
Diagnosis/monitoring tool availability	%	🛠	N/A	Under commission
Diagnosis/monitoring tool availability	%	✔	Current density monitoring was demonstrated in industrial electrolyser	Available for AEMWE electrolysis
Evaluation and verification of normal and accelerated test protocols	N/A	🛠	N/A	Due later. Main objectives enable evaluation of test protocols. Test protocols to start with have been designed.
Recommendation for improvements of water electrolysers	N/A	🛠	N/A	

* As identified in MAIP 2008-2013 and project's own objective, Target year 2018

Megastack

STACK DESIGN FOR A MEGAWATT SCALE PEM ELECTROLYSER

Project ID:	621233
Call topic:	SP1-JTI-FCH.2013.2.3 - Large capacity PEM electrolyser stack design
Project total costs:	€ 3,912,286
FCH JU max. Contribution:	€ 2,168,543
Project start - end:	01/10/2014 - 30/09/2017
Coordinator:	STIFTELSEN SINTEF, NO
Website:	www.megastack.eu

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, ITM POWER (TRADING) LIMITED

PROJECT AND OBJECTIVES

The main objective of MEGASTACK is to develop a cost efficient stack design for MW sized PEM electrolysers and to construct and demonstrate a prototype of this stack. The prototype will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (HHV) at a current density of 1.2 Acm-2 with a stack cost below €2,500/Nm3h-1 and a target lifetime in excess of 40,000 hours (< 15 µVh-1 voltage increase at constant load). In the project we aim to take advantage of the existing PEM electrolyser stack designs of ITM power as well as novel solutions in the low-cost stack design.

PROGRESS & MAIN ACHIEVEMENTS

- MW stack design successfully completed and prototype manufactured
- Multiphysics models developed for simulation of flow distribution and stack performance
- Improved understanding of two-phase flow and wetting properties in porous transport layers, including several new measurement methods developed

FUTURE STEPS & PLANS

- Dissemination of Project results
- Prototype demonstration and commercialisation

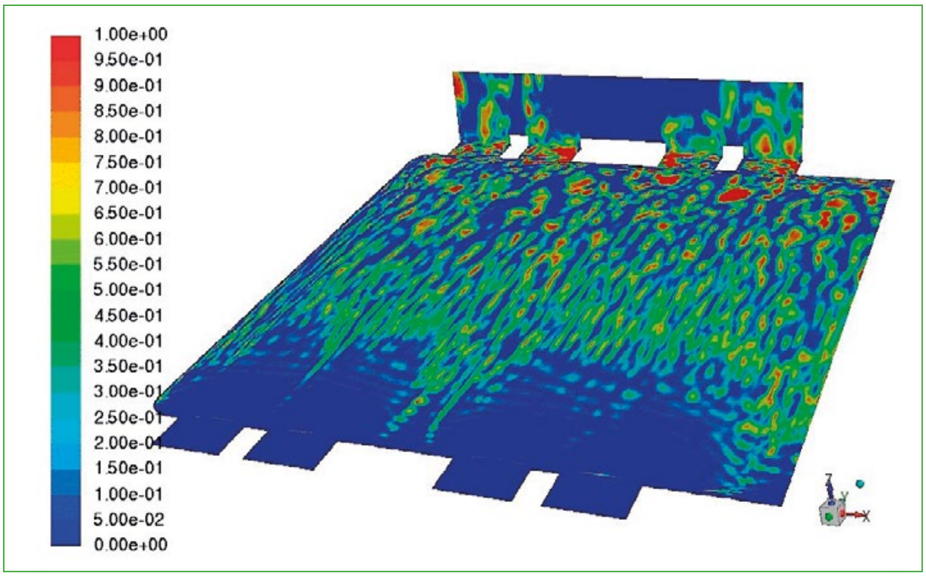
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

For large scale demonstration of hydrogen from renewables it is important to have cost effective electrolysers which megastack contributes to.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

For large scale demonstration of hydrogen from renewables it is important to have cost effective electrolysers which megastack contributes to.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Stack electricity consumption for H2 production	kWh/kg	50	✓
Current density	A/cm²	0.7	✓
Efficiency degradation per 1000 h for LT Electrolyser	%/1000h	0.12	✓
Cathode catalyst loading per W	mg/cm2	3.4	🔧
Anode catalyst loading per W	mg/cm2		

*As identified in MAWP Addendum 2018-2020, Target year 2020

MEMPHYS

MEMBRANE BASED PURIFICATION OF HYDROGEN SYSTEM

Project ID:	735533
Call topic:	**FCH-03-1-2016** - Development of innovative hydrogen purification technology based on membrane systems
Project total costs:	€ 2,088,195
FCH JU max. Contribution:	€ 1,999,925
Project start - end:	01/01/2017- 31/12/2019
Coordinator:	DUALE HOCHSCHULE BADEN-WURTTEMBERG, DE
Website:	www.memphys.eu

BENEFICIARIES: BORIT NV, FORSCHUNGSZENTRUM JULICH GMBH, HYET HYDROGEN BV, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, INSTITUT JOZEF STEFAN

PROJECT AND OBJECTIVES

Project MEMPHYS, MEMbrane based Purification of HYdrogen System, targets the development of a stand-alone hydrogen purification system based on an electrochemical hydrogen purification (EHP) system. The focus will be on high contaminant tolerance at low system cost, making the system suitable for different applications. Project MEMPHYS targets a 5 kg H2/day system with an energy consumption < 5 kWh/kg H2, a hydrogen recovery rate of > 90 %, producing high purity hydrogen at a system cost of < 1,500 €/kgH2/day with an output pressure of 200 bar. The project is now at the end of the first half.

PROGRESS & MAIN ACHIEVEMENTS

- Targeted recovery rate was reached in single cell tests
- Efficiency target was reached in single cell tests
- Comparable measurement results were achieved in the partners' laboratories at different institutions

FUTURE STEPS & PLANS

Purification and Compression in one step shall be realized with the EHP stack.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Hydrogen can be produced by biomass and with the MEMPHYS system we are able to clean and compress the hydrogen in one step.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

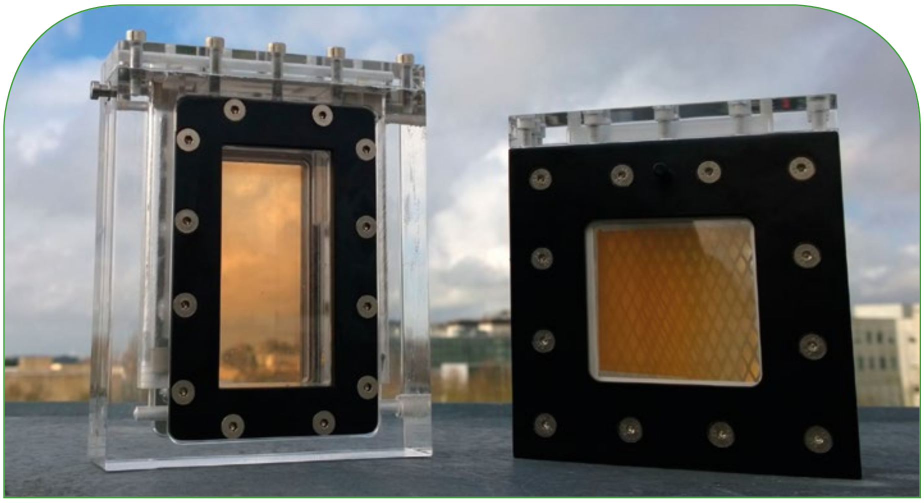
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Energy Consumption of EHP Stack	kWh/kg H2	3	9.8	🔧	N/A	energy consumption at the maximum reachable recovery rate of the stack
Recovery Rate EHP Stack	%	>90	78	✓	99 (2017)	N/A
Recovery Rate Single Cell	%	>90	>90	✓		N/A
Energy Consumption at Targeted Recovery Rate	kWh/kg H2	3	5	✓	N/A	For Single Cell

* Project's own objective, Target year 2019

PECDEMO

PHOTOELECTROCHEMICAL DEMONSTRATOR DEVICE FOR SOLAR HYDROGEN GENERATION

Project ID:	621252
Call topic:	**SP1-JTI-FCH.2013.2.5** - Validation of photoelectrochemical hydrogen production processes
Project total costs:	**€ 3,337,682.79**
FCH JU max. Contribution:	**€ 1,830,644**
Project start - end:	01/04/2014- 31/03/2017
Coordinator:	**HELMHOLTZ-ZENTRUM BERLIN FUR MATERIALIEN UND ENERGIE GMBH, DE**
Website:	**www.pecdemo.eu**



BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, EVONIK INDUSTRIES AG, SOLARONIX SA, TECHNION ISRAEL INSTITUTE OF TECHNOLOGY, UNIVERSIDADE DO PORTO

PROJECT AND OBJECTIVES

PECDEMO's main aim was to develop a photo electrochemical water splitting device based on low-cost and abundant materials that shows a solar-to-hydrogen efficiency of 10%, a stability of 1000 hours, and an area of at least 50 cm2. PECDEMO has addressed the challenges by focussing its efforts on three metal oxide photo electrode materials (Fe2O3, BiVO4, and Cu2O) and by combining them with a silicon- or halide perovskite-based photovoltaic cell in a tandem configuration. The highest solar-to-H2 efficiency achieved was 9.2% for BiVO4 combined with Fe2O3, the best stability was 1000 hours for Fe2O3.

NON QUANTITATIVE OBJECTIVES

- Dissemination and Outreach
- Staff exchange
- Management of IP

PROGRESS & MAIN ACHIEVEMENTS

- Solar-to-H2 efficiencies of 9.2% (HHV) for dual BiVO4/Fe2O3 photoanode in combination with Si heterojunction cell as bottom absorber
- A record stability of 1000 h was shown for Fe2O3 photoanodes
- Largest photo electrochemical metal oxide/silicon-based tandem cell ever reported (50 cm2)

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

We achieved a ~2 orders of magnitude increase in scale for a photo electrochemical cell (from < 1 cm2 to 50 cm2).

QUANTITATIVE TARGETS AND STATUS

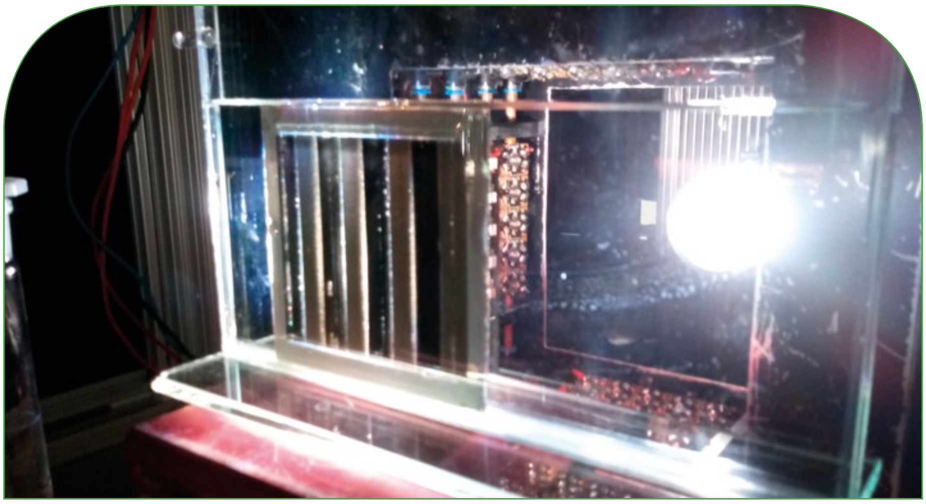
FCH JU Programme Targets

PARAMETER	UNIT	VALUE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Hours of operation - cumulative	hours	1263	1000	✓	Cumulative hours for concentrated and non-concentrated (lab-scale) systems
Conversion efficiency @ start of timeframe	%	0.42 (9.2 in lab)	8	✓ (only in lab)	Outdoor test under concentrated sunlight (note: best efficiency in lab was 9.2%)

*As identified in AWP 2013, Target year 2017

PECSYS

TECHNOLOGY DEMONSTRATION OF LARGE-SCALE PHOTO-ELECTROCHEMICAL SYSTEM FOR SOLAR HYDROGEN PRODUCTION



Project ID:	735218
Call topic:	FCH-02-3-2016 - Development of processes for direct production of hydrogen from sunlight
Project total costs:	€ 2,499,992.5
FCH JU max. Contribution:	€ 2,499,992.5
Project start - end:	01/01/2017- 31/12/2020
Coordinator:	HELMHOLTZ-ZENTRUM BERLIN FUR MATERIALIEN UND ENERGIE GMBH, DE
Website:	www.helmholtz-berlin.de/projects/pecsys

BENEFICIARIES: 3SUN SRL, CONSIGLIO NAZIONALE DELLE RICERCHE, ENEL GREEN POWER SPA, FORSCHUNGSZENTRUM JULICH GMBH, SOLIBRO RESEARCH AB, UPPSALA UNIVERSITET

PROJECT AND OBJECTIVES

The PECSYS project aims to demonstrate a system for solar driven electrochemical hydrogen generation with an area of at least 10 m2. Initial device concepts for PV-electrochemical cell integration have been developed so that under hot temperatures, improvements in the electrochemical process overcompensate the reduced PV conversion efficiency. The concepts with the highest hydrogen production and long term stability shall be selected scaled to prototypes of at least 100 cm2. A technical economic and life cycle analysis study shall be used to select the technology used in the demonstrator.

NON QUANTITATIVE OBJECTIVES

- Interaction between partners
- Increase public awareness of hydrogen production from renewable energy sources

PROGRESS & MAIN ACHIEVEMENTS

- 12.78% STH in a lab-scale CIGS-water splitting module using non-precious catalysts under alkaline conditions
- 20 cm² PEM cell using 0.4 mgIr/cm² and 0.1 mgPt/cm² catalyst loadings with optimized design and operating conditions validated in outdoor test.
- 7.5% active area STH in a lab-scale thin-film-silicon water splitting module with scalable design using nickel based catalysts in alkaline conditions

FUTURE STEPS & PLANS

- By 31 Dec 2018: integrated concepts on at least 100 cm² with long term stability developed
- By 31 Dec 2018: Technical economic study used to choose demonstrator concept
- September 2019: Modules (each 1 m² or larger) for demonstrator fabricated
- December 2019: demonstrator mounted and initial tests done. By Oct 2017 validation of 6 months operation
- Efforts shall be made to catch-up the delay in implementing a crystalline silicon based integrated device to achieve milestone 1 by the end of 2018

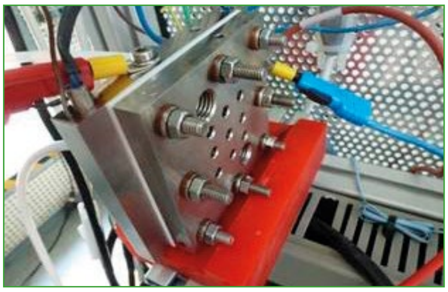
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs,

The PV-electrochemical cell integrated device design which keeps both components in thermal contact allows possible reductions of PV output as a result of heating under high irradiation, to be compensated by the simultaneous increase in electrochemical efficiency of hydrogen production.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Ultimate demonstration of an installation of and validated operation in outdoor conditions of the integrated PVElectrochemical device into a module array with a total area of at least 10 m² at the end of the project.



QUANTITATIVE TARGETS AND STATUS

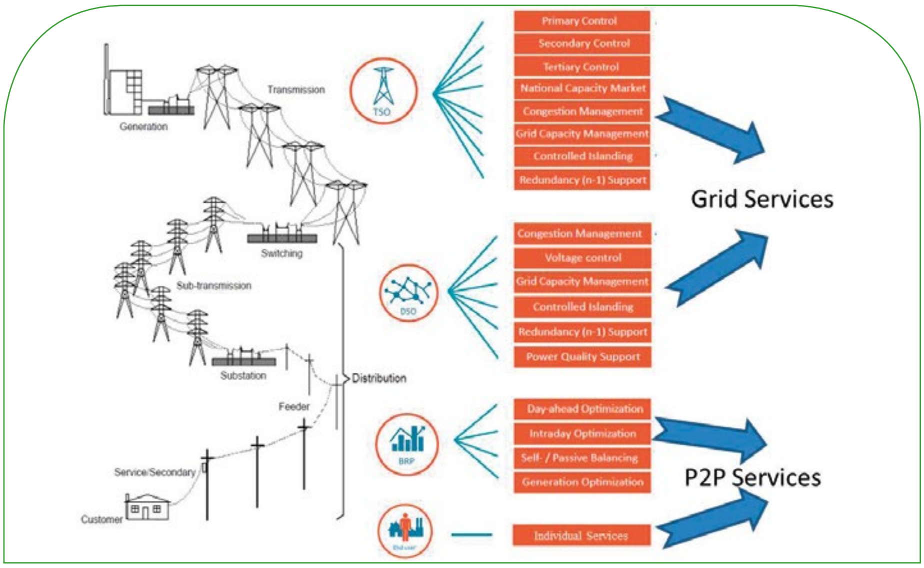
State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project	SOA YEAR	SoA Source
Solar to hydrogen efficiency	(%)	12.78 (CIGS) and 7.8 (Thin film silicon)	15.1	2017	Jan Ronge's Group at KU Leuven, Belgium. See: Sustainable Energy Fuels (2017), 1, 2061
Solar to hydrogen efficiency	(%)	12.78 (CIGS) and 7.8 (Thin film silicon)	16	2017	Todd Deutsch's group at NREL, US. See Nature Energy (2017)3, 17028
Stability	(%)	not yet tested	0% STH relative reduction(from an initial value of 3%) after 40 hours in alkaline conditions	2016	IEK-5 at FZJ, DE. See Nature Communications (2016) 7, 12681

* Available data provided by the project

QualyGridS

STANDARDIZED QUALIFYING TESTS OF ELECTROLYSERS FOR GRID SERVICES



Project ID:	**735160**
Call topic:	**FCH-02-1-2016** - Establish testing protocols for electrolysers performing electricity grid services
Project total costs:	**€ 2,811,262.5**
FCH JU max. Contribution:	**€ 1,996,795**
Project start - end:	01/01/2017 - 31/12/2019
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE**
Website:	**www.qualygrids.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, EUROPEAN FUEL CELL FORUM AG, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, IHT INDUSTRIE HAUTE TECHNOLOGIE SA, ITM POWER (TRADING) LIMITED, NEW NEL HYDROGEN AS, STICHTING NEDERLANDS NORMALISATIE - INSTITUUT

PROJECT AND OBJECTIVES

The overall objective of the QualyGridS project is to establish standardized testing protocols for electrolysers to perform electricity grid services. Alkaline and PEM electrolysers are both considered within this project. A variety of different grid services are addressed as well as multiple hydrogen end users. The protocols developed are applied to alkaline and PEM electrolysers systems, using electrolyser sizes from 50 kW to 300 kW. Additionally, a techno-economic analysis of business cases is performed covering the grid and market situations in the most relevant regions of Europe.

NON QUANTITATIVE OBJECTIVES

- AWP 2016: definition of specific KPIs for dynamic operation to provide grid services
- AWP 2016: Development of standardized tests and protocols for assessing the capability of electrolysers to provide grid services, providing a way to compare and assess improvements for manufacturers
- Project own objective: Evaluation of business cases, sensitivities and a roadmap for the successful introduction of electrolyser technologies considering energy and grid service markets

PROGRESS & MAIN ACHIEVEMENTS

- First draft of testing protocols for electrolyser systems performing electricity grid services
- Survey of electricity grid services in Europe with prequalification information
- 3 electrolyser test benches have been set up to carry out the grid serviced tests

FUTURE STEPS & PLANS

- Electrolyser testing protocols matching a selected grid service, ready for standardisation
- Electrolyser test run complying with developed testing protocol thus in principle being qualified for grid service operation
- Evaluation of business cases and a roadmap for the successful introduction of electrolyser technologies considering energy and grid service markets

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

OPEX cost reduction by application of grid services.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED	DESCRIPTION
Current density	A/cm²	0.92-2	2.2	🛠	QualyGridS - Electrolysis system -1,2, stack 2
Cold start ramp time	seconds	600-1140	30	🛠	QualyGridS - Electrolysis system -1,2 & stacks
Hot idle ramp time	seconds	5	2	🛠 (but achieved 2017 SoA)	QualyGridS - Electrolysis stack -2, system 2
Stack electricity consumption	kWh/kg	48.8	55	✓	QualyGridS - Electrolysis stack -2
Stack electricity consumption	kWh/kg	60.5	55	🛠	QualyGridS - Electrolysis system -2

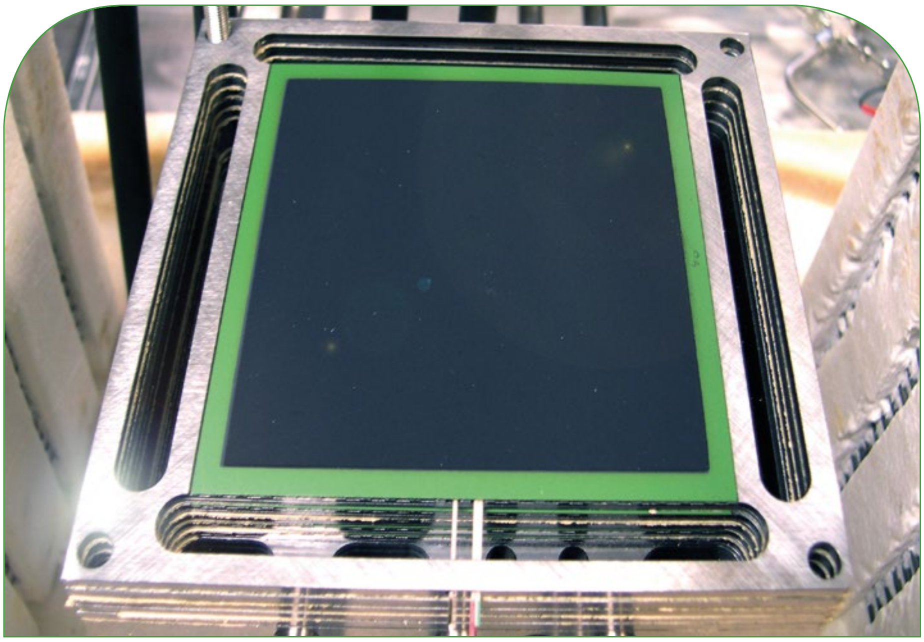
*As identified in MAWP Addendum 2018-2020, Target year 2020

SElySOs

DEVELOPMENT OF NEW ELECTRODE MATERIALS AND UNDERSTANDING OF DEGRADATION MECHANISMS ON SOLID OXIDE HIGH TEMPERATURE ELECTROLYSIS CELLS

Project ID:	**671481**
Call topic:	**FCH-02.1-2014** - Research in electrolysis for cost effective hydrogen production
Project total costs:	**€ 2,939,655**
FCH JU max. Contribution:	**€ 2,939,655**
Project start - end:	02/11/2015 - 01/11/2019
Coordinator:	**FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, EL**
Website:	**selysos.iceht.forth.gr**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, FORSCHUNGSZENTRUM JULICH GMBH, Prototech AS, PYROGENESIS SA, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE



PROJECT AND OBJECTIVES

SElySOs focuses on understanding of the degradation & lifetime fundamentals on both of the SOEC electrodes, for minimization of their degradation & improvement of their performance and stability mainly under H2O electrolysis and in a certain extent under H2O/CO2 co-electrolysis conditions. The main efforts comprise investigation of: (i) Modified SoA Ni-based cathode cermet, (ii) Alternative perovskite-type cathode materials, (iii) Thorough investigation on the O2 electrode and (iv). Development of a theoretical model for description of the performance & degradation of the SOEC H2 electrode.

NON QUANTITATIVE OBJECTIVES

- New materials and component design less prone to degradation
- Understanding of degradation mechanisms under dynamic operation
- Development of improved & robust SOEC systems (cells/stack/s)

PROGRESS & MAIN ACHIEVEMENTS

- Development and study of modified Ni-based & Ni-free cathodes and of new air electrodes with improved & "tailored" performance under SOEC operation
- "Operando" observation of Ni-based and Ni-free electrodes provided useful insight on their surface state during SOEC operation
- Thermodynamic analysis of the H2O & H2 & CO2 system towards the prediction of the most important reactions that take place under SOEC operation

FUTURE STEPS & PLANS

- Optimized cathodes (H2O electrodes) for H2O electrolysis & H2O/CO2 co-electrolysis in SOECs
- Optimized anodes (air electrodes) for H2O electrolysis SOECs
- Understanding of the underlying operation and degradation mechanisms towards improved and stable SOEC performance
- Manufacture and SOEC stability testing of high TRL cells & short stack/s, comprising the best performing electrodes in the framework of SElySOs

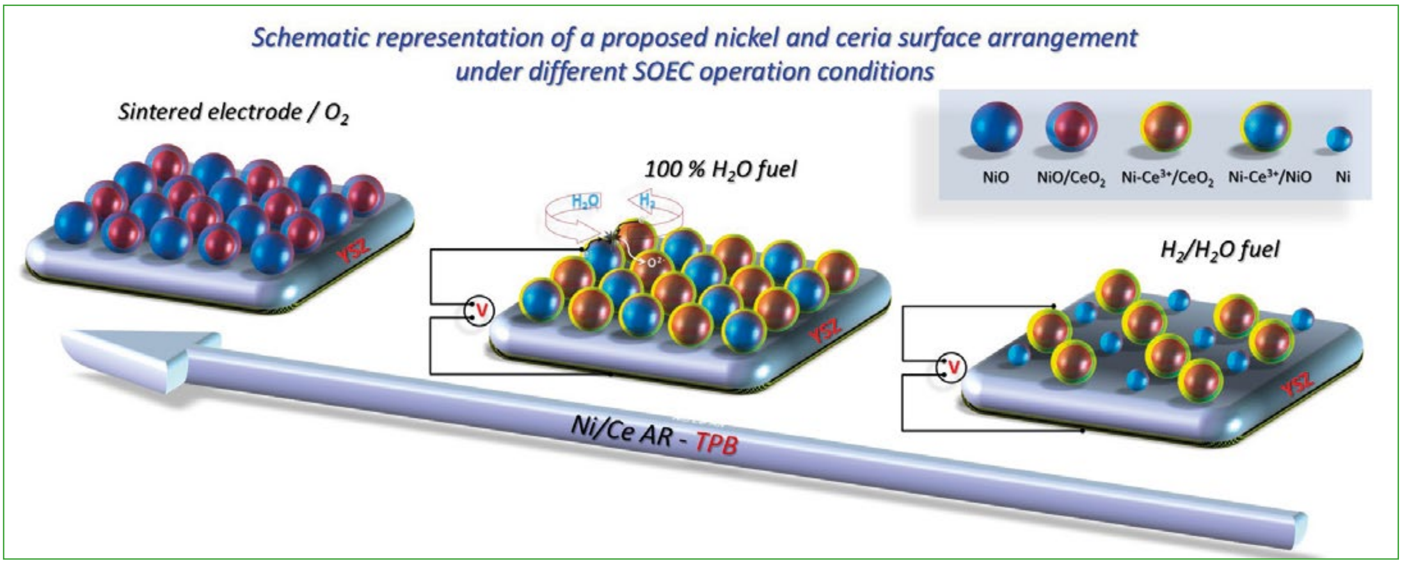
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

SElySOs contributes through the (i) improvement/development of new more efficient & stable electrodes and (ii) the understanding of the reaction mechanisms & processes that cause degradation on both SOEC electrodes. These will enable long-term SOEC electrical efficiency close to 90% (HHV).

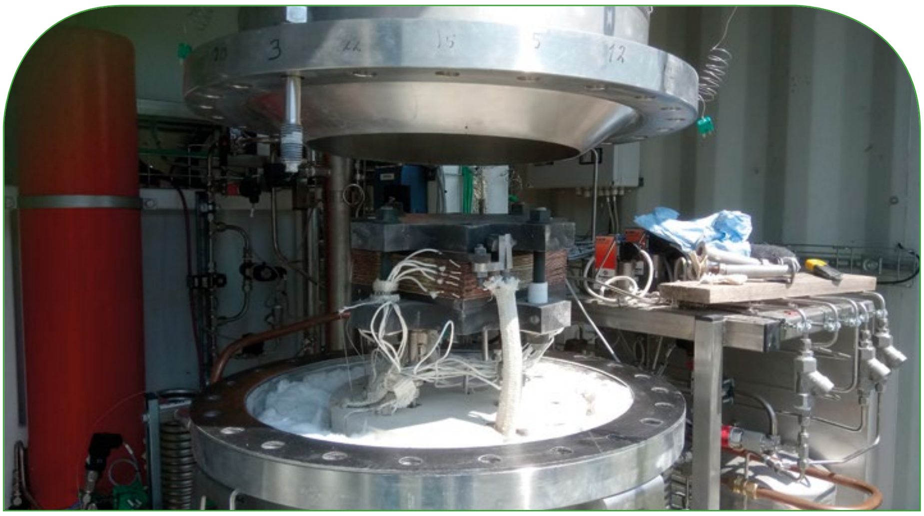
Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

SElySOs contributes to the identification of key operational/degradation processes, so as to assist in the development of new SOECs less prone to degradation with improved performance and stability. The latter will enable production of H2 with reduced electricity consumption.



SOPHIA

SOLAR INTEGRATED PRESSURIZED HIGH TEMPERATURE ELECTROLYSIS



Project ID:	**621173**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 6,080,105.14**
FCH JU max. Contribution:	**€ 3,325,751**
Project start - end:	01/04/2014 - 30/09/2017
Coordinator:	**HyGear B.V., NL**
Website:	**www.sophia-project.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, ENGIE, HTceramix SA, SOLIDPOWER SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy

PROJECT AND OBJECTIVES

The aim of the project is to develop a solar-powered High Temperature Electrolysis system, and develop technology for co-electrolysis. The complete system, comprising of the HTE stack-subsystem and solar receiver has been tested at the Solar Simulator at DLR at 3 bar. The HTE stack-subsystem has been tested at HyGear at 15 bar.
A market analysis shows that for systems producing hydro-carbons the availability of CO2 is not limiting, but the solar power is. Various cell, SRU, and stack tests have been done in (co-)electrolysis mode.

NON QUANTITATIVE OBJECTIVES

- Develop concepts for pressurized electrolysis for more economical systems (production of hydrogen, but also methane, methanol or DME are valuable)
- Test and evaluation of cells, stacks and systems under realistic conditions
- Manufacture of dedicated HTE cells and stacks for use in large systems for the conversion of electricity from renewable sources and from nuclear power, i.e. large area cells, high durability under realistic conditions

PROGRESS & MAIN ACHIEVEMENTS

- The HTE prototype system built including a separate steam generator for stand-alone system has been tested at 15 Bara
- A performance better than 1 A/ cm2 at 1.3 V and 10 bar in co-electrolysis mode was observed
- Microscopic models, supported by innovative characterization techniques to macroscopic models have been developed

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

High temperature electrolysis technology has been tested under pressure producing hydrogen, under realistic conditions with heat and steam coming from a solar steam generator. In addition co-electrolysis for syngas production has been demonstrated at elevated pressure.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

High temperature electrolysis has been demonstrated on a small scale but at elevated pressure.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Stack electricity consumption for H2 production	kWh/kg	33	40	✓	not measured
Current density	A/cm2	0.58-1	1	✓	determined in lab
Degradation	%/1000hrs	0 - 7	<0.5	🛠	N/A

*As identified in MAWP Addendum 2018-2020 and AIP 2013, Target years 2017-2020

Don Quichote

DEMONSTRATION OF NEW QUALITATIVE INNOVATIVE CONCEPT OF HYDROGEN OUT OF WINDTURBINE ELECTRICITY

Project ID:	**303411**
Call topic:	**SP1-JTI-FCH.2011.2.1** - Demonstration of MW capacity hydrogen production and storage for balancing the grid and supply to a hydrogen refuelling station
Project total costs:	**€ 4,936,804.57**
FCH JU max. Contribution:	**€ 2,954,846**
Project start - end:	01/10/2012 - 31/03/2018
Coordinator:	**HYDROGENICS EUROPE NV, BE**
Website:	**www.don-quichote.eu**

BENEFICIARIES: ETABLISSEMENTEN FRANZ COLRUYT NV, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, HYDROGEN EFFICIENCY TECHNOLOGIES (HYET) BV, ICELANDIC NEW ENERGY LTD, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, THINKSTEP AG, TUV Rheinland Industrie Service GmbH, WaterstofNet vzwy

PROJECT AND OBJECTIVES

Demonstrate the technical and economical viability of hydrogen as large scale renewable energy storage solution. Connection to a refuelling facility to investigate the commercial opportunity connecting intermittent renewable electricity to transport applications. Grid balancing using a fuel cell system. Demonstrate and validate the technology readiness. Generate facts based data for the exploitation of RE to H2.

NON QUANTITATIVE OBJECTIVES

- Study of regulatory aspects associated with this test platform
- Inventory and analyses of RCS related to the production, compression and storage of hydrogen
- Detailed analysis of LCA/LCI and total cost of ownership
- Assessment of feasibility/impact of large scale implementation
- Development of a comprehensive exploitation plan

PROGRESS & MAIN ACHIEVEMENTS

- One project covering two types of electrolysers, two types of compressors, a fuel cell system and H2 dispenser
- The hydrogen produced system is a strong example of "sector-coupling", connecting green electricity with hydrogen production
- Successfully integrated in an existing 'distribution centre' => knowledge/experience on permitting procedures and safety regulations in operation

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

A lot of effort went to optimizing the electrolyser to run on renewable source energy, intermittend and together with fuelling station where the run hours are low, so overhead energy losses are very important.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Separate work package to study large scale implementation.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Electrolyser Footprint	m2/MW	30	100	✓	PEM Electrolyser
Current Density	A/cm2	2	2.2	⚒ (SoA 2017 achieved)	
Efficiency degradation per 1000 h for LT electrolysers	%/1000hrs	3.7	0.12	⚒	Alkaline Electrolyser
Estimated Efficiency degradation per 1000 h @ 10 year lifespan for LT electrolysers	%/1000hrs	3.7	0.12	⚒	
Current Density	A/cm2	0.44	0.7	⚒	
System electrical efficiency (HHV, AC current)	%	65.3	55	✓	

* As identified in MAWP 2018-2020 and AIP 2011, Target years 2018-2020

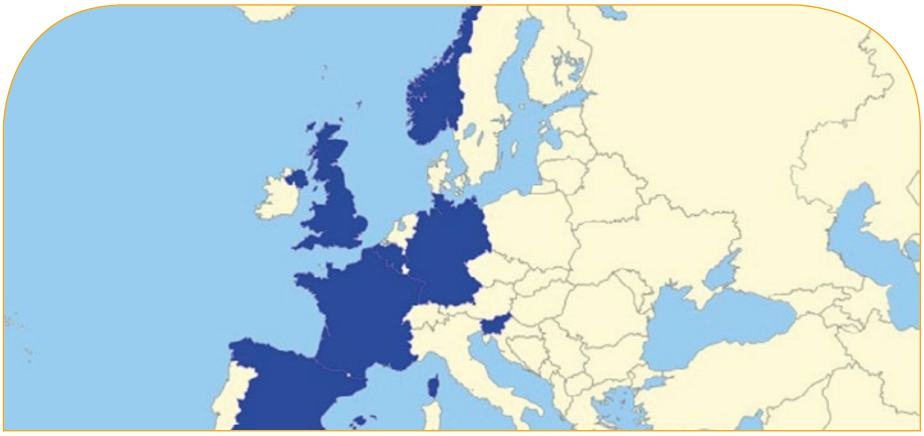
PANEL 6
SUPPORT FOR MARKET UPTAKE

HYACINTH

HYDROGEN ACCEPTANCE IN THE TRANSITION PHASE

Hyacinth

Project ID:	621228
Call topic:	SP1-JTI-FCH.2013.5.3 - Social acceptance of FCH technologies throughout Europe
Project total costs:	€ 999,383
FCH JU max. Contribution:	€ 661,584
Project start - end:	01/09/2014 - 31/05/2017
Coordinator:	CENTRO NACIONAL DE EXPERIMENTACIONDE TECNOLOGIAS DE HIDROGENO Y PILASDE COMBUSTIBLE CONSORCIO, ES
Website:	www.hyacinthproject.eu



BENEFICIARIES: ABERDEEN CITY COUNCIL*, CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, CONSULTORIA DE INNOVACION Y FINANCIACION SL, FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV, FUNDACION CIDAUT, I PLUS F FRANCE SARL, NORSTAT DEUSTCHLAND GmbH, RAZVOJNI CENTER ZA VODIKOVE TEHNOLOGIJE, UNIVERSITY OF LEEDS, UNIVERSITY OF SUNDERLAND

PROJECT AND OBJECTIVES

The project objectives are firstly to gain a deeper understanding of European-level social awareness and acceptance of Fuel Cell and Hydrogen (FCH) technologies. To achieve these objectives, two studies were undertaken related to awareness and acceptance of hydrogen technologies – one of the general public and one of selected stakeholders - in several EU countries. Finally, the data collected in both studies have informed the SAMT, a Social Acceptance Management toolbox. This provides an accessible interface to the study results and is intended to support queries relevant to developers.

NON QUANTITATIVE OBJECTIVES

- Projects own. Social Acceptance research Management Toolbox (SAMT)
- Impact of first use of hydrogen in the mobility sector in stakeholder
- Stakeholder's opinion on HYACINTH results. D 6.3. Optimized and tested

PROGRESS & MAIN ACHIEVEMENTS

- Study and Report on general public acceptance on hydrogen and fuel cell technologies
- Study and Report on Stakeholder's views on the acceptance of hydrogen fuel cell technologies
- Development a Social Acceptance Management toolbox (SAMT)

FUTURE STEPS & PLANS

Project is finished.

	Key Strenghts	Perceived weaknesses	Key expectations	Recommendations
Hydrogen supply and use	1. Environmental performance 2. Versatility	1. Cost 2. Inadequate/excessive regulation	1. Positive 2. Market development (near term) 3. Uncertainty by govt support	1. More govt and political support 2. Inform & engage stakeholders 3. R&D
Stationary applications	1. Utility of portable /UPS 2. Environmental advantages	1. Cost 2. Complexity of systems 3. Limited support by regulators	1. Mixed 2. Related to nat policies 3. Different between countries	1. More sustained govt support 2. Regulatory & public support
Mobile applications	1. Technical performance 2. Lack of local emmissions 3. Good vs other alternatives	1. Financial cost 2. Limited awareness of regulators 3. Rivalry vs other technologies	1. Divided: many possitive and many pessimistic in short term. 2. Differences between countries	1. Govt, political and regulatory support. 2. Investment in infrastructure

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	TARGET	DESCRIPTION
Public awareness and acceptance	%	The current state of public awareness of FCH technologies in Europe	D5.2. General Finding on Public aceptance.3.1.2,3.2.1, 3.4.1. 3.2.7, 3.3. and 3.4.8
Familiarity with hydrogen technology	%	Familiarity with hydrogen technology in stationary and mobile applications (micro-CHP and FCEV). These are closer to the market.	D5.2. General Finding on Public aceptance.3.2.3 and 3.4.4 pages 32, 44 and 73
Fears associated with FCH technology	%	In general public survey was asked about costs and benefits of both applications and the evaluation of consequences (see next target)	D5.2. General Finding on Public aceptance.3.2.4. and 3.4.5 pages 50 and 79
How is hydrogen safety perceived by the general public?	%	The majority of issues raised by respondents are related to the price and safety	D5.2. General Finding on Public aceptance.3.2.4. and 3.4.5 pages 50 and 79
Identify and understand acceptance of stakeholders	%	To examine public awareness, familiarity, perception of benefits and costs, global attitude and acceptance of FCH technologies (Recommendations)	D5.1. Report on the results of the Stakeholders survey

*As identified in AIP 2013 and project's own objectives, Target year 2017

HyCoRA
HYDROGEN CONTAMINANT RISK ASSESSMENT

Project ID:	621223
Call topic:	SP1-JTI-FCH.2013.1.5 - Fuel Quality Assurance for Hydrogen Refuelling Stations
Project total costs:	€ 3,842,049
FCH JU max. Contribution:	€ 2,159,024
Project start - end:	01/04/2014 - 30/06/2017
Coordinator:	Teknologian tutkimuskeskus VTT Oy, FI
Website:	www.hycora.eu

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, Powercell Sweden AB, PROTEA LIMITED, STIFTELSEN SINTEF, TEKNOLOGIAN TUTKIMUSKESKUS VTTHCOOH project results have been essential for the introduction of a total budget for these and CO into the standard.

PROJECT AND OBJECTIVES

The main objective of HyCoRA project was to provide information to reduce cost of hydrogen fuel quality assurance (QA). A probabilistic simulation model was developed to quantify the risk induced by fuel contaminants on FCEVs' performance and to assess the overall cost impact of quality control measure options. The HRS sampling strategy has been widely accepted and successful sampling campaigns culminated in its standardization in Annex I to 19880-1. HCHO and HCOOH project results have been essential for the introduction of a total budget for these and CO into the standard.

NON QUANTITATIVE OBJECTIVES

- Identifying the impurity limits of PEMFCs under automotive operation
- Technical data on fuel composition and impurity concentration at HRS
- Simplified and diversified set of requirements for H2 fuel quality
- Design and verification of gas sampling instrumentation to HRS

PROGRESS & MAIN ACHIEVEMENTS

- FC impurity measurements with HCHO and HCOOH have been essential for the introduction of a total budget for these and CO into the standard
- Three HRS sampling campaigns, fuel composition and impurity concentrations analysed. Standardization of the sampling by adding Annex I to 19880-1
- A probabilistic simulation model to quantify the risk induced by fuel contaminants on FCEVs' performance

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Data and support for correct limits and guidelines for standardization H2 fuel and H2 fuel QA assist promoting feasibility of using H2 in energy systems.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	RESULT ACHIEVED TO DATE	SoA Source
Identifying the impurity limits of PEMFCs under automotive operation	FC measurement test system is SoA, and has been introduced to other institutes. E.g. LANL is replicating and improving the recirculation system developed by VTT with the help of VTT	E.g. https://energy.gov/eere/fuelcells/downloads/hydrogen-fuel-quality-specifications-polymer-electrolyte-fuel-cells-road
Technical data on fuel composition and impurity concentration at HRS	Very unique sampling data sets: data is public and analysis has been performed in compliance with ISO 14687/SAE J2719	N/A
Probabilistic risk assessment model to quantify the risk from H2 fuel contaminant(s)	No other similar approach available (public)	N/A
Design and verification of gas sampling instrumentation to HRS	Commercial equipment utilized (as available), but the selection of equipment and the chosen strategy led successful sampling campaigns, and culminated in Annex I to 19880-1	N/A

* Data available as provided by the project

HyLAW

IDENTIFICATION OF LEGAL RULES AND ADMINISTRATIVE PROCESSES APPLICABLE TO FUEL CELL AND HYDROGEN TECHNOLOGIES' DEPLOYMENT, IDENTIFICATION OF LEGAL BARRIERS AND ADVOCACY TOWARDS THEIR REMOVAL

Project ID:	**735977**
Call topic:	**FCH-04-2-2016** - Identification and reduction of legal-administrative barriers for the installation and operation of key FCH technologies
Project total costs:	**€ 1,143,000**
FCH JU max. Contribution:	**€ 1,143,000**
Project start - end:	01/01/2017 - 31/12/2018
Coordinator:	**HYDROGEN EUROPE, BE**
Website:	**www.hylaw.eu**

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ASSOCIATION FRANCAISE POUR L'HYDROGENE ET LES PILES A COMBUSTIBLE, BRINTBRANCHEN, BULGARIAN ACADEMY OF SCIENCES, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANSK GASTEKNISK CENTER AS, DEUTSCHER WASSERSTOFF- UND BRENNSTOFFZELLENVERBAND EV, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, GREATER LONDON AUTHORITY, INSTYTUT ENERGETYKI, LATVIJAS UDENRAZA ASOCIACIJA, MAGYAR TUDOMANYOS AKADEMIA TERMESZETTUDOMANYI KUTATOKOZPONT, NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR CRYOGENICS AND ISOTOPIC TECHNOLOGIES ICSI RM VALCEA, OSTERREICHISCHE ENERGIEAGENTUR AUSTRIAN ENERGY AGENCY, STI - SISTEMAS E TECNICAS INDUSTRIAIS LDA, STICHTING NEDERLANDS NORMALISATIE – INSTITUUT, STIFTELSEN SINTEF, Teknologian tutkimuskeskus VTT Oy, THE SCOTTISH HYDROGEN AND FUEL CELL ASSOCIATION LTD, UK HYDROGEN AND FUEL CELL ASSOCIATION, VATGAS SVERIGE IDEELL FORENING, WaterstofNet vzw

PROJECT AND OBJECTIVES

HyLAW aims to deliver the most detailed and robust assessment to date of Legal and Administrative Processes and their impacts on FCH technologies across the EU. This will provide the facts and underlying evidence essential for discussions with regulatory agencies, policymakers and other stakeholders. The objective of the project is to identify regulatory barriers (due to in adapted or missing regulation) and to provide recommendations on how those can be improved. It was not in the scope of the project to ensure the regulatory / standard change within its timeline.

NON QUANTITATIVE OBJECTIVES

- CREATE: a coherent database covering 17 MSs and 1 associated State
- Identify significant variations and 'best practice' approaches implemented locally, regionally or/and nationally
- INFORM: provide accessibility via a single portal to information about FCH technologies
- COMMUNICATE AND DISSEMINATE: provide a coherent communication strategy and meet the dissemination needs of different FCH sectors and different member states

PROGRESS & MAIN ACHIEVEMENTS

- A list of 64 legal and administrative process relevant to hydrogen technology deployment, spanning 18 different hydrogen applications in 9 Categories
- Identification of the most severe legal and administrative barriers associated with deployment of hydrogen technologies
- An online database containing descriptions of relevant legal and administrative processes in 18 countries

FUTURE STEPS & PLANS

- The bulk of the analytical work (assessment of severity of barriers, identification of barriers takes place in Q2 2018
- Results of cross-country analysis and severity of barriers will be made public in August 2018 and will take the form of technical reports
- Information and descriptions of legal and administrative processes relevant to hydrogen technology deployment in 18 countries online July 2018
- 18 National Policy papers will be drafted with recommendations on how to address the major barriers identified (Q3 2018)
- 18 National Workshops and 1 EU Workshop will invite policy makers, administrations, industry and will be
- used as dissemination of results (Q4 2018)

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the use of the EU defined 'Critical raw materials'

The project focused on legal and administrative barriers and providing information to project developers on how to overcome them. This may speed-up the deployment and commercial uptake of hydrogen based technologies and provide significant benefits towards the EU's climate, energy and environmental goals.

QUANTITATIVE TARGETS AND STATUS

FCH JU Project Targets*

PARAMETER	UNIT	RESULT ACHIEVED
Progress vs knowledge gap	%	65
Regulatory bodies contacted to date	N/A	19
Number of meetings with regulatory organisations		19
Number of peer reviewed publications		1
Number of oral presentations @ scientific seminars/conferences		19
Number of posters at scientific seminars/conferences		1

* Project's own targets

HYPACTOR

PRE-NORMATIVE RESEARCH ON RESISTANCE TO MECHANICAL IMPACT OF COMPOSITE OVERWRAPPED PRESSURE VESSELS

Project ID:	621194
Call topic:	**SP1-JTI-FCH.2013.5.6** - Pre-normative research on resistance to mechanical impact of pressure vessels in composite materials
Project total costs:	**€ 4,049,293.42**
FCH JU max. Contribution:	**€ 2,143,665**
Project start - end:	01/04/2014 - 30/06/2017
Coordinator:	**COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.hypactor.eu**

BENEFICIARIES: ABERDEEN CITY COUNCIL*, CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, CONSULTORIA DE INNOVACION Y FINANCIACION SL, FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV, FUNDACION CIDAUT, I PLUS F FRANCE SARL, NORSTAT DEUSTCHLAND GmbH, RAZVOJNI CENTER ZA VODIKOVE TEHNOLOGIJE, UNIVERSITY OF LEEDS, UNIVERSITY OF SUNDERLAND

PROJECT AND OBJECTIVES

The main objective of HYPACTOR is to provide recommendations for Regulation Codes and Standards (RCS) regarding the qualification of new designs of Composite Overwrapped Pressure Vessel (COPV) and the procedures for periodic inspection in service of COPV subjected to mechanical impacts.

PROGRESS & MAIN ACHIEVEMENTS

- Recommendations for RCS regarding qualification of COPVs with respect to impact, inspection of impacted COPVs
- Understand & characterize the relationship between the impact, the damage and the loss of performance of COPV at short term
- Definition of a test configuration and inspection procedures for impacted COPVs

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Improvement of COPVs

QUANTITATIVE TARGETS AND STATUS

FCH JU Project Targets

PARAMETER	UNIT	RESULT ACHIEVED TO DATE
Identify the different types of alterations that may be produced by mechanical impacts and develop an understanding of their consequences	%	100
Establish a relation between severity of impact, level of damage, and effect on structural integrity		
Apply the results of the above to assess the reliability of composite pressure vessels in the foreseen applications and potential needs of protection		
Evaluate non-destructive examination methods, such as analysis of acoustic emissions, and associated pass/fail criteria for controlling pressure vessel structure		
Description and quantification of the effect of mechanical impacts on composite pressure vessel structure		
Assessment of the structural reliability of composite pressure vessels in the foreseen service conditions and opportunities of improvement and optimise		
Recommendations to industry and for international standards development		
Improved methods and criteria for inspection of pressure vessels in service		

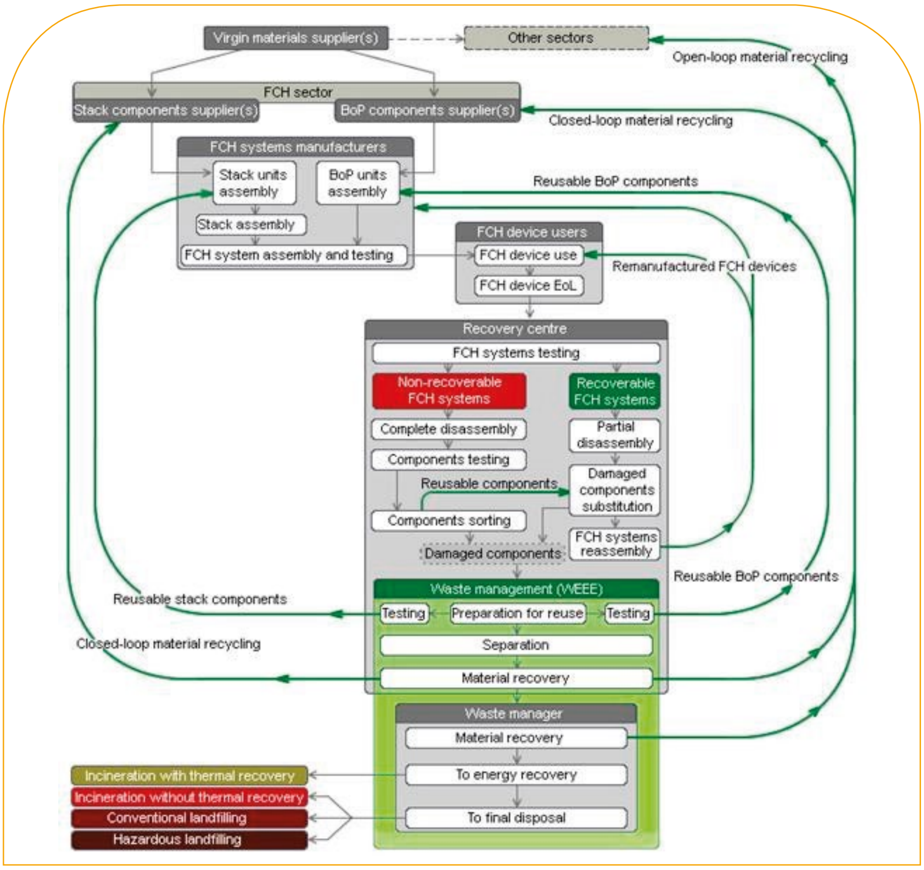
*** Project's own targets**

HYTECHCYCLING

NEW TECHNOLOGIES AND STRATEGIES FOR FUEL CELLS AND HYDROGEN TECHNOLOGIES IN THE PHASE OF RECYCLING AND DISMANTLING

Project ID:	**700190**
Call topic:	**FCH-04.1-2015** - Recycling and Dismantling Strategies for FCH Technologies
Project total costs:	**€ 497,666.25**
FCH JU max. Contribution:	**€ 497,666.25**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.hytechcycling.eu**

BENEFICIARIES: Fundacion IMDEA Energia, INDUSTRIAS LOPEZ SORIANO SA, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, UNIVERZA V LJUBLJANI



PROJECT AND OBJECTIVES

HyTechCycling has as objective precede the implementation of the technologies, facilitating the development of future actions and avoiding problems related to the implementation and regulatory framework in the recycling and dismantling of the FCH technologies in their different applications. HyTechCycling has classified the materials that appear in the FCH, identified barriers and needs from different points of view and worked in a LCA, considering the whole EoL and the new technologies and strategies studied. A business model will be developed with all the developments of the project.

NON QUANTITATIVE OBJECTIVES

- Research in regulation from the EU and how affects FCH during the EoL
- Classification of the FCH technologies according different criteria
- Research for new technologies and strategies in the recycling phase
- Identification of the needs and challenges for all actors through surveys
- Performing of a complete LCA of the whole life of the technologies. Work in Progress. LCA for the equipment partially done. Waiting for specific data for validate and for the results and validation

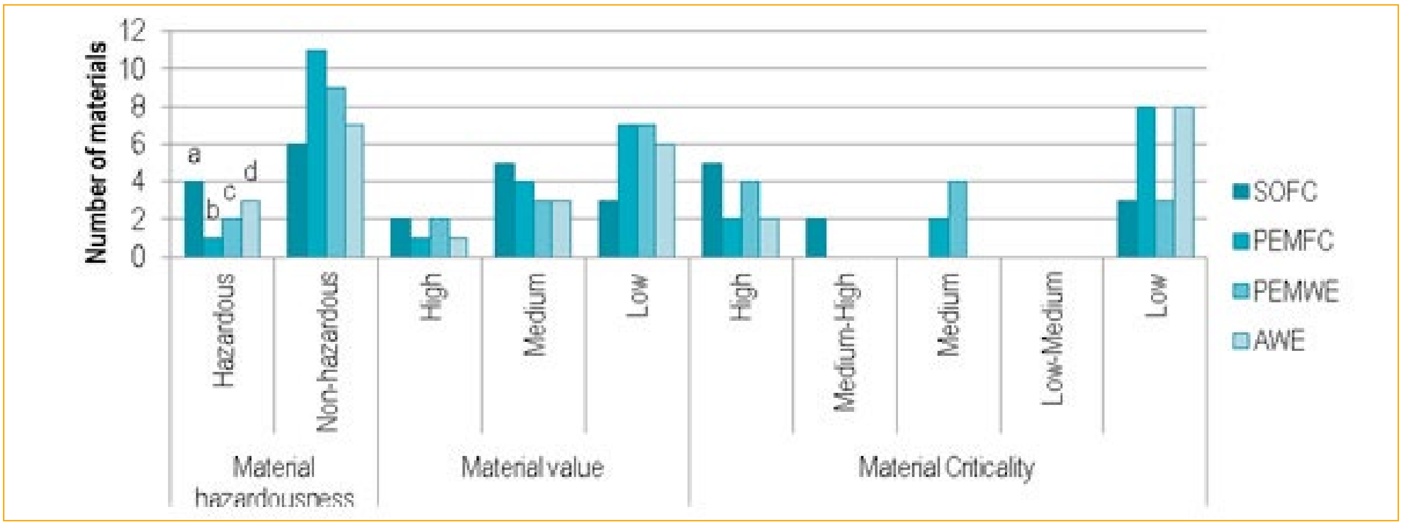
PROGRESS & MAIN ACHIEVEMENTS

- Identification of the critical materials that exists in the FCH technologies
- Create interest among the different actors of the FCH life about the project evolution.
- Selection of the new strategies and technologies in the recycling phase for critical materials

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the use of the EU defined 'Critical raw materials'

The project is mainly focused on the analysis of these materials and its impact in order to reduce their use.



HySEA

IMPROVING HYDROGEN SAFETY FOR ENERGY APPLICATIONS (HYSEA) THROUGH PRE-NORMATIVE RESEARCH ON VENTED DEFLAGRATIONS

Project ID:	**671461**
Call topic:	**FCH-04.3-2014** - Pre-normative research on vented deflagrations in containers and enclosures for hydrogen energy applications
Project total costs:	**€ 1,511,780**
FCH JU max. Contribution:	**€ 1,494,780**
Project start - end:	01/09/2015 - 30/11/2018
Coordinator:	**GEXCON AS, NO**
Website:	**www.hysea.eu**

BENEFICIARIES: FIKE EUROPE BVBA, HEFEI UNIVERSITY OF TECHNOLOGY, IMPETUS ADVANCED FINITE ELEMENT ANALYSES AS, THE UNIVERSITY OF WARWICK, UNIVERSITA DI PISA, University of Science and Technology of China

PROJECT AND OBJECTIVES

The main objective of the project Improving Hydrogen Safety for Energy Applications through pre-normative research on vented deflagrations (HySEA) is to conduct pre-normative research on vented hydrogen deflagrations with an aim to provide recommendations for European and international standards on hydrogen explosion venting mitigation systems.

NON QUANTITATIVE OBJECTIVES

Increased awareness of inherent limitations in current standards for vented hydrogen deflagrations.

PROGRESS & MAIN ACHIEVEMENTS

- Completed two experimental campaigns with vented hydrogen deflagrations in a small-scale enclosure
- Completed two experimental campaigns with vented hydrogen deflagrations in 20-foot ISO containers
- Completed two blind-prediction studies with vented hydrogen deflagrations in 20-foot ISO containers

FUTURE STEPS & PLANS

- Finalise reports from experiments in 20-foot containers
- Request extension of project period
- Submit outstanding publications
- Organize final dissemination event
- Organize final meeting/workshop with standardizing committee (CEN TC 305)

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Safe storage and handling of hydrogen will in many situations require proper design of explosion venting devices.

KnowHy

IMPROVING THE KNOWLEDGE IN HYDROGEN AND FUEL CELL TECHNOLOGY FOR TECHNICIANS AND WORKERS

Project ID:	621222
Call topic:	SP1-JTI-FCH.2013.5.2 - Training on H2&FC technologies for Operation & Maintenance
Project total costs:	€ 1,437,062.4
FCH JU max. Contribution:	€ 1,000,000
Project start - end:	01/09/2014 - 28/02/2018
Coordinator:	TECHNISCHE UNIVERSITEIT DELFT, NL
Website:	www.knowhy.eu

BENEFICIARIES: CAMPUS AUTOMOBILE SPA-FRANCORCHAMPSASBL, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, FUNDACION SAN VALERO, INSTITUTO SUPERIOR TECNICO, KIWA TRAINING BV, McPhy Energy SA, PARCO SCIENTIFICO E TECNOLOGICO PER L'AMBIENTE - ENVIRONMENT PARK SPA, PNO CONSULTANTS BV, TECHNISCHE UNIVERSITAET MUENCHEN, THE UNIVERSITY OF BIRMINGHAM

PROJECT AND OBJECTIVES

KnowHY aims to provide the FC&H2 sector with a training offer for technicians and workers featuring quality in contents, accessibility in format and language, practicality for the targeted audience, ease of scalability and update, and at competitive costs which make the training offer economically sustainable after project completion. An online tool for accessing to the training contents via web has been developed for all modules. Moreover, practical sessions have been designed in existing facilities, such as demo projects, or labs adapted to the training.

NON QUANTITATIVE OBJECTIVES

- Identification of target group, topics and modules definition
- Effective teaching methodology defined & the course platform set
- Establish a self-financing KnowHy legal entity
- Dissemination of results to industry, stakeholders and etc.

PROGRESS & MAIN ACHIEVEMENTS

- The number of trainees: 862 students have been undergone training for the core module and all 5 specialization modules.
- According to Second analysis of the feedback, from more than 400 surveys, the global satisfaction of the students is very high (3,7 over 4)
- Feedbacks from companies that sent students shows a positive evaluation rating with 8.5/10. They are willing to introduce KnowHy to other companies

FUTURE STEPS & PLANS

Project is finished

QUANTITATIVE TARGETS AND STATUS

FCH JU Project Targets*

PARAMETER	RESULTS ACHIEVED TODAY	DESCRIPTION
Total number of people trained in project	42	APU AND BACKUP POWER
Number of diplomas/certificates issued in the project	27	APU AND BACKUP POWER
Total number of people trained in project	680	CORE TRAINING
Number of diplomas/certificates issued in the project	259	CORE TRAINING
Total number of people trained in project	197	H2 production-handling
Number of diplomas/certificates issued in the project	56	H2 production-handling
Total number of people trained in project	208	HFC for transport
Number of diplomas/certificates issued in the project	62	HFC for transport
Total number of people trained in project	3	MICRO FUEL CELLS
Total number of people trained in project	60	CHP
Number of diplomas/certificates issued in the project	34	CHP

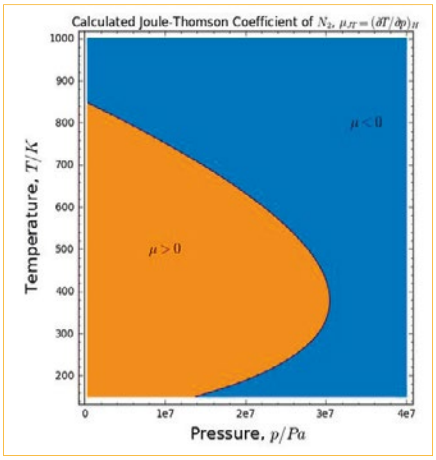
* Project's own targets

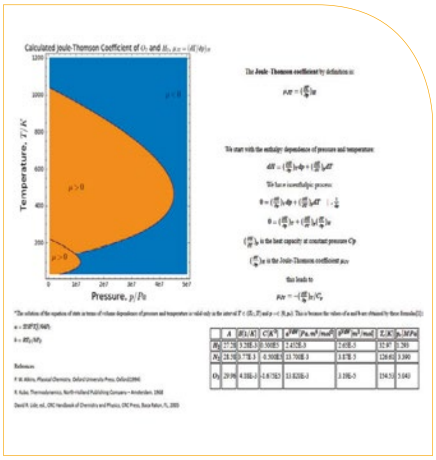
NET-Tools

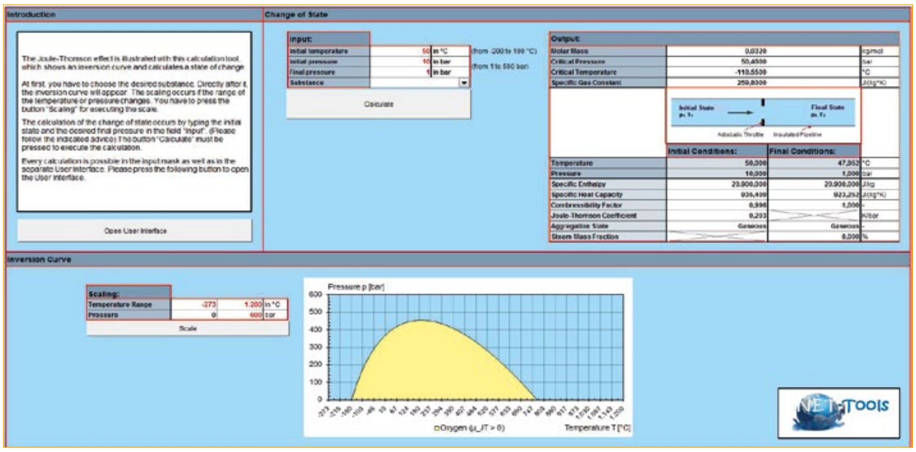
NOVEL EDUCATION AND TRAINING TOOLS BASED ON DIGITAL APPLICATIONS RELATED TO HYDROGEN AND FUEL CELL

Project ID:	**736648**
Call topic:	**FCH-04-1-2016** - Novel Education and Training Tools
Project total costs:	**€ 1,596,007.5**
FCH JU max. Contribution:	**€ 1,596,007.5**
Project start - end:	01/03/2017- 29/02/2020
Coordinator:	**Karlsruher Institut fuer Technologie, DE**
Website:	**www.h2fc-net.eu**

BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, ELEMENT ENERGY LIMITED, INSTITUTE OF ELECTROCHEMISTRY AND ENERGY SYSTEMS, NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS", PERSEE, UNIVERSITA DEGLI STUDI DI PERUGIA, UNIVERSITY OF ULSTER







PROJECT AND OBJECTIVES

Main objective of the project is to develop a unique European e-platform to support education in FCH technologies by providing e-content (teaching and training materials) via an LMS running under open access to a broad spectrum of stakeholders. In this relation NET-Tools starts to generate, construct and develop technically the e-platform. In parallel the development of specific e-tools was started and reviews of existing LMS content executed. The e-tools shall get implemented further in e-lectures as demonstration on "how to incorporate practically e-tools in modern e-Learning".

NON QUANTITATIVE OBJECTIVES

- Expert Workshop on the demands
- Webinars on status on the developed e-tools (outcome, usability and handling)
- Technical School (test lessons and lectures for feedback related to experts but also other stakeholders for demonstration)
- Demo courses (lectures) to be provided via LMS
- Technical School (test lessons and lectures for students and stakeholders)

PROGRESS & MAIN ACHIEVEMENTS

- Realisation and development of an open source based e-infrastructure dedicated to LMS and existing FCH knowledge and science
- Development of specific e-tools to be incorporated in LMS as approach for practical support on more theoretical oriented e-Learning materials
- Reviews of existing e-Learning materials and LMS systems as well as expert workshop to learn about different demands arising from industry/academia

FUTURE STEPS & PLANS

- Development of unique e-infrastructure under modified aspects and approach (webpage shall be used as an entry point providing linkage instead server)
- Guidelines and advise on "how to prepare e-lectures and content" via used external LMS
- Review of existing e-learning content and materials (external and internal) must get reworked
- Data management (also handling of personal data) must get reworked according the new regulatory
- Guidelines about responsibilities, liabilities and ownership (IPR) must get reworked according to the new structure of providing open access LMS

QUANTITATIVE TARGETS AND STATUS

FCH JU Project Targets*

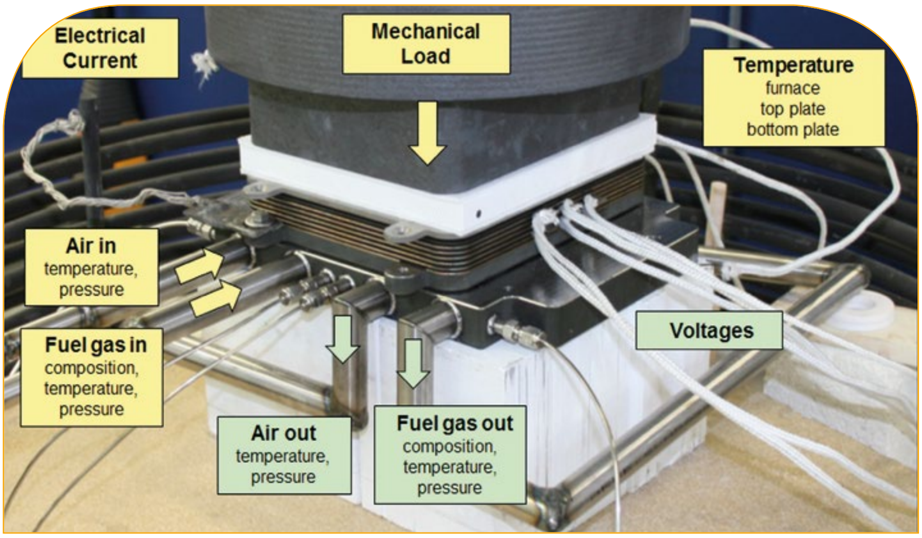
PARAMETER	RESULTS ACHIEVED TODAY
Total number of people trained in project	**30**

*** Project's own targets**

SOCTESQA

SOLID OXIDE CELL AND STACK TESTING, SAFETY AND QUALITY ASSURANCE

Project ID:	621245
Call topic:	SP1-JTI-FCH.2013.5.4 - Development of industry wide uniform performance test schemes for SOFC/SOEC cells & stacks
Project total costs:	€ 3,212,186.2
FCH JU max. Contribution:	€ 1,626,373.2
Project start - end:	01/05/2014 - 30/04/2017
Coordinator:	DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE
Website:	www.soctesqa.eu



BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF-KIT EWIV, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION

PROJECT AND OBJECTIVES

The aim of the project is to develop pre-normative and industry wide test modules and programs for solid oxide cell and stack (SOC) assembly units. The test procedures cover the solid oxide fuel cell (SOFC), the solid oxide electrolysis cell (SOEC) and the combined SOFC/SOEC operation mode. A close interaction with an industrial advisory board ensures to achieve industrial relevant outcome of the project. Additionally, a continuous liaison with standards developing organizations is aspired in order to implement the outcome of the project successfully into international standards.

NON QUANTITATIVE OBJECTIVES

- Training
- Safety

PROGRESS & MAIN ACHIEVEMENTS

- Altogether 11 pre-normative test modules for SOFC, SOEC and combined SOFC/SOEC have been developed which cover stationary and mobile applications
- The test procedures contain all important guidelines information in order to achieve high quality, reproducible and repeatable test results
- The project outcome is being transferred to standards developing organisations (e.g. IEC, CEN/CENELEC, ISO, VDMA)

FUTURE STEPS & PLANS

Project is finished.

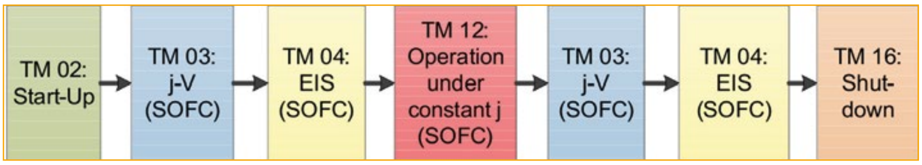
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

By applying the test modules, which address efficiency and durability, the quality and reproducibility of the stack results increases. Thus the efficiency and durability requirements of the stacks can be reached faster.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

By applying the test modules, which address the combined SOFC/SOEC application, the Quality and reproducibility of the stack results increases. Thus the operating and capital costs can be reduced.



QUANTITATIVE TARGETS AND STATUS

State of Art (SoA)*

PARAMETER	UNIT	RESULTS ACHIEVED TO DATE	SOA RESULT ACHIEVED TO DATE BY OTHER GROUP/PROJECT	SOA YEAR	SoA Source
Quality of test results	Number of test procedures for SOFC stacks	Altogether 11 test modules for SOFC stacks for stationary and mobile applications have been developed	In the previous project FCTESQA only two test modules for SOFC stacks were developed	2010	FCTESQA project (website closed)
Quality of test results	Number of test procedures for SOFC cells	Altogether 11 test modules for SOFC cells for stationary and mobile applications have been developed	Only one Standardisation document for SOFC cells was developed by IEC TC 105	2014	IEC 62282-7-2: Single cell and stack test methods - Single cell and stack performance tests for solid oxide fuel cells (SOFC), https://webstore.iec.ch/publication/6766

* Data available as provided by the project

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