FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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PROGRAMME REVIEW
REPORT 2019

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FCH JOINT UNDERTAKING

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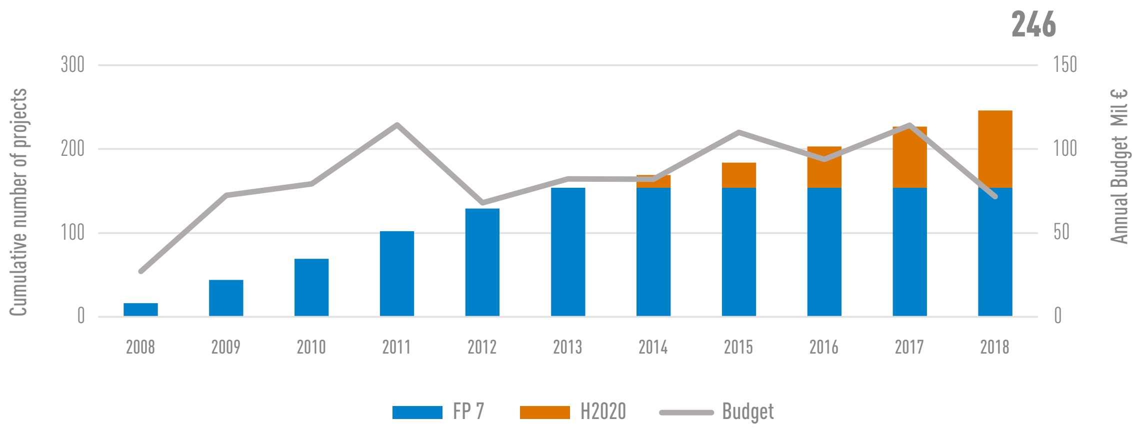
EXECUTIVE SUMMARY

As the strategic vision of the European Energy Union 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 2008-2018), 246 projects have been funded by FCH 2 JU (see the graph below – Figure 2 in the report), with a total budget of EUR 916 million complemented by more than EUR 940 million from other sources



The 2019 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 pillar).

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 sectoral integration); and one under the Support for Market Uptake (cross-cutting activities such as standards and consumer awareness).

This report covers all 81 projects that were ongoing for any time between April and October 2018 and assesses the strengths and accomplishments of each panel and areas that would benefit from further attention.

Activities under the Transport pillar aim to accelerate the commercialisation of FCH technologies in transport through a programme that includes demonstration and research projects. These 26 projects aim to reduce system costs for transport applications, 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, trucks, material handling vehicles and refuelling infrastructure. Research projects portfolio ((aeronautics, road and marine) focus on catalysts, stack manufacturing and process development, advanced refuelling, on-board hydrogen storage, auxiliary power units, FC system integration and diagnostics.

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;
- focus on the demonstration of heavy-duty vehicles;
- experience gained by the local authorities in hydrogen technologies;
- good practice and expertise sharing;
- efforts to harmonise testing procedures;
- focus on the reduction of use of EU-defined critical raw materials.

The goal of the 47 projects assessed under 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 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;
- Europe is currently a world leader in PEM electrolysis and SOE technologies.

Within the Support for Market Uptake (cross-cutting) activities, the report highlights progress made by 8 projects in providing knowledge for improved regulations, codes and standards, addressing safety, preparing the European workforce and increasing public awareness and social acceptance, as well as improving the environmental footprint of FCH technologies.

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

AFC	Alkaline fuel cell
AEL	Alkaline electrolyser
APU	Auxiliary power unit
AST	Accelerated Stress Tests
BoP	Balance of plant
CEF	Connecting Europe Facility
CHP	Combined heat and power
CO_2	Carbon dioxide
FC	Fuel cell
FCEV	Fuel cell electric vehicle
FCH 2 JU	Fuel Cells and Hydrogen Joint Undertaking. FCH 2 JU (2014-2020/Horizon 2020) succeeded FCH JU (2008-2014/FP 7)[1]
FCH	Fuel cell and hydrogen
FP7	EU's 7th Framework Programme for Research and Technological Development
GHG	Greenhouse gas
H2020	Horizon 2020
HRS	Hydrogen refuelling station
HT	High-temperature
IEC	International Electrotechnical Commission
IPHE	International Partnership for Hydrogen and fuel cells in the Economy
ISO	International Organization for Standardization
JRC	Joint Research Centre of the European Commission
KPI	Key performance indicator
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
Mt	Million tonnes
OEM	Original equipment manufacturer
PCEL	Proton ceramic electrolyser
PCFC	Proton ceramic fuel cell
PEM	Proton exchange membrane
PEMFC	Proton exchange membrane fuel cell
PGM	Platinum group metals
PNR	Pre-normative research
PoC	Proof of concept
PRD	Programme Review Days

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

QC	Quality control
R&D	Research and development
R&I	Research and innovation
RCS	Regulations, codes and standards
RCS SCG	Regulations, codes and standards Strategy Coordination Group
RES	Renewable energy sources
SME	Small and medium-sized enterprise
SoA	State of the art
SOEC	Solid oxide electrolyser cell
SOFC	Solid oxide fuel cell
TIM	Tools for Innovation Monitoring
TRL	Technology readiness level 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)
TWh	Terawatt hours

01

INTRODUCTION

1.1. EU AND INTERNATIONAL POLICY CONTEXT – 2019 UPDATE

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 has shaped the legislative initiatives of recent years and is translated into ambitious targets in the 2030 Energy Strategy published in 2015, updated with the third Clean Energy Package legislation in 2018 and further revised with the European Green Deal in 2019:

- a minimum 50 % reduction in greenhouse gas (GHG) emissions compared to 1990 levels by 2030 and 100 % by 2050;
- a minimum of 32 % of total energy consumption arising from renewable energy sources (RES);
- a minimum 32.5 % efficiency increase compared to a 'business as usual' scenario.

In parallel, the EU is a signatory of the Paris Agreement, which came into force in November 2016 and aims to enhance implementation of the United Nations Framework Convention on Climate Change by limiting global average temperature rise to less than 2 °C above pre-industrial levels and actually aiming to limit the increase in temperature to less than 1.5 °C.

2019 has seen greater interest in opportunities linked to hydrogen technologies. At the European level, the new Commission President, Ursula von der Leyen, has announced a European Green Deal (COM(2019) 640) as part of her political agenda for the next European Commission[2]. In summer 2019, the Commission published an overview of its open consultation on 'Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe', which emphasised the relevance of clean hydrogen as a cross-sectoral solution for decarbonisation. The aim to 'strengthen the European value chain for low-carbon hydrogen and fuel cells' was included as a key R&I orientation[3].

The Strategic Forum for Important Projects of Common European Interest (IPCEI) has identified hydrogen technologies and systems as a strategic key European industrial value chain appropriate for receiving support from Member States[4]. This choice will enable new joint investments for innovative initiatives which will have the potential to increase hydrogen technologies deployment and uptake across Europe. Regulation (EU) 2019/1242[5] set carbon dioxide (CO_2) emission standards for heavy-duty vehicles and includes an incentive mechanism for the uptake of zero- and low-emission vehicles in a technology-neutral way. The European Green Deal also announces a renewed impetus for measures which should appear in 2020 and 2021 aimed at reducing GHG emissions from transport. Regulation (EU) 2019/631[6] sets CO_2 emission performance standards for new passenger cars and new light commercial vehicles (vans) and includes a mechanism to incentivise the uptake of zero- and low-emission vehicles in a technology-neutral way.

At an informal meeting of the Transport, Telecommunications and Energy Council for energy ministries that took place in Bucharest on 2 April 2019, the delegates signed a declaration for a sustainable and smart gas infrastructure for all Europeans, to stimulate the potential of natural gas and use of clean energy sources such as hydrogen[7].

2 https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_en.pdf

3 European Commission (2019), Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe – available at https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

4 https://ec.europa.eu/docsroom/documents/37824

5 Setting CO_2 emission performance standards for new heavy-duty vehicles.

6 Setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles.

7 https://www.romania2019.eu/wp-content/uploads/2017/11/DECLARATION-on-Sustainable-and-Smart-Gas-Infrastructure.pdf

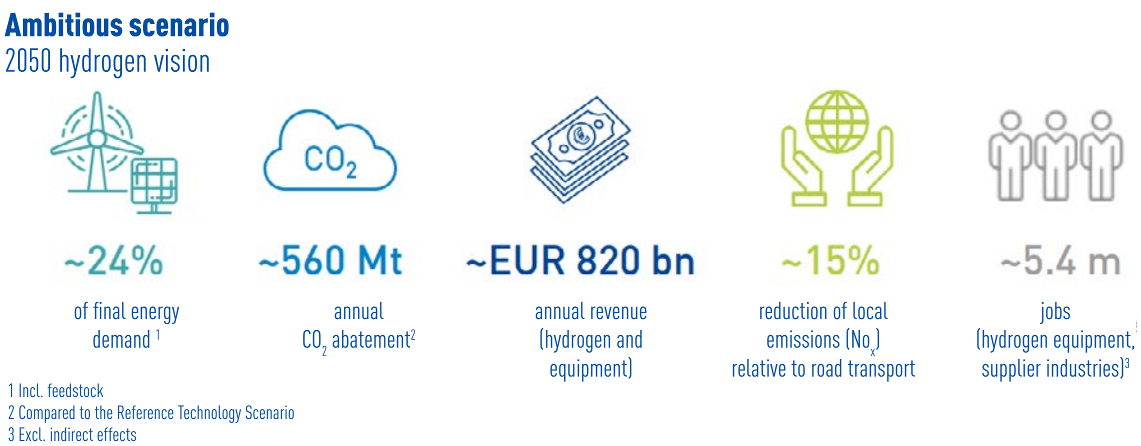
In 2019, the S3P platform launched the Hydrogen Valleys Partnership[8]. This region-led initiative aims to help Europe achieve its GHG reduction objectives by providing a forum in which information is shared and resources pooled, among regions interested in the deployment of hydrogen technologies.

From an international perspective, several new initiatives took place in addition to those already running, such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and Mission Innovation Challenge 8 on Renewable and Clean Hydrogen. A report dedicated to hydrogen by the International Energy Agency[9] was presented to a G20 group of energy and environment ministers gathering in Karuizawa (Japan). The new Clean Energy Ministerial (CEM) Hydrogen Initiative was announced at the CEM in Vancouver, Canada in May 2019[10].

1.2. FUEL CELL AND HYDROGEN TECHNOLOGIES CONTRIBUTING TO EU GOALS

Fuel cell and hydrogen (FCH) technologies can play a major role in achieving goals for climate change, energy efficiency, pollution mitigation and internal energy sourcing. The FCH 2 JU has recently commissioned a study for assessing the role hydrogen technologies could play in achieving the targets within the European national energy and climate plans[11]. A recent roadmap published by FCH 2 JU[12] sees the potential for generating approximately 2 250 terawatt hours (TWh) of hydrogen in Europe in 2050, representing roughly a quarter of the EU's total energy demand (see Figure 1). According to the roadmap estimates, this amount would fuel about 42 million large cars, 1.7 million trucks, approximately a quarter of a million buses, and more than 5 500 trains. It would heat more than the equivalent of 52 million households (about 465 TWh) and provide as much as 10 % of building power demand. In industry, approximately 160 TWh of hydrogen would produce high-grade heat and another 140 TWh would replace coal in steelmaking processes in the form of direct reduced iron. 120 TWh of hydrogen combined with captured carbon or carbon from biomass would also produce synthetic feedstock for 40 million tonnes (Mt) of chemicals in 2050. Achieving this vision would put the EU on a path to reducing about 560 Mt of CO_2 emissions by 2050; as much as half of the required abatements needed to achieve the 2 °C scenario (Figure 1).

Figure 1: Benefits of hydrogen for the EU, according to the 2019 FCH JU study



8 https://s3platform.jrc.ec.europa.eu/hydrogen-valleys

9 https://www.iea.org/reports/the-future-of-hydrogen

10 http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/hydrogen-initiative

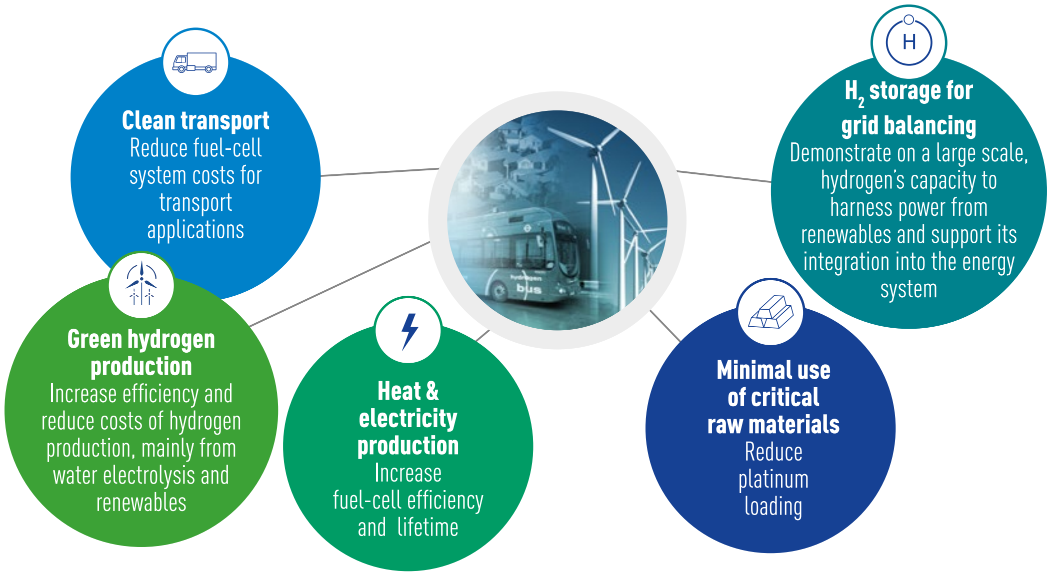
11 https://www.fch.europa.eu/sites/default/files/04.H2%20in%20NECP_Luc%20Van%20Nuffel%20%28ID%207360768%29.pdf

12 https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

1.3. THE ROLE OF THE FCH 2 JU

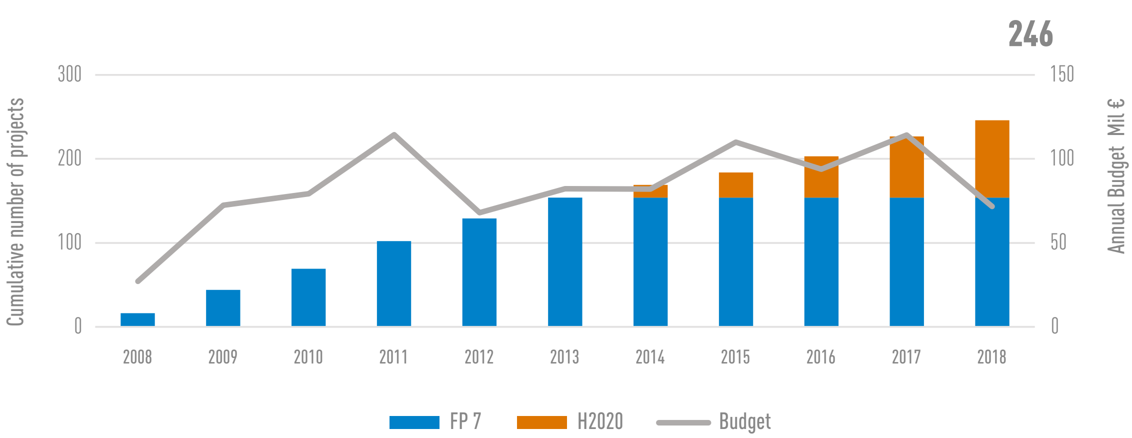
The overall objective of the FCH 2 JU is to implement an optimal research and innovation (R&I) programme at the EU level in order to develop a portfolio of clean and efficient solutions exploiting the properties of hydrogen as an energy carrier and fuel cells (FCs) as energy converters to the point of market readiness. This has enabled support for EU policies on sustainable energy and transport, climate change, job creation, the environment and industrial competitiveness as embodied in the Europe 2020 strategy. It will also help to achieve the EU's overarching objective of smart, sustainable and inclusive growth. The core objectives are described in Figure 2.

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



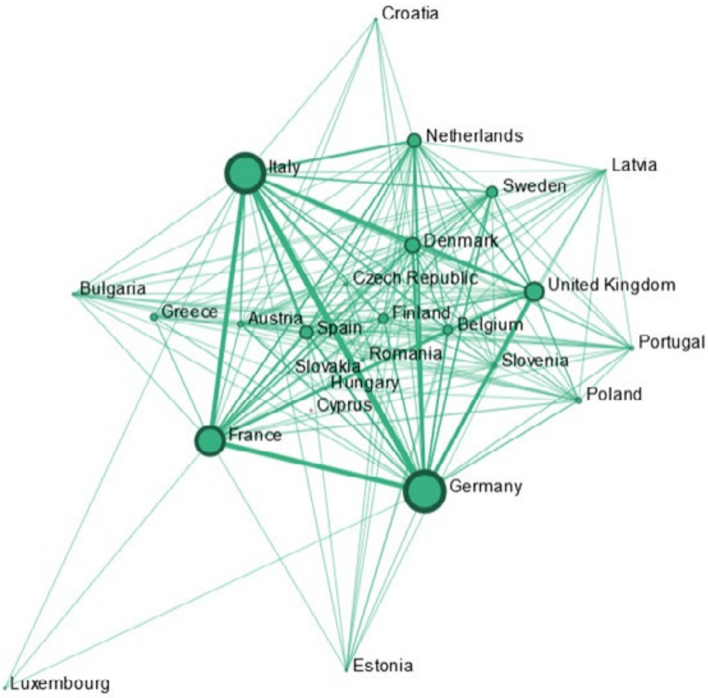
The cumulative number of projects supported by the FCH 2 JU programme since its foundation in FP7 is shown in Figure 3. To date (calls 2008-2018), 246 projects have been funded by FCH 2 JU with a total budget of EUR 916 million complemented by more than EUR 940 million from other sources (e.g. regional, national, private). FCH 2 JU has 884 beneficiaries from industry (68.2 %), research organisations (10 %), the public sector (4.5 %) and academia (13.7 %)[13] encompassing 26 EU and 11 non-EU countries.

Figure 3: Number of FCH 2 JU-supported projects and annual budget calls 2008-2017.



13 3.6 % legal entities have been categorised under 'others'.

Figure 4: Tools for Innovation Monitoring (TIM) visualisation of output from FCH 2 JU beneficiaries and collaborations grouped according to EU countries[14]



Member State	Number of documents
Germany	321
Italy	309
France	225
United Kingdom	142
Denmark	112

Knowledge management tools are developed to investigate connections and collaborations among actors. TIM is an online tool that contains three types of document: scientific publications, patents and granted EU projects. The JRC has prepared a tailor-made version of TIM, capturing technologies relevant to FCH 2 JU activities (calls 2008-2018). An example of the information that can be visualised in TIM is given in Figure 4. The size of the nodes represents the number of items with at least one contributing organisation from that country. The weight of the connecting lines represents the frequency with which there are common, co-authored entries between organisations from different countries.

1.4. PURPOSE AND SCOPE OF PROGRAMME REVIEW 2019

The purpose of the periodic Programme Review is to ensure that the FCH 2 JU programme is aligned with the strategy and objectives set out in the founding Council Regulation (EU) No 559/2014[15] and in the multi-annual work (MAWP) and annual work (AWP) plans. The FCH 2 JU programme structure consists of two main pillars (Transport and Energy) and cross-cutting activities. The reviewed projects have been assigned to six 'review panels' listed in Table 1.

14 Counting common articles, publications, conference participations, books, patents, EU projects. 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

15 OJ L 169, 7.6.2014, pp. 108-129.

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 proof of concept (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 tackling subjects related to FCH stationary heat and power applications
	5 - Hydrogen for Sectoral Integration	All projects addressing hydrogen production, distribution and storage issues
Cross-cutting	6 - Support for Market Uptake	Projects addressing cross-cutting issues

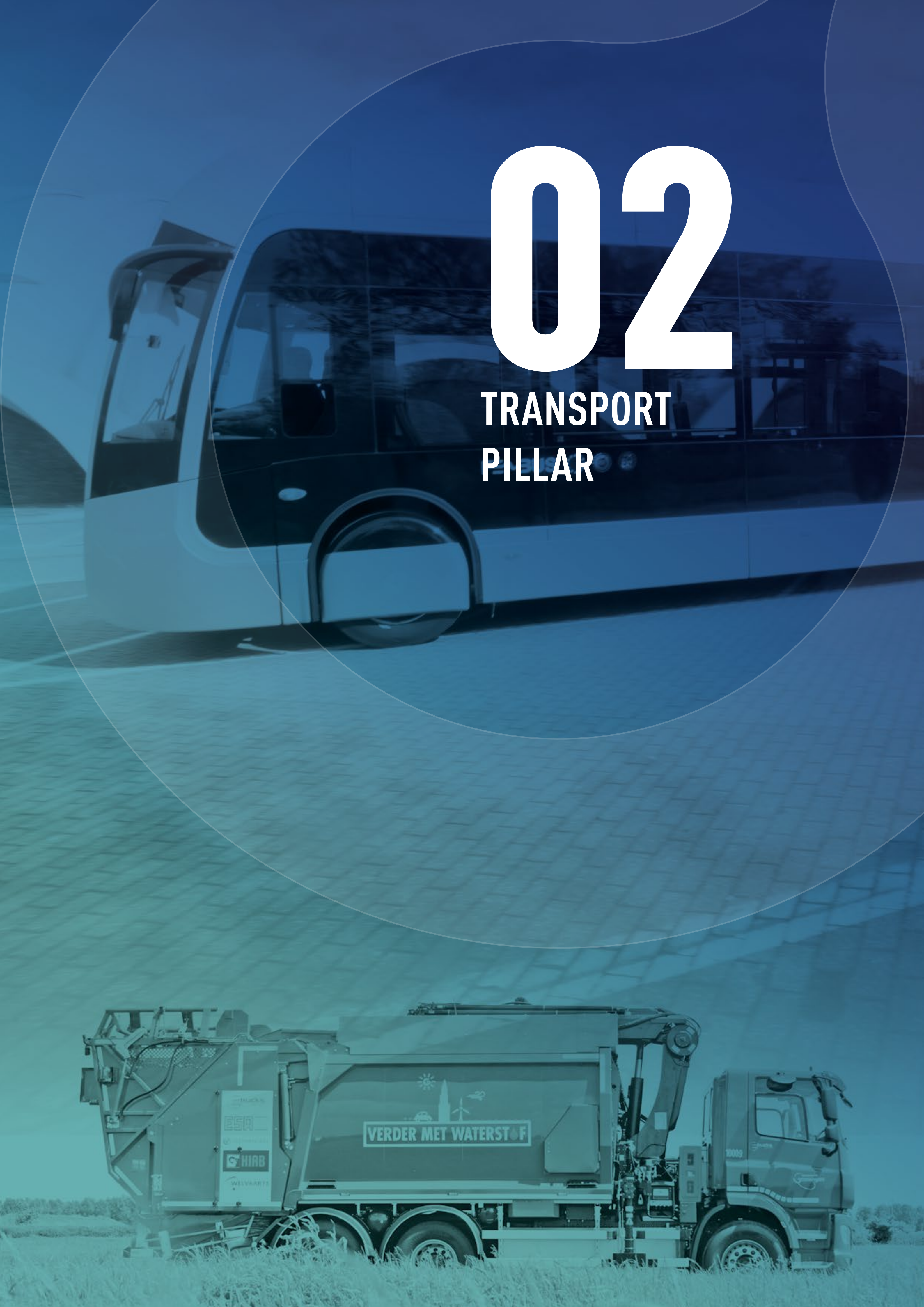
The 2019 Programme Review has included all ongoing projects (between project start date and project end date) in the period April-October 2018: 81 projects, of which 12 began under FP7 and 69 under Horizon 2020 (H2020). Of the 81 projects considered, 23 have been running for less than or equal to 18 months, as of 1 May 2019. 57 projects were reviewed for the Programme Review Report 2018 and 24 have been reviewed for the first time this year.

1.5. PRESENTATION OF THE REVIEW FINDINGS

The 2019 review pays particular attention to the added value, effectiveness and efficiency of FCH 2 JU activities. Specific recommendations covering these aspects are formulated to better meet the overall FCH 2 JU programme objectives and targets. This report summarises the assessment of the projects in the six panels listed in Table 1. Due to the wide range in their scope, the activities and applications of the included projects covering similar or related topics were grouped into a set of focus areas for each panel. The assessment was performed for each focus area. In this document, qualitative observations are provided regarding the major accomplishments of the projects and any difficulties they encountered. The six indicators used by reviewers for evaluation, and their relative weight towards the total score, are:

- target achievement (23 %)
- project impact (23 %)
- benchmarking against international state of the art (SoA) (23 %)
- exploitation plans and IP (15 %)
- interactions with other projects, sectoral organisations and initiatives (8 %)
- dissemination efforts (8 %).

A weighted sum for the six indicators was used to obtain an overall project score and a quantitative evaluation. Each panel review also identifies the strengths of the panel and areas that would benefit from additional focus and proposes a set of follow-up actions.



02

TRANSPORT PILLAR

2.1. OBJECTIVES

FCH technologies play an important role in reducing emissions (GHG, SOx, NOx, particulate matter), as well as noise from Europe's transportation activities, especially road transport. The use of 'green' hydrogen significantly reduces the carbon emissions in transport. FCH technologies also contribute to enhanced energy security through higher conversion efficiencies and reducing fuel import dependence. The aim of the activities under the Transport pillar is to accelerate the commercialisation of FCH technologies in transport through a programme including both demonstration and research projects. The main goals are to reduce FC system costs for transport applications, increase their lifetime and decrease the use of critical raw materials such as platinum group metals (PGM).

2.2. BUDGET

To date (project calls from 2008 to 2018), 68 projects in the Transport pillar have received financial contributions from the FCH 2 JU totalling approximately EUR 427 million. The distribution of projects in the two main activity areas (panels) is shown in Table 2.

Table 2: CH 2 JU financial contribution for the two main activity areas in the Transport pillar (in EUR)

Trials and Deployment of Fuel Cell Application - Transport	**289 million**
Next Generation of Products - Transport	**138 million**
Total	427 million

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

The demonstration actions of this panel aim to validate technologies to prove technology readiness, reliability, robustness, fuel efficiency and sustainability. Demonstration activities have historically focused on road transport, based on cars and buses, but they are now shifting towards heavy-duty transport, rail and maritime applications. A 'Study on use of fuel cells and hydrogen in railway environment' has been commissioned[16]. Demonstration projects considered in this year's Programme Review focus on the following areas:

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

The timeline for the FCH 2 JU programme portfolio of transport demo projects and their distribution across the four focus areas above is shown in Figure 5. The present review covers the 11 projects highlighted in black.

Following the calls between 2008 and 2018, the FCH 2 JU supported 25 projects[17] relevant to this panel, with a total contribution of EUR 289 million and a contribution from partners of EUR 491 million[18]. The distribution of the total budget over the four focus areas, from 2008 to 2018 (topic call year), is shown in Figure 6 and indicates that approximately 83 % of FCH 2 JU

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

17 Projects associated with APU development have been moved to Panel 2 since Programme Review 2018.

18 These figures include the overarching project H2ME2 which draws EUR 8 million (from a total of EUR 35 million) from the Energy pillar.

Panel 1 funding went to support on-road vehicles (cars and buses – the FCH 2 JU budget is split approximately 50/50 between the two).

Figure 5: Trials and Deployment of Fuel Cell Application within the Transport pillar. Projects highlighted in bold are included in PRD 2019

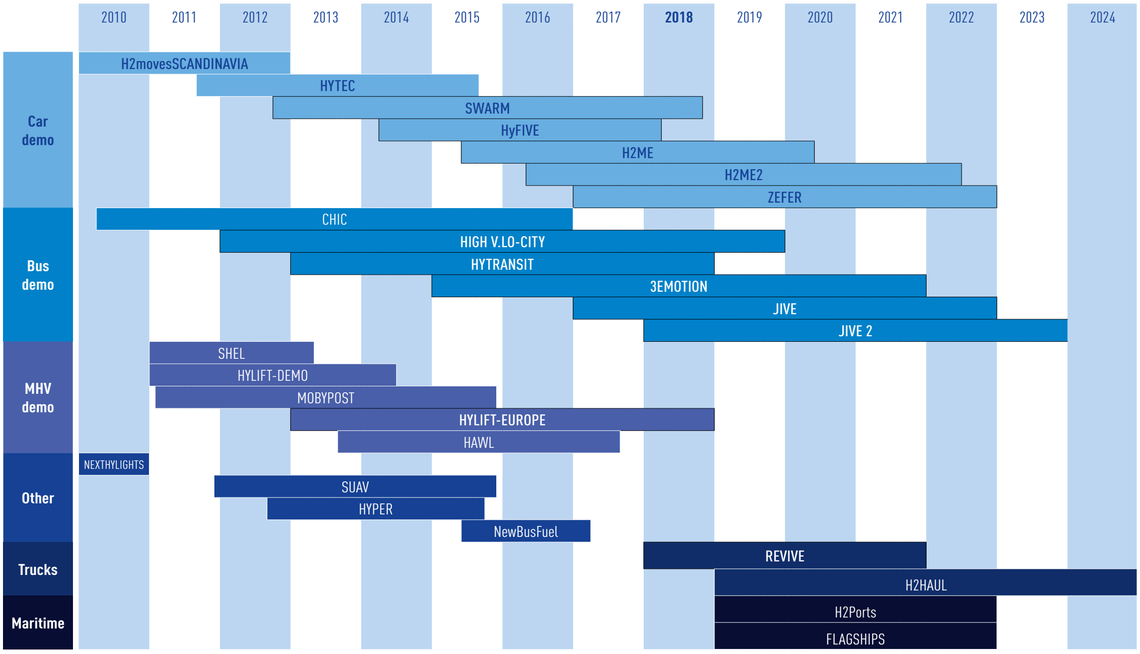


Figure 6: Funding for Panel 1 (Trials and Deployment of Fuel Cell Application – Transport) from 2008 and including the 2018 calls

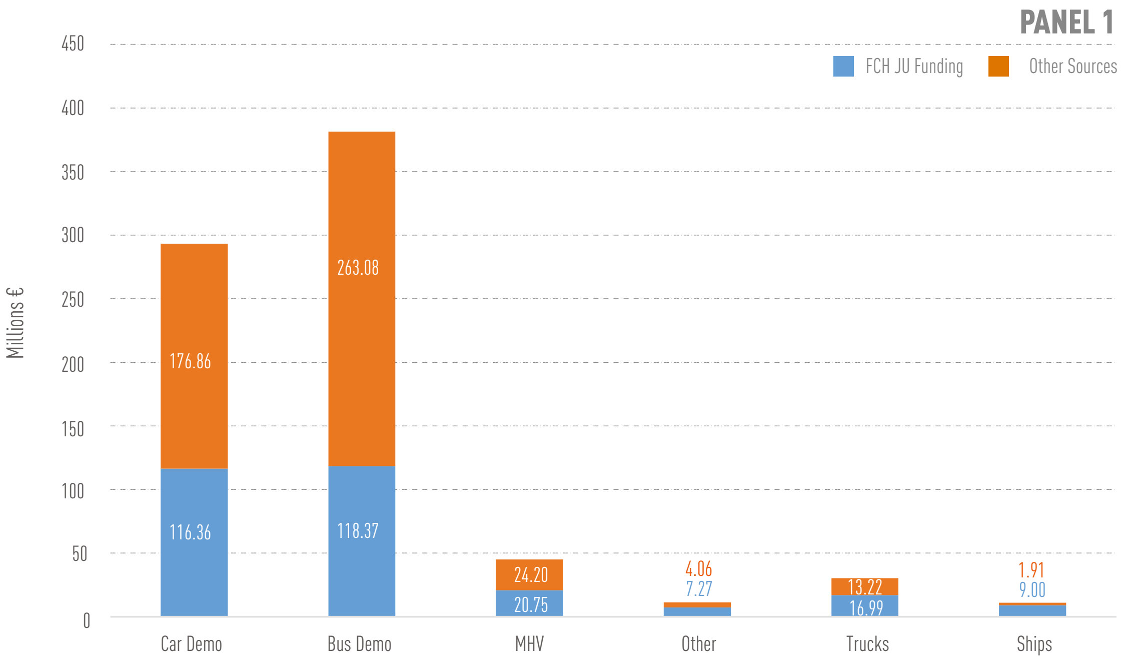
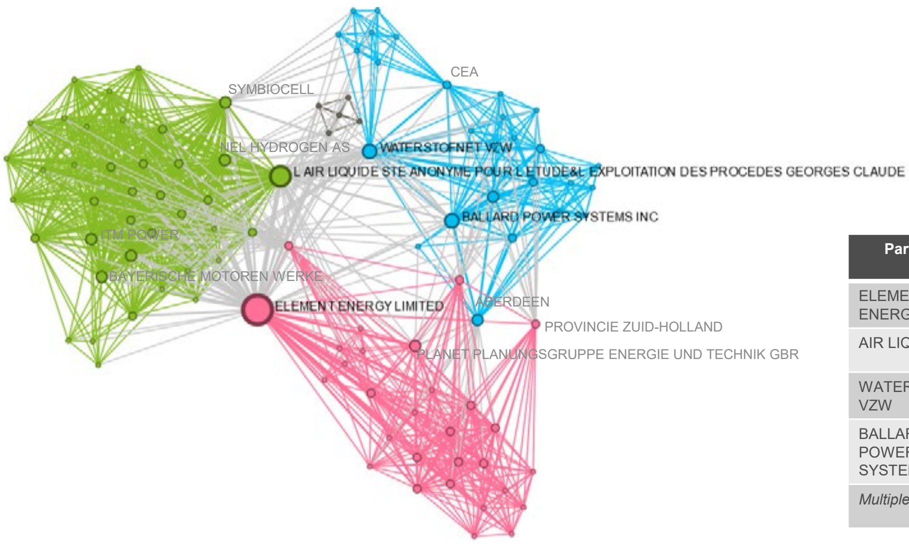


Figure 7 shows the connections between partners in the projects in Panel 1. For clarity, only the partners involved in the largest numbers of projects are named in the figure. The green grouping largely includes the car fleet-related projects of H2ME, H2ME2 and 3EMOTION, whilst the blue grouping contains the partners within the bus and MHV projects (e.g. High V.LO-City , HYTRANSIT, HYLIFT). The pink grouping features mainly the partners within the JIVE and JIVE2 consortia. The coloured groupings are potential clusters identified by TIM's algorithm. The inset table shows the top five participants.

Figure 7: TIM plot showing the participants in the 11 projects in Panel 1

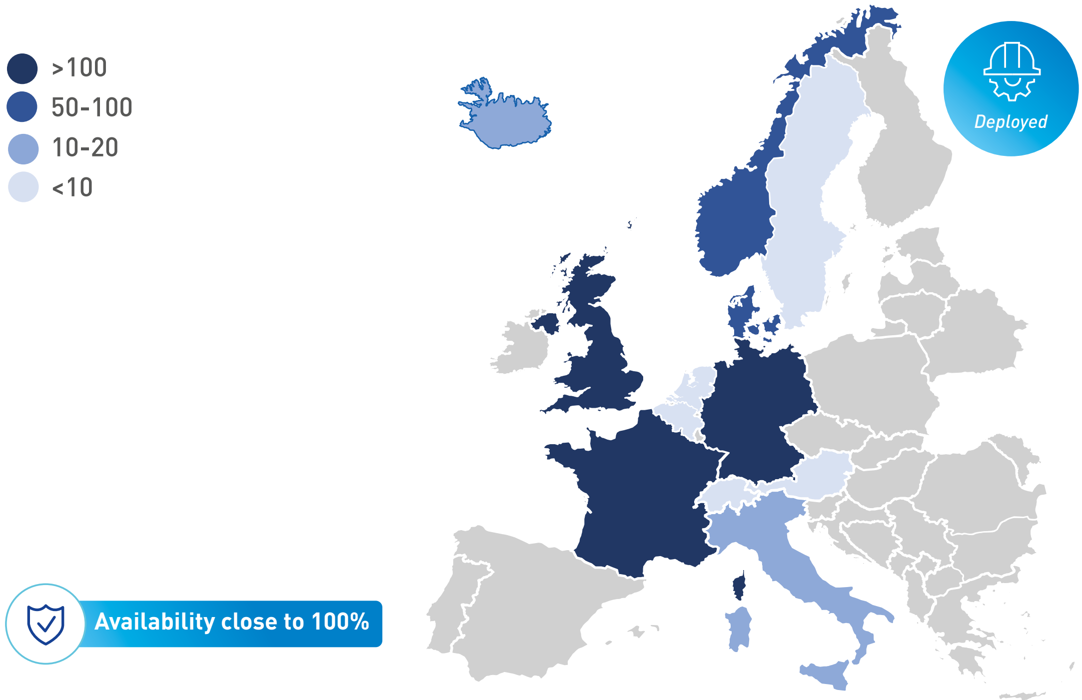


Participant	Number of projects
ELEMENT ENERGY LIMITED	9
AIR LIQUIDE	6
WATERSTOFNET VZW	4
BALLARD POWER SYSTEMS INC	4
Multiple partners	3

The projects included in the focus area **car** demo of the 2019 review are SWARM, H2ME, H2ME2 and ZEFER. The recently finished project SWARM has successfully deployed 13 small, low-weight hybrid electric-hydrogen vehicles in three European regions. The participation of universities and small and medium-sized enterprises (SMEs) has led to registration of two trademarks, one patent application, registration for a car design and the launch of a new company. Both H2ME and H2ME2 aim for the deployment of hydrogen cars and refuelling infrastructure across Europe; however, H2ME focuses on car original equipment manufacturers (OEMs) while H2ME2 focuses on end-users, emphasising grid-balancing activities using on-site electrolysers. If not explicitly labelled as H2ME or H2ME2, this review will refer to both projects as the 'H2ME initiative'. ZEFER aims to demonstrate viable business cases for captive fleets of fuel cell electric vehicles (FCEVs) – taxi, private hire and police services. Intensive use of vehicles and hydrogen refuelling stations (HRSs) is expected to prove their readiness for heavy-duty applications.

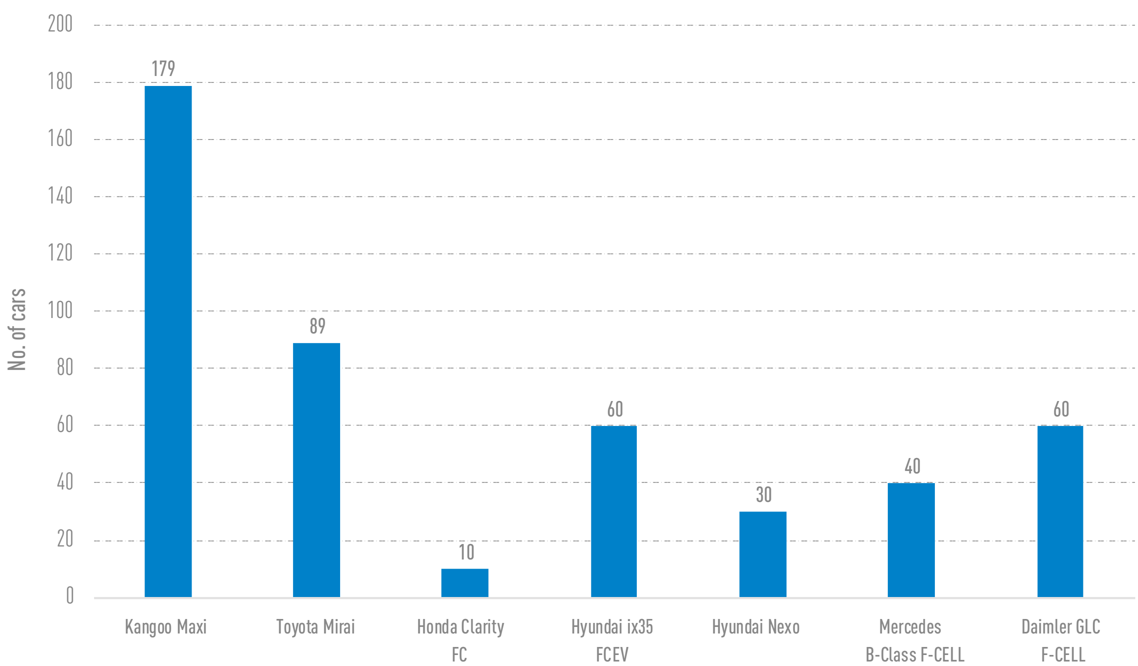
FCEV cars and vans are being deployed in nine EU Member States, Norway, Iceland and Switzerland, as shown in Figure 8, ranging from private small cars to medium/large cars.

Figure 8: Distribution of FCEV deployed by FCH 2 JU demonstration projects



The distribution of car models deployed is presented in Figure 9. The FCH 2 JU backed the demonstration activities of more than 2 000 cars, of which 725 were already deployed. From May 2017 to May 2018, 74 new vehicles were deployed within H2ME and 172 within H2ME2, while ZEFER had 71 cars in operation.

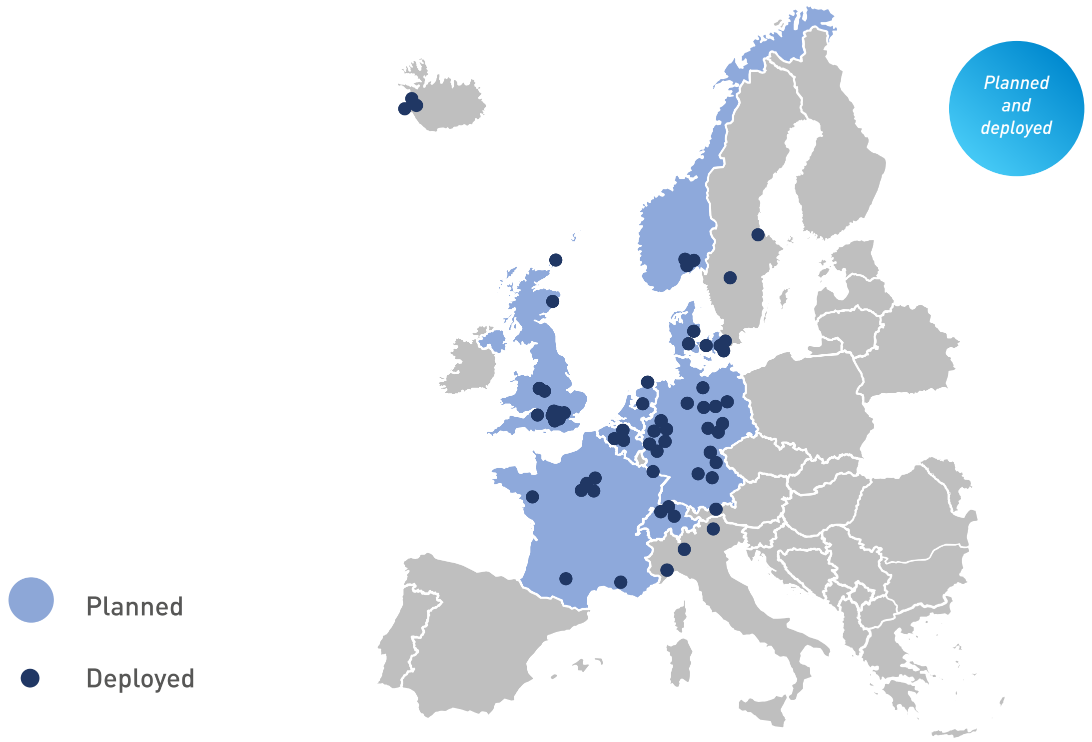
Figure 9: Total number of commercial cars operating at end 2018 grouped by model; according to data available in TRUST and presentations at the PRD2019



During 2018, at least 5.17 million km were driven and 57 tonnes of hydrogen consumed. This is a significant increase on the 1.83 million km driven and the consumption of about 23 tonnes of hydrogen reported in 2017, accounted for by taxi-fleet operations and the more intensive use of the deployed cars. The average fuel consumption of 1.17 kg per 100 km[19] is near the MAWP 2020 target and the average vehicle availability reached 99.7 % in 2018. The expected MAWP 2020 targets for availability and FC system durability have been reached[20]. The cars have been demonstrated to be ready for commercialisation, with up to 594 km driving range and more than 150 000 km travelled by one car. However, car prices are still high. In the future, if the market offer for FCEV also covers more popular and less premium car segments, the relative impact of FC cost on total vehicle price is expected to be larger.

The hydrogen refuelling infrastructure is expanding geographically into new cities and regions, supporting the increasing number of FCEV deployed (see Figure 10). Currently there is about one HRS per 15 vehicles and it is expected that, with the 66 HRSs planned for cars and the upcoming deployment of fleets, the ratio will be one HRS per 25 vehicles. Although demonstration projects are suffering from the lack of experience among local authorities and the absence of standardised processes for reviewing and approving HRS permit authorisation, it seems that the difficulties encountered are diminishing. Last year, the time to gain authorisation for an HRS in Germany fell from 24 to 12 months.

Figure 10: Distribution of HRSs co-funded by FCH 2 JU



19 Average fuel consumption was calculated by combining the reported driving ranges with declared fuel consumptions. Some projects reported only one of the two parameters and were therefore excluded from the average fuel consumption calculations.

20 For projects reporting these data.

The planned total number of HRSs under the Transport demo panel is 101[21], of which 64 (46 for cars, 10 for buses, 8 for MHVs) have already been deployed (48 were reported in 2017). Of those, 21 HRSs for cars dispense hydrogen at 700 bar; 13 also have a 350-bar dispenser. From the stations reporting in TRUST, 17 are publicly accessible while 14 are restricted to registered users (standard when an HRS is based in the forecourt of a bus depot, for example). H2ME refuelling stations are public and some are integrated in petrol station forecourts. The European HRS availability system (https://h2-map.eu/), an initiative sponsored by the FCH 2 JU, offers a portal providing information on the live status of each HRS in Europe, available as a mobile web tool for the convenience of FCEV users. Currently, 139 fuelling stations (some not funded by the FCH 2 JU) are connecting and sending live data.

Due to legal requirements to correctly bill the quantities of hydrogen delivered by an HRS, measurements have to be performed with a prescribed accuracy. Metrology is currently a bottleneck for hydrogen dispensing stations. 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 HRSs' was published[22]. Its objective is to define, in agreement with European national metrological institutes, a structured approach for enabling the certification of metering systems for HRSs in Europe. The test protocol was tested at seven HRSs (not all associated with FCH 2 JU projects) in Europe: five in Germany, one in the Netherlands and one in France. These tests were finalised in the spring of 2019.

To date, the FCH 2 JU-backed HRS network for cars covers eight countries, and in 2018 delivered 40.3 tonnes[23] of hydrogen via 18 557 refuelling operations. The average HRS availability was 90.4 % in 2018 (although average availability from 2016 is > 96 %), possibly due to the higher HRS usage resulting in more breakdowns. Most of these installations meet the MAWP 2020 targets for station CAPEX of EUR 2 100-4 000/(kg/day).

However, the MAWP 2020 hydrogen cost targets have yet to be consistently achieved and depend largely on the electricity price (in the case of hydrogen produced by electrolysis) or the distance to hydrogen production sites. Car demo projects report prices of hydrogen at the pump ranging from EUR 7/kg to EUR 11.5/kg (with EUR 10/kg being an average value), depending on the start date of the project and the hydrogen production method employed. The car demo projects report that 94 % of dispensed hydrogen (based on mass) was produced using electricity certified as 'green'. Eleven FCH 2 JU HRSs produce the hydrogen on-site.

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

A main obstacle to large-scale deployment is the lack of publicly viable business cases. Ongoing demonstrations provide the opportunity to raise awareness and deliver actual field-test data (Green Tomato, ZEFER, HysetCo). ZEFER is implementing a business model based on the assumption that a stable demand for hydrogen will reduce the cost of hydrogen at the dispenser, having also carried out a targeted dissemination campaign to make information available to potential interested parties to replicate its business case. HysetCo Joint Venture federating Air Liquide, Idex, Société du Taxi Électrique Parisien (STEP, a member of ZEFER and H2ME) and Toyota aims to promote the development of hydrogen mobility in the Paris region.

Since one of the main objectives of demonstration projects is to increase awareness among the public, authorities and other stakeholders, attention should be paid to the scope, depth and quality of the information shared in dissemination efforts. Public knowledge-sharing platforms containing information pertinent for both the general public and stakeholders should be established. This has been performed for the bus demos (see below) but should also be applied to all the car demos,

21 Including two discontinued stations.

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

23 This number does not match the consumption of hydrogen reported above for cars because some FCH 2 JU-backed HRS are also open to the public and are not simply restricted to FCH 2 JU-backed projects.

covering vehicle and HRS deployment numbers, achieved performance and lessons learned. This action may also facilitate the transfer of information and experience for educational and training purposes. It would be particularly interesting to create a 'network' of local authorities permitting HRS (within FCH 2 JU demo projects) that could facilitate the establishment of new HRSs and set the basis for a harmonised HRS approval process across the EU[24].

Some national organisations, such as AFHYPAC (FR)[25] and H2Mobility (DE), have started to develop such guidance documents. Current car incident records highlight a positive safety performance for hydrogen technologies used in transport applications: the Hydrogen Mobility Europe initiative reported that, even for FCEVs accruing a significant mileage (e.g. taxis), the total number of incidents was similar to those of comparable vehicles powered with conventional combustion engines.

Active exploitation of knowledge and experience acquired from the demos, through dissemination and training of first responders, warrants additional efforts. The example of HyFIVE's study on 'Safety at repair centres' should be followed by the other demonstration projects.

The projects High V.LO-City, 3Emotion, HyTransit, JIVE and JIVE2 have been considered within the **bus** demo focus area. Bus demonstrations financed by FCH 2 JU grants involve 360 vehicles in 11 countries. As of 2018, 54 vehicles were deployed in 10 cities[26] and 80 buses were ordered in 2018-19. The technology is approaching commercialisation with twelve European bus OEMs offering/preparing to offer FC buses for sale.

European FCH bus deployment can be considered SoA and has grown considerably in ambition (Figure 11). The level of interest and the willingness of regional and local operators to participate in the deployment of FCH buses is remarkable and highlights the potential of this application. The larger volumes are demonstrating the key issues to be targeted; however, the projects are progressing and next year is expected to see a significant number of buses deployed by JIVE and JIVE2 (joint target of approximately 300). Several OEMs that did not show earlier interest in offering FC buses are now showing interest and the list of suppliers is expected to grow in the coming years. Other non-FCH 2 JU initiatives, such as the H2Bus consortium supported by the Connecting Europe Facility (CEF) with EUR 40 million, are aiming to scale up by another order of magnitude (target 1 000) the deployment numbers of FCH buses in Europe. JIVE also benefits from CEF's EUR 5.5 million co-funding under MEHRLIN (Models for Economic Hydrogen Refuelling Infrastructure) project.

In 28 bus demonstrations reported in TRUST in 2018, a total distance of over 10 million km has been accumulated since the FCH 2 JU started, with more than 1 million km driven in 2018 alone. From 2016 to 2018, more than 421.4 tonnes of hydrogen were consumed, according to data reported on TRUST from bus demo projects; in 2018, the hydrogen consumed amounted to 163 093 kg. The average fuel consumption for buses fluctuates between 9 kg and 10.6 kg hydrogen per 100 km. Fuel consumption varies significantly and is dependent on the city where the buses are operating, age and seasonal factors.

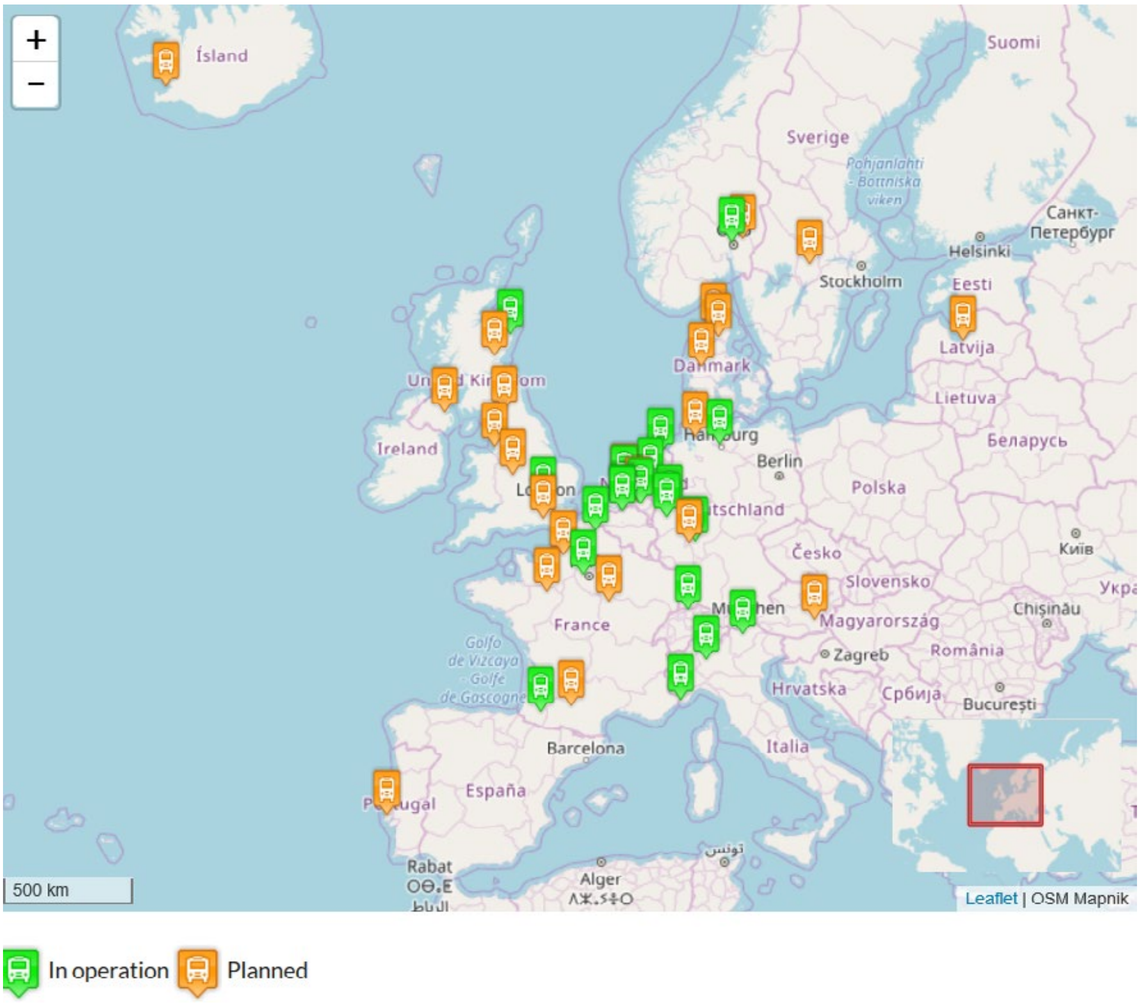
The bus demo projects under review cover deployment within cities; the feasibility of longer-haul trans-urban applications in the UK has been studied within HYTRANSIT. This project has deployed six FC buses and demonstrated them on long inter-urban routes in Scotland (15 to 30 km). Four full years of operating the buses has resulted in 1.4 million km driven and 1.3 million passengers transported.

24 There are already some positive initiatives in this respect, such as those in the H2ME initiative (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/).

25 AFHYPAC (FR) guidance document: http://www.afhypac.org/documents/divers/GUIDE-STATION-HYDROGENE-WEB.pdf

26 Excluding five deployed buses that have been discontinued.

Figure 11: FC bus demonstration sites in Europe (source: **https://www.fuelcellbuses.eu/**). All places are shown, including national initiative/Interreg-funded demos



Current bus demos have provided further positive evidence on the performance and functionality of FCH buses and associated refuelling infrastructure, steadily reducing barriers for their commercialisation in the near term.

The FCH 2 JU is supporting the installation of 23 bus HRSs, of which 14 have been deployed. They have reached an average availability of 97 % since the start of operations, higher than the MAWP 2020 target of 96 % availability. In 2018, the bus demo projects reported that 87 % of dispensed hydrogen (based on mass) was produced using electricity certified as 'green'.

Project REVIVE (started in January 2018), demonstrating **heavy-duty vehicles (HDVs)**, is included in the Programme Review for the first time, with the scope of advancing the development of FC refuse trucks and deploying them across eight sites in Europe. The trucks are currently under construction and the first vehicles were deployed at the end of 2019. REVIVE will set the basis and the SoA for future HDV demonstration projects. REVIVE activities include life cycle assessments (LCAs) accounting for reduction of CO_2 emissions, air pollution and noise. In addition, and following its own developed methodology, REVIVE aims to demonstrate 50 % TTW efficiency.

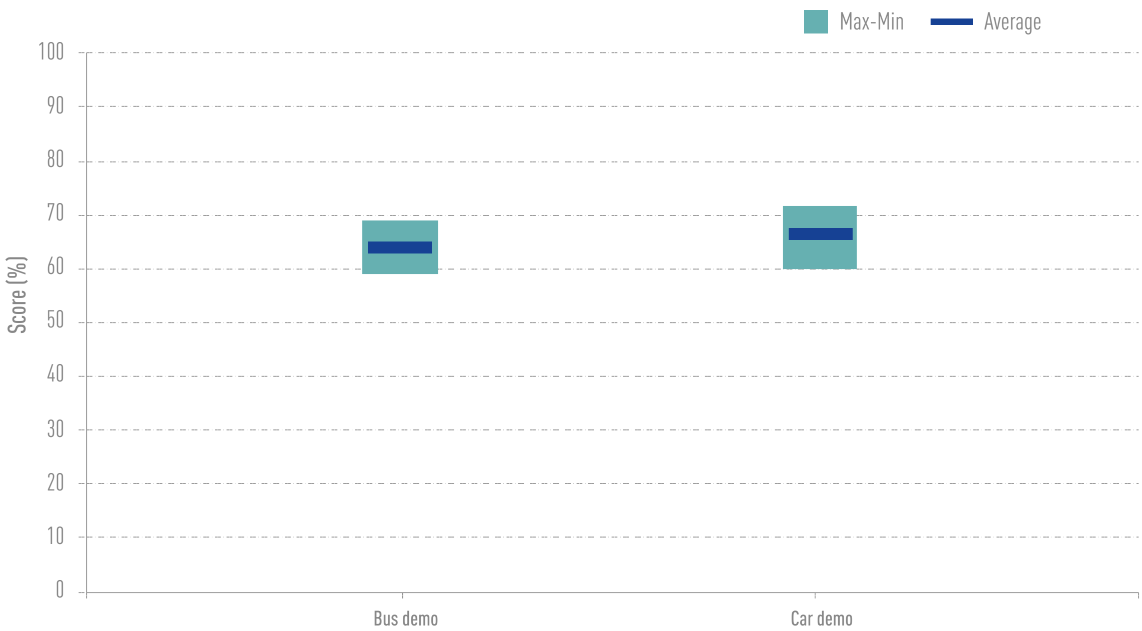
FCH 2 JU has been the main driving force behind **MHV** deployment in Europe. Project HyLIFT-Europe (finished at the end of 2018) has been evaluated as part of the 2019 Programme Review exercise. It managed a fleet of 212 MHVs across two sites. The project has also demonstrated real-world operation of indoor HRSs. The demonstrated FCH MHV are technically mature enough for commercialisation, and some European MHV manufacturers are already offering them for the European market. The MHV demo activities have accumulated more than 1 million hours of operation, with 335 360 hours in 2018 alone. From 2016 to 2018, 155 500 refuelling operations were performed. 2020 MAWP target of 20 000 hours for the lifetime of the MHV has been demonstrated; with a MAWP MHV availability target of 98 % (99.2 % obtained on average, improving 2017 and 2016 results) it has been achieved. HRSs have reached an average availability of 97.4 %, slightly lower than in 2017 (98%) due to the longer downtimes for hydrogen supply procedures. HyLIFT-Europe has deployed the targeted number of vehicles – the biggest demonstration of MHV in Europe. Furthermore, MHVs are showing potential for decarbonising logistics, for example container operations in urban ports. HyLIFT activities have served to provide insight into hydrogen MHV's total cost of ownership, performance and availability and represent a step forward towards hydrogen MHV commercialisation. To improve costs further, easily accessible financial support would be required.

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 for indoor applications. Thanks to the FCH 2 JU-funded demonstration of hydrogen MHVs, a national French regulation for hydrogen in warehouse applications has been established, as well as a best-practice document for obtaining approval when installing HRSs in airports.

2.3.1. PANEL 1 – SUMMARY

The overall assessment of Panel 1 projects is shown in Figure 12. The figure shows a small spread for the performance evaluation of bus and car demo projects. The overall evaluation is positive in both cases, but it appears that HRS approval processes (strongly dependent on regional and local administrations), procurement and supply chains have been critical issues hampering even more satisfactory achievements.

Figure 12: **Maximum, minimum and average scores for each focus area of Panel 1. For focus areas with fewer than three projects, only the average is given**



Strengths

- Partners participating in demonstration projects show a significant commitment to FCH technology and a clear interest in its commercialisation.
- Some projects stand out for their interactions with national and regional programmes.
- New projects are aiming to demonstrate heavy-duty vehicles.
- Training of bus drivers and repair and maintenance technicians has been consistent.
- Experiences are often shared between ongoing demonstration projects.
- Local authorities are gaining experience with hydrogen technologies and the time taken to grant permits is decreasing.
- There are bus project collaborations with city councils for dissemination to the general public, site visits and dissemination to attract new customers.
- Current efforts in increasing volumes could kick-start the development of a European FC supply chain for buses.

Additional focus needed

- The projects should better define their exploitation plans.
- In view of the departure of the UK from the EU, the consequences for the British sites should be defined.
- Social acceptance dimension: low response to user surveys (H2ME).
- Security in the supply of spare parts throughout the full project duration should be ensured.
- Projects should take account of potential delays when planning.
- Assessment of distribution and storage for large hydrogen volumes in view of increasing hydrogen demand should be tackled as soon as possible.

Follow-up actions

- The 15 Member States that have included hydrogen in their National Policy Frameworks should enhance participation in demonstration projects. Reaching out to Member States that have not considered hydrogen should be a focus for future actions. The ongoing FCH 2 JU study on NECPs should be of help to identify potential for hydrogen deployment in Member States.
- Vehicles should be available through lease agreements, following the example of SWARM.
- Use the operational experience arising from transport demo projects to update safety evaluations. The feasibility of expanding results from bus demos to heavy-duty vehicles should be investigated.
- The lessons learned from car and bus demos and the related documents produced by consortia should be gathered in a single repository and actively promoted.
- The regional dimension of coach demonstration projects, being used not only for local but also for intercity passenger transport (as foreseen in HyTransit), should be strengthened.

2.4. PANEL 2 – NEXT GENERATION OF PRODUCTS – TRANSPORT

R&I projects focus on the development of PGM-free FC catalysts, manufacturing of better-performing and more durable FCs for transport including auxiliary power units (APUs), and improved HRS systems and on-board hydrogen storage, while lowering costs. The project portfolio of transportation (aeronautics, road and marine) R&I activities covers the following focus areas:

- catalysts – development of non-PGM, low-cost catalysts;
- stack manufacturing and process development – activities to support the near-term production of components and subsystems;
- advanced refuelling and on-board hydrogen storage – projects to develop more cost-effective and increasingly efficient hydrogen refuelling technologies, in particular compressor performance as well as on-board hydrogen storage solutions;
- development and improvement of components for better-performing APUs; fuel cell system integration; diagnostics.

The 2019 Programme Review covers 15 projects. Figure 13 shows the timeline for all of the FCH 2 JU programme portfolio of transport research projects and their distribution across focus areas.

Between 2008 and 2018, the FCH 2 JU supported 43 projects relevant to this panel, with a total FCH 2 JU contribution of about EUR 138 million and a contribution from partners of EUR 66.7 million. Figure 14 shows the distribution of total budgets over the five focus areas across the 2008-2018 call topics.

Figure 15 shows the connections between partners present in the projects in Panel 2. For clarity, only the partners involved in the largest numbers of projects are named. Figure 15 shows how consortia in Panel 2 are often independent from each other, with individual partners often providing links between projects.

Figure 13: Date ranges of Next Generation of Products projects within the Transport pillar. Projects highlighted in bold are included in PRD 2019

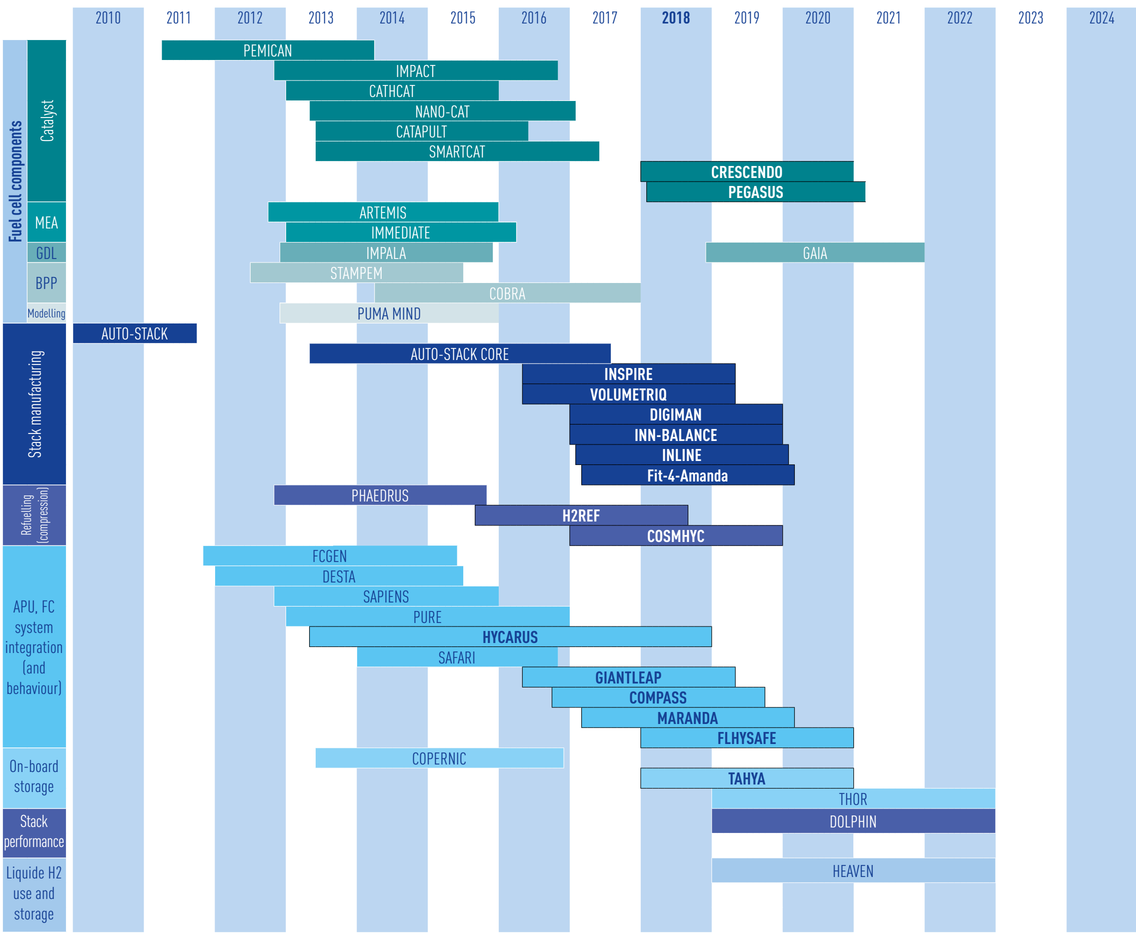


Figure 14: Funding for Panel 2 (Next Generation of Products – Transport) from 2008 and including the 2018 calls

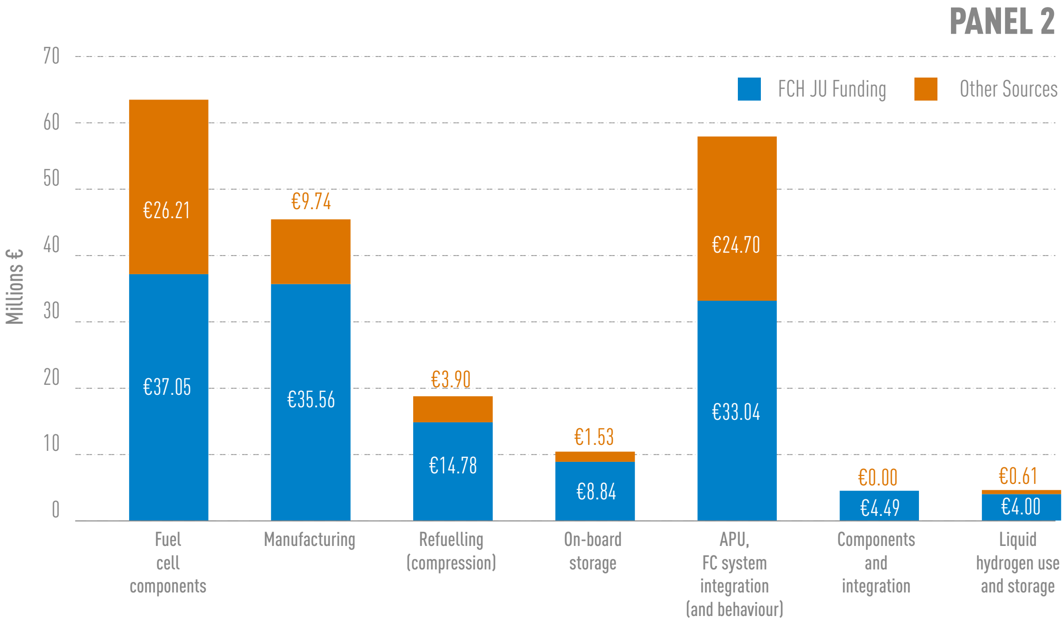
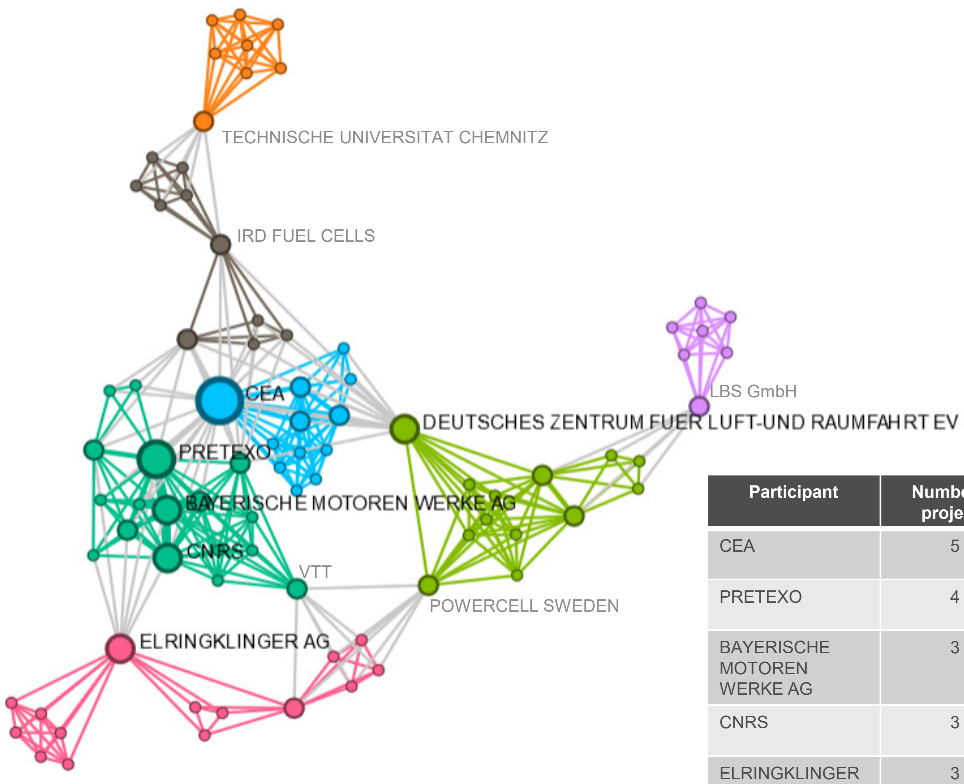


Figure 15: IM plot showing the participants in the 15 projects in Panel 2[27]



Participant	Number of projects
CEA	5
PRETEXO	4
BAYERISCHE MOTOREN WERKE AG	3
CNRS	3
ELRINGKLINGER AG	3
DLR	3

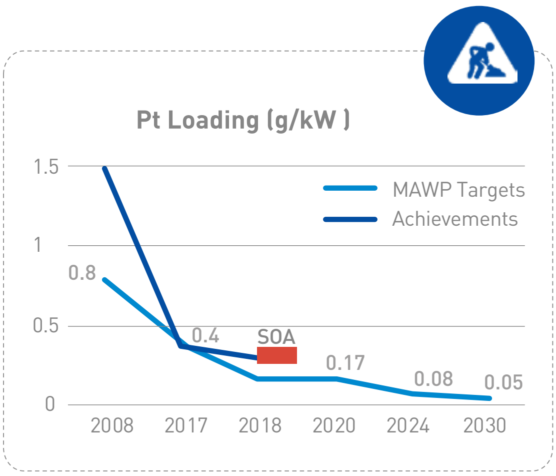
27 The size of the node represents the number of projects a partner is involved in, while the thickness of the links represents the number of projects in common between the linked partners. The coloured groupings are potential clusters identified by TIM's algorithm. The inset table shows the top six participants.

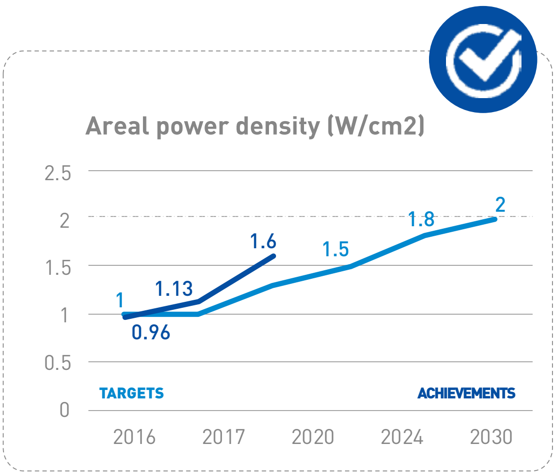
The 2019 review for the focus area **FC components: Catalyst** covers the projects PEGASUS and CRESCENDO. Technology readiness levels (TRLs) for these projects are quite low and fall in the range 2-3. PEGASUS achieved the synthesis of PGM-free catalysts with four different routes (pathways) and benchmarked different non-noble metals as active catalytic centres. It integrated the synthesised PGM-free catalyst in membrane electrode assemblies (MEAs) printed by the deposition of a thin (50 μm) active layer, and designed a scanning electrochemical microscopy setup to benchmark materials against *ex-situ* electrochemical measurements. CRESCENDO developed two diagnostic methods for determining active site density and turnover frequency of non-PGM catalysts. One of the catalysts developed reached ~ 0.92 A/g at 0.9 V vs. RHE, almost reaching the planned milestone of 1.0 A/g at 0.9 V vs. RHE. So far, CRESCENDO has reached most of the ambitious catalyst activity, MEA performance and durability targets in the call. Collaboration in the form of an IPHE non-PGM discussion group with research institutions in Japan and the USA is foreseen for CRESCENDO.

The 2019 review for the focus area **manufacturing** covers the projects DIGIMAN, Fit-4-AMandA, INLINE, INN-BALANCE, INSPIRE and VOLUMETRIQ, which made considerable progress in the production of SoA stacks for automotive applications, focusing on delivering mature stack components and production lines able to meet automotive performance specifications in large volumes along with innovative quality control (QC) techniques.

INSPIRE and VOLUMETRIQ developed hardware platforms for automotive stacks, which have potential uses in other transport applications with similar load demands. The projects examined included scale-up using realistic automotive cell and stack testing and produced FC stacks (rated capacities of 112 kW [VOLUMETRIQ], 150 kW [INSPIRE] and 98 kW [INN-BALANCE]). Volumetric energy densities and real energy densities are showing progress versus MAWP targets with reached values of 5.38 kW/l and 1.6 W/cm^2 respectively (see Figure 16). The achieved mass activity of 0.6 A/mg$_{Pt}$ (INSPIRE) meets the project's target; however, the cathode catalyst loading remains at 0.3 mg$_{Pt}$/cm^2 versus a MAWP target of <0.125 mg$_{Pt}$/cm^2 (Figure 16). INSPIRE achievements were obtained for scaled-up MEAs operating under real-life automotive conditions. VOLUMETRIQ demonstrated a new manufacturing technique optimised for large quantities guaranteeing high-quality manufacturing throughput and implementing new QC tools. The cost assessments for VOLUMETRIQ and INSPIRE for upscale production are yet to be provided.

Figure 16: Targets and achievements for platinum loadings and areal power density





DIGIMAN, Fit-4-AMandA, INLINE and INN-BALANCE all started in 2017. Their goals involve the scale-up of proton exchange membrane (PEM) manufacturing, balance of plant (BoP) definition (identifying and developing efficient and reliable components to reduce overall system costs), and development of QC practices for manufacturing and assembly procedures. At the same time, they should reduce the lifecycle environmental impacts of stacks and components. The quality assurance and QC activities performed in the aforementioned projects have the potential to act as enablers for market growth and in establishing an effective automated manufacturing chain.

The 2019 review for the focus area **refuelling (compression) and on-board hydrogen storage** covers the projects COSMHYC and H2REF regarding refuelling (compression) and TAHYA regarding on-board hydrogen storage. TRLs for these projects fall within the range 3-5. COSMHYC and H2REF both address the technology of compressing hydrogen at refuelling stations by focusing on building and testing novel prototype compressors. COSMHYC develops a hybrid system by combining a metal hydride compressor and a mechanical diaphragm compressor. H2REF developed and tested a novel hydraulic-based compression and buffering system. They both have high potential for improving techno-economic parameters for hydrogen compression at refuelling stations. The compressor is in fact a critical component of HRS and still the main source of downtime. COSMHYC defined the technical requirements for the compression solution in selected applications (refuelling of FC cars, buses and trains, hydrogen trailers). The compressor concept was finalised, accounting for improved diaphragm materials and heating/cooling at reduced noise levels. H2REF has built a full-scale prototype system of the compression and buffering module (CBM) and the compression device hydraulic actuation was successfully tested in hydrogen. It also identified a suitable bladder material, developed the accumulator and qualified them with functional and endurance testing of the CBM. In addition, a new hydrogen test area was set up within Haskel premises for the testing of systems in hydrogen service.

TAHYA is to provide a safe, complete and high-performance hydrogen storage system (liner, cylinder, on-tank valve) achieving cost competitiveness in mass production with a credible European chain, with suppliers from France, Belgium and Germany. TAHYA is also involved in regulation, codes and standards (RCS) activities, with the aim of updating Global Technical Regulation No. 13 on hydrogen and FC vehicles and the European General Safety Regulation (which also covers hydrogen vehicle safety) based on the test results obtained. The project merged the business practices of large OEMs and SMEs and has delivered a first prototype to VW for its implementation into a car. Following this step, the optimisation process will be launched. The efforts made towards meeting the project targets seem promising, particularly cost reduction. For example, the project reported a reduction in the number of machining tools to 42 while the target is 40, and a mounting time of 40 minutes (target is 30 minutes) down from 150 minutes. The technical target of an improved temperature tolerance between -40 °C and 100 °C using a combination of materials for the liner appears to be more challenging. The latter objective still needs to be demonstrated in the remaining project life, together with a new tests system defined for QC.

The 2019 review for the focus area **APU, FC system integration** covers the projects HYCARUS, FLHYSAFE, MARANDA and GiantLeap. TRLs for these projects fall in the range 4-6. The commitment by industrial players from the aviation and maritime transport sectors in these projects indicates that FCH technologies play a role in power generation in these two transportation modes.

MARANDA assembled and delivered three 100 kW S3 FC stacks. The first 82.5 kW system was subjected to durability testing. Experience from the project has also shown how deployment of hydrogen technologies in maritime applications has still to go through a lengthy, costly and risky qualification process. HyCarus developed an aviation APU as a final prototype.

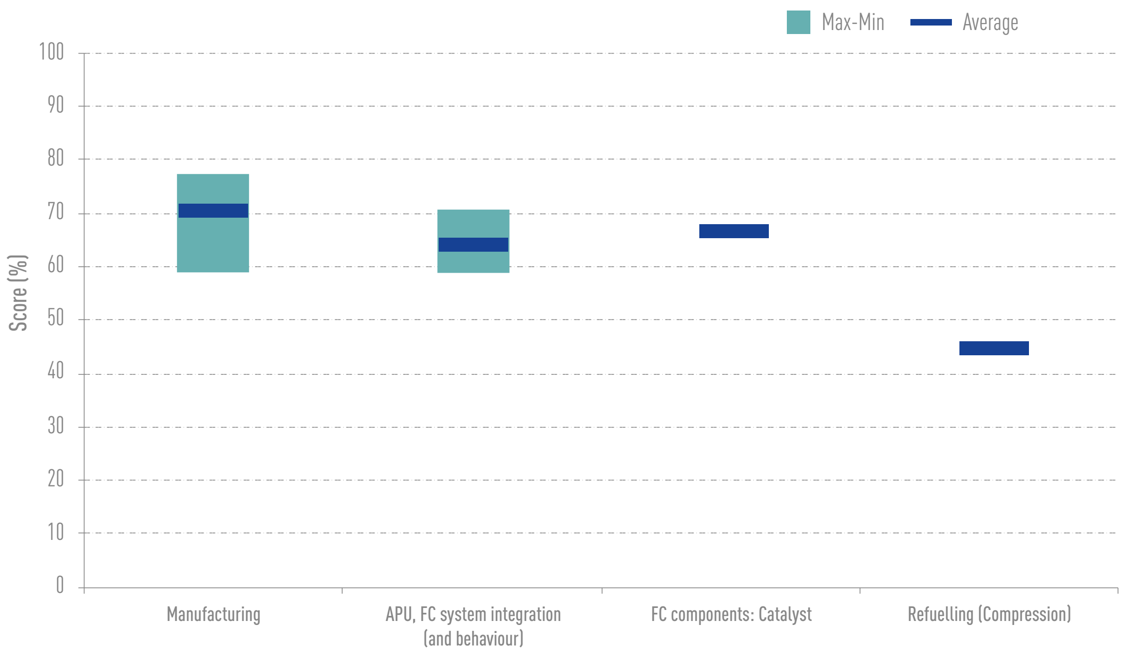
New in this year's review is the FLHYSAFE project, which draws on experience gained in HyCarus. Considering mass and volume design requirements, this project will develop and test a modular FC system (FCS) to replace the current ram air turbine technology used for emergency power in a commercial aircraft. Key to success are quality checks based on augmented reality. This allows operators to use visual comparison to verify that the final product is within the specification of the native 3D CAD model of the agreed design, before assembly takes place. The environment of the FCS around the physical demonstrator can also be visualised in this way. In addition, it will demonstrate procedures for training maintenance operators using a virtual reality tool. So far, this project has completed the emergency power unit system specification based on new Safran Power Units, including a detailed functional analysis.

GiantLeap developed advanced diagnostic, prognostic and control systems for automotive PEMFC stacks and systems, used as a detachable FC range extender in a hybrid battery bus. The project performed a systematic study of FC rejuvenation and a prognostic analysis of compressors in FC systems and developed a fast, automatic low-frequency electrochemical impedance spectroscopy with no additional equipment use. On-board diagnostic solutions such as those developed by GiantLeap are an important aspect if FC technologies are to be successful. However, such diagnostic tools will express their full potential especially in durability gains and cost reductions when operational data are made more commonly available.

2.4.1. PANEL 2 – SUMMARY

Figure 17 presents the overall results for the assessment of projects in the panel and aggregates them in focus areas. The manufacturing focus area is composed of projects offering promising opportunities considering their current achievements. Scores in the manufacturing and APU focus areas show some spread in the total scores, as can be expected from the larger numbers of projects in these focus area and the several specific challenges of each project in these portfolios.

Figure 17: Maximum, minimum and average scores for focus areas of Panel 2. For focus areas with fewer than three projects, only the average is given



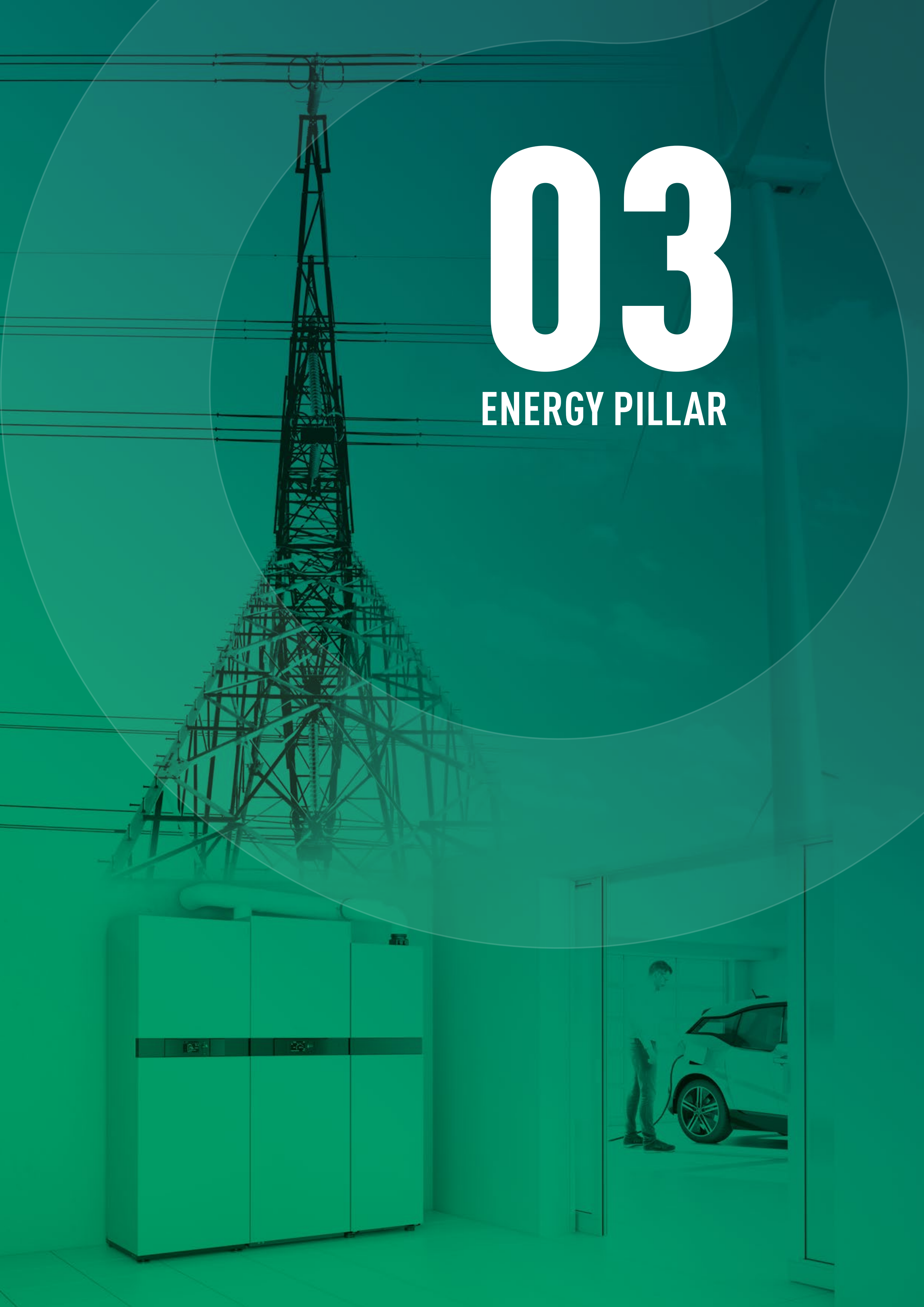
Strengths

- Joint workshops enable fruitful discussion on project results and technical exchanges and are increasingly commonplace.
- Projects have continued to contribute to harmonisation efforts, testing protocols and procedure development, and are committed to their implementation.
- New projects that explore the use of non-PGM for electro-catalysis serve the objective of the FCH 2 JU regulation to reduce the use of EU-defined critical raw materials.

Additional focus needed

- Future maritime, aviation and rail transport actions could also consider, where feasible, the development of solid oxide fuel cell (SOFC) and high-temperature proton exchange membrane fuel cell (HT PEMFC), and not simply PEMFC (investigating the feasibility of using hydrogen-based fuels like ammonia or methanol, coupled with large FC systems, and requesting larger FC systems [MW scale] in line with application requirements, especially in maritime applications).
- Focus on cost-effective and affordable automotive PEMFC, feasible low-PGM alternatives and their mass adoption worldwide (project portfolio demanding enlargement, exploitation of screening tools based on computational materials science prior to lab-scale candidate testing).
- Streamline and build sets of linked projects along an iterative and incremental research and development (R&D) planning, like the Auto Stack project family inspiring, for example, INSPIRE and VOLUMETRIQ (establishing a common product design for modular fuel cells).
- Synergies between manufacturing projects and research projects need to be exploited whenever possible.
- The development of QC techniques should remain a central aspect of all manufacturing-oriented projects.
- APU solutions will probably follow the expected fuel evolution of the different sectors (heavy-duty road transport, aviation, maritime).
- Field test activities largely depend on approval from different authorities, which is not always straightforward due to the absence of a well-established RCS framework.
- For manufacturing as well as aviation, rail and maritime transport sectors, specific MAWP targets are not available.
- The prospect of using FCs in aeronautics applications, considering the requirements in the heavily regulated aviation sector and the need for in-flight demonstration of prototypes, is fraught with obstacles. The ongoing study jointly launched by FCH 2 JU and CleanSky, with results expected in the first half of 2020, should assess the feasibility of using hydrogen and FC technologies for propulsion purposes in the aeronautic sector.

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. The widespread deployment of competitive FCH technologies can deliver substantial benefits in terms of energy efficiency, emissions and security, while enabling the integration of RES into the energy systems. As such, the FCH 2 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 RES; handling, distribution and storage technologies enabling hydrogen to become a major energy vector for Europe.

3.2. BUDGET

Between 2008 and 2018, 138 projects in the Energy pillar received financial contributions from the FCH 2 JU totalling more than EUR 435 million across several types of technologies. The distribution of projects is shown in Table 3[28,29].

Table 3: FCH 2 JU financial contribution (EUR million) for the three activity areas in the Energy pillar

Trials and Deployment of Fuel Cell Applications	160.0
Next Generation of Products	109.9
Hydrogen for Sectoral Integration	165.8
Total	435.7

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

Stationary FC systems for power and combined heat and power (CHP) generation at all levels, μ-CHP, mid-sized and large centralised installations, as well as for provision of back-up power, still need significant development to allow competition of CHP technologies with well-established traditional ones, aiming to reduce investment and operational costs while improving system durability. The focus areas for the 2019 review are:

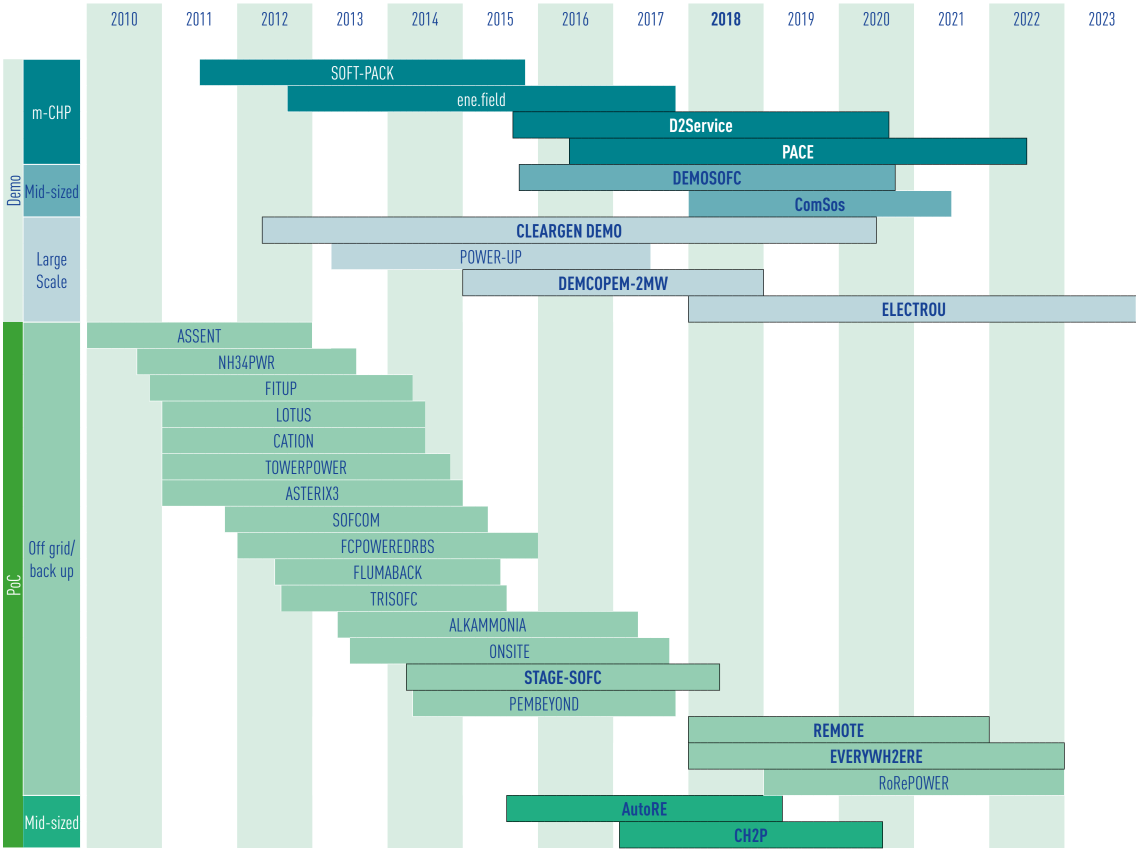
- demonstration projects aiming to prove technology readiness bringing the technology to end users and developing knowledge and experience in installing, operating and maintaining units in real applications;
- PoC projects seeking to test and validate whole-system concepts, usually around TRL 4-6, also aimed at improving performance, reliability, durability and cost of BoP and control sub-systems for FC installations.

The 2019 review covers 12 projects, shown in Figure 18. Almost 50 % of the projects in this year's review focus on SOFC; 60 % deploy PEMFC and 15 % alkaline fuel cell (AFC).

28 These figures include the full budget of an overarching project (BIG HIT) which draws half of its EUR 5 million funding from the Transport pillar. These projects have been allocated to Panel 5: Hydrogen production, storage and distribution, as this is the most appropriate panel for the topics.

29 This budget financed both R&I and demonstration actions.

Figure 18: Date ranges of Trials and Deployment of Fuel Cell Application projects in the Energy pillar. Projects highlighted in bold are included in PRD 2019



Following the calls between 2008 and 2018, the FCH 2 JU supported 29 projects relevant to this panel with a total FCH 2 JU contribution of EUR 160 million and a contribution from partners of EUR 164.1 million. The historic distribution of total budgets over the five focus areas is shown in Figure 19, and indicates that approximately 64 % of FCH 2 JU funding went to support demo projects (around 43 % of total FCH 2 JU funds went to support μ-CHP demos) and about 36 % PoC activities. The FCH 2 JU funding contribution amounts to about 52 % of the total funding for the portfolio of projects considered in this panel, in 2019.

Figure 20 shows the cumulative project contributions to various FC technologies from 2010. It is possible to see how, on average, funding has been more or less equally split between SOFC and PEMFC, with a slightly higher amount allocated to the latter. Since 2013, other FC technologies, namely AFC, molten carbonate fuel cell and Proton Ceramic FC (PCFC) have also been funded.

Figure 19: Funding for Panel 3 (Trials and Deployment of Fuel Cell Application – Energy) from 2008 and including the 2018 calls

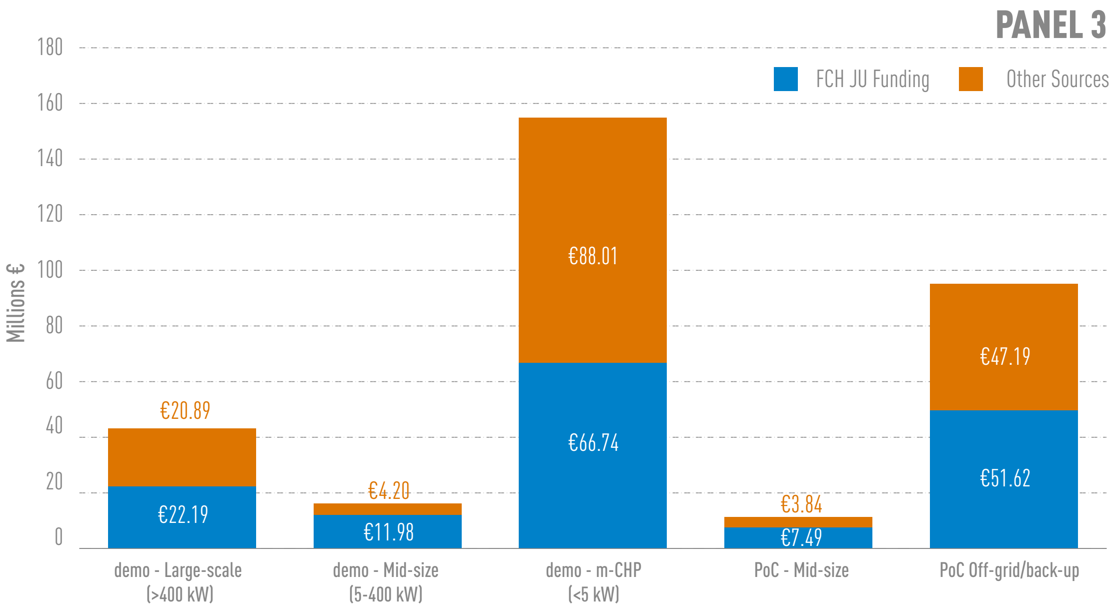


Figure 20: Cumulative EU funding for Panel 3 projects: funding per FC technology

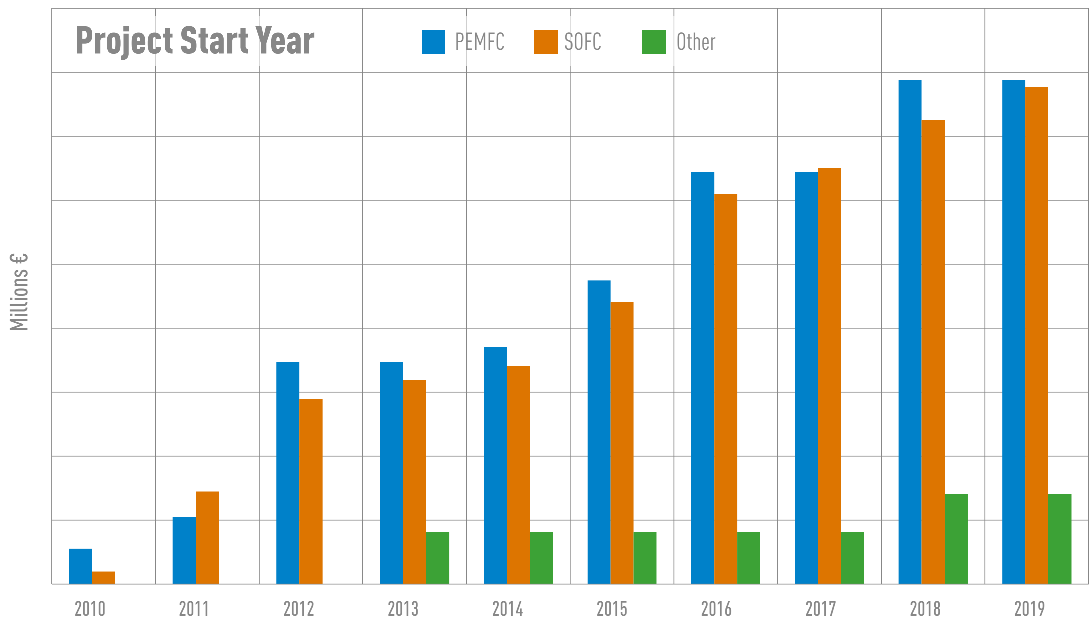
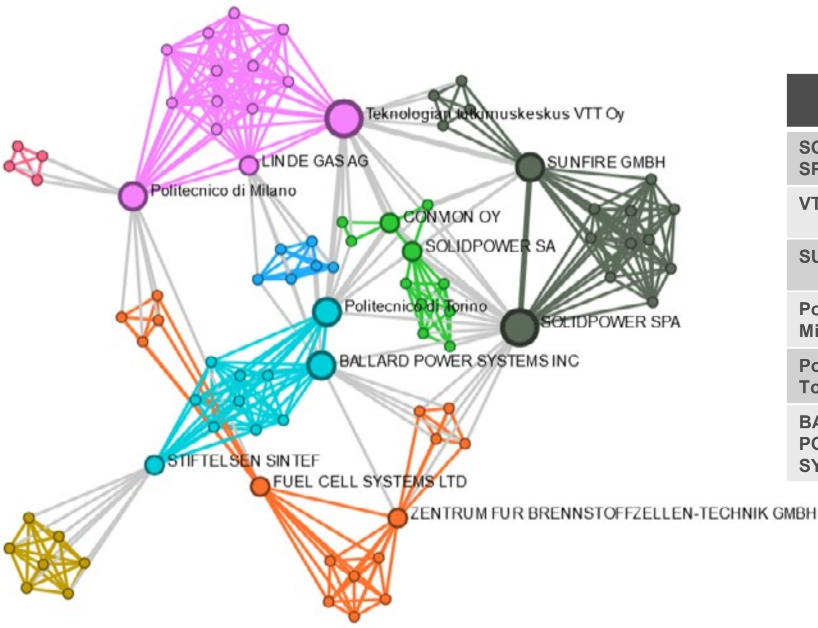


Figure 21[30] shows that the projects are strongly linked. There are only two projects with only one partner in common with other projects and no standalone projects with no interactions. All other consortia have multiple links. The key partners are the FC stacks/system providers SOLIDPower, Sunfire, Ballard, Convion; the universities Politecnico di Milano and Politecnico di Torino; and research institutes VTT, ZBT and Sintef.

Figure 21: TIM plot showing the participants in the 13 projects in Panel 3[31]



Participant	Number of projects
SOLIDPOWER SPA	4
VTT	4
SUNFIRE GmbH	3
Politecnico di Milano	3
Politecnico di Torino	3
BALLARD POWER SYSTEMS	3

The focus area **demo – μ-CHP demo (<5 kW$_e$)** covers the projects PACE and D2Service. FCs have proven potential to provide CHP in domestic and small commercial building sectors, due to their efficiency and ability to run on natural gas, a popular fuel for the domestic sector. European OEM leaders are approaching the commercialisation stage. However, with several thousand installed μ-CHP FC systems, Europe lags far behind Japan, which has deployed more than 305 000 units.

PACE is a successor of ENE.FIELD and plans to move the market towards mass commercialisation with up to 2 800 FC μ-CHP units expected to be installed by the end of the project. It also aims to reduce the average unit costs below EUR 10 000 per small FC system (<1 kWe) by 2020 and below EUR 10 000/kWe for systems above 1 kWe, through more automated production and introduction of next-generation systems. The project increased its commitment from 2 650 to 2 800 units. It is Europe's largest deployment of FC μ-CHP to date and has already allowed manufacturers to reduce costs and build markets, although higher deployment volumes are still required. PACE aims to extend stack lifetime to more than 10 years, and to model (without a field demonstration) the potential benefits to the electricity grid when a large number of μ-CHP units are combined in a virtual power plant. Finally, the project intends to identify further cost reductions that could be achievable by manufacturing and automation of the manufacturing process, and by developing a platform approach to component standardisation for FC μ-CHP across the EU supply chain.

30 The size of the node represents the number of projects a partner is involved in, while the thickness of the links represents the number of projects in common between the linked partners.

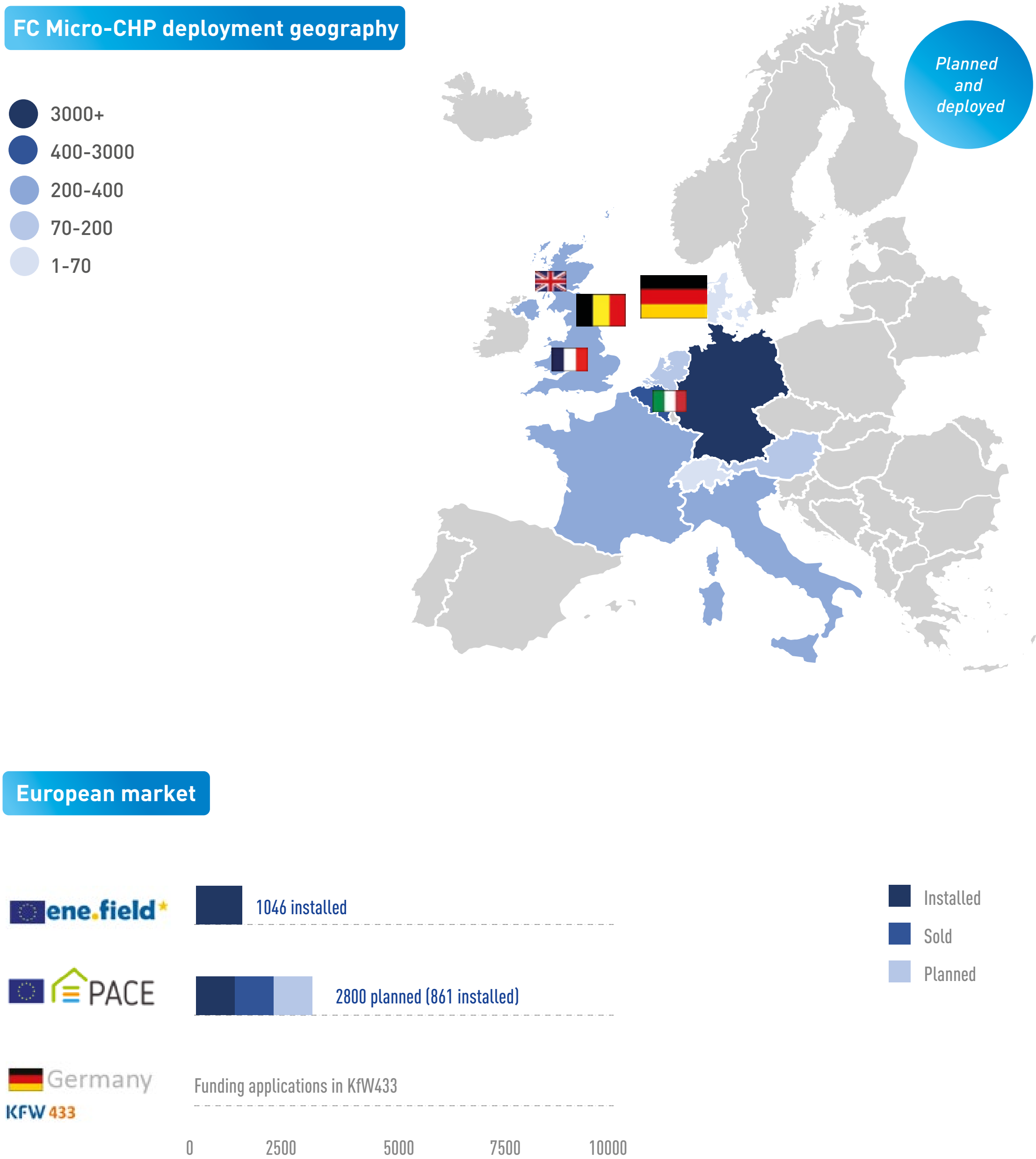
31 The table insert shows the top six partners. Note: SOLIDPower SPA and SOLIDPower SA are two separate business entities.

The D2Service project goal is to improve the design, installation and maintenance procedures of SOFC μ-CHP and PEMFC back-up power systems oriented at serviceability optimisation. The project results involved improvements in increasing system durability and simplification of the maintenance procedure. These modifications enabled it to reach the targeted SOFC μ-CHP extension of time between service intervals and reduction of service time with downtime for servicing needs.

In addition to FCH 2 JU support, a further financing option to the FC μ-CHP sector is being provided in Germany through a dedicated programme, KFW 433. Since 2016, 9 000 applications have been filed.

The deployment of the FC μ-CHP units in Europe resulting from FCH 2 JU and national support programmes is shown in Figure 22 as both the total number of supported installations and their geographical distribution. Based on these figures, it could be said that the technological development of μ-CHP installations is mature; however, this is not the complete picture.

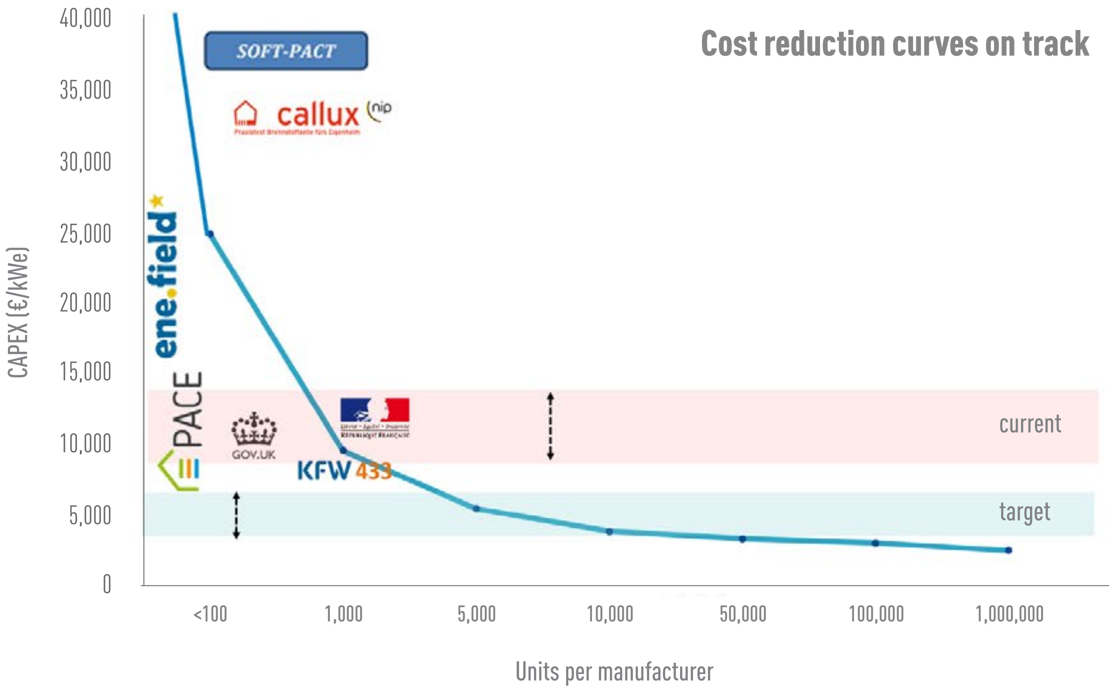
Figure 22: Deployed and planned FC μ-CHP installations across the EU



Current actions focus on technical development of next-generation units characterised by improved durability, availability and economics, and on increasing the manufacturing and deployment volumes as a means to reduce costs, which are currently the main barrier to wide technology deployment. Some CHP models have started being provided by private companies such as Elugie, the official distributor of SOLIDPower in Belgium.

Despite increasing the number of µ-CHP installations, there is still a risk that the technology will not be adopted by a free market without incentives, and it may still require targeted support. Following the Japanese deployment lessons from ENE.FARM, deployment in Europe might increase with the progressive decrease of µ-CHP system costs, which is expected. Lower costs and higher market penetration should trigger a progressive reduction of needs for subsidies (Figure 23).

Figure 23: The market penetration of µ-CHP systems in the EU



In the focus area µ-CHP **demo mid-size (5-400 kW$_e$)**, the DEMOSOFC project aims to demonstrate the advantages of a commercial-size SOFC-based CHP system in an industrial environment. The planned 175 kW$_e$ system is being installed with some difficulties (two out of three modules were put into operation, the third is planned for 2020) in a wastewater treatment plant in the Turin area. It is expected to supply ~30 % of the site's electricity consumption, and almost 100 % of the thermal energy consumed by the plant. A cumulative 7 470 hours of operation were completed for both units. There is still a need for complex and costly BoP systems, mainly for biogas purification. The lessons learned have informed the design of the next generation of units developed under the R&I project INNOSOFC. The COMSOS project aims to demonstrate the advantages of a mid-sized SOFC-based CHP system in an industrial or utility services environment. The consortium plans to install 23 demo systems.

In the focus area **large-scale FC installation demo (>400 kW$_e$)** the project CLEARgenDemo aims to demonstrate a 1 MW$_e$ PEMFC system utilising by-product hydrogen in the real industrial environment of a refinery. The demo site on the island of Martinique is being prepared and the system was installed in December 2019. The lessons learned will be taken up by a power-to-power project (using RES, hydrogen storage and FCs for energy production) in French Guiana that is being developed by one of the partners, Hydrogen de France.

The project DEMCOPEM-2MW aims to demonstrate a CHP PEM FC power plant (2 MW_e and 1.5 MW_{th}[32]) integrated into a chlor-alkali production plant. The by-product hydrogen has been used to generate electricity, heat and water for the chlor-alkali production process, lowering electricity consumption by 20 %. Special attention has to be paid to the purity of feedstock, which strongly affects the lifetime of the FCs and the maintenance costs of the integrated plant. The demonstration site was selected in China for its high electricity price, problems with stability of electricity supply and high potential of the chlor-alkali production (50 % of world capacity). The system has been in operation since September 2016 and has been working for 11 240 hours. Plant average availability reached 95 %. The project claims excellent flexibility in terms of part-load, standby operation and on-off control for plant operation.

The focus area **off-grid/back-up applications/demonstrations** gathers the demo projects focused on off-grid applications, both in remote places and in temporarily powered event areas. The REMOTE project aims to prove the technical and economic feasibility of FC technologies combined with RES and hydrogen storage solutions in island grids or remote areas. The systems will completely replace fossil fuels (in three locations) and remove costs for new transmission lines (two locations), serving local communities with residential and small industrial needs. All the demonstration sites are based on PEM FCs fed with pure oxygen, or air and alkaline, or PEM electrolysers. The technology platforms and geographical and climate conditions will be evaluated. The EVERYWH2ERE project aims to demonstrate FC technology replacing diesel-fuelled internal combustion engine temporary gensets, 4x25 kW + 4x100 kW during music festivals, temporary events and at construction sites, and to evaluate the logistic and techno-economic feasibility of this solution.

The focus area **off-grid/back-up applications/PoC** gathers the projects ALKAMMONIA and STAGE-SOFC, both focused on developing new solutions for off-grid applications, targeting both back-up power and CHP. The portfolio of fuels covers ammonia as an energy storage medium and natural or biogas. Both projects have ended. TRLs fall in the range 4-6. The ALKAMMONIA project aimed to develop a prototype of a small-scale power system for remote applications. It integrates a fuel delivery system producing hydrogen from ammonia and feeding into an AFC. The aim of STAGE-SOFC was to develop a 5 kW_e PoC SOFC system prototype for small-scale CHP and off-grid applications. It combined the reliability of CPOx with the high efficiencies of steam reforming, without a costly heat exchanger.

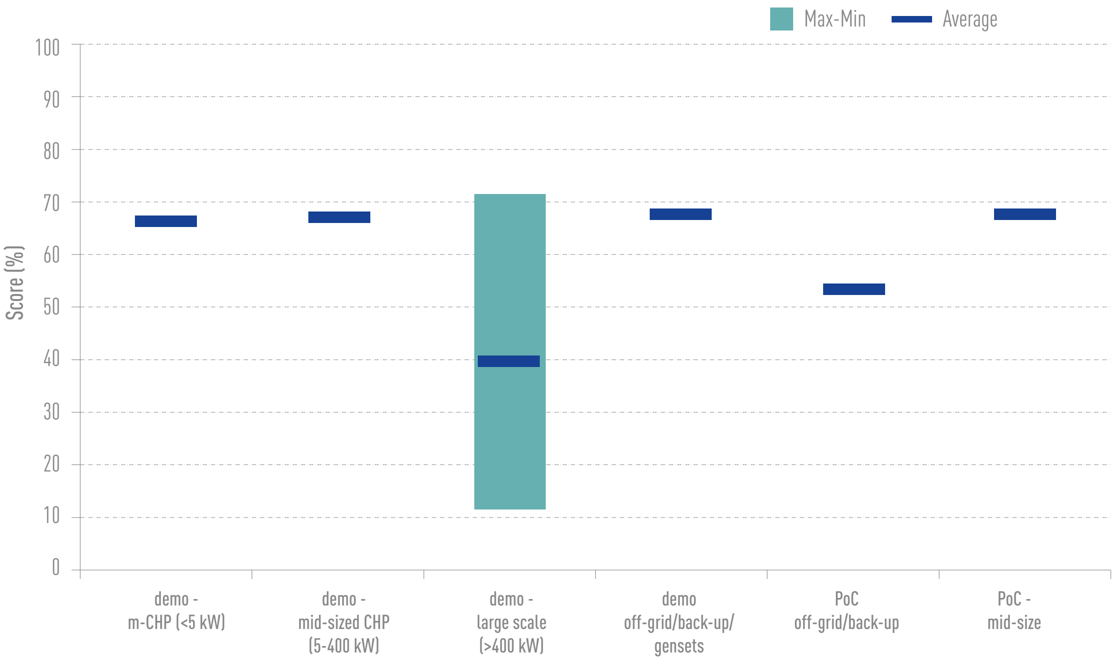
In the focus area **PoC – mid-size CHP**, TRLs fall in the range 4-5 and are significantly lower than those for other focus areas in this panel. The project AUTORE targeted the PoC of a CHP system deployed in an industrial environment, based on a 50 kW_e automotive (PEM) FC stack. The goal was to reduce system costs, using a FC that is already produced in commercial volumes for the automotive sector. The CH2P project focuses on flexible SOFC-based co-generation of heat, power and hydrogen for distributed hydrogen production in HRSs. The feed used is a methane-rich gas. High conversion efficiency (exceeding 65 %, based on the energy content of the input gas and the produced hydrogen, together with the output power), and a low cost for hydrogen (<EUR 4.5/kg) are expected. Hydrogen purity compliant with use in on-board PEM FC is anticipated.

32 Although foreseen conceptually, there is no plan to integrate heat in the industrial system.

3.3.1. PANEL 3 – SUMMARY

This section presents the assessment of Panel 3 projects grouped into focus areas, based on the aggregated scores from all the reviewed categories (see Figure 24). Due to the small number of projects in this year's focus areas, it shows only average values, except for industrial-scale demonstrations.

Figure 24: 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 technical development of μ-CHP systems reached a level for which the reported average system lifetime key performance indicator (KPI) is approaching the MAWP 2020 target.
- The technology development allowed some improved products to match the MAWP system cost target.
- First FC μ-CHP systems are being included in the product portfolio of EU heating solution providers.
- European integrators of SOFC offering products in the market include SMEs.
- Europe is relatively strong in developing SOFC μ-CHP systems. Knowledge transfer to SOE-SOFC co-generation hybrid technology is expected to enable growth for both sectors; the first synergies in this respect are already observed.

For mid-size applications

- The technical development of the technology allowed the attainment of MAWP 2020 KPIs for electrical and thermal efficiencies while other KPIs, e.g. durability, are improving.
- Expertise from the manufacturing of automotive FC system can be exploited for CHP stationary applications.
- CH2P is opening up additional market opportunities in transport thanks to tri-generation.
- Cost reductions are still a challenge for future actions.

For large-scale applications

- Products developed in the EU might be interesting for non-EU markets, as demonstrated with examples in the chlor-alkali industry.
- The development of FC solutions for large-scale stationary applications may induce positive spill-over of know-how and increased manufacturing capabilities for other, emerging application fields, e.g. in maritime or aviation sectors.
- A next generation of MW-scale PEMFCs is being developed using the results of recent projects.

Additional focus needed and follow-up actions

- The mid-size and large-scale systems working in an industrial environment are often exposed to increased levels of local contaminants, not present in those seen by μ-CHP, and inducing durability and degradation issues.
- The duration of demo system operation phases should be extended, to better assess the actual technology performance, especially the durability, long-term availability, rate of degradation and serviceability.
- Stronger links with the family of projects supported by the other parts of H2020, targeting energy efficiency, especially in the building sector, should be created
- Data from projects should be exploited, including after completion.
- Consider advocating for public procurement support for public European institutions and Member States, thus allowing for market support of the products developed by financed projects.

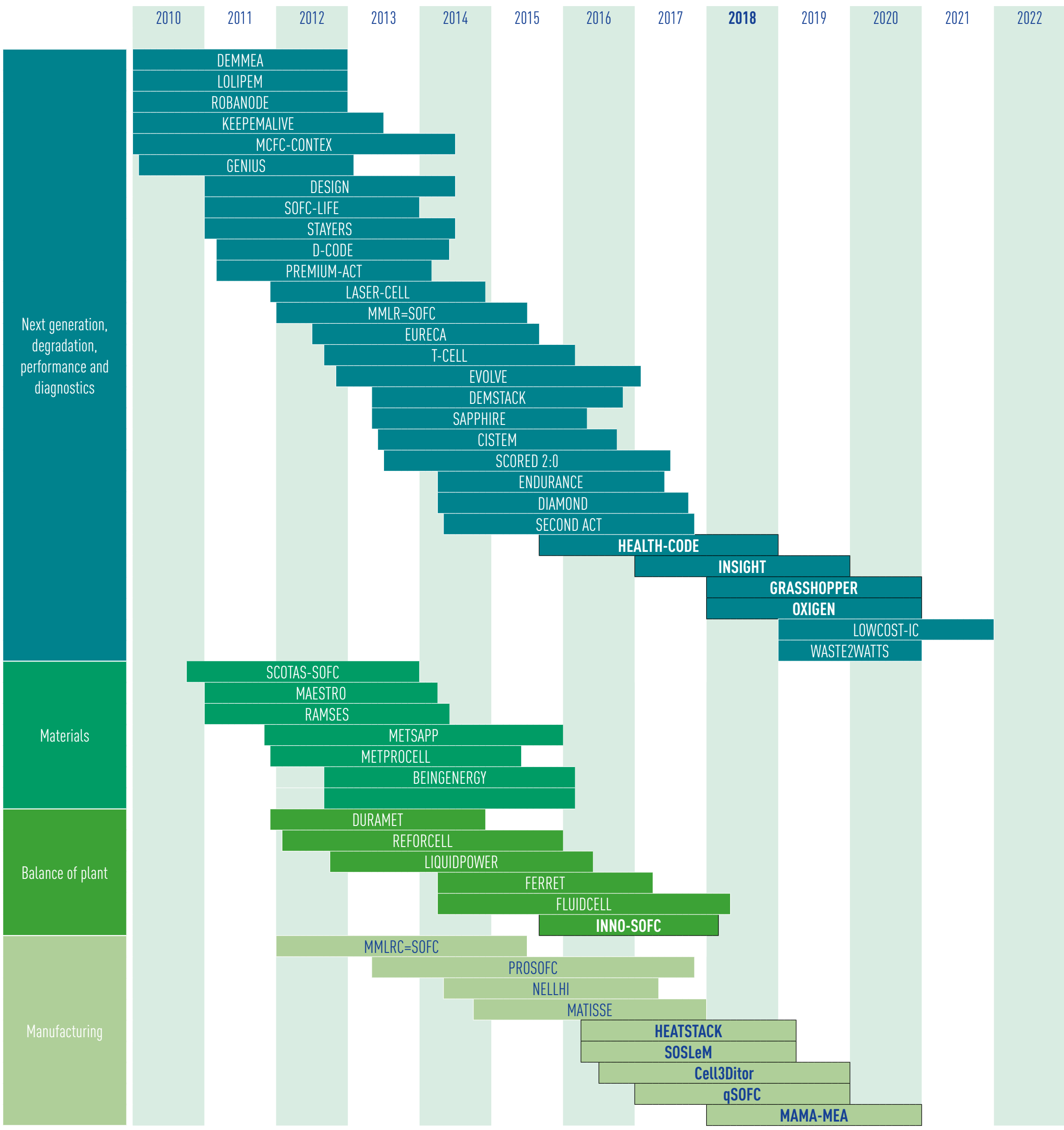
3.4. PANEL 4 – NEXT GENERATION OF PRODUCTS – ENERGY

The projects in this panel were grouped into three focus areas:

- Next generation, degradation, performance and diagnostics: four projects
- Manufacturing: five projects
- Balance of plant: one project

Of the 10 projects under review in this panel, seven focus on SOFC. The FCH 2 JU programme portfolio of research projects on stationary FCs is shown in Figure 25. It should be noted that all projects in the Materials focus area were completed prior to this review.

Figure 25: Date ranges of Next Generation of Products projects in the Energy pillar. Projects highlighted in bold are included in PRD 2019



Following the calls between 2008 and 2018, the FCH 2 JU supported 49 projects relevant to this panel with a total FCH 2 JU contribution of about EUR 109.9 million and a contribution from partners of EUR 76.7 million. The historic distribution of total budgets over the four focus areas is shown in Figure 26.

Figure 26: Funding for Panel 4 (Next Generation of Products – Energy) from 2008 and including the 2018 calls

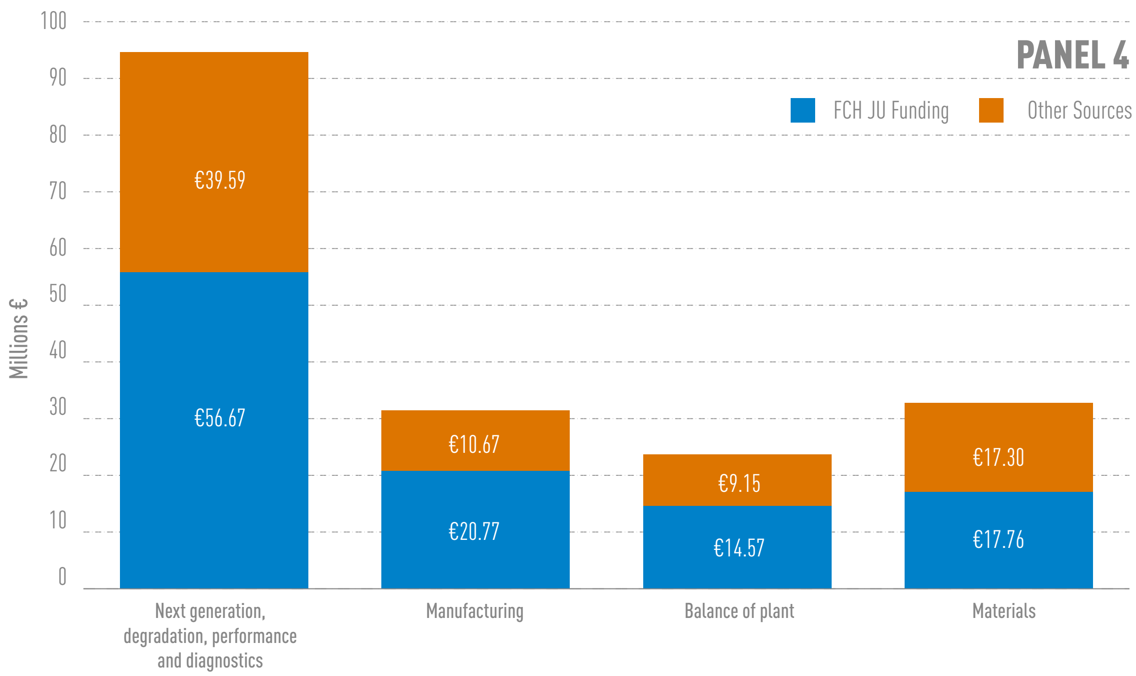


Figure 27 shows the cumulative funding contribution for different technologies from 2010 onwards. It can be seen that, prior to 2014, funding for SOFC was slightly higher than for PEMFC; it markedly surpassed PEMFC funding after 2016 and continues to grow at a much higher rate than PEMFC.

Figure 27: Cumulative EU funding for Panel 4 projects: funding per FC technology used

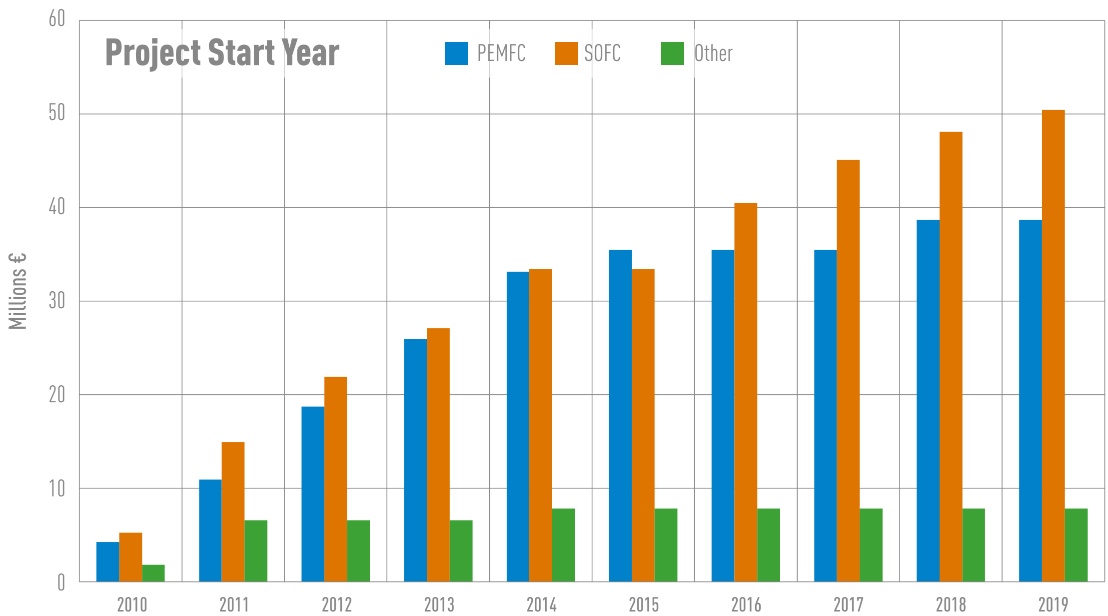
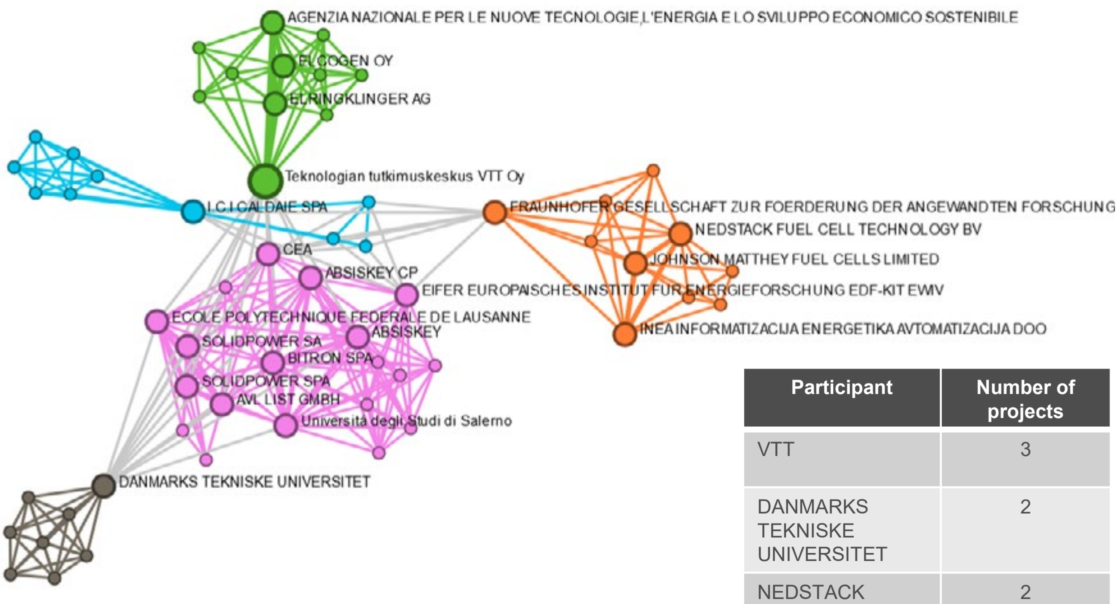


Figure 28[33] shows the connections between partners in the projects in Panel 4. For clarity, only the partners involved in the largest numbers of projects are named. Consortia in Panel 4 are independent from each other, with the only exception being HEALTH-CODE and INSIGHT.

Figure 28: TIM plot showing the participants in the 10 projects in Panel 4. The inset table shows the top five participants



Participant	Number of projects
VTT	3
DANMARKS TEKNISKE UNIVERSITET	2
NEDSTACK	2
JOHNSON MATTHEY	2
Multiple other participants	*2*

In the **focus area next generation, degradation, performance and diagnostics**, TRLs of projects fall in the range 3-5. The focus of projects HEALTHCODE and INSIGHT has been on developing diagnostic tools for PEMFCs and SOFCs respectively. Both projects have achieved the expected targets in fault detection accuracy and claim to have enabled an increase in FC lifetime with a small financial impact (less than 3 % on system cost). Both projects build on a sequence of previous consortia that developed the algorithms and the techniques exploited. There seems to be a well-defined constant core of participants across the consortia developing the different testing tools and methods. VTT, EIFER, BITRON and especially the University of Salerno were present in all the precursor projects (GENIUS, D-CODE, DESIGN, DIAMOND). A significant experimental result of INSIGHT is the build-up of a library of data associated with typical faults and mitigation measurements. Detection of faults at cell level has been satisfactorily proven with a good level of accuracy. Positive technical results and several project targets have been achieved. The upcoming project RUBY should take on the developed intellectual property and improve exploitation opportunities, finally achieving the inclusion of innovative diagnostic tools into the design of commercial systems.

The project GRASSHOPPER is developing the concept for a new MW-size PEMFC power plant. A 100 kWe FC pilot plant with improved components and BoP will be tested soon in an industrial site

33 The size of the node (circle) represents the number of projects a partner is involved in, whilst the thickness of the lines linking the nodes represents the number of projects two partners have in common.

in Delfzijl (NL). The objective of this project is to come up with a FC that is more cost-effective and flexible in power output, achieving an estimated CAPEX below EUR 1 500/kWe at a yearly production rate of 25 MWe. The design phase is completed and it focused on reducing the cost and increasing the durability of a MW-size FC. Another H2020 project (GoFlex) involved in the development of a distribution grid integrating RES was consulted. The project was the first FCH 2 JU project supported by the EHSP in addressing its safety dimension.

The project OxiGEN aims to develop an all-ceramic SOFC platform based on the Saint-Gobain SOFC design, and focuses on improving efficiency and durability of the stack. The first short-stack test will start soon, and the project seems to be progressing successfully. A new ceramic electrolyte has been developed and future stack designs are expected to reach their goals. The project has also considered different market specifications for different potential users; it seems that the targeted outcome will be a CHP product ready for market entry.

In the focus area **manufacturing**, all but one project (MAMA-MEA, focusing on PEMFC manufacturing) investigate SOFC manufacturing options (qSOFC, HEATSTACK[34], CELL3DITOR and SOSLeM). The overall goal of the projects is to make an efficient manufacturing upscaling of FC technologies possible.

Figure 29 summarises general improvements in manufacturing achieved across the years. With the exception of MAMA-MEA, all projects explicitly mention CHP applications: mid-size CHP (CELL3DITOR, SOSLeM, qSOFC) and μ-CHP (HEATSTACK, qSOFC). The efforts of these projects are expected to reduce costs, use of critical raw materials and production of pollutants, without adversely affecting durability, therefore enabling the penetration potential of FC use in European CHP markets.

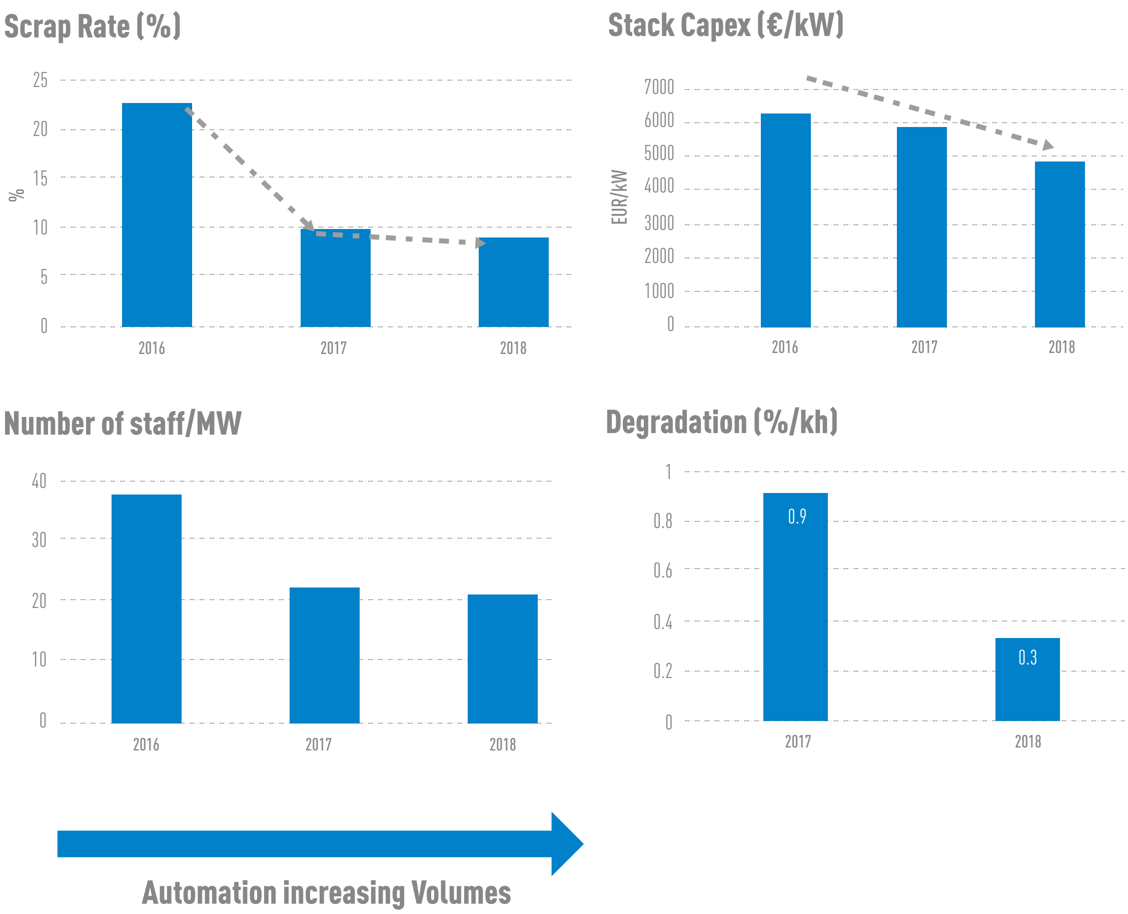
CELL3DITOR is working on manufacturing technology for SOFC based on 3D printing. The process materials (inks and slurries), the 3D printer and the manufacturing process have all been developed and the progress towards targets is good. However, the actual stack still needs to be assembled and tested. The HEATSTACK project aims to drive down production costs for μ-CHP systems by improving overall stack assembly procedures and cathode air preheater design and production. The project has achieved good results in terms of design, including the reduction of chromium evaporation in the cathode air preheater. Sunfire could install FC μ-CHP units in the order of thousands in the years to come, some of them within the project PACE. For the cathode air preheater, this large volume could offer the opportunity to exploit the outcomes of the project at a production volume necessary for actual cost reductions of this component. The work done at stack level in the project has also supported Sunfire in developing its FC μ-CHP Sunfire-Home unit (launched in 2020).

SOSLeM (finished in 2019) is developing new and optimised processes for the production of FC interconnectors by lean manufacturing processes, improved sealing adhesion and automation of the welding process for SOFC stack production. Its objective is to drive down costs and reduce the environmental impact caused by the use of cobalt and nickel (whose presence in waste waters should be reduced). The project has achieved several of its objectives and it is well within the expected MAWP μ-CHP targets for 2020. New monitoring, testing equipment and procedures have all been implemented and they build on results and knowledge from other FCH 2 JU projects. Substitution of cobalt with copper in the coatings has proved feasible. Chromium evaporation has not been directly optimised as yet and the use of filters has been necessary during stack testing. It is expected that SOLIDPower will develop a new production facility with a capacity of 25 MW/year. The cost reductions for wastewater treatment (economy of scale) should facilitate nickel removal.

qSOFC focuses on replacing manual labour in all key parts of the stack manufacturing process with automated manufacturing and quality control, driving down costs and improving overall SOFC stack quality. The project has developed new automated vision machine inspection methods and novel stack manufacturing/conditioning procedures. The manufacturing line speed has been increased.

34 HEATSTACK has been moved from Panel 3 to Panel 4 for the 2018 Programme Review exercise.

Figure 29: Improvements in selected TRUST KPIs relevant for manufacturing projects focusing on stationary applications



MAMA-MEA is developing a single, continuous roll-to-roll manufacturing process for the PEMFC industry. The new process will manage to produce a catalyst-coated membrane continuously, thus increasing by 10 times the production rate with respect to the SoA Johnson Matthey Fuel Cell production process.

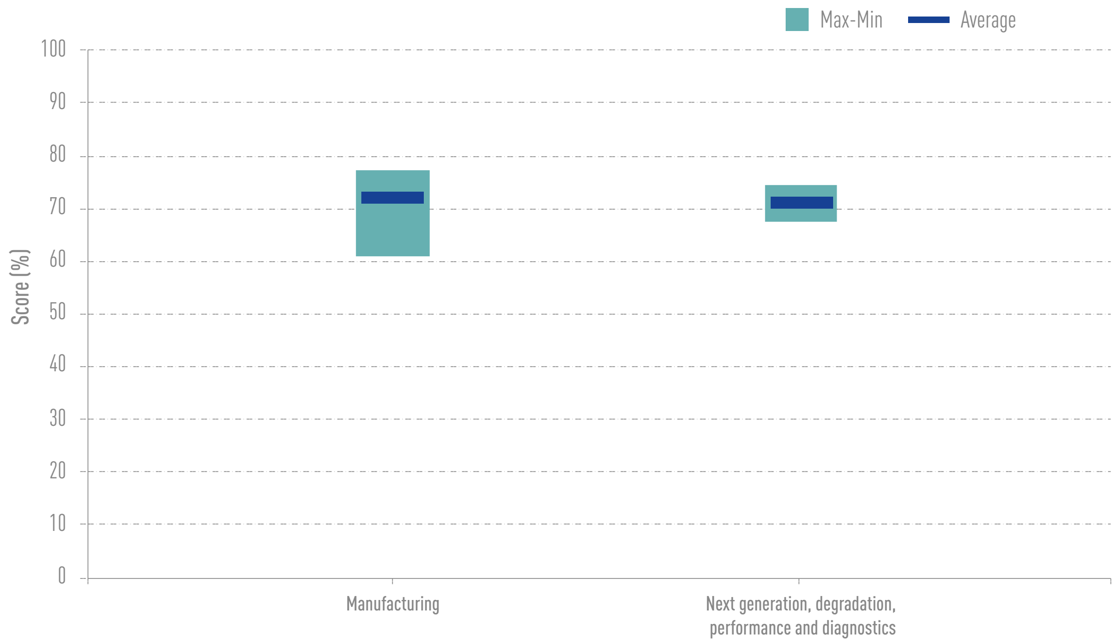
Cost projections (especially for smaller FC applications like μ-CHP) highlight the potential savings offered by the scale-up of manufacturing volumes (see Figure 29). The reported rated electrical efficiency for SOFC has reached an impressive maximum of 74 $\%_{el}$ at stack level.

In 2019, the focus area **balance of plant** covers only the INNO-SOFC project, which developed a 60 kW SOFC system based on an all-European value chain. The project interfaced with other FCH 2 JU activities, adopted the stack developments brought forward by the NELLHI project, and exchanged technical information with other consortia (qSOFC and DEMOSOFC in particular). The results have been positive: 30 000 hours of rated lifetime at stack level, 60 % system electrical efficiency (with a significant 74 % total stack efficiency) and a total rated efficiency of 85 %. System cost estimates for large volumes are around EUR 4 000/kW. If accurate, the MAWP 2020 targets for large-scale FC installations will be achieved. In 2019, it is expected that two systems based on INNO-SOFC developments will be demonstrated in a smart grid system in Lempäälä (FI). One of the two systems will be sold and evidences a commercially successful dimension for the product developed by the consortium.

3.4.1. PANEL 4 – SUMMARY

Figure 30 shows the overall assessment of the projects reviewed in Panel 4. The projects obtained overall positive evaluations (with some achieving very good marks). The low spread in scores also shows consistency in project performance within focus areas.

Figure 30: Maximum, minimum and average scores for the relevant Panel 4 focus area. For focus areas with fewer than three projects, only the average is given



Strengths

- Manufacturing projects have helped FC and system producers establish modern assembly lines, even without stronger market demand (opening of a new production plant in Italy using IP from SOSLeM).
- One of the members of HEATSTACK is considering opening a new production line in Czechia, thanks to the demand of hundreds of units triggered by PACE.
- An FC unit developed using the INNO-SOFC know-how will be commercially sold.
- Use of expertise from actors not having a background in the hydrogen technologies alone (e.g. smart grids).
- A variety of manufacturing process designs are being supported.
- Several developments from previous FCH 2 JU projects were carried over in projects considered in this year's portfolio.
- Significant progress in advancing the general SoA for SOFC, improved understanding of degradation processes and availability of effective diagnostic tools were reported.

Additional focus needed

- Project strategies rely on volumes (market demand) if costs are to be driven down.
- Manufacturing consortia are closed around a single manufacturer.
- In general, testing seems to be working fine at cell level but struggling at stack level.

3.5. PANEL 5 – HYDROGEN FOR SECTORAL INTEGRATION

The projects in Panel 5 contribute towards achieving the techno-economic objectives of making hydrogen production from RES competitive, with a clear focus on demonstrating high-capacity electrolysis, demonstrating hydrogen as a medium for energy storage, and sector coupling. Green hydrogen production systems are being designed for integration in the energy system and industrial processes. The technologies involved have different technology maturity and potential market size. Six 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;
- innovative green hydrogen production methods for sustainable hydrogen production – development of hydrogen production technologies with long-term potential;
- hydrogen territories;
- hydrogen separation;
- hydrogen storage and distribution.

This report covers the 25 projects highlighted in black in Figure 31. Following the calls between 2008 and 2018, the FCH 2 JU supported 59 projects relevant to this panel with a total FCH 2 JU contribution of EUR 166 million and a contribution from partners of EUR 117 million[35].

The distribution of funding over eight focus areas considered in this panel is shown in Figure 32. In total, 66 % of Panel 5 FCH 2 JU funding went to electrolysis (48 % of Panel 5 FCH 2 JU funds supported LT electrolysis and 18 % supported HT electrolysis).

For the 2019 review, the FCH 2 JU funding contribution amounts to about 72 % of the total funding for the portfolio of projects. For the 25 projects under review, 58 % of the funding budget was allocated to low-temperature (LT) electrolysis projects and 17 % to HT electrolysis, with the remaining 25 % distributed among all other topics. Figure 33 shows the cumulative contribution to projects working on various electrolyser technologies from 2010 onwards.

35 These figures include the overarching project BIG HIT which attracts EUR 5 million of FCH 2 JU funding, split between the Energy (EUR 2.5 million) and Transport (EUR 2.5 million) pillars, as well as MEMPHYS, which is funded by Energy (EUR 1 million) and Transport (EUR 1 million).

Figure 31: Date ranges of Hydrogen for Sectoral Integration projects in the Energy pillar. Projects highlighted in bold are included in PRD 2019

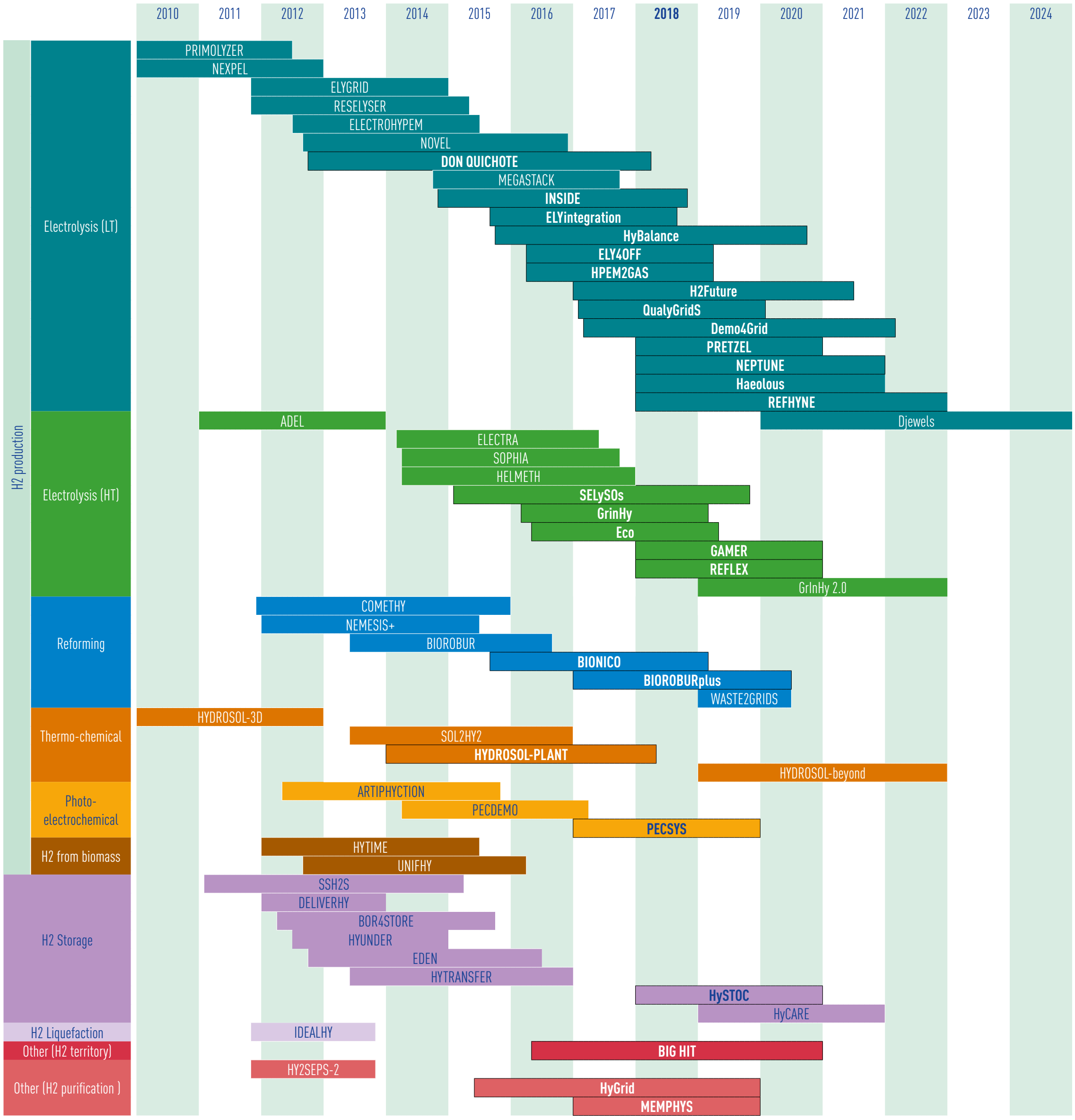


Figure 32: Funding for Panel 5 (Hydrogen for Sectoral Integration – Energy) from 2008 and including the 2018 calls

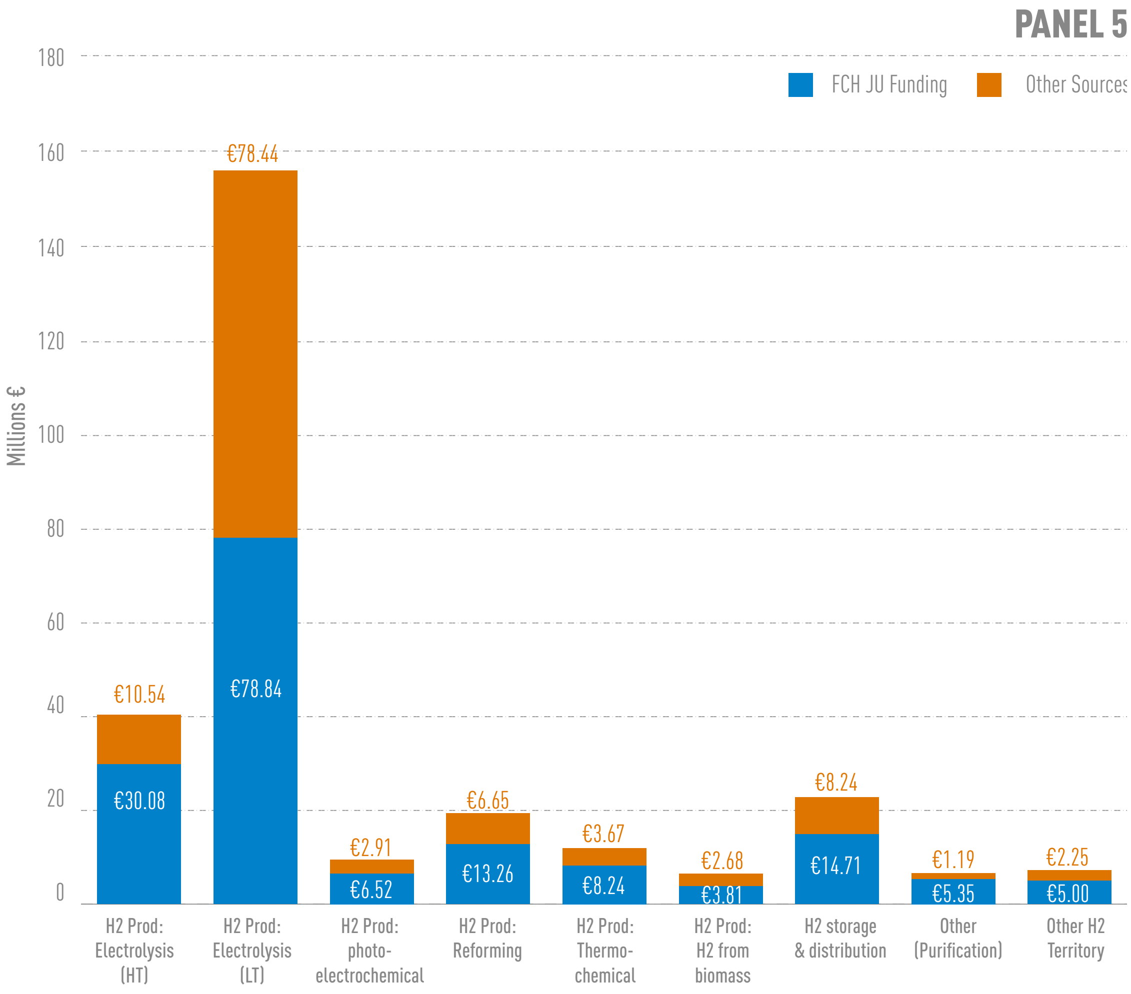


Figure 33: Cumulative EU funding for projects related to different electrolyser technologies

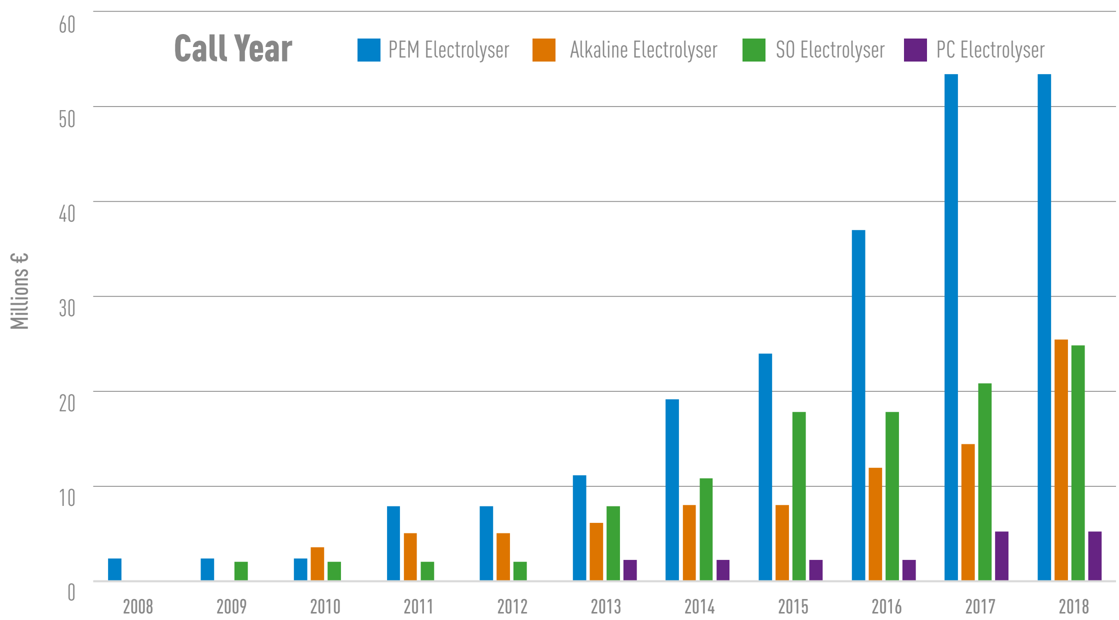
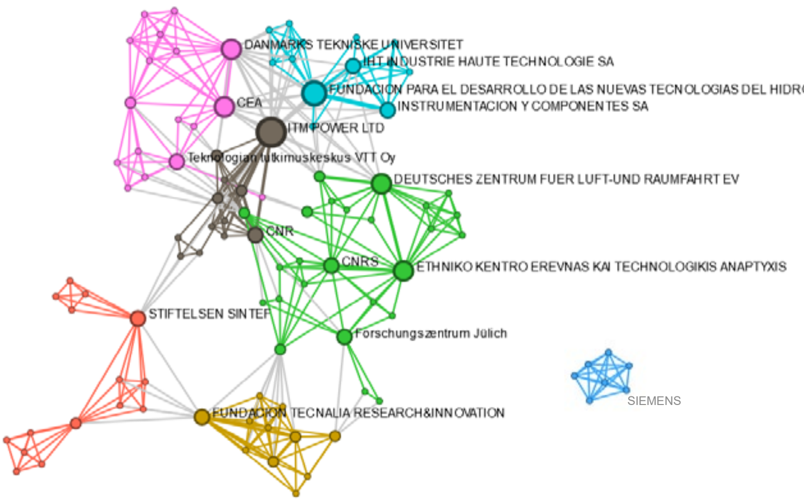


Figure 34[36] shows the connections between partners in the projects in Panel 5. The participants of projects grouped under Panel 5 have strong links to each other, with the exception of H2FUTURE, which is somewhat surprising given the diversity of the technologies supported. The key participants in this panel are the universities and research institutes CEA, FHA, DTU, DLR and CERTH and electrolyser manufacturer ITM Power.

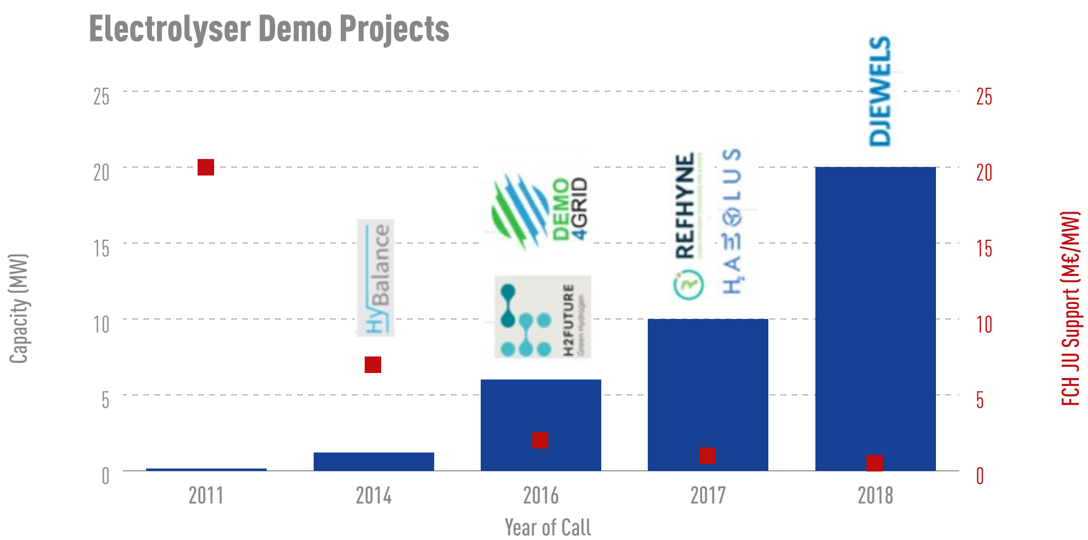
Figure 34: TIM plot showing the participants in the 25 projects in Panel 5



Participant	Number of projects
ITM POWER	6
FUNDATION HIDROGENO DE ARAGON	5
CEA	4
DANMARKS TEKNISKE UNIVERSITET	4
DEUTCHES ZENTRUM FUER LUFT UND RAUMFAHRT EV	4
ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	4

The focus area **low temperature electrolysis** currently consists of 12 projects: two on alkaline electrolysis, eight on PEM electrolysis, one on testing protocols for grid services and one on monitoring/diagnostics. Figure 35 shows that funding received by demonstration projects has decreased significantly with installed capacity.

Figure 35: Capacity of electrolyser demonstration projects vs. project funding per MW

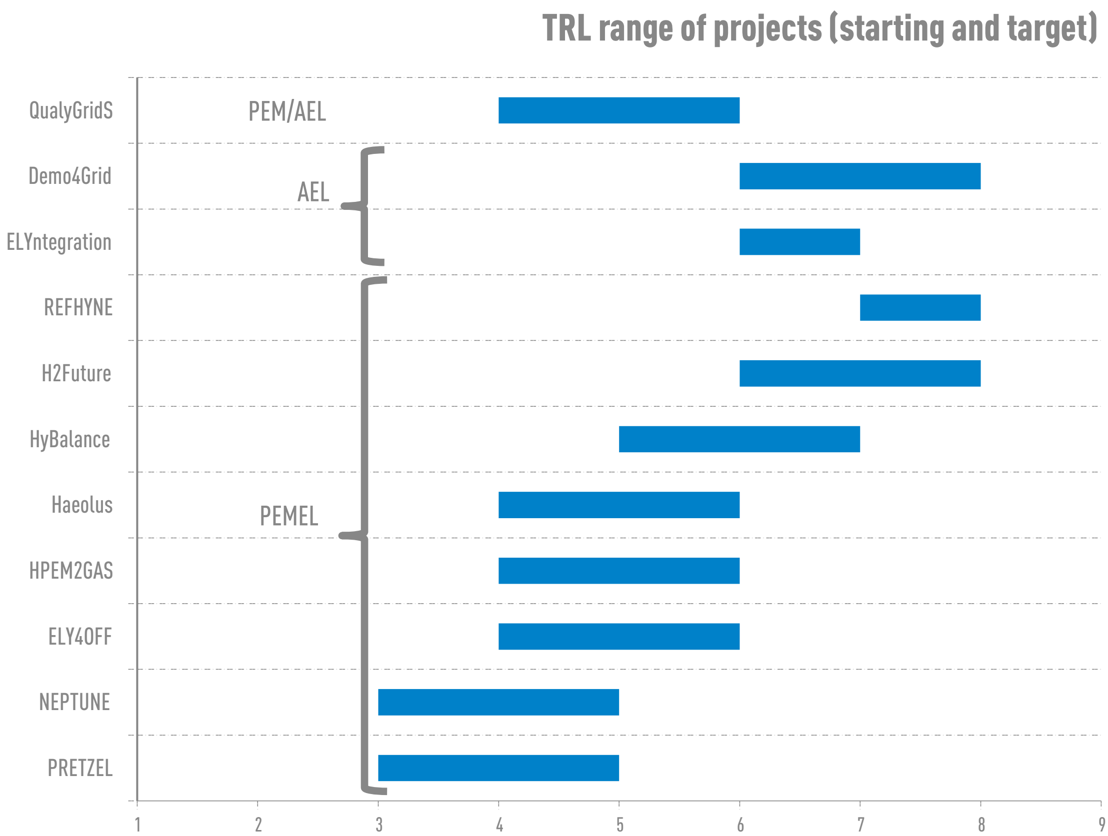


36 The size of the node (circle) represents the number of projects a partner is involved in, while the thickness of the lines linking the nodes represents the number of projects two partners have in common.

The FCH 2 JU has also supported the deployment of LT electrolysers for providing hydrogen for refuelling in transport applications. In several projects in the Transport pillar (Panel 1), electrolysers are being demonstrated as onsite hydrogen generation systems, with several MW of capacity. The electrolysers deployed in the Transport pillar projects are not being evaluated as part of this focus area. Additionally, BIG HIT has deployed a 1 MW PEM electrolyser. Even if considered in Panel 5, BIG HIT is classified as an overarching project, meaning it receives financing from both the Energy and Transport pillars.

Figure 36 shows that PEM electrolysis projects have a large range of start and target TRL, with an overall range covering TRL 3-8, while alkaline electrolysis projects have an overall TRL range between 6 and 8.

Figure 36: TRL range of LT electrolyser projects



Alkaline electrolysis: The main focus of the projects DEMO4GRID and ELYNTEGRATION is to demonstrate alkaline electrolyser (AEL) technology in environments where dynamic operation is needed, such as the provision of grid services. Apart from addressing the general challenge of integration of electrolysers with RES, cost reduction and upscaling are key aims of these projects. The AEL developed under the project ELYNTEGRATION (finished May 2019) has achieved an operational range of 15 to 130 % of rated power. The system has also been optimised for highly dynamic operation with a hot idle ramp time of 2 seconds. The system lifetime is stated as 30 years. Another important project achievement is a system efficiency of 52 kWh/kg H_2. The advanced components and materials developed in the project were tested with accelerated stress tests (AST) procedures, and input on testing procedures was provided to the QUALYGRIDS project. The stack design developed in this project was then implemented at a larger scale in the DEMO4GRID project, which will install a 3.2 MW pressurised AE. The project has a target of manufacturing costs for the single-stack PAE below EUR 725/kW, excluding some external components. Once operational, the hydrogen produced will be combusted for a hydrogen-to-heat application in the food industry. Additional revenues are expected from the provision of grid balancing services. The business case analysis showed that among the most important factors for profitability were the cost of electricity and the geographical location of the investment, reflecting a lack of harmonisation of the regulatory framework between Member States.

PEM electrolysis: The EUR 55 million awarded to PEM electrolysis projects since the beginning of the programme has enabled a remarkable advance by the SoA for this technology. For the projects under review this year, four groups can be distinguished.

Large-scale production of hydrogen for industry: The high-pressure 1.25 MW PEM electrolyser deployed as part of the HYBALANCE project has been designed by Hydrogenics specifically for dynamic production of hydrogen to provide electricity grid services. The electrolyser will be operated by following electricity price signals. Appropriate hydrogen demand in the area is one of the challenges. The project is linked to the nationally funded study Power2Hydrogen, which investigated the potential for sector coupling through hydrogen in Denmark.

Through the H2FUTURE project, an atmospheric pressure 6 MW PEM electrolyser, developed by Siemens, will be installed and operated at the Voestalpine Linz steel plant in Austria. The aim is to show that the PEM electrolyser is able to produce green hydrogen dynamically from RES and to provide grid services for additional revenue. The hydrogen produced will support fossil fuel-based steelmaking technology, as part of a decarbonisation approach to steel production proposed by the steel manufacturer. In the future, the direct reduction of iron ore by hydrogen will lower the carbon footprint of steelmaking significantly.

The REFHYNE project plans to deploy a high-pressure 10 MW electrolyser of ITM Power at a Shell refinery, also providing grid services. The project has finalised a detailed engineering design for the electrolyser system, fulfilling the refinery requirements. A highly dynamic operating mode would be enabled through the targeted hot start time of 1 second. Another outcome will be an analysis for policymakers recommending changes to existing policies.

Next-generation PEM electrolyser: The main challenges for electrolysers targeting large-scale provision of hydrogen to industry customers is reduction of the cost of hydrogen. The HPEM2GAS project has succeeded in lowering energy consumption at high current densities, as well as reduced degradation, at low PGM loading. The 180-kW prototype system with the newly developed components is being validated in a field test to demonstrate the provision of grid services. The hydrogen produced will be injected into the local gas grid. The outcome of this project will be taken up by the 2018 call project NEPTUNE, which is aiming to achieve a current density of 4 A/cm^2 at low PGM loading. An increase in output pressure to 100 bar is targeted, while retaining the nominal energy consumption of <50 kWh/kg H_2. The operation of an electrolysis cell at 140 °C has been demonstrated. NEPTUNE is addressing the challenge of reducing membrane thickness. The newly developed components will ultimately be demonstrated in a system of 48 kW capacity.

The PRETZEL project aims to reduce CAPEX by operation at a high current density of 4 A/cm^2 and 100 bar, at a maximum temperature of 90 °C. The novel stack, which will be integrated in a 25-kW system, is based on a hydraulic concept for pressurisation, for which the stack is encased in a pressure vessel. This concept could enable a homogeneous pressure and current distribution independent of the size of the active area, which is expected to decrease degradation.

Remote areas: In remote regions or islands with high potential of RES but high curtailment rates, power is often supplied by highly polluting diesel generators. The main goal of the ELY4OFF project is the development and demonstration of an autonomous off-grid, high-pressure (20 bar) electrolysis system of 50 kW linked to RES. The ITM Power electrolyser has a nominal efficiency of 82 % and a 150 % maximum overload capacity. The project (finished in 2019) has performed its demonstration phase of the integrated system also including lead-acid batteries, PEMFC and hydrogen storage. By using a photovoltaic ELY4OFF system, a reduction of 62 % of GHG emissions can be achieved, compared to hydrogen from steam methane reforming.

HAEOLUS will deploy a 2.5 MW high pressure (Hydrogenics) electrolyser with a rated system efficiency of 76 % and a current density of 2 A/cm^2. In a remote location in Norway, the project plans to combine wind power and hydrogen production by several modes of operation (re-electrification, mini-grid, fuel production). Based on local electricity costs, the plant could be able to produce hydrogen for a cost of EUR 4-5 /kg. Among the possible operation cases, energy storage with subsequent re-electrification is being considered. HAEOLUS will develop and test control strategies for each mode of operation in wind-hydrogen systems: energy storage, mini-grid and fuel production. The results will be relevant to many wind farms across Europe and worldwide. The project also aims to use the oxygen produced in an adjacent fish farm, which would make it the sole FCH 2 JU project using both gases produced by the electrolyser.

The BIG HIT project is demonstrating several hydrogen energy solutions in the Orkney Islands, which has a poor grid connection to the mainland and is therefore facing curtailment of RES of around 30 %. Hydrogen will be used in Orkney for power, heat and transport applications, and serves to both store and transport energy. BIG HIT has deployed a 1 MW high-pressure electrolyser, hydrogen trailers, HRS, hydrogen boilers, FCs and five FC vans. Part of the hydrogen will be transported via ferry to another island. For this model to be replicated in other remote territories, a tool has been prepared to enable the sharing of experiences. The project has a close link to two national projects: SURF & TURF and PITCHES. The implementation of hydrogen technologies as part of the BIG HIT project can enable a significant reduction in GHG emissions compared to the current energy system.

Testing protocols and monitoring tools: The INSIDE project has developed diagnostic tools for monitoring locally resolved current densities in water electrolysers and contributed to the development of AST protocols. Segmented bipolar plates for locally resolved current density measurements for alkaline, PEM and anion exchange membrane water electrolysers were developed. QUALYGRIDS has developed testing protocols for AEL and PEM electrolysers considering a variety of grid services as well as multiple hydrogen end users. The grid service tests have been experimentally validated on different types and sizes of electrolysers, to establish which services can be performed. The project has also identified the necessary system adaptations made by OEMs to provide grid services, such as accurate power control. The testing protocols will be used for the development of a standard. In the focus area **high-temperature electrolysis**, the main research directions of the projects ECO, GAMER, GRINHY, SELYSOS and REFLEX, apart from addressing MAWP targets such as increased efficiency and lifetime, are co-electrolysis and reversible operation. All of these projects are aiming to achieve TRL 5.

The GRINHY project has built, and operated in a steel mill, a 180 kW SOEL plant with a 20 % reversible capacity. The prototype has been running for around 10 000 hours in electrolysis, FC or hot standby mode, reaching electrical efficiencies of 78 % lower heating value (LHV) (without drying and compression) in electrolysis and 52 % LHV in FC mode, with a nominal power of 25 kW. The HTE/HTFC can provide a positive and negative load for grid services. For operation under variable loads, the long-term stability of the cells has to be maintained, with degradation rates in line with the MAWP targets. A low degradation rate of 0.4 %/1 000 hours was observed, which is an encouraging result regarding the suitability of solid oxide electrolyser cells (SOEC) for dynamic operation[37]. GRINHY is followed by the GRINHY2.0 project (not under review this year), which will implement a (non-reversible) 720 kW electrolyser at Salzgitter.

The REFLEX project is developing reversible solid oxide cell (rSOC) technology to be implemented as an integrated energy storage solution (smart energy hub) at community/district level. The project aims to reach an efficiency > 80 % higher heating value in SOEC mode and > 55 % LHV in SOFC mode with CH_4 fuel supply. Achievements of this ongoing project include a current density of 1.25 A/cm^2 at 700 °C in SOEC mode, and fuel utilisation of 85 %. Among the remaining challenges are improving durability and lowering system costs.

37 Schefold, J. et al., 80 000 current on/off cycles in a one-year steam electrolysis test with a solid oxide cell, *International Journal of Hydrogen Energy*, 2019.

The ECO project investigates the durability of operating an electrolyser in co-electrolysis mode and has achieved a degradation rate below 1 %/1 000 hours. Electrode optimisation has led to a reduction of the operating temperature by 50-100 °C. The project has also performed techno-economic analysis for several case studies (cement plant, gasification unit and methanation plant, or biogas upgrading unit). For gasification and methanation, the ECO concept enables a 66 % increase in the production of methane by recovering the CO_2 contained in the biogas. The project has investigated the effect of impurities in the CO_2 stream and found that more research is needed to assess long-term effects.

The SElySOS project is testing modified Ni-based and Ni-free cathodes and new air electrodes, seeking to enable the development of new SOECs less prone to degradation, and with improved performance and stability. Experimental work is combined with theoretical modelling to understand reaction mechanisms and processes that cause degradation. The GAMER project, building on the results of the project ELECTRA, aims to build a 10-kW electrolyser integrating proton-conducting ceramics based on tubular electrochemical cells (PCEL) that can be operated at a lower temperature as protons have a lower activation energy than oxide ions. The cells will be tested at intermediate temperature (500-700 °C) and pressures enabling 30 bar outlet pressure. PCEL can produce dry hydrogen and, unlike SOEL, any unreacted steam does not dilute it. This project, if successful, will strengthen European leadership for PCEL technology, as the international SoA appears at lower TRL. A degradation rate of 2 %/500 hours has been observed during testing, meeting the project target.

In the focus area **reforming,** decentralised hydrogen production from biogas through reforming is the target of two ongoing projects, BIONICO and BIOROBURPLUS. Both projects aim to demonstrate the technology in the relevant environment (TRL 6) and the size of the reformers is similar, with a capacity of around 100 kg H_2/day. According to a literature study[38], hydrogen production from biogas could have less than half the CO_2 footprint[39] of conventional reforming from natural gas. Both projects aim to improve the reactors' resistance to impurities in the biogas, reducing the need for upgrading of raw biogas (and associated energy demand and cost).

The technology developed by the BIOROBURPLUS project is oxidative steam reforming (OSR), whereas the predecessor project BIOROBUR tested autothermal reforming. OSR enables flexible operation, well suited for integration with a biogas plant. The LCA performed by the BIOROBUR project revealed that there is a strong impact of the gas purification system on GHG emissions, therefore reduction of the energy consumption of this stage has a high environmental benefit. In the last part of the project, the concept will be demonstrated in a biogas facility. If the testing campaign proves successful, this technology should reach TRL 6.

Building on the achievements of numerous predecessor projects, the BIONICO project is developing and testing a catalytic membrane reactor (CMR). Here the separation of hydrogen is integrated, which enables cost and energy savings on downstream purification. The single-stage reactor will decrease the volume and the need for auxiliary heat management units. The project has developed and produced 120 Pd-based ceramic-supported tubular membranes able to work at high temperature (550 °C) for the pilot reactor. According to simulations, 72 % efficiency could be achieved. The cost of hydrogen produced is estimated to be approximately EUR 4/kg, lower than the reference cases considered[40].

38 Hajjaji, N. et al., Life cycle assessment of hydrogen production from biogas reforming, *International Journal of Hydrogen Energy*, 2016, 41(14): pp. 6064-6075.

39 According to the study, 96 % of the GHG emissions derive from the anaerobic digestion plant and are mainly due to methane emissions from the digestate.

40 Such as steam methane reforming and autothermal reforming for raw biogas reforming, at a hydrogen delivery pressure of 20 bar.

In the focus area **thermo-chemical hydrogen production**, the MAWP 2020 targets for high-temperature water splitting specify a system energy use of 100 kWh/kg H_2, system capital costs of EUR 2 500/(kg/day), and a system lifetime of two years. The Hydrosol-Plant project has demonstrated the production of hydrogen through thermo-chemical cycles and completed construction and integration of the 750 kW_{th} solar reactors and peripherals on the solar platform. At lab scale, it has exceeded 3 kg/week hydrogen production with a durability of more than 1 000 hours of the redox material. This is the largest solar redox reactor in the world to date, putting Europe in a leading position for the implementation of this technology. The project has been extended for 18 months in order to reach some critical targets. The development of redox materials and structures with enhanced stability will be further taken up by the follow-up project HYDROSOL-beyond.

In the focus area **photo-electrochemical hydrogen production**, the PECSYS project is targeting the development of an integrated PV-electrochemical cell device up to prototype scale. The targeted application is to provide a decentralised energy supply for residential buildings or smaller commercial buildings. By directly coupling an electrolyser to rooftop PV panels, easily storable hydrogen can be produced, even in off-grid situations. If successful, the project will build a 10 m^2 integrated device, which would be one of the largest single unit photovoltaic integrated electrolysers ever demonstrated. 8.5 % solar-to-hydrogen efficiency has been demonstrated (KPI target of 10 %) at a hydrogen generation rate of 2.75 g/h/m^2 (ambient conditions 1 000 W/m^2, 25 °C) for a 100 cm^2 CIGS/NiO|NiMoV unit. The project aims to improve catalysts based on earth-abundant metals for the CIGS approach.

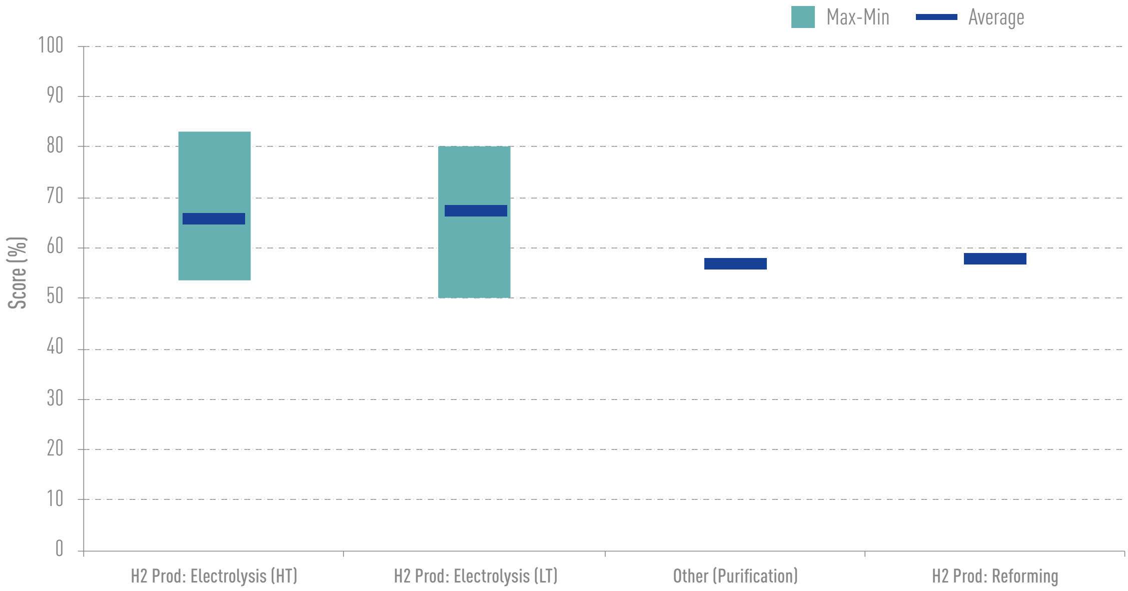
Regarding the focus area **hydrogen storage and distribution,** liquid organic hydrogen carriers (LOHC) are compounds able to release or accept hydrogen. These compounds are interesting for hydrogen distribution, as they have a high volumetric energy density, are liquid at room temperature, can be stored and transported at ambient conditions for long periods without significant losses, and can be handled in infrastructure already employed for liquid fossil fuels (e.g. ship tankers). The HYSTOC project is aiming to develop and demonstrate a storage system for supplying HRSs; the LOHC being considered is dibenzyltoluene. Heat integration of both hydrogenation and dehydrogenation processes can help reduce the overall energy demand. According to the market analysis, the cost of LOHC-based storage and distribution could be significantly lower than compressed or liquid hydrogen options.

In the focus area **other hydrogen purification**, the HYGRID project is focusing on hydrogen separation from a mixture with natural gas, thereby supporting the possible transport of hydrogen through the natural gas grid and then separating it at the location where it is needed. The targets for hydrogen separation technologies are recovery rates above 95 %, for mixtures containing less than 10 % of hydrogen in H2NG. Under these conditions the cost of hydrogen should be less than EUR 1.5/kg and the energy efficiency of extraction of hydrogen from very low hydrogen concentration streams should be below 5 kWh/kg. The potential market for this technology depends on the scale of implementation and the cost of hydrogen. The project MEMPHYS is working to overcome the technical challenges of a low-energy electrochemical hydrogen purification system, which combines purification and compression to 200 bar in a one-step process. The concept is based on electrochemical hydrogen pumping. The project builds on the results of numerous predecessor projects, such as DON QUICHOTE and PHAEDRUS. It aims to achieve an energy consumption of < 5 kWh/kg H_2. With this approach, the purification of hydrogen is to be achieved by using a set of selective membranes. Working with a 50 % concentration of hydrogen in a matrix gas, a recovery rate of 90 % is targeted.

3.5.1. PANEL 5 – SUMMARY

The overall assessment of the projects in Panel 5 is shown in Figure 37. In addition to the average, the range between minimum and maximum ratings for the focus areas with more than three projects are shown (LT and HT electrolysis). The range of scores for LT and HT electrolysis projects shows that, in general, the projects largely achieve their objectives.

Figure 37: 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

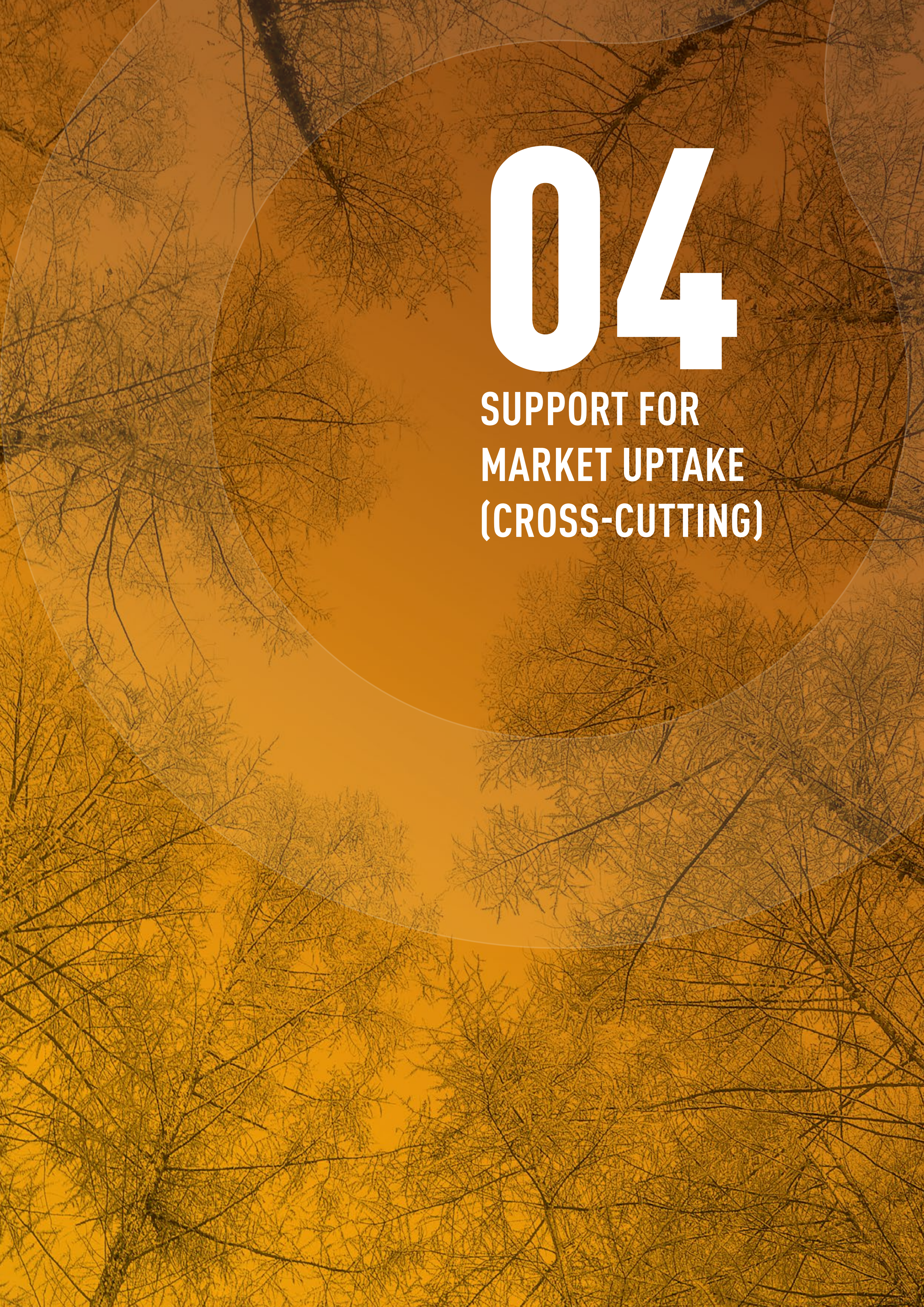


Strengths

- Europe is currently a world leader in PEM electrolysis and SOE technologies. LT and HT electrolysis projects advance the SoA, ensuring the competitiveness of European manufacturers.
- Newer concepts such as next-generation PEM electrolysis are being developed.
- Demonstration projects in relevant environments and at an increasing scale attract interest from industry and policymakers.
- The installed capacity of electrolysers has increased significantly over recent years.
- Some MAWP 2020 targets have already been exceeded, for example in PEM electrolysis.
- Sustainability aspects are investigated by several projects through LCA.

Additional focus needed and follow-up actions

- With an increase in operating hours, CAPEX has less influence on the cost of hydrogen.
- Definition of specific KPIs for electrolysis in dynamic and steady-state operations is needed.
- Specific call topics are needed to address fundamental KPIs such as current density/ degradation rate/system efficiency levels for AEL.
- For further research and development, a prioritisation should be made or the overall budget specifically for SOEL development should increase.
- More efforts are needed to increase production capacity to the MW range.
- There is a need to establish whether palladium membranes are ready for upscaling.
- The business case and environmental benefits of admixture of hydrogen with natural gas need to be carefully evaluated.
- Fundamental performance targets need to be provided for clearly defined standardised conditions. An update of KPI definitions by the FCH 2 JU is needed.



04

SUPPORT FOR MARKET UPTAKE (CROSS-CUTTING)

4.1. OBJECTIVES

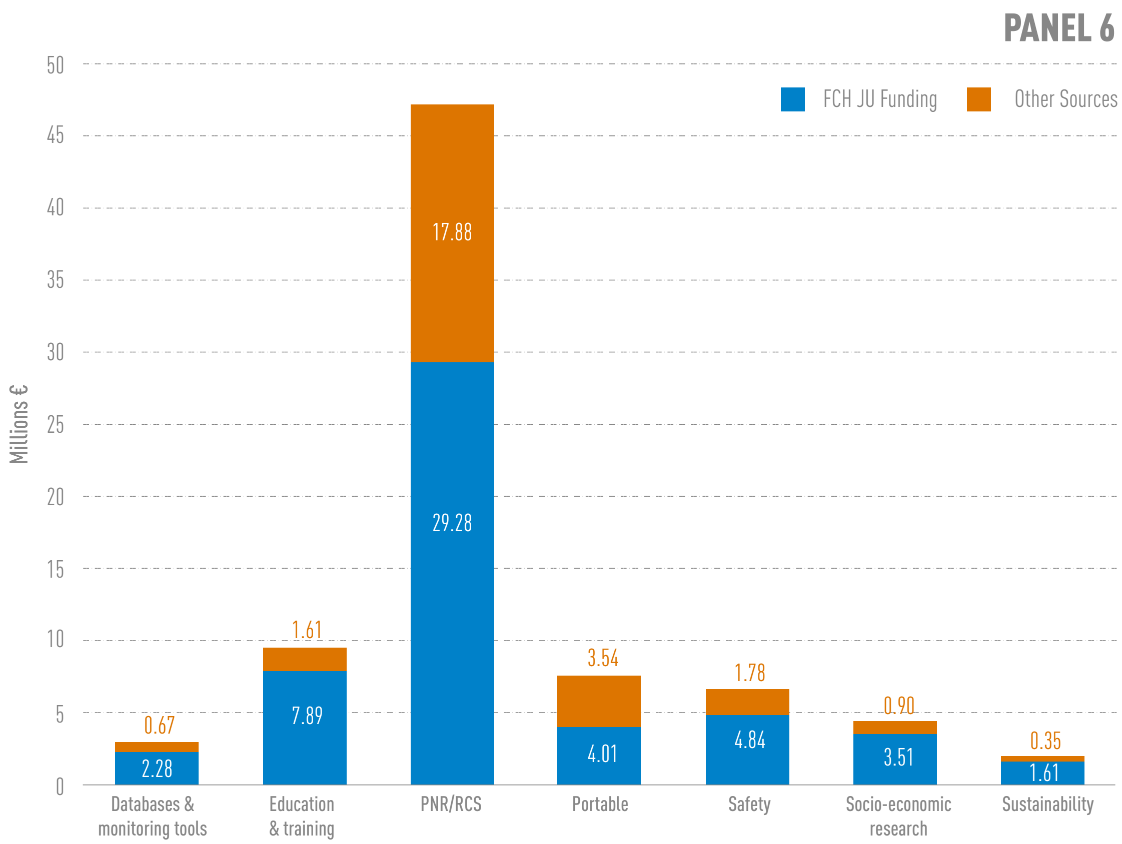
Support for Market Uptake (Cross-cutting) activities support the whole programme horizontally. Projects are intended to support market preparation and readiness by:

- providing new knowledge for improved 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 social acceptance;
- characterising and improving the environmental footprint of FCH technologies.

4.2. BUDGET

To date (2008 to 2018 calls), the FCH 2 JU supported 40 projects relevant to this panel with a total contribution of EUR 53.4 million complemented by EUR 26.7 million of other contributions. The proportion for these activities is approximately 5.8 % of the total budget. The distribution of total historical budgets over the seven focus areas is shown in Figure 38.

Figure 38: Funding for Panel 6 Support for Market Uptake (Cross-cutting) from 2008 and including the 2018 calls



4.3. PANEL 6 – SUPPORT FOR MARKET UPTAKE (CROSS-CUTTING)

In line with the MAWP, the Panel 6 projects portfolio supports a number of distinct fields (with emphasis on the first three):

- Pre-normative research (PNR) and input into RCS;
- Safety aspects – strongly related to the previous field, it covers all aspects from studies on fundamental hydrogen behaviour up to safe deployment of FCH technologies in all the envisaged applications;
- Education and training;
- Socio-economic research - increase of social acceptance and public awareness.
- Supporting the development of specific tools for the sustainability assessment, LCA methods, and recycling and dismantling aspects.
- Databases on environmental, economic and socio-economic aspects, supporting the knowledge management activity.

The 2019 Review covered the eight projects highlighted in black and with bigger font names shown in Figure 39.

Figure 39: Date ranges of Support for Market Uptake (Cross-cutting) projects. Projects highlighted in bold are included in PRD 2019

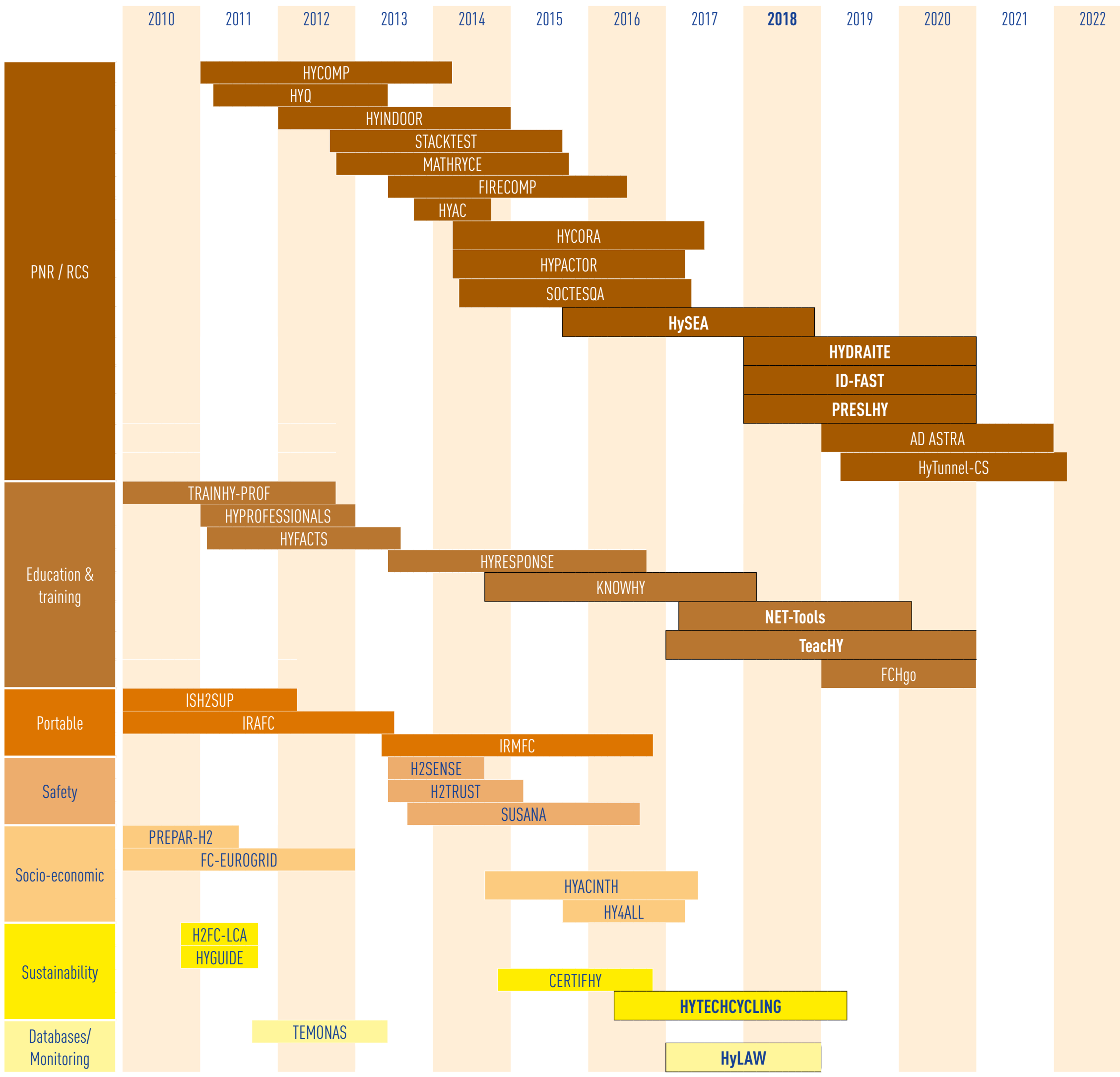
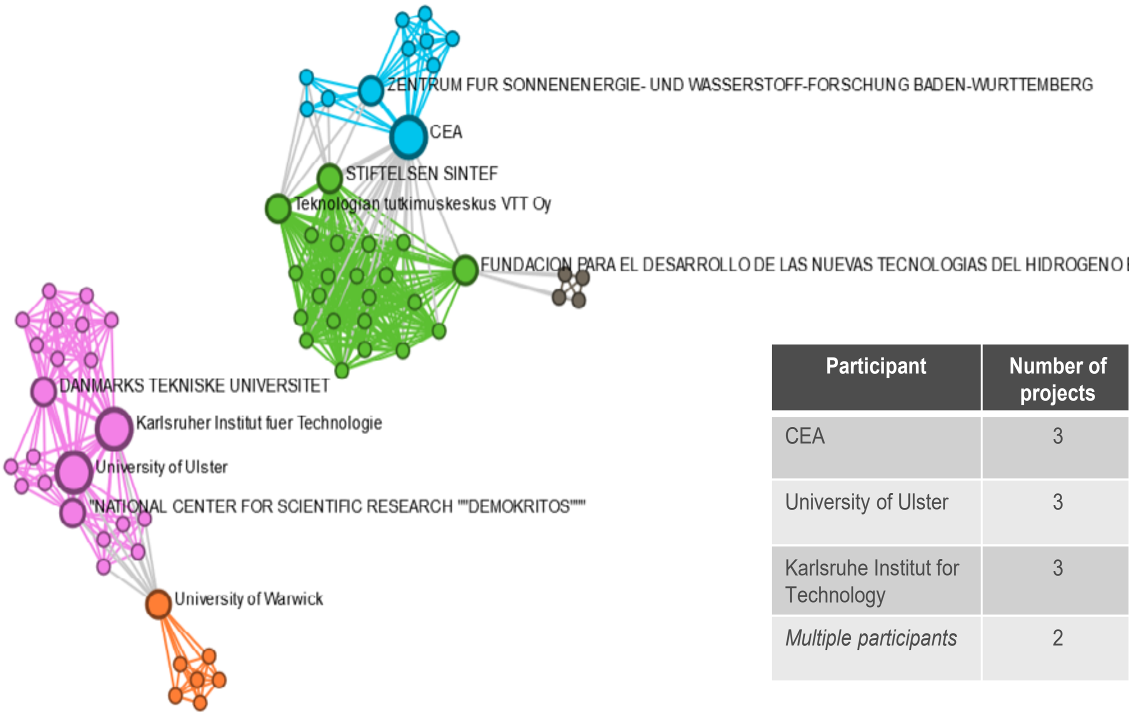


Figure 40[41] is a plot produced using TIM (as described in Section 1.3). This shows the connections between partners present in the projects in Panel 6. In general, there is major participation of public research centres and universities in the Support for Market Uptake (Cross-cutting) activities. This is not completely surprising, considering the predominant public dimensions in this portfolio: from public safety (HySEA, PRESLHY) and legal barriers analysis (HyLAW) to public education (NET-TOOLS, TEACHY). Moreover, consortia of Panel 6 are clustered in two separate islands, with some participants active in two or three consortia. A cluster is formed around the two projects exclusively focused on specific safety topics, reflecting the specialised competences necessary to advance specific safety themes.

Figure 40: TIM plot showing the participants in the eight projects in Panel 6



Participant	Number of projects
CEA	3
University of Ulster	3
Karlsruhe Institut for Technology	3
Multiple participants	2

The focus area **PNR/RCS** is mainly composed of four PNR projects: HYDRAITE, ID-FAST, HySEA and PRESLHY. HYDRAITE studies the effects of hydrogen contaminants on FC systems in automotive applications, building on the results of the previous project HyCORA. A major achievement of this project is the development in Europe of certified laboratories capable of measuring hydrogen impurities against the entire set of species according to the specifications laid down in international standards. Part of the overall challenge is the implementation of a method for in-line continuous monitoring of the fuel quality at hydrogen dispensers and the support to international standardisation activities in the field, specifically to the revision of the standard ISO 14687 on hydrogen fuel quality specification.

Project ID-FAST is developing AST for PEMFC in automotive applications and a methodology allowing durability prediction. This project fits well into a multiannual effort for the identification of realistic performance indicators. Beneficial from the point of view of the FCH 2 JU programme, AST tests will

41 The size of the node (circle) represents the number of projects a partner is involved in, while the thickness of the lines linking the nodes represents the number of projects two partners have in common. For clarity, only the partners involved in the largest numbers of projects are named.

allow a shorter testing time. Finally, ID-FAST plans to propose a new working item to the International Electrotechnical Commission IEC TC 105 standard on FC technologies.

The PNR/RCS dimension is coordinated at programme level by the RCS Strategy Coordination Group (SCG), which is industry-led. The overarching goal of the RCS SCG is to set and implement a strategy enabling the development and use of harmonised performance-based standards for FCH appliances and systems. The FCH 2 JU tests harmonisation working groups are another initiative aiming at a coordinated approach on how projects assess technical progress.

The two projects in the focus area **safety** (HYSEA and PRESLHY) also have a genuine PNR/RCS dimension. HySEA has studied the behaviour of hydrogen releases in semi-confined spaces by means of full-scale field experiments, and by validated computer models. The project has produced an impressive collection of experimental evidence, enabling improved understanding and increased prediction capabilities. PRESLHY tackles the safety of liquid hydrogen, with the very ambitious goal of closing knowledge gaps related to its behaviour in accidental conditions. PRESLHY is the first European project for more than 10 years dedicated to the study of liquid hydrogen. Safety-related findings from these projects will be used, as far as possible, to formulate safety requirements in standards and regulations presently under development. Table 4 specifies the contribution to the safety dimension given by these and other projects belonging to the PNR area.

Table 4: Safety dimensions of Panel 6 projects

Support for Market Uptake (Cross-cutting) projects with a safety dimension	Focus area	Project contribution to safety assessment and safety progress
HYSEA	PNR/RCS	Improving hydrogen safety for energy applications through pre-normative research on vented deflagrations
PRESLHY	PNR/RCS	Closure of knowledge gaps related to liquid hydrogen behaviour in accidental conditions related to the new public use cases
NET-Tool	Education	Safety and pre-normative research is an integral part of the e-laboratory
TEACHY	Education	One of the training modules is dedicated to all aspects of hydrogen safety
HYLAW	Databases	Safety is an important and often critical dimension of the regulatory/ legal requirements
HyDRAITE	PNR	Safety-related aspects for hydrogen sampling in HRSs

The European Hydrogen Safety Panel (EHSP), formed in 2017, has the goal of coordinating safety strategy at programme level. In the 2018-2019 period, the EHSP delivered a first draft multiannual safety roadmap and a handbook on safety planning for projects. It has also reviewed all data in the HIAD2.0 database, aiming to identify lessons learned, and provided, reviewed and streamlined other sources of data, enabling a major expansion of the dataset in 2019. Recently the EHSP has also started engaging with projects requiring assistance on safety aspects (awareness, consultancy, assessment).

The focus area **education and training** is composed of the projects NET-TOOLS and TEACHY. NET-TOOLS focuses on developing new e-education methods based on ICT tools, enhancing the knowledge, productivity and competitiveness of those interested in FC and hydrogen technology deployment, addressing a broad range of groups and educational levels – from high schools and universities (undergraduate and graduate students) to professionals and engineers from industry. The tangible output of NET-TOOLS will be an e-learning platform based on open-source software. The project TEACHY is developing learning tools and materials addressing a broad range of customers, mainly university students (undergraduates and postgraduates), but it also includes vocational training. The overarching goal of the project is to offer students across Europe access to high quality, harmonised, and certified training material. A major effort is the development, trial and deployment of a master's course in various European universities.

The focus area **sustainability** is composed of the project HYTECHCYCLING (2016-2019), which studies recycling, dismantling technologies and strategies applied to the whole FC and hydrogen technology chain, thus paving the way for more effective future demonstration actions and advances in legislation. A major achievement has been the identification and classification of critical materials in FCs (PEMFC and SOFC) and water electrolysers (alkaline and PEM), and their material flows in existing recycling and dismantling technologies. The project represents a first structured approach to the critical raw material challenge.

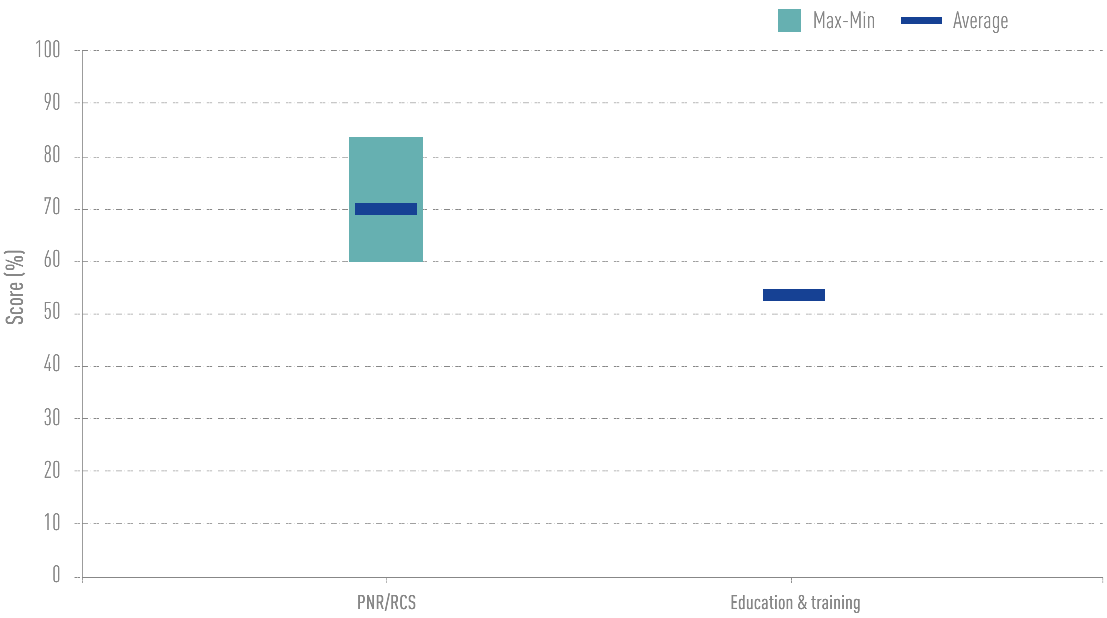
In the **socio-economic** focus area, HYACINTH has delivered a methodology to explore supportive acceptance, barriers and challenges, and to develop communication strategies and other means to manage acceptance processes. It can be used by demonstration projects for involving local communities and pave the way to social acceptance.

In the focus area **databases,** the project HYLAW (2017-2018) has performed a complete analysis of the legal rules applicable to FC and hydrogen technology deployment at Member State level, mapping the relevant legal frameworks and administrative processes. An interactive online database allows for a publicly accessible, detailed and well-structured assessment of the findings. HYLAW has also identified and ranked related barriers and provided recommendations on how to improve them. The project NET-TOOLS will offer an e-learning platform that will work as a meta-database, linking to existing ones. Experimental data from HySEA have allowed benchmarking of computational fluid dynamics models and have been shared with the scientific community at large. At programme level, the HIAD2.0 and HELLEN databases contain the description and analysis of safety-related events along the FC and hydrogen whole technology chains.

4.3.1. PANEL 6 – SUMMARY

The average assessment of focus areas is shown in Figure 41: where three or more projects are available, in addition to the average, the minimum-to-maximum range is also shown. Figure 41 confirms the good to excellent performance of PNR projects in this panel and the need to address the specificities of education and training deliverables.

Figure 41: 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

- The two projects on hydrogen safety included in this review will deliver a critical contribution to understanding hydrogen behaviour under realistic release conditions.
- In recent years, the FCH 2 JU has succeeded in covering the gap originally existing between PNR projects and their natural utilisation for standardisation goals.
- Project HyLaw has delivered the first mapping and analysis of the legal and administrative barriers to deployment of FC and hydrogen technology at EU Member State level, with specific recommendations to policymakers.
- In the area of education and training, FCH 2 JU learning tools will be available to a broad range of users, from technicians and professional operators to university students, regulators and public safety officials, including emergency responders.
- The project HYTECHCYCLING has addressed, for the first time in a coordinated way, the aspects of sustainability and the circular economy.
- At programme level, the FCH 2 JU has achieved further progress in the strategic coordination of RCS themes.

Additional focus needed and their follow-up actions

- The RCS SCG should organise annual workshops to bring together the RCS community, including the EHSP, and selected demonstration projects.
- Before planning further activities in the education and training focus area, the FCH 2 JU or one of its members should analyse how all the training and education tools and services have been used so far.
- The FCH 2 JU or one of its members should evaluate how present and past demonstration projects have planned and implemented public engagement actions.
- The RCS SCG should investigate and evaluate the possibility of implementing a permanent and strategic role for the FCH 2 JU (or Hydrogen Europe) in CEN/CENELEC, ISO TC197 and IEC TC105.
- LCA performed by FCH 2 JU projects should be verified by a third party, as a quality check.
- LCA reference cases for conventional technologies (e.g. steam reforming) or SoA systems (e.g. commercial AE) should be defined in order to facilitate the comparison against alternative technologies or new designs.
- Although life-cycle inventories are key for successful LCA, there is a lack of data when referring to FCH technologies. FCH 2 JU should look actively for strategies to motivate industry members to provide data.
- FCH 2 JU could support and fund projects that include some life-cycle sustainability assessment methodology development relevant for FCH technologies.

05

PROJECT POSTERS

INDEX OF POSTERS

PANEL 1
TRIALS AND DEPLOYMENT OF FUEL CELL APPLICATIONS – TRANSPORT

3EMOTION

ENVIRONMENTALLY FRIENDLY, EFFICIENT ELECTRIC MOTION

Project ID:	633174
Call topic:	SP1-JTI-FCH.2013.1.1 - Large scale demonstration of road vehicles and refuelling infrastructure VI
Project total costs:	€39 232 162.60
FCH JU max. contribution:	€14 999 983
Project start - end:	01/01/2015 - 31/12/2022
Coordinator:	VAN HOOL N.V, BE
Website:	www. 3EMotion.eu

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, UNIVERSITÀ DEGLI STUDI DI ROMA LA SAPIENZA, FIT CONSULTING SRL, AALBORG KOMMUNE, VLAAMSE VERVOERSMAATSCHAPPIJ DE LIJN, REGION NORDJYLLAND (NORTH DENMARK REGION), AZIENDA PER LA MOBILITA DEL COMUNE DI ROMA SPA, DANTHERM POWER A.S, LONDON BUS SERVICES LIMITED, AIR LIQUIDE ADVANCED BUSINESS, PROVINCIE ZUID-HOLLAND, WATERSTOFNET VZW, AIR LIQUIDE ADVANCED TECHNOLOGIES SA,REGIONE LAZIO,ROTTERDAMSE ELEKTRISCHE TRAM NV, COMMUNAUTE URBAINE DE CHERBOURG, COMPAGNIA TRASPORTI LAZIALI, ACETILENE & GASTECNICI DI BAGNOLI MARIA & C. SAS, COMMUNE DE CHERBOURG-EN-COTENTIN,CENTRO INTERUNIVERSITARIO DI RICERCA PER LO SVILUPPO SOSTENIBILE, SERVICES AUTOMOBILES DE LA VALLEE DE CHEVREUSE SAS, SYNDICAT MIXTE DES TRANSPORTS URBAINS DE PAU PORTE DES PYRENEES, CONNEXXION VLOOT BV, B.E. GREEN

PROJECT AND OBJECTIVES

The 3EMotion project aims to operate 29 FCBs in 5 leading EU cities: London, Pau, Versailles (2x), Rotterdam, Aalborg and and to develop 3 new HRS.
Objectives:

- Lower H_2 consumption <9 kg/100 km
- Integrate latest drive train, FC & Batt technologies < TCO and > actual lifetime
- Ensure availability >90 %
- Increase warranties (>15 000 hours) and improved delivery times of key components
- Reduce bus investment costs to €850 K for a 13 m bus

Status:
12 operational buses, all other FCBs will have hit the road by autumn 2019
1 HRS operational, 2 in build phase

NON-QUANTITATIVE OBJECTIVES

Contribution was made by hydrogen sensors on the hydrogen storage system in the buses. The sensors gave the wrong readings from the factory settings, indicating hydrogen leaks that did not exist. This glitch was fixed and future problems are not expected.

PROGRESS AND MAIN ACHIEVEMENTS

- 12 fuel cell buses are already in operation delivering data, 4 will follow soon and the other buses will hit the road before the end of 2019
- To date, all sites have bought their buses for the price set by the FCH JU call and are either being produced or are in production at 3 different EU OEMs
- To a large extent, the buses are meeting H_2 consumption [<9 kg/100 km] with an average of 8 kg/100 km and availability is steadily progressing to >90 %.

FUTURE STEPS AND PLANS

- Starting full operations with the FCBs at the remaining project sites, catching up on the delays encountered
- Start of operations and use of the 2 newly-built HRS or upgrades by the FCBs in the project
- Gathering of operational data and performance of the KPIs for the FCBs and HRS and provide monitoring reports
- Consolidating and extending the network of H2 Bus Centres of Excellence to the project sites, in collaboration with the H2 Bus Alliance Global H2 Bus.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives/AIP 2013	Lower H_2 consumption for FCBs to less than 9 kg/100 km	kgs/100 km	9	average of 8 kg/100 km	✓	N/A	2019
	Ensure availability >90 %	%	90	<=80 %		N/A	
	Increase warranties (>15 000 hours)	hours	15 000	15 000	✓	N/A	
	Reduce bus investment costs to €850 K for a 13 m bus	Euro	850 000	850 000	✓	625 000	

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:	**€62 840 820.79**
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: DAIMLER AG, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, RENAULT SAS, LINDE AG, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ICELANDIC NEW ENERGY LTD, TOYOTA MOTOR EUROPE NV, NEL HYDROGEN AS, AIR LIQUIDE ADVANCED BUSINESS, NISSAN MOTOR MANUFACTURING (UK) LIMITED, WATERSTOFNET VZW, NUCELLSYS GMBH, MCPHY ENERGY, CENEX - CENTRE OF EXCELLENCE FOR LOW CARBON AND FUEL CELL TECHNOLOGIES, ITM POWER (TRADING) LIMITED, INTELLIGENT ENERGY LIMITED, AREVA H2GEN, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, SYMBIOFCELL SA, HYUNDAI MOTOR EUROPE GMBH, AGA AB, HONDA R&D EUROPE (DEUTSCHLAND) GMBH, BOC LIMITED, OMV REFINING & MARKETING GMBH, DANISH HYDROGEN FUEL AS, HYOP AS, FALKENBERG ENERGI AB, COMMUNAUTE D'AGGLOMERATION SARREGUEMINES CONFLUENCES, H2 MOBILITY DEUTSCHLAND GMBH & CO KG, LINDE GAS GMBH, ELEMENT ENERGY

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 has expanded their developing networks of HRS - 29 new stations will be deployed in total - and the fleets of FCEVS operating on Europe's roads - 325 vehicles - creating both a physical and strategic link between these four regions and three 'observer countries' - Austria, Belgium and the Netherlands - which are using what has been learnt from this project to develop their own strategies.

NON-QUANTITATIVE OBJECTIVES

- Further activities for deployment of HRS and FCEVS after the project
- 294 vehicles and 22 HRS deployed to date - 325 FCEVs and 29 HRS by the end of the project
- HRS to be accessible for private users and preferably integrated into petrol forecourts
- Ensure cross-fertilisation of knowledge acquired in the project and comprehensive dissemination.

PROGRESS AND MAIN ACHIEVEMENTS

- Successful continuation of demonstration of 220 vehicles and 6 HRS and additional deployment of 74 vehicles and 12 HRS in 2018
- Launch and beginning of operation for first Daimler GLC in Europe and delivery of all vehicles planned for Toyota and Symbio
- Three-quarters of the planned HRS are now in operation, contributing to creating a pan-European network and enabling cross-border driving.

FUTURE STEPS AND PLANS

- All 29 HRS planned for the project expected to have been commissioned and to 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 station and further fact-based analysis on vehicles and HRS performances
- Further exploitation of results.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
FC vehicles							
Project's own objectives aligned with AWP 2014/MAWP Addendum (2018-2020)	Min. vehicle operation during the project	months	12	60	✓	12	2017
	Vehicle availability	%	>95	>99	✓	98	
HRS							
Project's own objectives aligned with AWP 2014/MAWP Addendum (2018-2020)	HRS availability	%	97	95.1		98	2017
	Min. HRS operation	months	24	36	✓	32	2017
	Hydrogen purity	%	99.99	99.99	✓	99.99	2015

H2ME 2
HYDROGEN MOBILITY EUROPE 2


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:	**€103 181 910.83**
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: THE UNIVERSITY OF MANCHESTER, DAIMLER AG, OPEN ENERGI LIMITED, AUDI AKTIENGESELLSCHAFT, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, RENAULT SAS, STEDIN NETBEHEER BV, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ICELANDIC NEW ENERGY LTD, NEL HYDROGEN AS, RENAULT TRUCKS SAS, AIR LIQUIDE ADVANCED BUSINESS, NISSAN MOTOR MANUFACTURING (UK) LIMITED, NUCELLSYS GMBH, MCPHY ENERGY, hySOLUTIONS GmbH, KOBENHAVNS KOMMUNE, CENEX - CENTRE OF EXCELLENCE FOR LOW CARBON AND FUEL CELL TECHNOLOGIES, ITM POWER (TRADING) LIMITED, MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, INTELLIGENT ENERGY LIMITED, MINISTERIE VAN INFRASTRUCTUUR EN WATERSTAAT, SOCIETE D'ECONOMIE MIXTE DES TRANSPORTS EN COMMUN DE L'AGGLOMERATION NANTAISE (SEMITAN), AREVA H2GEN, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, SYMBIOFCELL SA, AGA AB, GNVERT SAS, HONDA R&D EUROPE (DEUTSCHLAND) GMBH, HYDROGENE DE FRANCE, COMPAGNIE NATIONALE DU RHONE SA, NEW NEL HYDROGEN AS, BRINTBRANCHEN, HYOP AS, H2 MOBILITY DEUTSCHLAND GMBH & CO KG, SOCIETE DU TAXI ELECTRIQUE PARISIEN, STEDIN DIENSTEN BV, COMMUNAUTE URBAINE DU GRAND NANCY, ISLENSKA VETNISFELAGID EHF, LINDE GAS GMBH, ALPHABET FUHRPARKMANAGEMENT GMBH, TECH TRANSPORTS COMPAGNIE, B. KERKHOF & ZN BV

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 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

- >1 200 fuel cell vehicles and >20 HRS foreseen at the end of the project
- H2ME 2 has a dedicated WP to assess the way in which electrolytic hydrogen production in the mobility sector can link to the wider energy system
- Ensure cross-fertilisation of knowledge acquired in the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Most of the 20 HRS planned for the project expected to be in operation
- >30 % of all 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 station and further fact-based analysis on vehicles and HRS performances
- Further exploitation of results.

FUTURE STEPS AND PLANS

- All 20 HRS planned for the project expected to have been commissioned and to be in operation
- Most of the 1 100 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 of vehicles and HRS performances
- Further exploitation of results with key event during the European Week of Cities and Regions in Brussels.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
HRS							
Project's own objectives aligned with AWP 2015/MAWP Addendum (2018-2020)	HRS availability	%	98	95.1	🔧	98	2017
	Min. HRS operation	months	36	~24	🔧	32	
FC vehicles							
Project's own objectives aligned with AWP 2015/MAWP Addendum (2018-2020)	Min. vehicle operation during project	months	36	25	🔧	12	2017
	Vehicle availability	%	98	>99	✓	98	

HIGH V.LO-CITY

CITIES SPEEDING UP THE INTEGRATION OF HYDROGEN BUSES IN PUBLIC FLEETS

Project ID:	278192
Call topic:	**SP1-JTI-FCH.2010.1.1** - Large scale demonstration of road vehicles and refuelling infrastructure III
Project total costs:	**€30 494 110.49**
FCH JU max. contribution:	**€13 491 724.00**
Project start - end:	01/01/2012 - 31/12/2019
Coordinator:	**VAN HOOL N.V, BE**
Website:	**highvlocity.eu**

BENEFICIARIES: UNIVERSITÀ DEGLI STUDI DI GENOVA, FIT CONSULTING SRL, VLAAMSE VERVOERSMAATSCHAPPIJ DE LIJN, SOLVAY SA, REGIONE LIGURIA, DANTHERM POWER A.S, HYDROGEN, FUEL CELLS AND ELECTRO-MOBILITY IN EUROPEAN REGIONS, WATERSTOFNET VZW, ABERDEEN CITY COUNCIL*, RIVIERA TRASPORTI SPA, BALLAST NEDAM INTERNATIONAL PRODUCT MANAGEMENT B.V., CNG NET BV, QBUZZ BV, PITPOINT.BE, PITPOINT.PRO BV

PROJECT AND OBJECTIVES

The High V.LO-City project aimed to facilitate at facilitating the deployment of fuel cell buses and hydrogen refuelling stations in four sites across Europe: Antwerp (BE, Aberdeen (UK), Groningen (NL) and San Remo (IT). The key project objectives are to increase the energy efficiency of the buses and reduce the cost of ownership, as well as to demonstrate an operational availability of the buses close to diesel. Another objective of the project was to contribute to the commercialisation of FC buses in Europe. All the 14 buses and refuelling infrastructure in the project are now in operation.

NON-QUANTITATIVE OBJECTIVES

- Training bus drivers and technicians
- A number of bus drivers have received specific training for hydrogen buses. Maintenance technicians received training from the bus manufacturer as well as from the fuel cell supplier at the beginning of the project
- Refuelling protocols have been improved
- Awareness-raising activities around hydrogen and fuel cell buses have taken place in the four regions where the deployment sites are located
- Local supply chains have been improved. More bus manufacturers are now producing hydrogen buses on the market.

PROGRESS AND MAIN ACHIEVEMENTS

- More than 920 000 km driven by the fleet of buses since the start of the project
- More than 938 tonnes of CO_2 saved
- Buses and refuelling infrastructure successfully demonstrated.

FUTURE STEPS AND PLANS

- Technical availability of the buses - expected to improve, especially for the Antwerp and Sanremo sites
- Increased mileage – especially for the Sanremo and Antwerp sites, where buses are expected to drive more kilometres
- Relocation of the Antwerp refuelling station at the DeLijn depot - for higher usage of the buses / better efficiency
- Availability of the buses getting closer to diesel equivalent at all sites.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET
HRS			
Groningen site	Distance	km	100 071
Sanremo site	Distance	km	23 833
Aberdeen site	Distance	km	497 994
Antwerp site	Distance	km	213 242
FC vehicles			
Hydrogen consumption	Hydrogen dispensed	km	96 426

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:	**www.hylift-europe.eu**

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

PROJECT AND OBJECTIVES

The aim of HyLIFT-EUROPE was to demonstrate more than 200 hydrogen-powered fuel cell materials-handling vehicles and associated hydrogen refuelling infrastructure at ≥ 2 sites across Europe (the initial plan foresaw 5-20 sites), making it the largest European trial of hydrogen-powered 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 demonstrated 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, and 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 support for European industry, comprising two workshops at vehicle-user sites, finished at the end of the project.

PROGRESS AND MAIN ACHIEVEMENTS

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

FUTURE STEPS AND PLANS

Project has finished.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
FC MHVs							
MAIP 2008-2013	Number of industrial and off-highway vehicles	[-]	200	212	✓	>25 000	2019
AIP 2011	Number of FC systems	[-]	200	212	✓	>25 000	2019
	FC system efficiency	[%]	45-50	>45	✓	53	2015
HRS							
AIP 2011	Refuelling time	[min]	~3	2.5	✓	2.18	2017
	HRS availability	[%]	>98	>98	✓	N/A	N/A

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:	€17 850 708.85
FCH JU max. contribution:	€6 999 999
Project start - end:	01/01/2013 - 31/03/2019
Coordinator:	BOC LIMITED, UK
Website:	hytransit.eu

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

PROJECT AND OBJECTIVES

HyTransit aimed to trial a fleet of six hybrid fuel cell buses in daily fleet service, together with one state-of-the art hydrogen refuelling station in Aberdeen, Scotland. By operating the vehicles rigorously on long inter-urban routes, the project aimed to prove that a hybrid fuel cell bus is capable of meeting the operational demands of an equivalent diesel bus, whilst offering significant benefits in terms of environmental performance.
The project finished in March 2019. This allowed for four full years of operation of the FCBs and the HRS.
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).

NON-QUANTITATIVE OBJECTIVES

- Develop six A330 hybrid fuel cell buses specifically modified for long sub-urban routes
- Initiate the first step for a large-scale roll-out of hydrogen buses in Scotland. Following the success of HyTransit, Aberdeen City Council have committed to deploy more FCBs through the JIVE project. In addition, other Scottish cities, such as Dundee, have committed to deploy FCBs
- The results from the project can be evidenced to prove the capability of FCBs.
- Address the main commercial barrier to the technology (namely bus capital cost) by deploying state-of-the-art components. The premium of fuel cell buses has reduced significantly and now equal to c. £70 000/year, down from c. £170 000/year
- Disseminate the results of the project to the public and key stakeholders.

PROGRESS AND MAIN ACHIEVEMENTS

- The Kittybrewster HRS has been highly reliable throughout the project, with an average availability of 99.5 %. This exceeds industry's expectations
- Nearly 1.4 million kilometres have been driven by the fleet of buses and approximately 1.3 million passengers have used the service
- By using FCBs instead of conventional diesel vehicles, >400 000 litres of diesel has been saved and >1 000 tonnes of direct GHG emissions avoided.

FUTURE STEPS AND PLANS

Project finished - the HyTransit buses continued to operate until the end of 2019, after which their operation is to be reassessed.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
FC buses						
AIP 2011 target for fleet	Availability	%	>85	78		85
HRS						
Project's own objectives	Availability of the hydrogen refuelling unit	%	>98	99.5	✓	98
	Amount of hydrogen dispensed	kg	>140 000	146 823	✓	N/A
	Operating hours drivetrain	hours	70 000	88 824	✓	N/A
	Number of passengers	number	>1 000 000	1 302 487	✓	N/A

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:	**€110 375 045.24**
FCH JU max. contribution:	**€32 000 000**
Project start - end:	01/01/2017 - 31/12/2022
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Websites:	**www.fuelcellbuses.eu/projects/jive**

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

PROJECT AND OBJECTIVES

The overall objective of JIVE is to advance the commercialisation of hydrogen fuel cell buses through large-scale deployment of vehicles and infrastructure so that by the end of the project (early 2020s) hydrogen buses are commercially viable for bus operators to include in their fleets without subsidy, and local and national governments feel empowered to regulate for zero-emission propulsion for their public transport systems. The specific project objectives are discussed below.

NON-QUANTITATIVE OBJECTIVES

- Lessons learnt from joint procurement reflected in the Operators' guide to FCB deployment
- Lessons learnt in the operator forum; the report is ongoing
- Collation of training materials
- Zero Emission Bus Conference held in Cologne in November 2018; additional dissemination and communication events ongoing.

PROGRESS AND MAIN ACHIEVEMENTS

- Offers significantly under the €650 k bus capex limit have been received in some procurement processes
- A number of OEMs have entered the FCB market in response to the demand stimulated by the project
- TfL has developed a procurement framework that allows cities to order FCBs more quickly than would otherwise be possible.

FUTURE STEPS AND PLANS

- Despite delays, we expect most buses to be operating in 2020
- Zero Emission Bus Conference 2020 to be held in Paris in March 2021
- Ongoing collection of lessons learnt and best practice through project reporting and workshops.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
AWP 2016	Vehicle operational lifetime	hours	Tender specifications and project require a bus operation of over 8 years.	Vehicles not yet deployed	Conventional diesel bus should do 32 000 hours; at least one FCB supplier suggests 40 000 hours will be possible for FCBs under JIVE.
	Distance travelled	km	Minimum distance travelled will be 44 000 km/year, an average of 59 000 km and a maximum of 90 000 km (in Herning).		Route specific. Minimum distance travelled will be 44 000 km/year, average of 59 000 km and a maximum of 90 000 km (in Herning).
	Operating hours per fuel cell system	hours	15 000 hours or 5 years, whichever is lower (at the project start), >20 000 hours by project end – stack replacements built into maintenance costs.		N/A
	Availability	%	Tender specifications and contracts require >90 % vehicle reliability, but allow for a 6-month teething period during which lower reliability is expected		85 % availability (2012) from High V.LO.City
	Mean time (distance) between failures	km	An MTBF of >2 500 km (after the teething period)		N/A

JIVE 2

JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE 2

JIVE

ZERO EMISSION

Project ID:	**779563**
Call topic:	**FCH-01-5-2017** - Large scale demonstration in preparation for a wider roll-out of fuel cell bus fleets (FCB) including new cities – Phase two
Project total costs:	**€107 398 381.75**
FCH JU max. contribution:	**€25 000 000.00**
Project start - end:	01/01/2018 - 31/12/2023
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**www.fuelcellbuses.eu/projects/jive-2**

BENEFICIARIES: HYDROGEN EUROPE, UNION INTERNATIONALE DES TRANSPORTS PUBLICS, NOORD-BRABANT PROVINCIE, VATGAS SVERIGE IDEELL FORENING, PROVINCIE ZUID-HOLLAND, RUTER AS, BRIGHTON & HOVE BUS AND COACH COMPANY LIMITED, THINKSTEP AG, KOLDING KOMMUNE, RIGAS SATIKSME SIA, WSW MOBIL GMBH, DUNDEE CITY COUNCIL, REGIONALVERKEHR KOLN GMBH, REBELGROUP ADVISORY BV, LANDSTINGET GAVLEBORG, PAU BEARN PYRENEES MOBILITES, OPENBAAR LICHAAM OV-BUREAU GRONINGEN EN DRENTHE, STRAETO BS, SOCIETE PUBLIQUE LOCALE D'EXPLOITATION DES TRANSPORTS PUBLICS ET DES SERVICES A LA MOBILITE DE L'AGGLOMERATION PALOISE, RHEINSCHE BAHNGESSELLSCHAFT AKTIENGESELLSCHAFT, CA DE L'AUXERROIS, ENGIE ENERGIE SERVICES

PROJECT AND OBJECTIVES

The overall objective of JIVE 2 is to advance the commercialisation of hydrogen fuel cell buses through large-scale deployment of vehicles and infrastructure so that by the end of the project (early 2020s) hydrogen buses are commercially viable for bus operators to include in their fleets without subsidy, and local and national governments feel empowered to regulate for zero-emission propulsion for their public transport systems. The key project objective is the order of 152 fuel cell buses for delivery to, and operation in, 14 cities across Europe, securing the lowest possible prices.

NON-QUANTITATIVE OBJECTIVES

- Lessons learnt from joint procurement reflected in the Operators'guide to FCB deployment
- Lessons learnt in the operator forum; the report is ongoing
- Collation of training materials
- Zero Emission Bus Conference held in Cologne in November 2018; additional dissemination and communication events ongoing.

PROGRESS AND MAIN ACHIEVEMENTS

- Most procurement exercises are expected to return bus price offers under the €625 k limit
- A number of OEMs have entered the FCB market in response to the demand stimulated by the project
- Ongoing collection of lessons learnt are invaluable for the further roll-out of FCBs beyond the project.

FUTURE STEPS AND PLANS

- Despite delays, the project expected most buses to have been ordered by the end of 2019
- Zero Emission Bus Conference 2020 to be held in Paris in 2021
- Ongoing collection of lessons learnt and best practice through project reporting and workshops.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
AWP 2017	Vehicle operational lifetime	hours	Operational lifetimes as close to traditional buses as possible (8+ years as a minimum). The target is set in terms of bus lifetime (rather than stack life) as this is more relevant to operators	Vehicles not yet deployed	Not project specific. Conventional diesel bus should do 32 000 hours; at least one FCB supplier suggests 40 000 hours will be possible for FCBs under JIVE
	Distance travelled	km	150 000 km per bus /three years of operation.		Route specific. Minimum distance travelled will be 44 000 km/year, an average of 59 000 km and a maximum of 90 000 km (in Herning)
	Operating hours per fuel cell system	hours	>20 000 hours by project end		N/A
	Availability	%	>90% vehicle reliability, but allow for a 6-month teething period where lower reliability is expected (based on CHIC learning)		85 % availability (2012) from High V.LO.City
	Mean time (distance) between failures	km	An MTBF of >3 500 km (after the teething period) will be stipulated in the contracts. The expectation is higher		N/A

REVIVE

REFUSE VEHICLE INNOVATION AND VALIDATION IN EUROPE

Project ID:	779589
Call topic:	**FCH-01-7-2017** - Validation of Fuel Cell Trucks for the Collect of Urban Wastes
Project total costs:	€8 706 255
FCH JU max. contribution:	€4 993 851
Project start - end:	01/01/2018 - 31/12/2021
Coordinator:	TRACTEBEL ENGINEERING, BE
Website:	h2revive.eu

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, GEMEENTE AMSTERDAM, ELEMENT ENERGY LIMITED, WATERSTOFNET VZW, STAD ANTWERPEN, SYMBIOFCELL SA, GEMEENTE BREDA, GEMEENTE GRONINGEN, E-TRUCKS EUROPE, SWISS HYDROGEN SA, SEAB SERVIZI ENERGIA AMBIENTE BOLZANO SPA, AZIENDA SERVIZI MUNICIPALIZZATI DI MERANO SPA, SUEZ NEDERLAND HOLDING BV, SAVER NV, GEMEENTE GRONINGEN

PROJECT AND OBJECTIVES

REVIVE stands for 'Refuse Vehicle Innovation and Validation in Europe'. The project will run from the beginning of 2018 until the end of 2021. REVIVE will significantly advance the state of development of fuel cell refuse trucks by integrating fuel cell powertrains into 15 vehicles and deploying them across 8 sites in Europe. The first trucks are being constructed and the first deployment was expected at the end of October 2019 in the city of Breda in the Netherlands.

NON-QUANTITATIVE OBJECTIVES

- EU fuel cell suppliers: Proton Motor was selected to provide FC systems for the trucks
- Raise the profile of the technology as a viable option for waste collection through several dissemination activities performed targeting the waste sector.

PROGRESS AND MAIN ACHIEVEMENTS

- Final order for the trucks. In total, 5 trucks have been ordered by project partners
- First trucks under construction. The first truck was expected to be deployed in Breda in Q4 2019
- New partners identified for truck deployment and for providing the FC system for E-trucks.

FUTURE STEPS AND PLANS

- Introduce new partners to allocate all 15 trucks
- Introduce new consortium partner and help develop a European fuel cell supply chain
- First truck deployment in Breda (October 2019).

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT
AWP 2017	Number of FCs deployed in the project	#	15	11
	FC power	kW	>40 kW	45 kW
	Tank-to-wheel efficiency	%	50 %	N.A.
	Lifetime	hours	25 000	N.A.
	Availability	%	90 %	N.A.

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:	**€15 803 804.24**
FCH JU max. contribution:	**€6 712 985.6**
Project start - end:	01/10/2012 - 31/10/2018
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**www.swarm-project.eu**

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

PROJECT AND OBJECTIVES

The project set out to establish fleets of small passenger vehicles supporting and expanding upon existing hydrogen refuelling infrastructure across three clusters: British Midlands and Wales (UK), Brussels/Wallonia (Belgium) and North Rhine Westphalia (DE). The vehicles demonstration was organised by three SME OEMs, Riversimple (UK), Microcab (UK) and H2O e-mobile (DE). Two Air Liquide 200 kg/day stations were built in Frechen and Brussels while smaller stations were built and upgraded in the UK: a 20 kg/day station in Abergavenny and 2 recommissioned stations in Coventry and Birmingham.

NON-QUANTITATIVE OBJECTIVES

- Low cost small vehicles - the vehicles produced in this project will have low volume production costs
- The project enabled the deployment of clusters of hydrogen filling stations in all three European regions and fostered further deployment
- The project involved a range of European SMEs facilitating the exchange of IP and the introduction of dynamic new European companies into Europe's hydrogen economy as well as European research institutions
- The vehicles deployed were all built in battery-dominant hybrid mode. This is a novel approach which optimised the cost, performance and energy efficiency of both battery and fuel cell/hydrogen storage technologies.

PROGRESS AND MAIN ACHIEVEMENTS

- Development of three generations of powertrains by Microcab and Riversimple with first vehicles in operation since 2015
- Preparation for trial of 20 Riversimple cars in Abergavenny (UK) with HRS in operation and set-up ready
- Air Liquide HRS in Brussels and Frechen in operation since mid-2016 and mid-2018 respectively, supporting further deployment of fleets.

FUTURE STEPS AND PLANS

Project has finished.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
FC vehicles							
Project's own objectives (aligned with programme's objectives)	Vehicle efficiency/energy consumptn	kg/km	1 kg/100 km	<1 kg/100 km	✓	N/A	N/A
HRS							
Project's own objectives (aligned with programme's objectives)	HRS availability	%	>95 %	97	✓	98	2016
	H_2 price dispensed at pump	€/kg	10	9.5-10	✓	10	

ZEFER

ZERO EMISSION FLEET VEHICLES FOR EUROPEAN ROLL-OUT

Project ID:	**779538**
Call topic:	**FCH-01-9-2016** - Large scale validation of fuel cell bus fleets
Project total costs:	**€25 883 005**
FCH JU max. contribution:	**€4 998 843**
Project start - end:	01/09/2017 - 31/08/2022
Coordinator:	**ELEMENT ENERGY LIMITED, UK**
Website:	**zefer.eu**

BENEFICIARIES: MAYOR'S OFFICE FOR POLICING AND CRIME, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, LINDE AG, VILLE DE PARIS, AIR LIQUIDE ADVANCED BUSINESS, CENEX - CENTRE OF EXCELLENCE FOR LOW CARBON AND FUEL CELL TECHNOLOGIES, ITM POWER (TRADING) LIMITED, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, SOCIETE DU TAXI ELECTRIQUE PARISIEN, BREATH, GREEN TOMATO CARS LIMITED

PROJECT AND OBJECTIVES

In 2017, ZEFER began to demonstrate a viable business case for hydrogen mobility in fleet applications and to highlight a solution to the problem of low FCEV uptake and poor hydrogen refuelling station utilisation. The project will deploy 180 FCEVs into high-mileage fleet services, such as taxis, private hire vehicles and emergency services, across three major European cities (London, Paris and Brussels). Through intensive use of the vehicles, ZEFER will test the performance of FCEVs, and their supporting HRS, to ascertain whether FCEVs can provide a direct alternative to diesel counterparts.

NON-QUANTITATIVE OBJECTIVES

- Develop comprehensive understanding from the deployment project
- ZEFER will test market six HRS in real-world operation. Data collected will feed into a business case analysis on HRS roll-out. Lessons learnt in this exercise will be passed on to HRS investors and policymakers
- Maintain, and if possible, increase SME participation in FCH JU projects: 50 % of partners in ZEFER are SMEs.

PROGRESS AND MAIN ACHIEVEMENTS

- Of the 180 FCEVs to be deployed, 71 are currently in everyday operation – 36 in Paris and 35 in London – in high-demand fleet applications
- The FCEVs are being used rigorously in everyday service amassing more than 1 million km driven with no reports of reliability problems
- Project HRS are being highly utilised and are performing well, even prior to the completion of HRS upgrades.

FUTURE STEPS AND PLANS

- Confirm approach for vehicle deployment and associated HRS upgrade for remaining trials
- All HRS upgrades are expected to be completed
- Collection of operational data from the HRS and FCEV will continue. Further fact-based analysis will be conducted
- Greater dissemination efforts are expected to publicise project milestones such as 'last vehicle delivered'.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
FC vehicles							
Project's own objectives	Min. distance for vehicles	km/vehicle	90 000	average of ~ 42 000 km per year. Will achieve targets after ~ 2+ years	🔧	10 000	2016
	Vehicle operation lifetime	hours	>6 000	average of ~ 2 800 hrs per year. Will achieve targets after ~ 2+ years	🔧	>2 000	
	Vehicle availability	%	> 98 %	>98	✓	98%	
HRS							
Project's own objectives	HRS availability	%	>98	96	🔧	98 %	2016
	Hydrogen purity	%	99.99	99.99	✓	99.99	2018

PANEL 2
NEXT GENERATION OF PRODUCTS – TRANSPORT

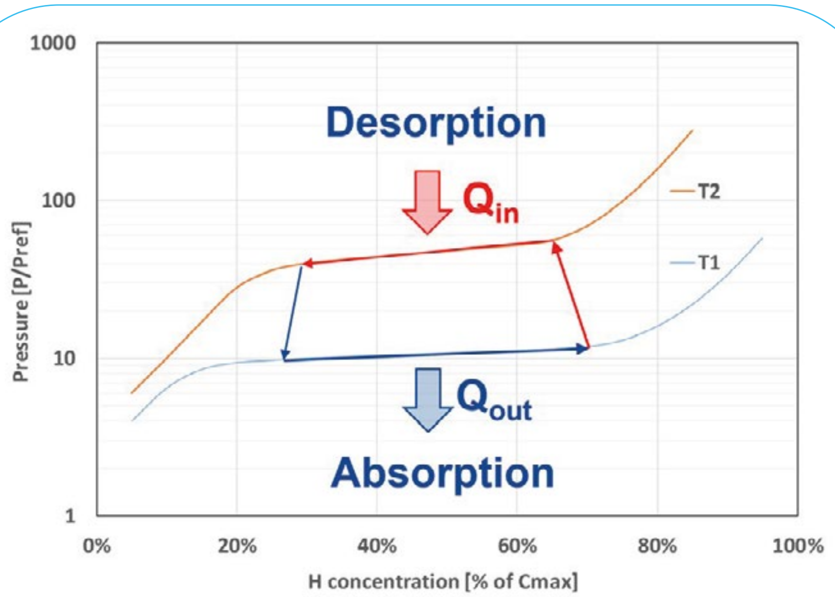
COSMHYC

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

COSMHYC
INNOVATIVE H2 COMPRESSION

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: STEINBEIS INNOVATION GGMBH, LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH, NEL HYDROGEN AS, MAHYTEC SARL, STEINBEIS 2I GMBH



PROJECT AND OBJECTIVES

COSMHYC is developping a hybrid compression solution for hydrogen refuelling stations by combining an innovative metal hydride compressor with a mechanical compressor, for a compression from 1 to 1 000 bar. The objectives are to decrease investment and operational costs, to reduce noise level, to increase the availability of stations, and thus to increase the efficiency of hydrogen delivery. MAHYTEC, EIFER and NEL are currently focusing on the integration of both technologies, which are being tested in a comprehensive way. Techno-economic assessment is being performed to ensure competitiveness.

NON-QUANTITATIVE OBJECTIVES

- Modularly scalable
- Increase reliability, currently no moving parts in the innovative compressor
- Perform a cost-of-ownership assessment.

PROGRESS AND MAIN ACHIEVEMENTS

- Definition of technical requirements for the compression solution for selected applications (refuelling of FC cars, buses and trains, H_2 trailers)
- Production of three hydrides without rare earths with appropriate features for the innovative compressor, the concept of which has been finalised
- Design of a new concept of mechanical compression due to improved materials for the diaphragm, performing heating/cooling and noise reduction.

FUTURE STEPS AND PLANS

- Long-term testing of COSMHYC compression solution as a virtual compressor following joint testing programs and protocols of both compressors and analysis
- Collection of operative and performance data and technical economic evaluation comparing processor concepts for selected applications
- Final economic feasibility and consumer value proposition analysis
- Definition of a roadmap towards exploitation of the different compression solutions developed in COSMHYC for preparing for market deployment.

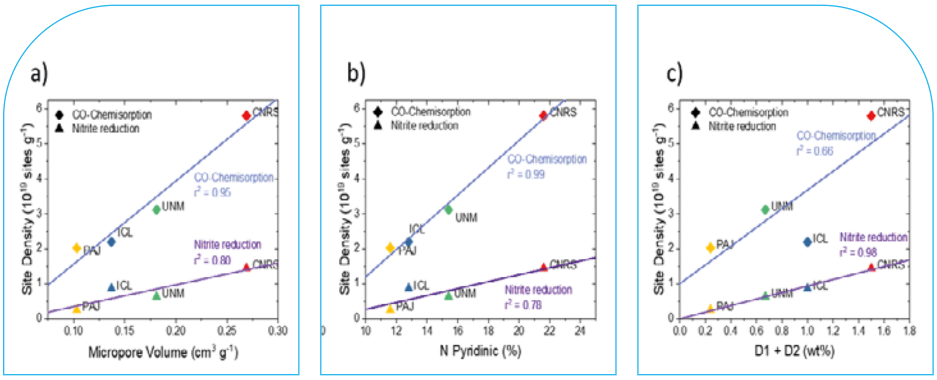
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Energy consumption	kWh/kg	6	6	✓	N/A	N/A
	Degradation	%/month	1	0.5	✓	N/A	N/A
	Specific costs	€k/kg*day	N/A	3.7	(SoA exceeded)	5-12	2015
	Electricity consumption	kWh/kg	N/A	<1.5	(SoA exceeded)	3	2017
	Noise	DB	N/A	<60	(SoA exceeded)	85	2017

CRESCENDO

CRITICAL RAW MATERIAL ELECTROCATALYSTS REPLACEMENT ENABLING DESIGNED POST-2020 PEMFC

Project ID:	779366
Call topic:	**FCH-01-2-2017** - Towards next generation of PEMFC: Non-PGM catalysts
Project total costs:	€2 739 602.5
FCH JU max. contribution:	€2 739 602.5
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR
Website:	www.crescendo-fuelcell.eu



BENEFICIARIES: UNIVERSITA DEGLI STUDI DI PADOVA, IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, TECHNISCHE UNIVERSITAT BERLIN, JOHNSON MATTHEY PLC, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, PRETEXO, JOHNSON MATTHEY FUEL CELLS LIMITED, UNIVERSITÉ DE MONTPELLIER

PROJECT AND OBJECTIVES

CRESCENDO aims to advance research on non-PGM fuel cell catalysts, develop diagnostic methods to characterise their active site density and turnover frequency and develop successful approaches for the stabilisation in operations of non-PGM cathode catalysts, as well as advance research on non-PGM and ultra-low PGM hydrogen oxidation catalysts.
The reasons for the high losses with current non-PGM cathode catalyst layers are analysed, and the learning used to re-design the catalyst layer, with the objective of achieving 0.42 W/cm^2 at 0.7 V and 1 000 h of operation with the finally configured MEA.

NON-QUANTITATIVE OBJECTIVES

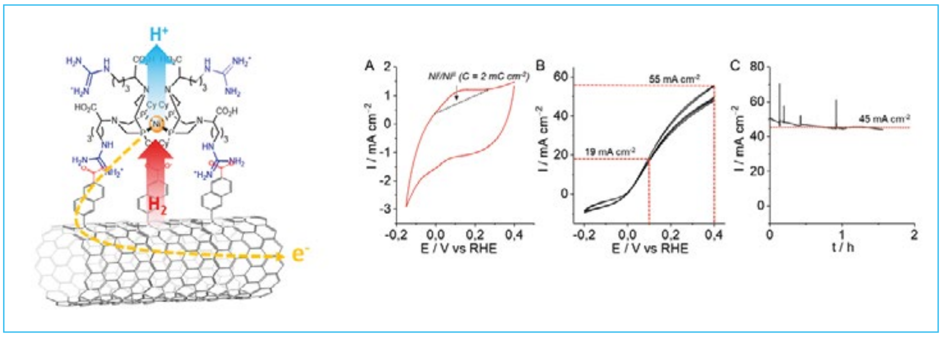
International collaboration with IPHE countries. Two meetings between CRESCENDO and scientists working in IPHE countries (mainly USA) were held in the first 12 months of the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Two diagnostic methods were developed to determine active site density and turnover frequency of non-PGM catalysts, thereby facilitating materials design
- A project catalyst reached ~ 0.92 A g-1 at 0.9 V vs. RHE, nearly reaching the M12 stage-gate target of 1.0 A g-1 at 0.9 V vs. RHE
- Analysis of the losses in MEAs with the reference non-PGM catalyst has led to layer redesign and improved performance.

FUTURE STEPS AND PLANS

- Improve cathode non-PGM catalyst activity and stability to reach AWP targets
- Implement the most prospective cathode non-PGM catalysts in improved catalyst layers to reach AWP targets
- Demonstrate H_2S tolerance of anode non-PGM catalysts
- Implement the most prospective CRESCENDO anode and cathode catalyst in an all non-PGM MEA
- Accelerate catalyst development by further study of the relation between site density, turnover frequency, catalyst physical properties and activity.



QUANTITATIVE TARGETS AND STATUS

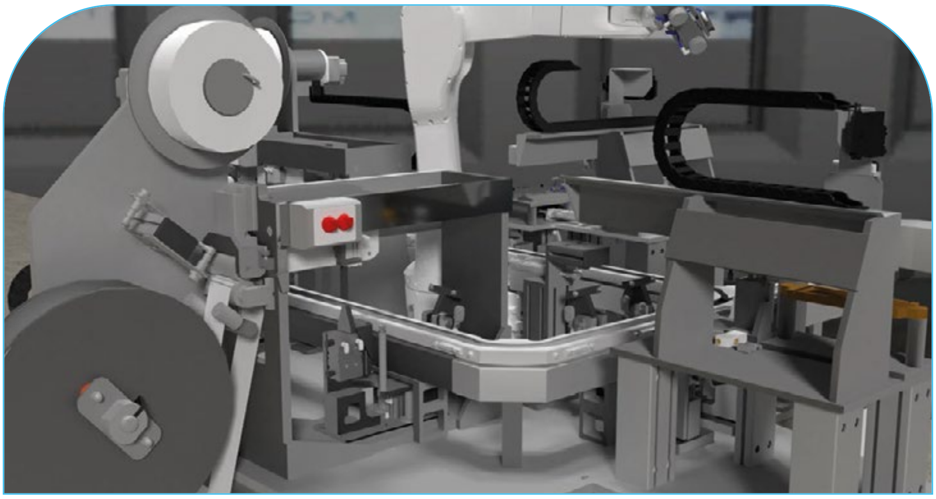
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project month 18 ex-situ performance target from RDE or floating electrode for non-PGM cathode catalyst	Mass activity at 0.9 V IR free	A/g	1	0.92		Mass activity SoA not available. SoA current density at 0.9 V IR free reported as 36 mA/cm^2	2019
AWP 2018 for non-PGM cathode catalyst	Cell voltage at 600 mA/cm^2, on H_2/air	V	0.7	0.47		0.49	2019
	Durability at 1.5 A/cm^2	hours	1 000	Planned for RP2		No data available at 1.5 A/cm^2	N/A
Project's own objectives for non-PGM anode catalyst	Mass activity at 0.9 V IR free	A/mg non-PGM	35	25	✓	7	2016

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:	**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 advances (MRL4 > MRL6) the critical steps of the PEM fuel cell assembly processes and associated in-line QC and demonstrates a route to automated volume process production capability, within an automotive best practice context. This includes characterisation and digital codification of the physical attributes of key materials (e.g. GDLs) to establish yield-impacting digital cause and effect relationships within the value chain of Industry 4.0 standards. The main outputs are a Proof of Process and a blueprint design for beyond current state automotive PEM fuel cell manufacturing in Europe.

NON-QUANTITATIVE OBJECTIVES

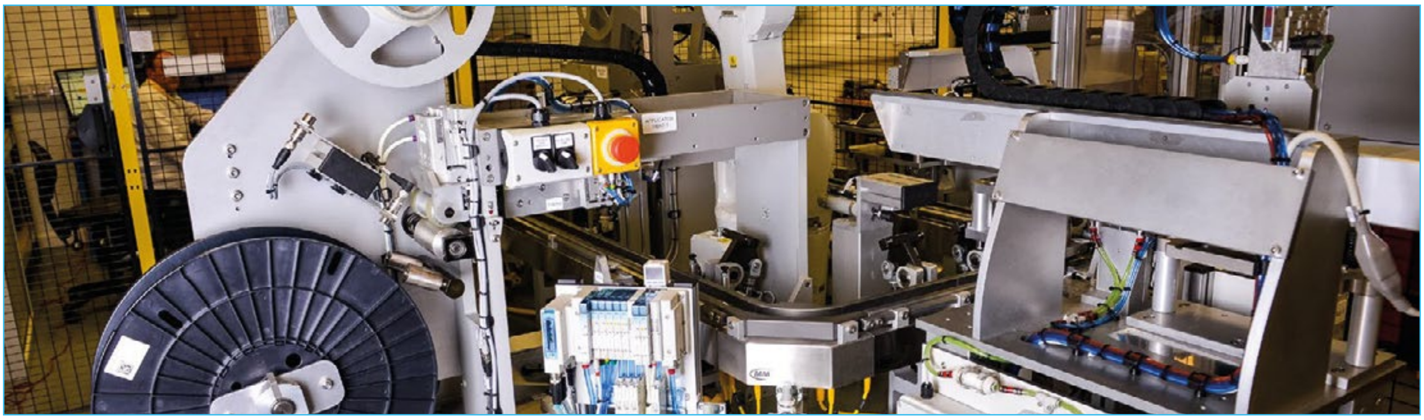
- Inline digital detection and marking of surface non-uniformities via Vision line
- Integration of inline non-destructive quality control tools
- Development of beyond-state technologies, specific to PEMFC stack production
- Improvement, modification, adaptation of component production steps
- Development of methods to link digital boundary limits to empirically derived homogeneity data.

PROGRESS AND MAIN ACHIEVEMENTS

- KPIs for i) fully automated stack assembly / test via automotive best practice and ii) stack performance at handover into an automated production line
- Proof-of-process demonstrator equipment for the uplifted cell assembly automation has been manufactured and is undergoing validation tests
- Deep characterisation of GDL properties has enabled the development of meaningful automatic scanning techniques for digital QC and upstream/downstream.

FUTURE STEPS AND PLANS

- Finalize PoP validation and blueprint design
- Finalize QC analysis and recommendations
- Identify inline defect marking concept for AC64 GDL-type
- Complete automation uplift and provide proof of MRL6 attainment
- Complete specification of blueprint design and technical cost model demonstrator.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Stack weight	kg	2.9	2.9	✓
	Stack volume	l	2.85	2.85	✓
	Stack capacity	t	2.1	2.1	✓

Fit-4-AMandA

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

FIT-4-AMANDA

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: FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV, TECHNISCHE UNIVERSITAET CHEMNITZ, IRD FUEL CELLS A/S, PROTON MOTOR FUEL CELL GMBH, UPS EUROPE SA, AUMANN LIMBACH-OBERFROHNA GMBH

PROJECT AND OBJECTIVES

Fit-4-AMandA's ambition is to modify the current design of PEMFC stacks and stack components, and build new equipment to facilitate automation of the stack assembly process (including inline non-destructive tests). Furthermore, it will demonstrate the resulting mass-produced stacks in real environment – by integrating the output into a light- and medium-sized commercial vehicle. The project will offer the mass production machines and innovative solutions to affect processes, products and tools, to bring the MRL from 5 to 7.

NON-QUANTITATIVE OBJECTIVES

- Feasibility study for commercial FC electrical vehicle completed
- Consolidate the technical requirements in detail for standard FC operation and need for special demands.

PROGRESS AND MAIN ACHIEVEMENTS

- FAT acceptance test of the mass manufacturing machine for automatic fuel cell stack assembly
- BPP design for moulding verified
- Concept of FC integration into a UPS base vehicle is complete and vehicle performance requirements are ready.

FUTURE STEPS AND PLANS

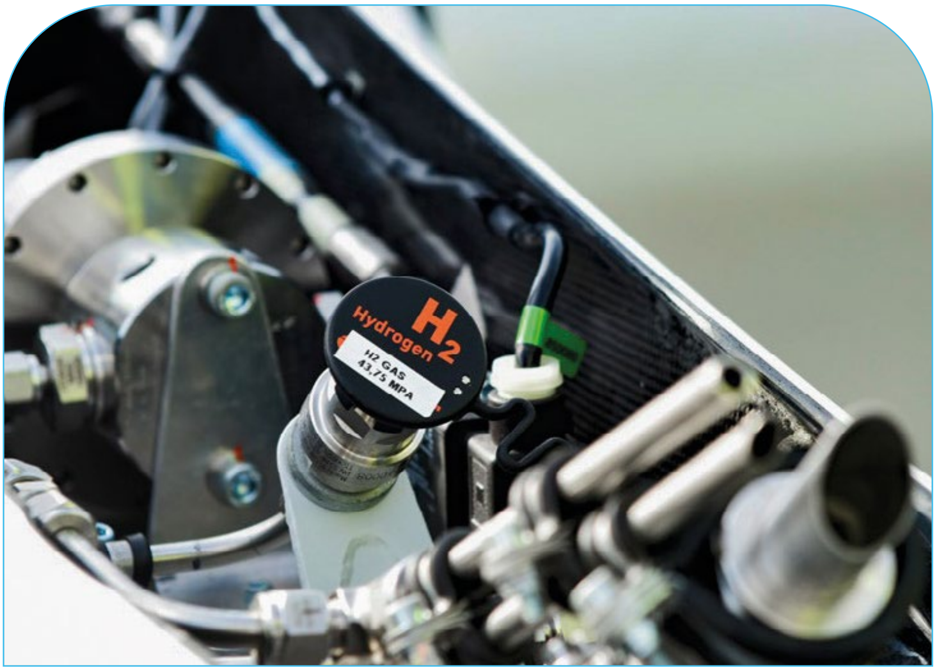
- Solve BPP sealing - currently replaced with adhesive bonding methods`
- Statistical analysis and optimisation of the inline testing methods and validation of the inline testing methods
- Continue to see suppliers of relevant hydrogen storage tanks and evaluate proposed solutions, including ensuring specification update and available engineering.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Project process: Energy per MW	Kwh/MW	200	✔
	FC system lifetime	hours	6 000	🛠
	Specific FC system cost	€/kW	100	🛠

FLHYSAFE

FUEL CELL HYDROGEN SYSTEM FOR AIRCRAFT EMERGENCY OPERATION



Project ID:	779576
Call topic:	**FCH-01-1-2017** - Development of fuel cell system technologies for achieving competitive solutions for aeronautical applications
Project total costs:	**€7 365 901.25**
FCH JU max. contribution:	**€5 063 023**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**SAFRAN POWER UNITS, FR**
Website:	**www.flhysafe.eu**

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, UNIVERSITAET ULM, ARTTIC, INSTITUTO NACIONAL DE TECNICA AEROESPACIAL ESTEBAN TERRADAS, ZODIAC AEROTECHNICS SAS

PROJECT AND OBJECTIVES

FLHYSAFE overall objectives:

- To demonstrate that the current Ram Air Turbine of a commercial aircraft can be replaced by a fuel-cell-based modular system able to increase functionality and safety, while reducing costs
- Virtually demonstrate that an FC-based modular system can be integrated into current aircraft design and comply with mass and volume requirements and maintenance constraints.

NON-QUANTITATIVE OBJECTIVES

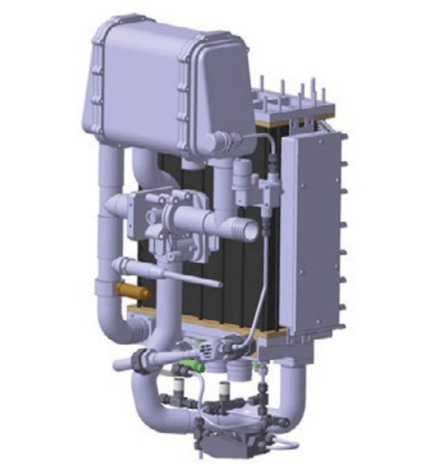
- Prepare a plan of environmental tests to get airworthiness qualification. INTA has initiated the regulations study and the test plan is being developed
- Compliance with current regulation codes and standards. Design is ongoing, based on functional analysis and FHA results.

PROGRESS AND MAIN ACHIEVEMENTS

- Delivery of the emergency power unit system specifications
- Delivery of the functional analysis
- All subsystem developments are in progress.

FUTURE STEPS AND PLANS

- Use the functional analysis and the FHA to determine the technical specifications of the system and its sub-systems
- Design and validate systems and sub-systems in accordance with technical specifications through testing and analysis
- Demonstrate procedures for maintenance training with a VR tool
- Integrate the completed fuel cell into an aircraft.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	EPU weight	kg	150	
	EPU volume	L	200	
	EPU efficiency at rated power	%	40	
	Power density FC subsystem	kW/kg	2	
	Power density FC subsystem	kW/L	2.5	

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 - 31/10/2019
Coordinator:	**SINTEF AS, NO**
Website:	**giantleap.eu**

BENEFICIARIES: STIFTELSEN SINTEF, UNIVERSITÉ DE FRANCHE-COMTE, SVEUCILISTE U SPLITU, FAKULTET ELEKTROTEHNIKE, STROJARSTVA I BRODOGRADNJE, 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, VDL BUS & COACH BV, VDL BUS ROESELARE, VDL BUS CHASSIS BV, VDL ENABLING TRANSPORT SOLUTIONS BV

PROJECT AND OBJECTIVES

Giantleap's objectives are to develop advanced diagnostic, prognostic and control systems for automotive PEM fuel cell stacks and systems, and to test them in a hybrid battery bus connected to a detachable fuel-cell range extender.

The project has delivered improved understanding of rejuvenation phenomena to reverse fuel-cell degradation, prognostics of critical BoP components such as compressors, estimator algorithms able to run a pseudo-EIS with no extra equipment, and a demonstration that has been extended from TRL 6 to 7.

NON-QUANTITATIVE OBJECTIVES

- Report being written for evaluation of business case for H_2 range extenders for battery-buses
- Report published for rejuvenation techniques
- Concept has been demonstrated and further experiments are being conducted for on-board diagnostics without the need for extra equipment.

PROGRESS AND MAIN ACHIEVEMENTS

- Systematic study of fuel-cell rejuvenation
- Prognostic analysis of compressors in FC systems
- Fast, automatic low-frequency EIS with no extra equipment.

FUTURE STEPS AND PLANS

- Demonstration of prototype on track (TRL 6)
- Demonstration of prototype on road (TRL 7)
- Analysis of data from demonstration
- Collection and publication of data.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	**Energy consumption of EHP stack**	**kWh/kg H_2**	**3**	**3**	✓
	Recovery rate EHP short stack	**%**	**>90**	**90**	✓
	Recovery rate single cell	**%**	**>90**	**90**	✓
	Energy consumption at targeted recovery rate	**kWh/kg H_2**	**3**	**5**	🔧

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
Project total costs:	**€7 127 941.25**
FCH JU max. contribution:	**€5 968 554**
Project start - end:	01/09/2015 - 31/12/2019
Coordinator:	**CENTRE TECHNIQUE DES INDUSTRIES MECANIQUES, FR**
Website:	**www.h2ref.eu**

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

PROJECT AND OBJECTIVES

H2REF addresses compression and buffering of H_2 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 the core compression device, a full-scale prototype compression and buffering module (CBM) was built in the test area. The full CBM will be tested in a closed loop and demonstrated in a vehicle.

NON-QUANTITATIVE OBJECTIVES

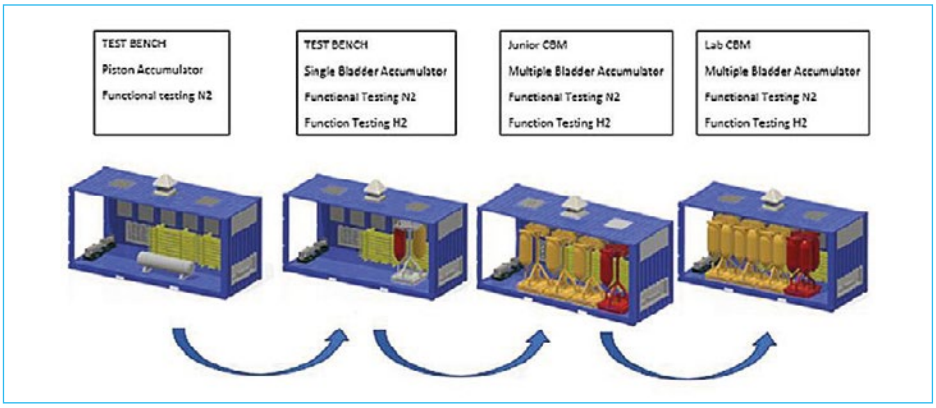
- Techno-economical analysis based on project results
- Have the technology covered by the RCS framework (CEN TC 54).

PROGRESS AND MAIN ACHIEVEMENTS

- CBM process developed, full-scale prototype system built, and compression device hydraulic actuation successfully tested in hydrogen
- Suitable bladder material identified, and accumulator developed and qualified successfully for functional and endurance testing in CBM
- Hydrogen test area set up on Haskel's premises.

FUTURE STEPS AND PLANS

- Closed loop functional testing of the CBM process
- Dispensing tests with mock vehicle tank
- Certify the purity of hydrogen dispensed by the system
- Endurance testing of the CBM.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	TRL	n/a	6	4	
	Unit cost	k€	300	N/A	
	Capacity	kg/hour	30	N/A	
	Consumption	kWh/kg	1.5	N/A	

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 - 31/03/2019
Coordinator:	ZODIAC AEROTECHNICS SAS, FR
Website:	www.hycarus.eu

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

PROJECT AND OBJECTIVES

The main objective of HYCARUS is to develop a Generic Fuel Cell System (GFCS) to power non-essential aircraft applications such as a galley in a commercial aircraft or to be used as a secondary power source on board business jets. Demonstration of GFCS performance in relevant and representative cabin environments (TRL6) will be achieved through flight tests on board a Dassault Falcon aircraft. In addition, HYCARUS will assess how to valorise the by-products (heat and ODA) produced by the fuel cell system to increase its global efficiency. The project is now completed.

NON-QUANTITATIVE OBJECTIVES

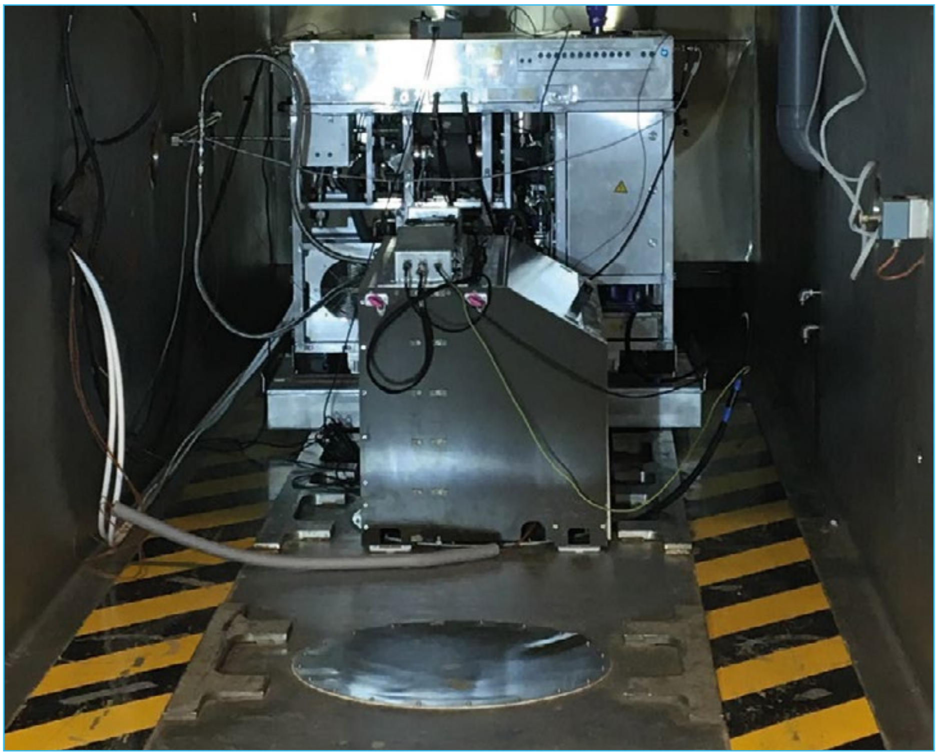
- Demonstrate operational capacity at various altitudes and in-flight variations typical of such packaged systems in aircraft
- Fuel cell system specification and qualification plan completed. Environmental tests (DO160) completed successfully in 2018.

PROGRESS AND MAIN ACHIEVEMENTS

- Demonstration in the 20-100 kW power range: 12.5 kW demonstrated. Only one configuration for one targeted application was tested
- TRL6 demonstration: successful.

FUTURE STEPS AND PLANS

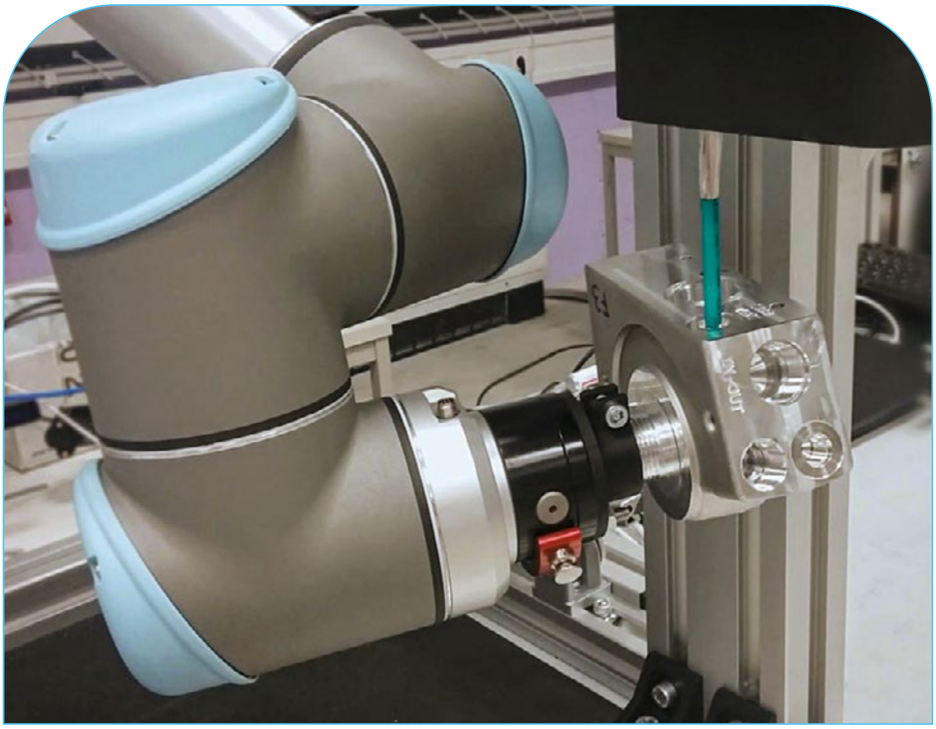
Project finished.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AIP 2011	Technology Readiness Level for demonstrator	TRL	6	6	✓
	Power range	kW	20	12.5	🛠
	Stack durability	hours	2 500	2 000	🛠
	Fuel cell system efficiency (LHV) at 25 % of rated power	%	55	45	🛠

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:	www.inline-project.eu

BENEFICIARIES: ELRINGKLINGER AG, FRONIUS INTERNATIONAL GMBH, KARLSRUHER INSTITUT FUER TECHNOLOGIE, OMB SALERI SPA

PROJECT AND OBJECTIVES

The project INLINE aims to design a flexible, scalable, high-quality production line for PEMFC manufacturing. The three objectives are: (a) redesign the media supply unit, (b) develop automated quality inspection methods to improve the end-of-line test, and (c) determine the scalability of the manufacturing process. The project is heading to the demonstration number 3, where all of the developed components and processes are put together to produce 20 HyLOG fleet systems.

NON-QUANTITATIVE OBJECTIVES

- The system improves workers' safety by preventing short-circuits during mounting of the batteries in the accu pack
- The projection-based assembly instructions shorten workers' training time
- The built chamber and installed semi-automation provides a safety enhancement for the worker who performs the end-of-line test.

PROGRESS AND MAIN ACHIEVEMENTS

- The MSU manufacturing process and the tank valve have both been significantly improved, reducing cycle time and costs
- The end-of-line test of the whole fuel cell system has been semi-automated, which also reduces cycle time
- The assembly steps are projected in real time to help the worker, while a robot puts in the screws.

FUTURE STEPS AND PLANS

- Integration of all developed components and quality control systems in production lines
- Manufacturing of 20 sample fuel cell systems, including the newly designed components
- Simulation of the scalability of the production process up to 50 000 pcs/year.

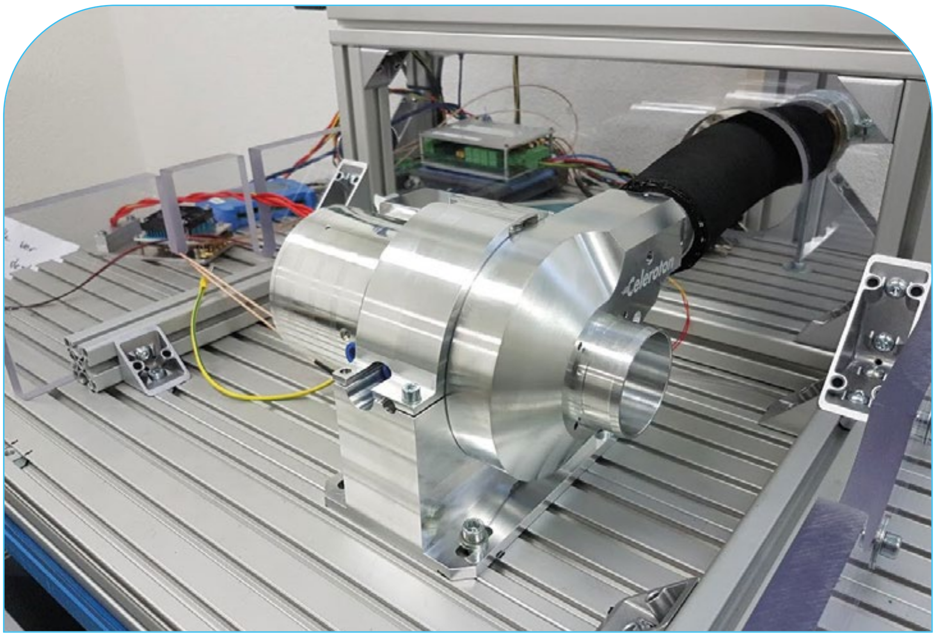
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Smart camera: detection rater	%	99	95	🔧
	Simulation model: scalability factor	%	100	100	✓
	Endoscope sensor: detection rate	%	100	85	🔧
	Screwing time	seconds	5	4.82	✓

INN-BALANCE

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

INN·BALANCE
AUTOMOTIVE FUEL CELL



Project ID:	**735969**
Call topic:	**FCH-01-4-2016** - Development of industrialisation-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: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, UNIVERSITAT POLITECNICA DE CATALUNYA, AVL LIST GMBH, VOLVO PERSONVAGNAR AB, STEINBEIS INNOVATION GGMBH, POWERCELL SWEDEN AB, CELEROTON AG, BROSE FAHRZEUGTEILE GMBH & CO, KOMMANDITGESELLSCHAFT WURZBURG, STEINBEIS 2I GMBH

PROJECT AND OBJECTIVES

The aim of INN-BALANCE is to develop a novel, integrated platform for producing advanced balance-of-plant (BoP) components in current fuel-cell based vehicles, to improve their efficiency and reliability. This should reduce costs and provide European car manufacturers and system integrators with a stable supply chain.

NON-QUANTITATIVE OBJECTIVES

- Develop different types of system models
- Advanced supervisory control strategies under development
- Test the fuel cell system in a vehicle powertrain
- Develop a technology plan undertake communication and dissemination activities.

PROGRESS AND MAIN ACHIEVEMENTS

- Develop an air turbo compressor and test it in a tailored cathode subsystem
- Design the anode module, composed of the BoP components, that allow for regulation of hydrogen flow to the stack
- Anti-freeze procedure for an optimised start-up of the fuel cell system.

FUTURE STEPS AND PLANS

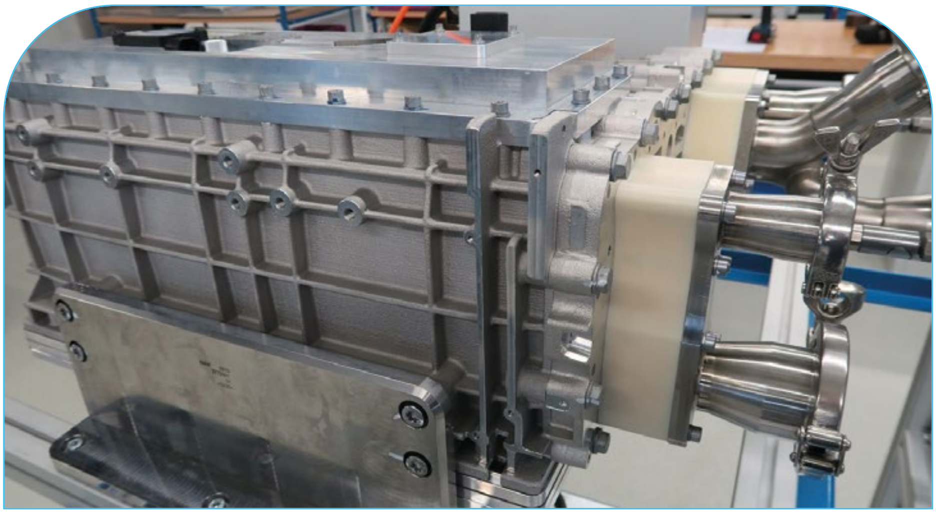
- Full validation of the air turbo compressor at system level
- Validation of the anode module at system level
- Validation of the thermal management module at system level
- On-board diagnostics software
- Vehicle integration of the fuel cell system.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Cold start	degrees Celsius	-40	
	Air compressor power	kW	10-12	
	Manufacturing cost of the air compressor	€/unit	250	
	Manufacturing cost of the anode	€/unit	220	
	Manufacturing cost of BoP	€/kW	100	

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 - 31/10/2019
Coordinator:	**JOHNSON MATTHEY PLC, UK**
Website:	**www.inspire-fuelcell.eu**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, TECHNISCHE UNIVERSITAT BERLIN, TECHNISCHE UNIVERSITAET MUENCHEN, REINZ-DICHTUNGS GMBH, ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, SGL CARBON GMBH, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, PRETEXO, JOHNSON MATTHEY FUEL CELLS LIMITED, UNIVERSITÉ DE MONTPELLIER, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

PROJECT AND OBJECTIVES

The overall aim of INSPIRE is to develop and integrate the most advanced MEA components (electrocatalysts, membranes, gas diffusion layers and bipolar plates) into 3 generations of automotive stacks meeting a beginning-of-life power density of 1.5 W/cm^2 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 third generation, 150 kW stack is now in operation and the leading new catalyst meeting the 0.44 A/mg Pt target has been scaled up.

NON-QUANTITATIVE OBJECTIVES

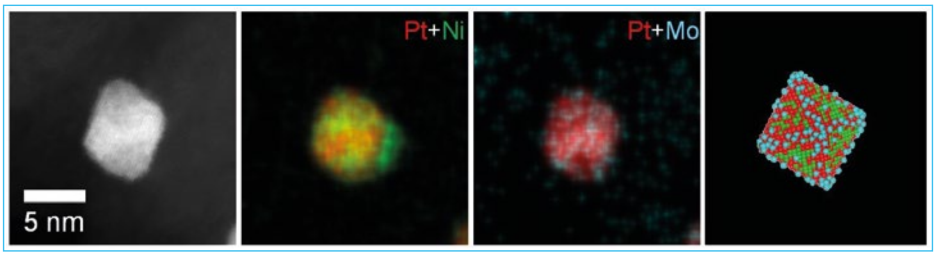
- New catalysts have passed through the performance and durability stage gates in WP3 and are being scaled up for MEA optimisation and testing in WP4
- INSPIRE workshop held, bringing together several FCH JU H2020 projects focused on PEM fuel cell components.

PROGRESS AND MAIN ACHIEVEMENTS

- Catalyst meeting the project mass activity target (>0.44 A/mg Pt) and stability requirements (equal to benchmark) now scaled up
- 1.41 W/cm^2 was achieved with the GEN 2.5 MEA design in the GEN 2.0 hardware at BMW
- GEN 3.0 383-cell stack manufactured and demonstrated.

FUTURE STEPS AND PLANS

- Full performance and durability testing of GEN 3.0 383-cell stack
- Assessment of best catalyst and catalyst layers in a large single cell
- Economic assessment of GEN 3.0 components
- Accelerated degradation testing in short stacks.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2015	Areal power density	W/cm^2	1.5	1.4	SoA achieved	1.3 (50 cm^2 cell, 250 kPaabs, outlet, 94 °C, 65 % RH)	2018
Project's own objectives	Catalyst	A/mg	0.6	0.6	✓	0.6 (GM)	2016
MAWP 2014-2020	Performance loss over 6 000 hours	%	10 %	N/A		5 605 hrs (NREL)	2015
	<0.125 mg/cm^2	mg/cm^2	0.125	0.3		0.125 (GM)	2017
	CAPEX @ 50 000 units/year	€/kW	50	N/A		50 $/kW @100 000 units/year 45 $/kW @ 500 000 units/year (USDOE analysis)	2017

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:	**€3 704 757.50**
FCH JU max. contribution:	**€2 939 457.50**
Project start - end:	01/03/2017 - 28/02/2021
Coordinator:	**Teknologian tutkimuskeskus VTT Oy, FI**
Website:	**www.vtt.fi/sites/maranda**

BENEFICIARIES: SUOMEN YMPARISTOKESKUS, ABB OY, POWERCELL SWEDEN AB, OMB SALERI SPA, PERSEE, SWISS HYDROGEN SA

PROJECT AND OBJECTIVES

The MARANDA project is developing an emission-free, hydrogen-fueled PEMFC-based hybrid powertrain system (3 x 82.5 kW AC) for marine applications. It will be validated in test benches and on board the research vessel Aranda. The project will increase the market potential of hydrogen fuel cells in the marine sector. General business cases for different actors in the marine and harbor or fuel cell business will be created. The project has passed the system design phase. Fuel cell stack, system and key BoP components are being characterised.

NON-QUANTITATIVE OBJECTIVES

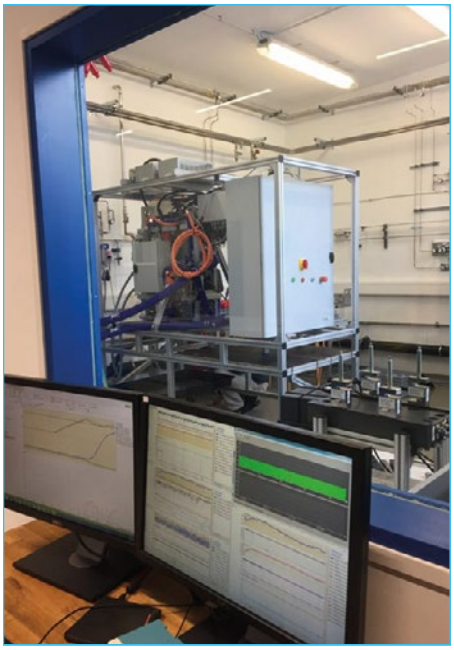
- MARANDA has already had a significant impact on the development of RCS for maritime applications
- Fuel cell systems should be able to withstand shocks, vibrations, saline environment and ship motions
- Evaluation of the economic and environmental impact for a prospective for prospective customers
- Prepare a report on business analysis tool design and use
- Formulate an initial go-to-market strategy
- Map opportunities for future demonstration actions.

PROGRESS AND MAIN ACHIEVEMENTS

- Three 100 kW S3 stacks have been assembled and delivered for use in fuel cell systems
- First 82.5 kW system has been assembled and delivered for durability testing
- Regulations, codes and standards for fuel cells in marine applications have been reviewed and gaps identified.

FUTURE STEPS AND PLANS

- Commissioning of the first fuel cell system at durability test site (M28)
- Acceptance from Finnish Transport Safety Agency (Trafi) for the installation of fuel cell system and hydrogen storage on board the Aranda (M36)
- Field trial start on board the Aranda (M38)
- First fuel cell system to complete 4380 testing (M36)
- Field trial start completed (M45).



QUANTITATIVE TARGETS AND STATUS

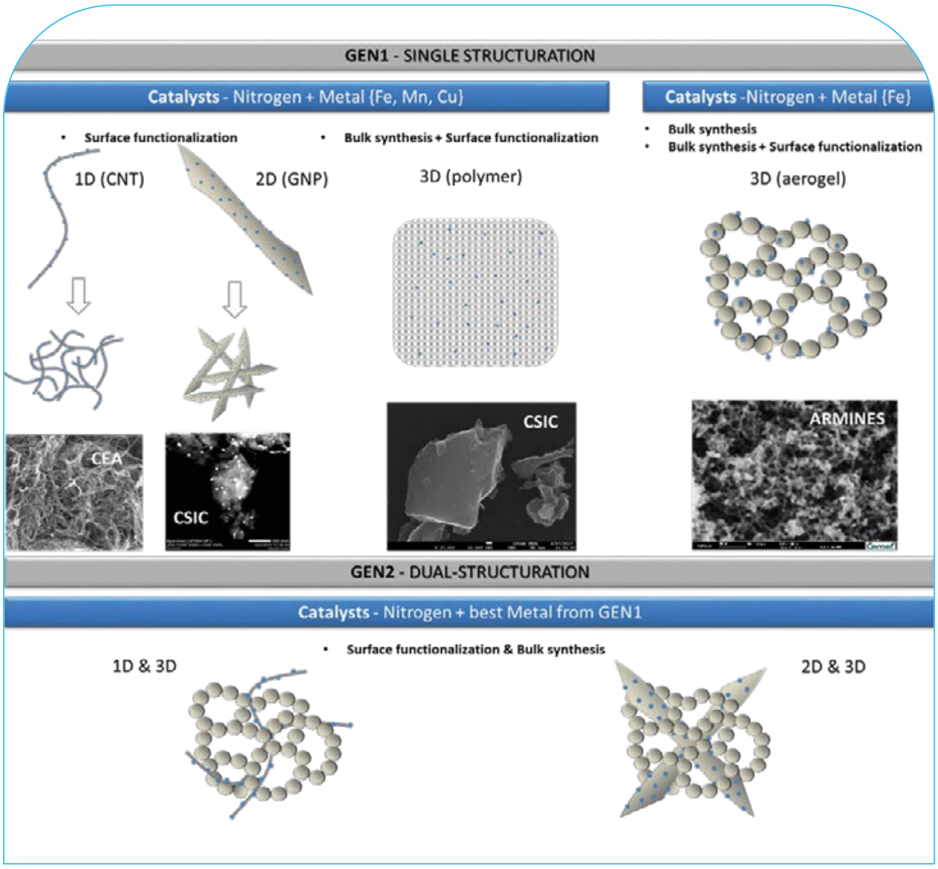
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2016	**Fuel cell system effect**	**kW**	**75**	**82.5**	✓
	Freeze start capability	**C**	**-35**	**N/A**	🛠
	Stack durability	**mV/1 000h**	**4.6**	**1.7**	🛠
	Fuel-to-electric efficiency (AC)	**%**	**48**	**45**	🛠

PEGASUS

PEMFC BASED ON PLATINUM GROUP METAL FREE STRUCTURED CATHODES

Project ID:	779550
Call topic:	FCH-01-2-2017 - Towards next generation of PEMFC: Non-PGM catalysts
Project total costs:	€2 829 016.88
FCH JU max. contribution:	€2 829 016.88
Project start - end:	01/02/2018 - 31/01/2021
Coordinator:	COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Website:	www.pegasus-pemfc.eu

BENEFICIARIES: AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS, TECHNISCHE UNIVERSITAET MUENCHEN, ECOLE NATIONALE SUPERIEURE DES MINES DE PARIS, IRD FUEL CELLS A/S, TOYOTA MOTOR EUROPE NV, HERAEUS FUEL CELLS GMBH



PROJECT AND OBJECTIVES

PEGASUS is exploring a promising route to removing Pt and other critical raw materials from PEMFC, and replacing them with non-critical elements and structures, to enable efficient and stable electro-catalysis. The aim of this project is to develop the experimental proof-of-concept for novel catalytic materials and structures.

NON-QUANTITATIVE OBJECTIVES

- Contribution to determination of active site structure, characterisation of catalyst active centre using XAS
- Intrinsic performance of catalyst, implementation of scanning electrochemical spectroscopy to characterise the PGM-free catalyst
- International benchmark, cooperation with US-DoE and Japan NEDO.

PROGRESS AND MAIN ACHIEVEMENTS

- Synthesis of PGM-free catalysts with different routes (4 different pathways). Benchmark of different non-noble metals as active centres
- Integration of PGM-free catalyst in MEA. Impact of the printing process on the MEA performances. Thin (50 µm) active layer deposition achieved
- Set up scanning electrochemical microscopy to benchmark material via ex-situ fine electrochemical measurement.

FUTURE STEPS AND PLANS

- Measurement of the active layer porosity by FIB-SEM and the ionomer coverage rate on PGM catalyst, then structure optimisation to improve performance
- Cartography of the performance of catalyst vs agglomeration state at sub-micro scale to optimise the 3D structure of the developed catalysts
- Improve the number of active sites on the catalyst, and better define the active site structure
- Operando characterisation of water distribution in the PGM-free cathode
- Reduce Pt loading. Development of PGM-free catalysts (for both anode and cathode).

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Catalyst activity @ 0.9 V under O2	mA/cm²	77	-		21	2018
		mA/cm²	44	-		-	-
	Cell perfomance - current density @ 0.7 V	mA/cm²	600	140		320	2018
	MEA durability - performance loss	%	30	not started		-	-

TAHYA
TANK HYDROGEN AUTOMOTIVE

Project ID:	**779644**
Call topic:	**FCH-01-3-2017** - Improvement of compressed storage systems in the perspective of high-volume automotive application
Project total costs:	**€3 996 943.75**
FCH JU max. contribution:	**€3 996 943.75**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**OPTIMUM CPV, BE**
Website:	**tahya.eu**

BENEFICIARIES: VOLKSWAGEN AG, TECHNISCHE UNIVERSITAET CHEMNITZ, BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG, RAIGI SAS, ANLEG GMBH, POLARIXPARTNER GMBH, ABSISKEY

PROJECT AND OBJECTIVES

1. Preparatory work to provide a high-performance H_2 storage system that meets health, safety and environmental standards.
2. The storage system can be mass produced and is cost competitive.
3. Work on regulation codes and standards (RCS) to propose updates to GRT13 and EC79, using test results obtained during the project's lifetime.

The first prototypes are being delivered to VW for integration and optimisation in cars.

NON-QUANTITATIVE OBJECTIVES

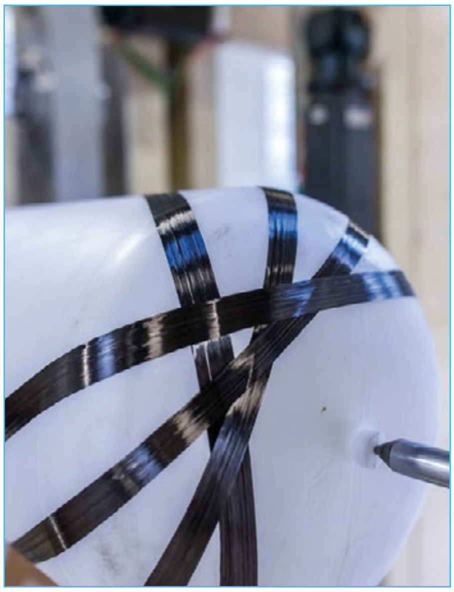
- Develop tools able to rapidly calculate Monte Carlo simulations, to assess and analyse RCS
- Determine the accepted risk level
- Monte Carlo simulation to analyse RCS
- Understand the statistical nature of the initial testing.

PROGRESS AND MAIN ACHIEVEMENTS

- Development of a complete and competitive H_2 storage system prototype (liner, cylinder, OTV)[2]
- Development of an entirely European system with suppliers from France, Belgium and Germany
- Increased credibility from European OEM's.

FUTURE STEPS AND PLANS

- Implement the H_2 system prototype using an R&D car platform
- Optimise the first prototype (alternative materials and geometries)
- Validate the probabilistic approach with a test campaign to discuss harmonising the requirements for RCS
- Validate optimised manufacturing processes
- Validate alternative tank geometries.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Liner: Improved temperature tolerance -40 °C to +100 °C using combination of materials- Improvement temperature tolerance	Softening Temperature	Glassy Temperature <-40 °C, Softening Temperature >110 °C	N/A	✓
	Liner: New tests system to be defined for quality control and repeatability - liner thickness, air bubbles, tensile test	N/A	Analysis of the part	N/A	🔧
	OTV: Reduction of machining costs (actual use of 56 tools down to 40) -Parts/tools	tools	40	42	🔧
	OTV Reduction of OTV mounting time (from 150 down to 30 minutes) and reduction of testing time	Minutes	30	40	🔧

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 - 31/08/2019
Coordinator:	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR
Website:	www.volumetriq.eu

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

Automated Stack Assembly Line (ASAL)

PROJECT AND OBJECTIVES

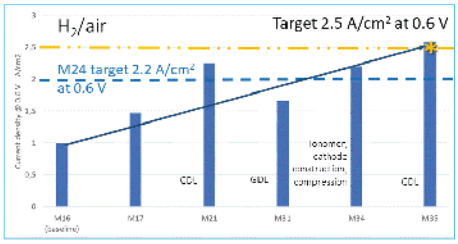
VOLUMETRIQ aims to develop a European supply base for automotive PEM fuel cell stacks and their key components with volume manufacturing capability and embedded quality control. Targets are 1.5 W/cm² at single cell and stack levels. VOLUMETRIQ has achieved a leading single cell power density of 2.67 A/cm² at 0.6 V (1.6 W/cm²) with catalyst-coated membranes produced at volume in automotive-size, single-cell hardware developed by the project. This power density reduces the number of cells required for the 90 kW stack (under construction) and will positively impact the stack cost.

PROGRESS AND MAIN ACHIEVEMENTS

- A novel, electrospun, nanofibre-reinforced membrane is 4 times more durable than the state of the art developed by a previous project
- VOLUMETRIQ has achieved a leading single-cell power density of 2.67 A/cm² at 0.6 V (1.6 W/cm²)
- Novel, automotive-size hardware has been manufactured and validated.

FUTURE STEPS AND PLANS

- Short stack (project hardware) testing with VOLUMETRIQ CCMs
- Full stack (90 kW) build and testing
- Costs analysis.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP addendum (2018-2020)	Single cell power density	W/cm²	1.5	1.6	✓	1.43	2019
Project's own objectives	Stack cost	€/kW	50 (Expect to significantly improve on this target, exceeding SoA)	Expected, given outstanding power density at single cell level	🔧	30	2016
	In situ AST RH cycles at OCV, 90 °C	Cycles	20 000	48 000	✓	ca. 40 000	2018

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** - 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**
Project start - end:	01/05/2013 - 30/06/2018
Coordinator:	**AFC ENERGY PLC, UK**
Website:	**alkammonia.eu**

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

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 project formally ended in 2018 but testing continues on the integrated system and the results will be shared with potential end-users.

NON-QUANTITATIVE OBJECTIVES

- Partner ZBT proceeded with the more strict and onerous process of TUV certification for the ammonia cracker instead ➔ Achieved
- The long-term testing of the integrated system is still in progress at AFCEN, despite the project formally ending. PSI LCA, total system cost and sustainability analyses completed with interim data ➔ Achieved.

PROGRESS AND 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 subsystems into the ALKAMMONIA system.

FUTURE STEPS AND PLANS

- Project finished
- Longevity testing of the integrated system, funded commercially
- Scale-up of ALKAMMONIA prototype to address EV charging and other diesel generator displacement opportunities.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Cracker efficiency (based on LHV)	%	80	90	✓	N/A	N/A
	AFC stack weight	kg/kW	150	28	✓	200 kg, based on a 5 kWe stack	2013
	Projected cracker costs	€/kW	1 000	2 183		N/A	N/A

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, UK**
Website:	**www.autore-fch.com**

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

PROJECT AND OBJECTIVES

The main project objective is to create the foundations for commercialising an automotive derivative fuel cell system in the 50 to 100 kWe range, for CHP in commercial and industrial buildings. Specifically:

- develop system components allowing reduced costs, increased durability and efficiency and, ultimately, allowing the levelised cost of electricity to reach grid parity
- build and validate a first 50 kWe PEM prototype CHP system
- create the required value chain from automotive manufacturers

The project was completed in April 2019.

PROGRESS AND MAIN ACHIEVEMENTS

- Prototype test system has been built and commissioned and systems testing undertaken
- Modelling of the CHP concept with improved reformer to include membranes has been completed
- An initial engineering configuration for the improved reformer has been proposed.

FUTURE STEPS AND PLANS

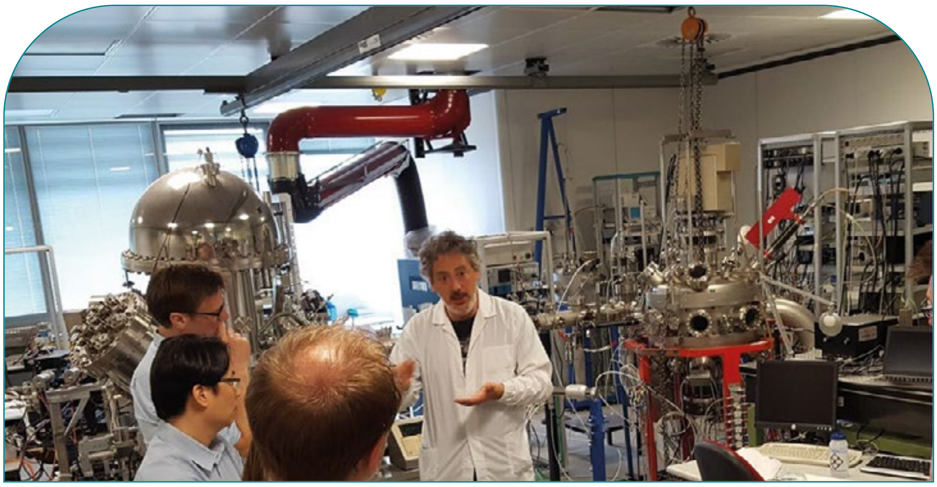
Project finished.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP 2014-2020	electrical efficiency	% LHV	40	47	✓	52-60	2018
	thermal efficiency	% LHV	45	45	✓	40	n/a
	durability	hours	16 000	N/A	🛠	20 000	2018

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)
Project total costs:	**€6 868 158.75**
FCH JU max. contribution:	**€3 999 896**
Project start - end:	01/02/2017- 31/07/2020
Coordinator:	**FONDAZIONE BRUNO KESSLER, IT**
Website:	**www.ch2p.eu**

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

PROJECT AND OBJECTIVES

CH2P is focused on polygeneration of hydrogen, power and heat using novel SOFC technology fuelled by methane-rich gases. Objectives of CH2P are:

- Distribution of hydrogen and power compliant with the EU's DAFI, using a single technology
- Flexible production of hydrogen and power following end user demand at the station
- H_2 purity level compliant with the use in fuel cell electric vehicles
- Bring the cost of hydrogen production below 4.5 €/kg, using an innovative cost model.

NON-QUANTITATIVE OBJECTIVES

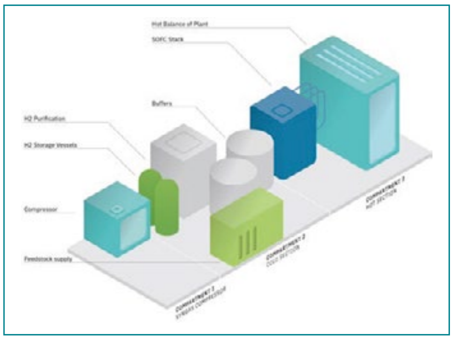
- CH2P will contribute to creating new jobs in EU
- CH2P will deliver gas, H_2 and power with a single technology
- CH2P will be able to reach hydrogen generation costs far below 4 €/kgH_2.

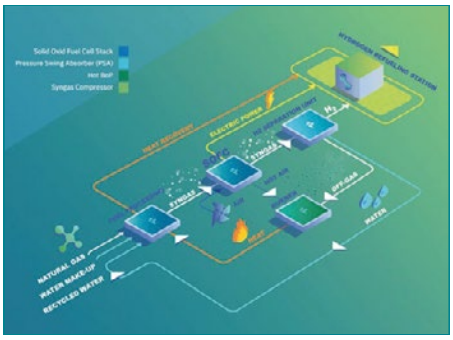
PROGRESS AND MAIN ACHIEVEMENTS

- The CH2P project covers a large range of H_2 and power production. The total efficiencies depend on the operating mode, expected to exceed 65 %
- Hydrogen purity. CH2P system produces 5N purity level, compliant with use in the transport sector, for on-board PEMFC
- Hydrogen cost estimated at 4.5 €/kg with novel cost model.

FUTURE STEPS AND PLANS

- The project has been delayed. A revised plan has been drafted, with the project's end now scheduled for 12/2020
- The full 20 kgH_2/day system will be fully tested by October 2019. This alfa version will be tested in Hygear
- A second 20 kgH_2/day system will be realised by Hygear as a beta version by July 2020
- A 40 kgH_2/day CH2P system, combining alfa and beta version of 20 kgH_2/day each, will be tested in SHELL by December 2020
- A final full LCA and LCC will be delivered by December 2020.





QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2016	System size	kgH_2/day	20	N/A		N/A	2019
	Flexible cogeneration of H_2 and power	%	50 + 50	50 + 50	✓	N/A	2019
	System efficiency	%	65	79	✓	65	2017

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:	**€8 578 142.6**
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: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM, LOGAN ENERGY LIMITED, LINDE GAS MAGYARORSZAG ZARTKORUEN MUKODO RESZVENYTARSASAG, JEMA ENERGY SA, HYDROGENE DE FRANCE, AQUIPAC SAS

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
- Validation of technical and economic readiness of the fuel cell system power generation at megawatt scale
- Field demonstration and deployment.

The site construction is progressing. All equipment was delivered on site (Martinique) including fuel cell, PSA system, cooler for hydrogen flow, tanks, analyser and valves. The system will be operational in autumn 2019.

NON-QUANTITATIVE OBJECTIVES

- Training of technicians
- Safety improvements: due to the refinery environment, safety requirements are extraordinarily high.

PROGRESS AND MAIN ACHIEVEMENTS

- All equipment has been manufactured and shipped to Martinique
- The civil work on the site is progressing
- Sara Martinique entered as 100 % investor in Aquipac, the company in charge of operating the fuel cell.

FUTURE STEPS AND PLANS

- Installation and commissioning is expected in September 2019
- Mid-term conference is planned for 5 December
- Business model for large stationary fuel cell.

QUANTITATIVE TARGETS AND STATUS

Target Source	Parameter	UNIT	Target	Achieved to date by the project	Target Achieved?
AIP 2011	Lifetime (between FC refurbishment)	hour	>10 000	40 000	Work in progress
	Performance loss	%	< 3	0	
Project's own objectives	Electrical efficiency	%	50	48	
	Cost	€/MW	<3.0 mil	3.0 mil/euro/MW	
	Availability	N/A	N/A	90-95 %	

COMSOS
COMMERCIAL-SCALE SOFC SYSTEMS

Project ID:	**779481**
Call topic:	**FCH-02-11-2017** - Validation and demonstration of commercial-scale fuel cell core systems within a power range of 10-100 kW for selected markets/applications
Project total costs:	**€10 277 897.50**
FCH JU max. contribution:	**€7 486 954.75**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.comsos.eu**

BENEFICIARIES: POLITECNICO DI TORINO, SOLIDPOWER SA, SOLIDPOWER SPA, SUNFIRE GMBH, CONVION OY, ENERGY MATTERS BV

PROJECT AND OBJECTIVES

The project objective is to validate and demonstrate fuel cell based CHP solutions in the mid-sized power ranges. The outcome proves the advantages of such systems, business models, and benefits for the customer. The overall target amount of installations is 23 units with a total power output of 450 kW, distributed as follows: Convion, 2 units of 60 kW each (total 120 kW); Sunfire, 6 units of 25 kW each (total 150 kW) and SOLIDpower, 15 units of 12 kW each (total 180 kW).

NON-QUANTITATIVE OBJECTIVES

Business models for niche markets to understand business drivers. The development of a techo-economic model of the project's three SOFC-CHP systems under consideration has started by collecting data from manufacturers.

PROGRESS AND MAIN ACHIEVEMENTS

- System design and engineering has been finalised as scheduled
- First site chosen for each manufacturer and site preparation started
- Business case analysis for the 10-50 kW units has been finalised.

FUTURE STEPS AND PLANS

- All system should be installed and in operation
- Installed systems are meeting performance and emission targets
- Gather at least 6 months of data for all systems.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2017	Amount of installed power	kW	450	Work In progress	N/A	N/A
	Availability	%	97		97	2017
MAWP addendum (2018-2020)	Cost	€/kW	<4 000		>15 000	2017
	Lifetime	years	10		3-5	2017
Project's own objectives	OEMs pays 30 % of the cost of installed SOFC system	%	30		N/A	N/A

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 - 31/03/2020
Coordinator:	**DLR-INSTITUT FUR VERNETZTE ENERGIESYSTEME EV, DE**
Website:	**project-d2service.eu**

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

PROJECT AND OBJECTIVES

D2Service aims to improve the serviceability of residential and commercial fuel cell systems. Installation and maintenance procedures of SOFC and PEM fuel cell-based units are analysed and optimised to reduce service times and costs, and to avoid mistakes during installation and service. Design and the components of the units are optimised to ensure simplified exchangeability, increased longevity and standardisation, thus decreasing service frequency and duration. The main improvements have been realised and are currently being tested in a dedicated field trial.

NON-QUANTITATIVE OBJECTIVES

- Elaboration of guidelines for easily understandable service manuals
- Life-time desulphurisation (type HDS). Suitable catalyst and adsorbed materials identified for 60 000h. Laboratory verification is currently being performed
- Water treatment optimisation. Better material identified, leading to extended service intervals.

PROGRESS AND MAIN ACHIEVEMENTS

- Improvement of design of SOFC mCHP units with respect to efficiency, serviceability, durability and cost reduction
- Identification of suitable catalyst and absorber materials for 60 000h lifetime of hydrodesulphurisation component
- Elaboration of guidelines for designing easily understandable service manuals.

FUTURE STEPS AND PLANS

- Execution and analysis of field trial
- Project achievements dissemination and communication
- Laboratory long-term tests of mCHP units
- Development of BlueGen variant prototype.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2014	Service time / presence time of maintenance technician (SOFC)	hours	<4	4	✓
	Total down time for servicing (SOFC)	hours	<48	48	✓
	Service interval (SOFC)	1/a	<1	1	✓
	Service costs (SOFC)	€/(kW*a)	<600	1 000	🛠

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 BV, NL**
Website:	**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 a combined heat and power PEM fuel cell power plant and its integration into a chlor-alkali production plant.
The PEM system was installed at the chlor-alkali plant in Yingkou, China, in September 2016. The project was completed in December 2018.
The planned capacity of 2 MW was reached, even if some technical problems (related to air and hydrogen quality) were encountered.

NON-QUANTITATIVE OBJECTIVES

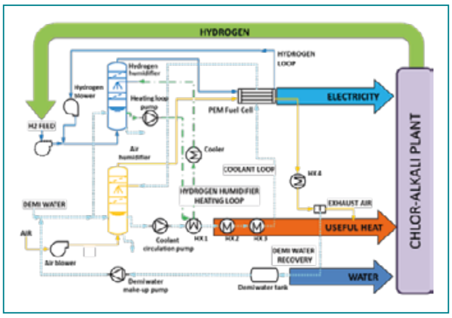
- Training of system operators in China achieved
- More than 850 tons of hydrogen have been recovered, avoiding emission of 15 000 tCO2
- Developed open-source calculation tool for preliminary economical assessment.

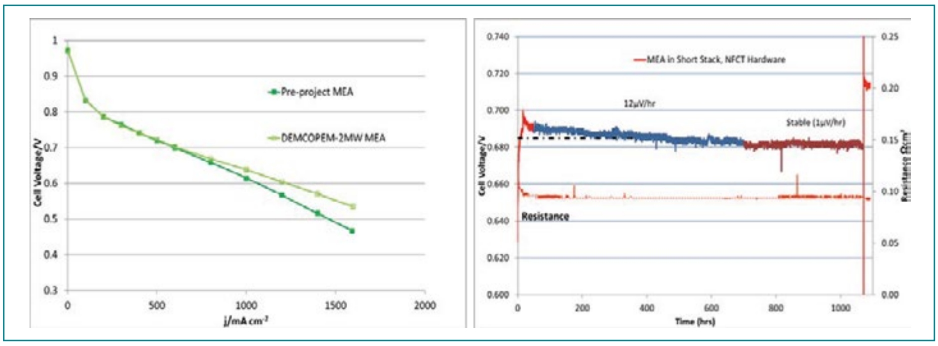
PROGRESS AND MAIN ACHIEVEMENTS

- 2 MW system operational for over 2 years (heat recovery available) with remote monitoring and control
- Modelling of the complete system performed, with good accuracy (BoL)
- Analysis and basic design for roll-out phase performed, showing significantly reduced costs.

FUTURE STEPS AND PLANS

Project finished.





QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives (aligned with MAWP addendum 2018-2020	System operation energy	MW	2	✓ (even if temporarily)
	System operation lifetime	hours	16 000	✗
	Costs per kW	€/kW	3 000	✓

DEMOSOFC

DEMONSTRATION OF LARGE SOFC SYSTEM FED WITH BIOGAS FROM WWTP

DEMOSOFC
FCH2-JU PROJECT

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 SPA, SOCIETÀ METROPOLITANA ACQUE TORINO SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

PROJECT AND OBJECTIVES

The EU-funded DEMOSOFC project demonstrates the technical and economic feasibility of operating a 174 kWe SOFC system in a wastewater treatment plant. The present work is related to the results of the operation of the SOFC system: the first SOFC module was activated in October 2017 and the second in October 2018. More than 6 300 hours of operation have been reached onsite. Measured SOFC efficiency from compressed biogas to AC power has been 50-53 %, with peaks of 56 %. Emissions show NOx <20 mg/m^3, SO_2 <8 mg/m^3 and particulate lower than ambient air values (0.01 mg/m^3).

NON-QUANTITATIVE OBJECTIVES

- Training of end-user (SMAT) technicians on the new fuel cell system
- Visits to the demo sites organised, in a standardised format, for people from all over the world
- Build technical knowledge, customer and investor confidence. Lessons learned for replication of detailed engineering, construction, installation, management in the long run
- A complete FMEA of the demo has been developed, providing useful experience for the future
- Dissemination via press releases, social media, website, workshops at demo site and elsewhere, conferences, public events and technical papers.

PROGRESS AND MAIN ACHIEVEMENTS

- Electrical efficiency always higher than 50 %, with peaks at 56 %
- Zero emissions to atmosphere, NOx SO_2 and PM below detection limits
- >7 000 hours of operation on site.

FUTURE STEPS AND PLANS

- First and second SOFC modules operation in parallel (long-term operation)
- First SOFC module stacks repair activity
- Third SOFC module delivery to the site
- Exploitation plan to maximise the project's impact
- Analysis of the potential replication impacts in other WWTPs.

QUANTITATIVE TARGETS AND STATUS

Target Source	Parameter	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	Target Achieved?
MAWP 2014-2020	Electrical efficiency	% LHV	42-60	50-56	✓
	NOx emissions	mg/kWh	< 40	(Measured value onsite was < 20 mg/m3)	✓
	Availability of the plant	%	97	60	
	Thermal efficiency	% LHV	24-42	30-35	✓
	Lifetime	years of plant operation	8 - 20	2	

EVERYWH2ERE

MAKING HYDROGEN AFFORDABLE TO SUSTAINABLY OPERATE EVERYWHERE IN EUROPEAN CITIES

Project ID:	**779606**
Call topic:	**FCH-02-10-2017** - Transportable FC gensets for temporary power supply in urban applications
Project total costs:	**€6 762 324.46**
FCH JU max. contribution:	**€4 999 945.76**
Project start - end:	01/02/2018 - 31/01/2023
Coordinator:	**RINA CONSULTING SPA, IT**
Website:	**www.everywh2ere.eu**

BENEFICIARIES: ACCIONA CONSTRUCCION SA, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, ICLEI EUROPEAN SECRETARIAT GMBH (ICLEI EUROPASEKRETARIAT GMBH)*, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, POWERCELL SWEDEN AB, THT CONTROL OY, GENPORT SRL - SPIN OFF DEL POLITECNICO DI MILANO, IREN SPA, IREN ENERGIA SPA, IREN RINNOVABILI SPA, MAHYTEC SARL, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SWISS HYDROGEN SA, DELTA1 GUG (HAFTUNGSBESCHRANKT), LINDE GAS ITALIA SRL, FRIEM SPA.

PROJECT AND OBJECTIVES

EVERYWH2ERE aims to demonstrate how fuel cells can replace diesel-fuelled internal combustion engines in temporary gensets. The project will realize 4x25 kW + 4x100 kKW gensets to be tested at music festivals, temporary events and on construction sites. The results of the demonstration campaign will be used to evaluate techno-economic feasibility and marketability.

NON-QUANTITATIVE OBJECTIVES

- Demonstration of economic viability, safety and environmental sustainability of the novel solutions. HSE assessment performed for design and operation. LCA started and market and competitors' analysis conducted
- Promote FC gensets among cities. Realisation of a dedicated event and connection with FCH JU regions and cities initiative.

PROGRESS AND MAIN ACHIEVEMENTS

- Design of the fuel-cell based gensets layout: FC SuSy, H2Bottles, Power converters, containerisation
- Interaction with several stakeholders for demonstration, regulation and business models insights
- Starting the manufactue of FC SuSy and H_2 storage

FUTURE STEPS AND PLANS

- Realisation of the first prototypes
- Validation testing of gensets in lab
- Validation testing of hydrogen bottles in lab
- First demonstration on ACCIONA construction sites and at festivals.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Start in sub-zero of the FC SuSy	°C	-20	(Demonstration not started yet)
	CAPEX	€/kW	5 500	
	Efficiency of the genset	%	50	
	Lifetime	hours	20 000	
	OPEX Increase if compared with diesel genset	%	15	

PACE

PATHWAY TO A COMPETITIVE EUROPEAN FC µCHP 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**

BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, HEXIS AG, ELEMENT ENERGY LIMITED, VAILLANT GMBH, EWE AKTIENGESELLSCHAFT, SOLIDPOWER SPA, BOSCH THERMOTECHNIK GMBH, SUNFIRE GMBH, VIESSMANN WERKE GMBH & CO KG, SOLIDPOWER GMBH, BDR THERMEA GROUP BV, VIESSMANN WERKE ALLENDORF GMBH, VIESSMANN ELEKTRONIK GMBH

PROJECT AND OBJECTIVES

PACE unlocks the large-scale European deployment of the state-of-the art smart energy solution for private homes: fuel-cell micro cogeneration. PACE will see 2 800 householders across Europe reap the benefits of this home energy system. The project enables manufacturers to move towards product industrialisation and fosters market development at national level by working with building professionals and the wider energy community. The project uses modern fuel cell technology to produce efficient heat and electricity at home, empowering consumers in their energy choices.

NON-QUANTITATIVE OBJECTIVES

Field demonstration of 2 500 units: 446 units delivered already.

PROGRESS AND MAIN ACHIEVEMENTS

- Winner of the 2018 FCH JU Award for Best Success Story
- More than half the units (1 416) were sold by the end of March 2019
- PACE technical workshop for EU Commission "Fuel Cell micro-Cogeneration in the Future Energy System – State of Play and Outlook", 9 October 2019, Brussels.

FUTURE STEPS AND PLANS

All the 2 800 units to be deployed in the project will be installed.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET	FULL REFERENCE	COMMENTS
Project's own objectives	Sold units	N/A	2 800	1 416		1 046	2017	ene.field	N/A

REMOTE

REMOTE AREA ENERGY SUPPLY WITH MULTIPLE OPTIONS FOR INTEGRATED HYDROGEN-BASED TECHNOLOGIES

Project ID:	**779541**
Call topic:	**FCH-02-12-2017** - Demonstration of fuel-cell-based energy storage solutions for isolated micro-grid or off-grid remote areas
Project total costs:	**€6 761 557.50**
FCH JU max. contribution:	**€4 995 950.25**
Project start - end:	01/01/2018 - 31/12/2021
Coordinator:	**POLITECNICO DI TORINO, IT**
Website:	**www.remote-euproject.eu**

BENEFICIARIES: STIFTELSEN SINTEF, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, BALLARD POWER SYSTEMS EUROPE AS, ENEL GREEN POWER SPA, HYDROGENICS EUROPE NV, IRIS SRL, POWIDIAN, ORIZWN ANONYMH TECHNIKI ETAIREIA, TRONDERENERGI AS, EPS ELVI ENERGY SRL, SINTEF AS

PROJECT AND OBJECTIVES

REMOTE will demonstrate the technical and economic feasibility of 2 fuel-cells-based H_2 energy storage solutions (integrated P2P, non-integrated P2G+G2P systems), deployed in 4 demos, based on renewables (solar, wind, biomass, hydro), in isolated micro-grid or off-grid remote areas. The analysis of the economic and regulatory framework, technical solutions and control strategies for the demos was performed by year 1.5 (May 2019). Design, engineering, plan for O&M and permitting procedures have been assessed for all the demos and site preparation is ongoing.

NON-QUANTITATIVE OBJECTIVES

- Validate real demonstration units in isolated micro-grid or off-grid areas so that suppliers, end users and general stakeholders can gain experience for future deployments of P2P solutions
- Contribution to regulation: identification of gaps
- Through demo design, installation and operation, REMOTE will create fundamental know-how for the next generation of fully integrated P2P chains, based on fuel cells and H_2 technologies adapted to market and society's needs. The project will contribute to scientific advances in managing isolated micro-grids.

PROGRESS AND MAIN ACHIEVEMENTS

- Detailed analysis of the technical and business cases of the 4 demos of P2P systems based on H_2
- Definition of detailed engineering of the demos 1, 2 and 3 in southern Europe (including construction permits). Milestone 4 of the project
- Detailed risk assessment and permission procedure for the demo 4 in northern Europe.

FUTURE STEPS AND PLANS

- January 2020: construction, installation and commissioning of Agkistro and Rye demos
- June 2020: construction, installation and commissioning of Ginostra and Ambornetti demos
- January 2021: performance analysis of the 4 demos
- October 2021: market analysis and value chain, business cases
- October 2021: environmental impact, LCA, pre-normative feedback from the demos.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP addendum 2018-2020 (target year 2020)	Rated efficiency electrolyser (PEM)	kWh/kg	55.5	50.5	✓ (rated value)	50	2020
	Lifetime	years of plant operation	8-20	15 (fuel cell) - 20 (surrounding equipment)	✓ (rated value)	N/A	N/A
	Electrolyser footprint (PEM)	m^2/MW	100	273		10	2018-2020
	Rated efficiency electrolyser (alkaline)	kWh/kg	50	50.6	✓ (rated value)	N/A	N/A
	Rated efficiency fuel cell (PEM)	%LHV	42-60	45	✓ (rated value)	51	2018

STAGE-SOFC

INNOVATIVE SOFC SYSTEM LAYOUT FOR STATIONARY POWER AND CHP APPLICATIONS

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

The aim of the STAGE-SOFC project was to develop a proof-of-concept (PoC) prototype of a new SOFC with a serial connection of one exothermal CPOX stage, with one - or a multiple of - endothermic steam-reforming stages. The system combined the benefits of the simple and robust CPOX layout with the high efficiencies obtained by the steam-reforming process. The first prototype achieved the set targets for electrical power: >5 kW AC and electrical efficiency >45 %. The PoC prototype was designed, constructed, and commissioned. The project is now finished.

NON-QUANTITATIVE OBJECTIVES

- New SOFC concept successfully developed
- Know-how gained about reforming through a developed control of carbon formation in fuel processing units for SOFC applications and process integration designs
- CFD modelling of planar SOFC through numerical predictions of process efficiency, validated simulations of characteristics of equipment units and dynamic responses.

PROGRESS AND MAIN ACHIEVEMENTS

- The PoC system was successfully designed, constructed and commissioned and all the main design parameters were met
- Potential markets, business cases and techno-economic analyses were studied
- Active dissemination of project results, via conferences, exhibitions and scientific papers, among others.

FUTURE STEPS AND PLANS

Project finished.

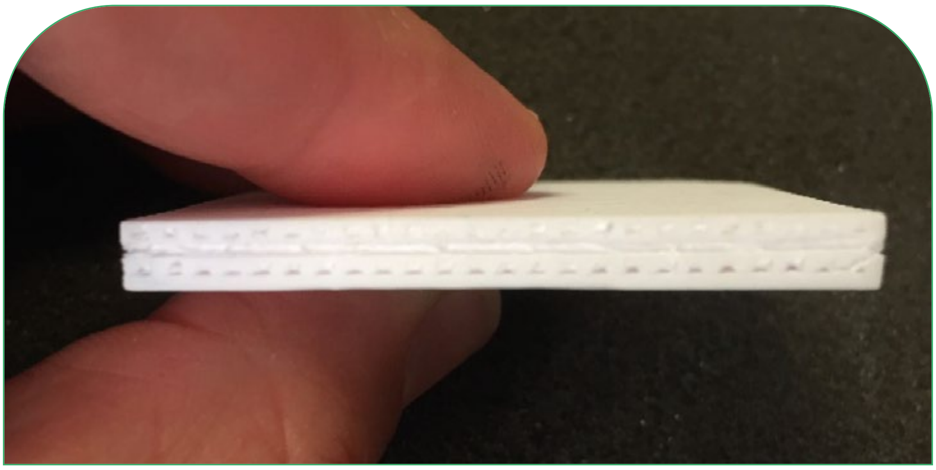
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAIP 2008-2013	Electrical efficiency (AC, LHV) at system level	%	45	45	✓	50	2012
	Total efficiency (LHV) at system level	%	80	80	✓	95	2012
	Cost per unit @ 5 kW class	€/kW	4 000	4 000	✓	N/A	2012
	Stack lifetime	hours	40 000	20 000	🔧	40 000	N/A
Project's own objectives	Prototype running time	hours	3 000	980	🔧	N/A	N/A

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 BV, PROMETHEAN PARTICLES LTD, SAAN ENERGI AB, UNIVERSIDAD DE LA LAGUNA

PROJECT AND OBJECTIVES

The main goal of the Cell3Ditor project is to develop a 3D printing technology for the industrial production of SOFC stacks by covering research and innovation in all the stages of the industrial value chain (inks formulation, 3D printer development, ceramics consolidation and system integration).

At this stage, inks and slurries of SOFC materials have been formulated and tested for printing, a multi-material 3D printer for ceramics has been developed and patented and fabrication of SOFC cells of the multilayer system is being optimised.

NON-QUANTITATIVE OBJECTIVES

- Analysis of the exposure to nanoparticles has been completed
- Scientific papers and articles in industrial magazines published. Conferences, fairs and expositions attended. Two workshops are being organised (one in Denmark and another one in Naples) and profiles in scientific/social networks updated
- Business plan looking for the commercialisation of two outcomes of the project, already a primary market analysis and a business plan performed
- 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 AND MAIN ACHIEVEMENTS

- A multi-material hybrid (additive and subtracting manufacturing) 3D printer for ceramic materials has been developed, patented and commercialised
- Formulation of printable inks and slurries of technical ceramic materials
- Fabrication of SOFC components and fully printed SOFC button cells.

FUTURE STEPS AND PLANS

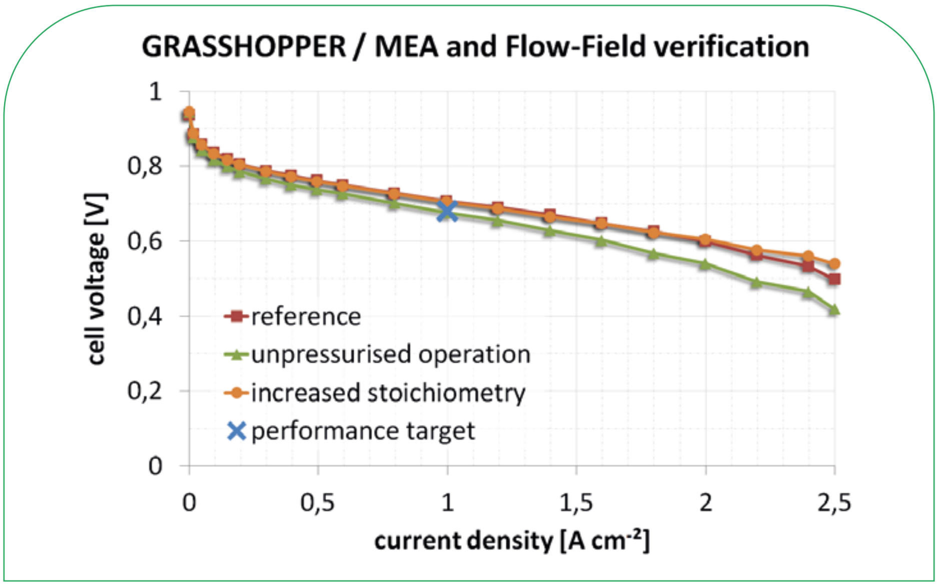
- Fabrication of complex design multi-material parts
- Fabrication of multi-material SOFC components
- Fabrication of SOFC stacks.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Area-specific resistance of electrolyte	Ohm*cm^2	<0.15	0.31		0.15	2003
	Area-specific resistance of electrodes	Ohm*cm^2	<0.75	Not assessed yet		0.7	1997
	Area-specific resistance of interconnect	Ohm*cm^2	<0.2			0.013	2013
	Power density of single repetition unit	mW/cm^2	ca. 250			280	2016

GRASSHOPPER

GRID ASSISTING MODULAR HYDROGEN PEM POWER PLANT



Project ID:	**779430**
Call topic:	**FCH-02-7-2017** - Development of flexible large fuel cell power plants for grid support
Project total costs:	**€4 387 063.75**
FCH JU max. contribution:	**€4 387 063.75**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, SI**
Website:	**www.grasshopperproject.eu**

BENEFICIARIES: POLITECNICO DI MILANO, NEDSTACK FUEL CELL TECHNOLOGY BV, ABENGOA INNOVACION SOCIEDAD ANONIMA, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH, JOHNSON MATTHEY FUEL CELLS LIMITED

PROJECT AND OBJECTIVES

The GRASSHOPPER project aims to create a next-generation MW-size fuel cell power plant (FCPP), which is more cost-effective and flexible in power output. The FCPP will be demonstrated in the field as a 100 kW sub-module pilot plant, implementing newly developed stacks with improved MEAs and BoP system components.
Large area bipolar plate development is ready to start. Operating conditions of stacks and systems have been fixed and the new cell plate design has been finalised. The detailed design of the 100 kW FCPP is almost completed, with the main components selected and ordered.

NON-QUANTITATIVE OBJECTIVES

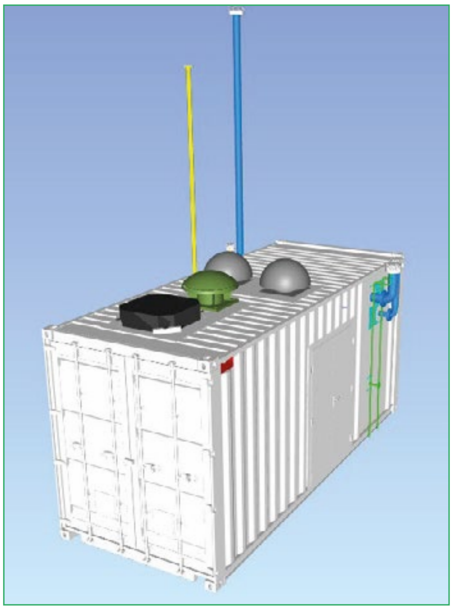
- Operational flexibility and grid stabilisation capability via fast response
- Safe plant operation. European Hydrogen Safety Panel contacted. An intro session was held in May 2019.

PROGRESS AND MAIN ACHIEVEMENTS

- Power density targets on 25 cm^2 area have been met as a combination of newly developed MEAs and the GRASSHOPPER flow fields
- New design of the stack without housing has been completed
- Design of a flexible pilot power plant based on simulations has been completed.

FUTURE STEPS AND PLANS

- Verification of new design
- Power plant construction finish
- Factory acceptance tests
- Site acceptance tests and operation start
- Plant validation.

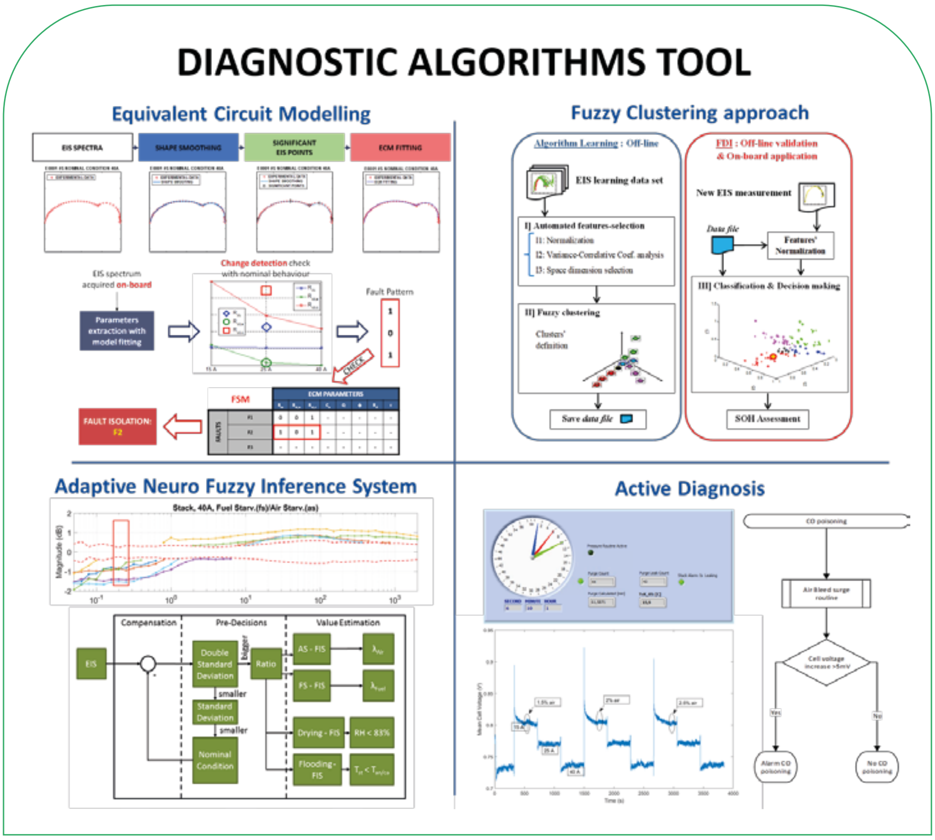


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	MEA cost reduction	%	65	(demonstration hasn't started yet)	MEA cost price of electricity 0.04 €/kWh	2018
	Stack efficiency	%	55		55	
MAWP addendum (2018-2020)	System electrical efficiency	%	50		50	
	CAPEX	€/kWe	1 500		3 000	
AWP 2017	Stack lifetime	hours	20 000		16 000	

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:	**€2 358 736.25**
FCH JU max. contribution:	**€2 358 736.25**
Project start - end:	01/09/2015 - 31/12/2018
Coordinator:	**UNIVERSITÀ DEGLI STUDI DI SALERNO, IT**
Website:	**pemfc.health-code.eu**

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

PROJECT AND OBJECTIVES

HEALTH-CODE implemented an advanced monitoring and diagnostic tool (MDT) for μ-CHP and backup PEMFC systems, to determine FC status (condition monitoring) and infer on residual useful lifetime. Six faults were detected: fuel and oxidant starvation; flooding and drying; CO-contamination and sulphur poisoning. The main objectives dealt with the enhancement of EIS-based diagnosis: the development of a monitoring and diagnostic tool for state-of-health assessment. The reduction of experimental campaign time and costs was achieved through a scaling-up algorithm.

NON QUANTITATIVE OBJECTIVES

- Database of EIS spectra: +2 300 EIS spectra in nominal and faulty conditions for 2 PEMFC technologies
- Know-how for the design of future PEMFC converters.

PROGRESS AND MAIN ACHIEVEMENTS

- More than 2 300 EIS spectra acquired on two different PEMFC technologies for either single cells or short/full stacks, in nominal and faulty states
- Developed EIS board able to acquire high-quality EIS spectra and to isolate faults while the system runs, once interfaced with system converters
- Three diagnostic algorithms designed and tested on board along with 1 active diagnosis approach. One scaling-up algorithm developed.

FUTURE STEPS AND PLANS

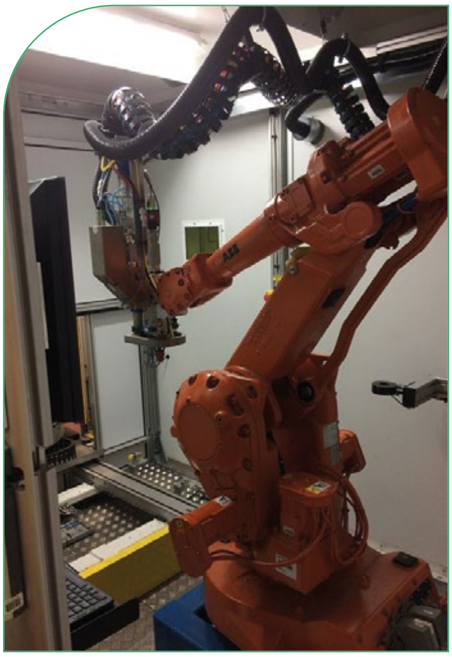
Project finished.

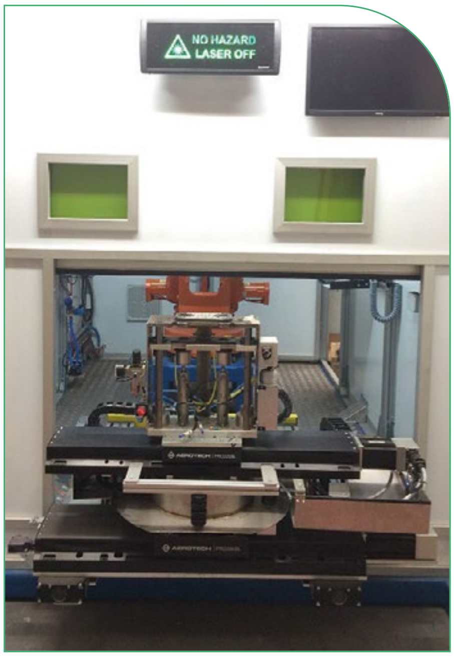
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2014	Nr of stacks	2	6	✓
	Nr of failure modes	5	5	
	Nr of tested systems	2	2	
	Nr of methodology	1	1	
	Cost (%)	<3 %	<3 %	

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 for fuel cell systems
Project total costs:	**€2 899 760**
FCH JU max. contribution:	**€2 899 760**
Project start - end:	01/04/2016 - 30/09/2019
Coordinator:	**SENIOR UK LTD, UK**
Website:	**www.heatstack.eu**

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

PROJECT AND OBJECTIVES

The project focuses on the industrialisation of manufacturing the cathode air preheater (CAPH) and full cell stack to realise a 50 % cost saving once these two most expensive components of microCHP systems are in volume production. 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 its longevity, further enhancing microCHP lifetime cost. The project is currently 36 months into a proposed 42-month duration.

NON-QUANTITATIVE OBJECTIVES

Change to micro TIG welding from laser to reduce the health and safety risk to the operator, and also to prevent cracking of the material and ensure greater precision.

PROGRESS AND MAIN ACHIEVEMENTS

- Research results showing a x10 reduction of Cr evaporation using AluChrom318 in CAPH compared with the current standard of Inconel 625, SS309, Al SS309
- Redesigned CAPH that resists deformation under rigorous testing, tooling/equipment validated for automated welding of CAPH cells and plates above target
- Process development: printing for seal glass established, tailored glass paste characterised, stencil printing set up, automated line concept created.

FUTURE STEPS AND PLANS

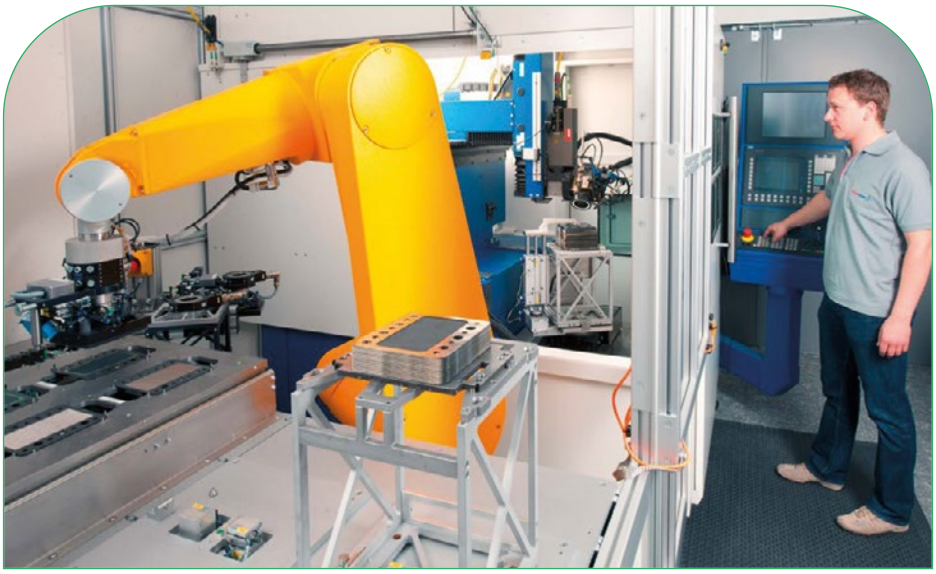
- Transfer of CAPH automated production equipment/ tooling from SFC (Wales) to SFO (Czech Republic)
- Sunfire to continue testing their first 5 prototype units
- Sunfire to continue developing their prototype system units post-HEATSTACK, under the PACE project, expecting to manufacture 500 systems in 2020/21
- Delivery of techno-economic assessment of the improved processes compared with the pre-project approaches (including LCA analysis)
- Compilation and finalisation of business/exploitation plans based on final project results and market assessment.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	CAPH cost (sale) from 2000	%	60	Unable to confirm until high volume production (10 000+ per annum) has been realised	
	CAPH manufacture time reduction from 8.83 hours	hours	1.32	The target will be achieved once in production	
	Reduction of process time for glass sealant from 200 minutes	minutes	100	The target will be exceeded in due course, but depends on the final automated process	
	Reduction of glass needed for stack	%	50	Process development completed and target achieved.	✓

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 - 31/10/2019
Coordinator:	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Website:	www.innosofc.eu

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

PROJECT AND OBJECTIVES

INNO-SOFC project brings together leading European SOFC technology companies and research centres to collaborate and form required phases in the SOFC value chain. A next generation 60 kW SOFC system and its key components will be developed, manufactured, and validated. This system will be demonstrated in Lempäälä industrial park as a key part of their smart grid. The system is estimated to be up and running in the autumn of 2019.

NON-QUANTITATIVE OBJECTIVES

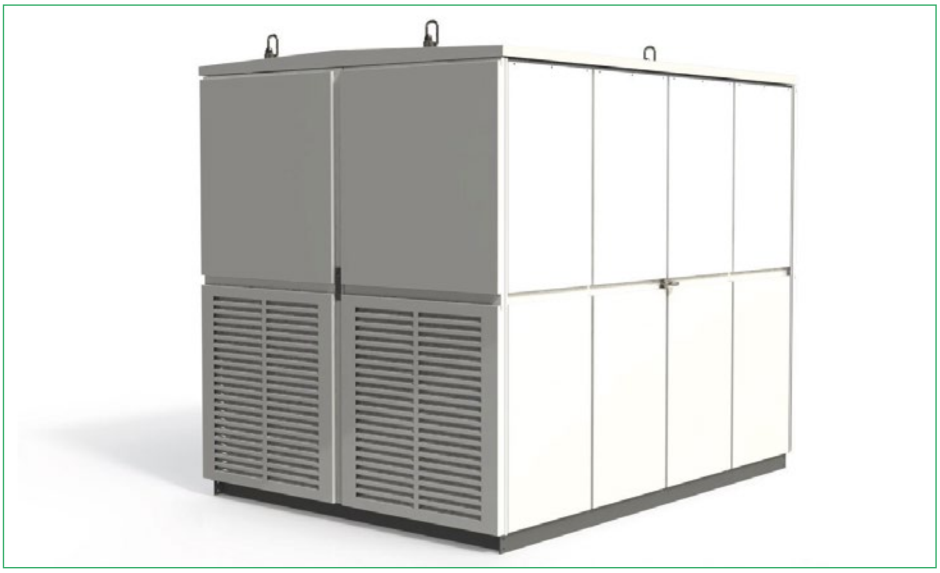
Identification of most promising applications and end users for SOFC CHP - finalised and publicly presented e.g. in EFCF 2018.

PROGRESS AND MAIN ACHIEVEMENTS

- System design ready
- Stacks manufactured, QA passed and delivered for system assembly.

FUTURE STEPS AND PLANS

3 000 hours system demonstration.

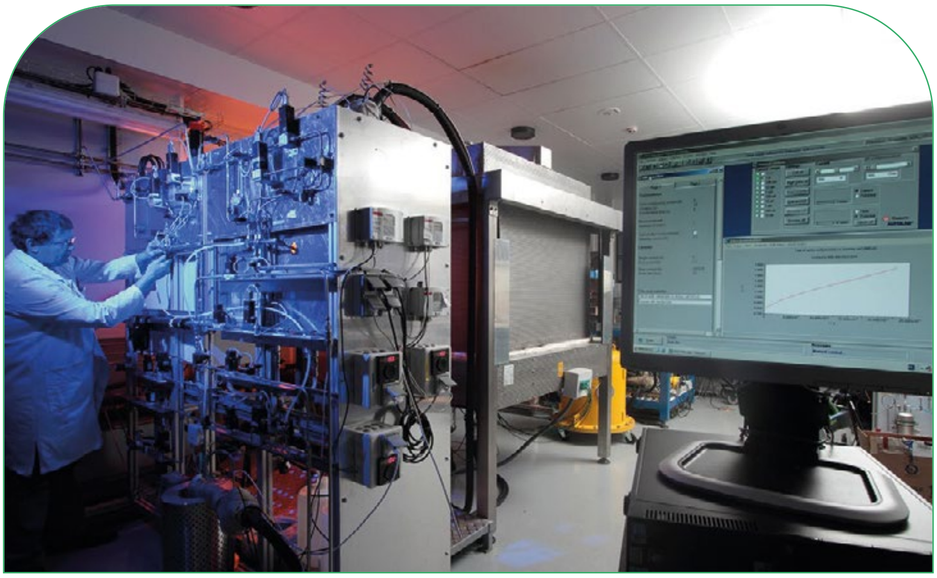


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	System CAPEX	€/kW	4 000	N/A		9 000	2018
	System lifetime	hours	30 000	N/A		N/A	N/A
	Electrical efficiency	%	60	>60 % based on system modelling	✓	60 %	2017
	Total efficiency	%	85	>85 % based on system modelling	✓	82 %	2017

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:	**insight-project.eu**

BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, INSTITUT JOZEF STEFAN, AVL LIST GMBH, UNIVERSITÀ DEGLI STUDI DI SALERNO, ABSISKEY CP, SOLIDPOWER SA, BITRON SPA, SOLIDPOWER SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, ABSISKEY

PROJECT AND OBJECTIVES

The INSIGHT project aims to develop 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 of a single board able to embed the tool will be developed and integrated in a commercial microCHP, which will be tested in the field.

NON-QUANTITATIVE OBJECTIVES

- A mitigation matrix has been designed. The severity of each main fault selected has been defined. It correlates the 3 faults with detection and mitigation variables
- The DC/DC converter of the EnGen 2 500 micro-CHP system has been modified, and the Bitron Box developed.

PROGRESS AND MAIN ACHIEVEMENTS

- Non-linear perturbations techniques (THD and PRBS) have been found as quick analysis tools, with an answer consistent with conventional EIS measurements
- DC/DC converter of the EnGen 2 500, Bitron Box (developed to embed the monitoring, diagnostic and lifetime tools) have been developed and manufactured
- A mitigation matrix and the severity of each main fault selected have been designed. It correlates the 3 faults with detection and mitigation variables.

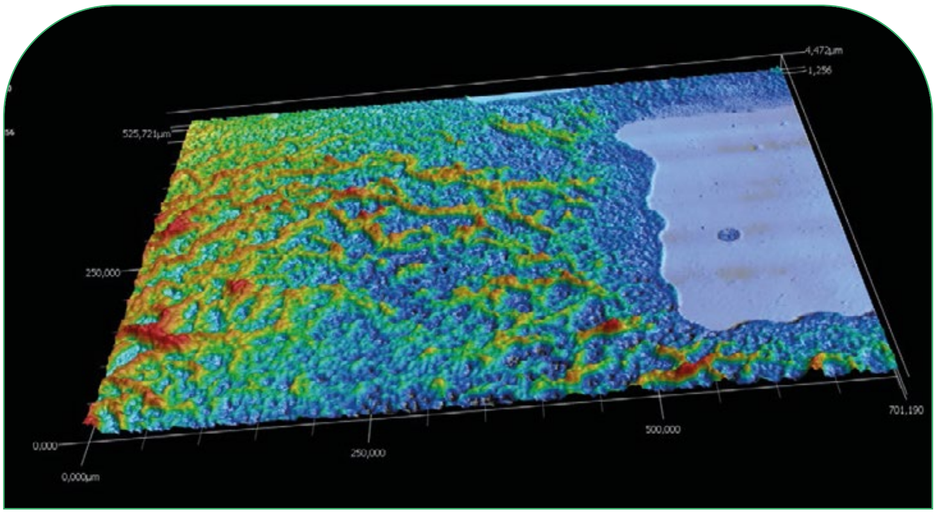
FUTURE STEPS AND PLANS

- Isolate faults on a full-scale stack where there is less instrumentation, due to averaging effect
- Finalise the installation of the Bitron Box and MDLT tools on the Engen system
- Perform the in-field test
- Continuation of data exchange between WP2 testing and WP4/5 MDLT to fine-tune algorithms.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Perform test with faults added on purpose	Test 3 faults	3 planned fault tested, plus two additional reported	✓	Evaluation of C deposition	2016
	Develop monitoring, diagnostic and lifetime tool (MDLT)	Tool developed	In progress		No other similar tool for SOFC, as far as open literature is concerned	N/A
	Implement the MDLT on board	Implementation done	In progress		N/A	N/A
AWP 2016	Lifetime	Prolong lifetime by 5 %	Quantification will be done in 2019		Degradation rates <1 %/1000 h	N/A
	Cost	System cost increase due to additional hardware for MDLT less than 3 %	Evaluation in 2019		N/A	N/A

MAMA-MEA
MASS MANUFACTURE OF MEAS USING HIGH SPEED DEPOSITION PROCESSES



Project ID:	**779591**
Call topic:	**FCH-02-8-2017** - Step-change in manufacturing of fuel cell stack components
Project total costs:	**€3 189 816**
FCH JU max. contribution:	**€3 189 816**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**TECHNISCHE UNIVERSITAET CHEMNITZ, DE**
Website:	**mama-mea.eu**

BENEFICIARIES: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV, UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA, NEDSTACK FUEL CELL TECHNOLOGY BV, INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, JOHNSON MATTHEY FUEL CELLS LIMITED, SYSTEM SPA

PROJECT AND OBJECTIVES

The task of the MAMA-MEA project is to develop an innovative additive layer deposition process integrating all main CCM components (membrane, catalyst layers, sealing) using a single, continuous roll-to-roll manufacturing process for the PEM fuel cell industry, thus enabling an increase in the volume manufacturing rate by over 10 times compared with state-of-the-art processes, while also increasing key material utilisation and reducing materials and costs. Currently, a multilayer deposition process is being developed and multilayer structures have been prepared.

NON-QUANTITATIVE OBJECTIVES

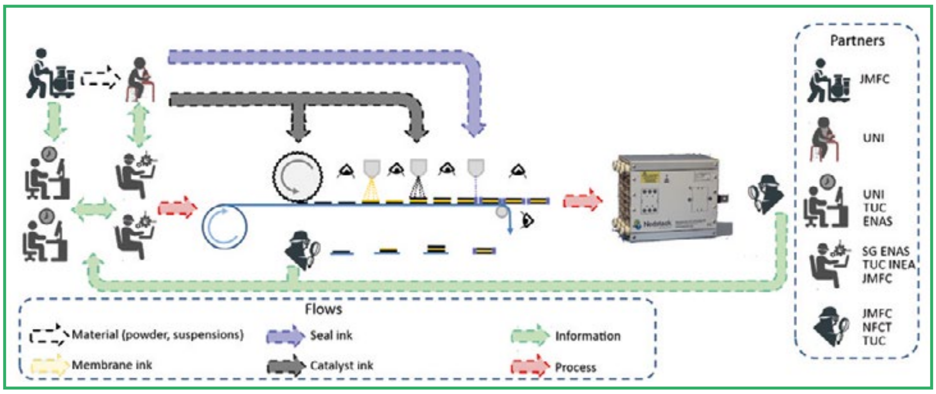
- Workshop on ionomer ink preparation scheduled for end of May
- INSPIRE workshop in Marseille, integration of several FCHJU projects (MAMA-MEA, INSPIRE, Fit-4-AMandA, etc).

PROGRESS AND MAIN ACHIEVEMENTS

- Ink optimisation for chosen deposition techniques based on state-of-the art catalysts. Multilayer deposition with gradients attempted
- Down-selection of mature production techniques from other industries, including an assessment of their suitability for the deposition of each layer
- Project performance parity achieved on test cell level (50 cm^2) with the baseline deposited using the most promising down-selected technique.

FUTURE STEPS AND PLANS

- Characterisation and selection of additive manufactured MEAs
- Adapting and showing the possibility for scaling up the laboratory results to mass-manufacturing-ready equipment
- Low batch production of sufficient amount of full-size MEAs for stacks
- Stack assembly and test preparation with chosen MEAs
- Further future improvement of the selected processes and corresponding inks.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVE TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2017	CAPEX	€/kW	12 000		N/A	N/A
	Lifetime	hours	20 000		23 000	2017
	Degradation	% /1 000 hour	0.25		3 µVh	2017
Project's own objectives	Material utilisation	%	95		N/A	N/A
	Production/web speed	m/s	1		N/A	N/A

OxiGEN

NEXT-GENERATION SOLID OXIDE FUEL CELL STACK AND HOT BOX SOLUTION FOR SMALL STATIONARY APPLICATIONS

OxiGEN
Next generation SOFC solutions

Project ID:	**779537**
Call topic:	**FCH-02-9-2017** - Development of next-generation SOFC stack for small stationary applications
Project total costs:	**€2 996 873.75**
FCH JU max. contribution:	**€2 996 873.75**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**SOCIETE EUROPEENNE DES PRODUITS REFRACTAIRES, FR**
Website:	**oxigen-fch-project.eu**

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, EIFER EUROPAEISCHES, INSTITUT FUER ENERGIEFORSCHUNG EDF KIT EWIV, ENGIE, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV, ICI CALDAIE SPA, SAINT-GOBAIN CENTRE DE RECHERCHES ET D'ETUDES EUROPEEN, SAINT GOBAIN RECHERCHE SA, SINTEF AS, SOCIETE EUROPEENNE DES PRODUITS REFRACTAIRES, STIFTELSEN SINTEF

PROJECT AND OBJECTIVES

OxiGEN aims to develop an innovative SOFC platform, including an all-ceramic stack design and a modular hotbox, thanks to its higher durability and simpler design for micro-CHP.
The objectives are:

- Define the most suitable hotbox functional specifications for residential and commercial segments (completed)
- Develop a higher power stack and modular hotbox to build a 1 kWe prototype and assess the performance and durability targets (in progress)
- Propose material-based solutions for future long-term improvements (in progress)
- Study the cost-of-ownership of the solution.

NON-QUANTITATIVE OBJECTIVES

Definition of market specifications for residential and small commercial applications and boundary limits of the hotbox.

PROGRESS AND MAIN ACHIEVEMENTS

- Definition of market specifications for residential and small commercial applications and boundary limits of the hotbox
- First stack manufacturing and pre-test with Gen1 short stack at CEA and hotbox at ICI Caldaie
- Novel electrolyte development for better cell performances.

FUTURE STEPS AND PLANS

- Manufacturing of stacks reaching DC efficiency of at least 55 % and a lifetime above 90 000 h
- GEN 1 and 2 hotbox development and integration in stack
- Assessment of durability and performance of the stack and hotbox combination
- Assessment of the cost of the hotbox up to boundary limits to achieve 1 000€/kWe
- New anode functional layer development to improve the stack performance.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective: short stack	DC electrical efficiency	%	59	50		47	2016

qSOFC

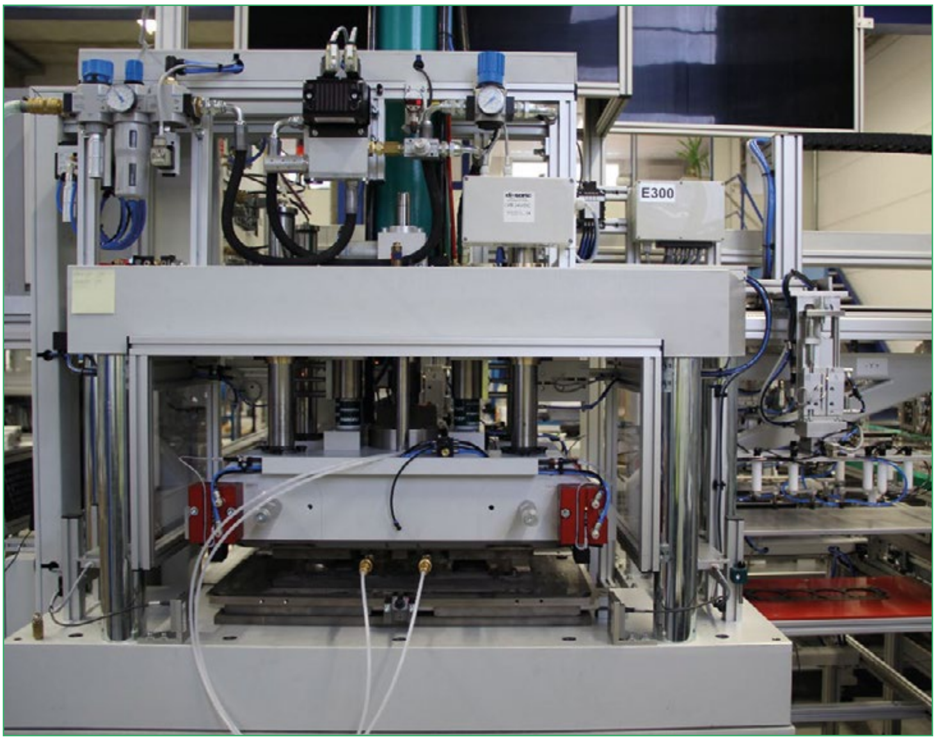
AUTOMATED MASS-MANUFACTURING AND QUALITY ASSURANCE OF SOLID OXIDE FUEL CELL STACKS

Project ID:	735160
Call topic:	FCH-02-6-2016 -Development of cost-effective manufacturing technologies for key components of 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, AKTIEBOLAGET SANDVIK MATERIALSTECHONOLOGY, AKTSIASELTS ELCOGEN, ELRINGKLINGER AG, ELCOGEN OY, HAIKU TECH EUROPE BV, MUKO MASCHINENBAU GMBH

PROJECT AND OBJECTIVES

The 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 1 000 €/kW and create a further cost reduction potential down to 500 €/kW at mass production (2 000 MW/year). During the qSOFC project, key steps in cell and interconnect manufacturing and quality assurance will be optimised to enable mass manufacturing. The project is currently validating the developed methods, materials and procedures.



PROGRESS AND MAIN ACHIEVEMENTS

- Automated machine vision inspection system for cell manufacturing quality assurance
- Novel stack manufacturing/conditioning procedures have been developed, leading to a significant reduction of CAPEX needed to upscale the production
- Cell manufacturing process has been modified to allow high-speed manufacturing necessary for mass production.

FUTURE STEPS AND PLANS

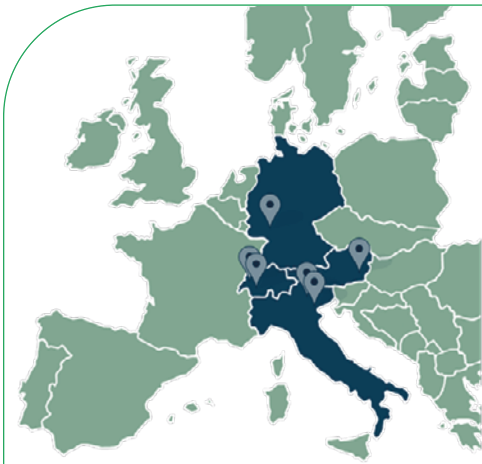
- Validation of novel stack conditioning processes to reduce manufacturing time and cost
- Validation of interconnect assembly manufacturing QA procedures
- Long-term test of final validation stack.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Cell layer QC time	Second/cell layer	10	11		N/A	N/A
	Stack cost at 50 MW/year production volume	€/kW	1 000	N/A		€6 500 for full system	2018
	Electrical efficiency	%	74	74	✓	N/A	N/A

SOSLeM
SOLID OXIDE STACK LEAN MANUFACTURING

Project ID:	**700667**
Call topic:	**FCH-02.6-2015** - Development of cost-effective manufacturing technologies for key components of 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: ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, AVL LIST GMBH, SOLIDPOWER SA, ATHENA SPA, GREENLIGHT INNOVATION GMBH

PROJECT AND OBJECTIVES

The SOSLeM project aimed to reduce solid oxide fuel cell (SOFC) stack manufacturing costs, while making production more resource-efficient and realising environmental benefits.

NON-QUANTITATIVE OBJECTIVES

Reduce environmental impact of SOFC manufacturing. New coatings of stack parts were developed and tested and reduced the amount of volatile chromium in the stack exhaust.

PROGRESS AND MAIN ACHIEVEMENTS

- The project resulted in a significant reduction of SOFC manufacturing costs and time
- The project led to an increase in SOFC lifetime and reliability
- The project developed and investigated novel technologies for end-of-line monitoring.

FUTURE STEPS AND PLANS

Project finished.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Reduction in stack manufacturing costs	€/kW	3 519	5 779	✓
	Nr staff/MW	Nr staff/MW	54.2	49.2	

PANEL 5
HYDROGEN
FOR SECTORAL
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: DANMARKS TEKNISKE UNIVERSITET, THE EUROPEAN MARINE ENERGY CENTRE LIMITED, ITM POWER (TRADING) LIMITED, SYMBIOFCELL SA, GIACOMINI SPA, ORKNEY ISLANDS COUNCIL, MINISTRY FOR TRANSPORT, INFRASTRUCTURE AND CAPITAL PROJECTS, COMMUNITY ENERGY SCOTLAND LIMITED, SHAPINSAY DEVELOPMENT TRUST, THE SCOTTISH HYDROGEN AND FUEL CELL ASSOCIATION LTD, CALVERA MAQUINARIA E INSTALACIONES SL

PROJECT AND OBJECTIVES

This 'Building Innovative Green Hydrogen Systems in an Isolated Territory' (BIG HIT) project is a world-leading pilot project which aims to demonstrate a hydrogen territory in the Orkney Islands. Curtailed energy from tidal and wind turbines (on average more than 30 % of the annual renewable output in Orkney) is being used to produce 'green' hydrogen from electrolysis, which is then transported across the Orkney Islands and used for local transport, heat and power end-uses. The project involves 12 partners based across 6 EU countries, to enhance the value of European collaborations.

NON-QUANTITATIVE OBJECTIVES

- Delivering the local authority's Orkney Hydrogen Economic Strategy
- The project has established a new commercial entity (Orkney Hydrogen Trading) to operate the integrated hydrogen system across the islands
- On 16 May, the project launched the Hydrogen Territories Platform, a tool to replicate the BIG HIT project concepts to other territories
- Improve local public acceptance of hydrogen.

PROGRESS AND MAIN ACHIEVEMENTS

- Certification of the multi-element gas containers (MEGC) transporting hydrogen (specific/novel design for Orkney ro-ro ferries)
- HRS (350 bar) and 5 RE-FCEV deployed and operating, 2 MEGCs for transporting high-pressure hydrogen and a 75 kW CHP FC for cold ironing commissioned
- Lessons learnt replicable to other demo projects and regions (it will be done via the Hydrogen Territories Platform being created in BIG HIT).

FUTURE STEPS AND PLANS

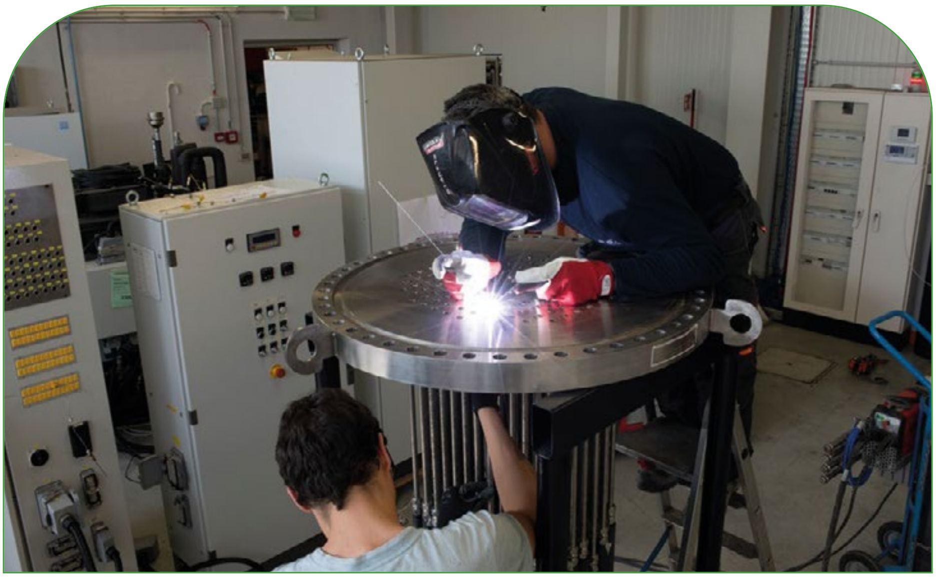
- Operation and monitoring of the fully integrated hydrogen system operation in Orkney
- Validation of commercial/business models for integration of RES locally via local hydrogen, and promotion of the project replicability
- Reduces (grid) investment and improves load management
- Overcomes grid constraints and harnesses local (otherwise curtailed) renewable resources (wind and marine) by the integration of hydrogen technologies
- Boosts local economy, including development of local skills and qualified jobs in emerging technologies like hydrogen and fuel cells.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP Addendum (2018-2020)	**FC VEHICLES**						
	Availability	%	98	100	✓	98	2017
	HRS						
	Energy consumption	kWh/kg	5	8.1	🔧	10	2017
	Availability	%	96	85.65	🔧	95	
	COMPRESSED GAS TUBE TRAILERS						
	Capacity	kg	1 000	250	🔧	850	2017

BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED HYDROGEN PRODUCTION



Project ID:	**671459**
Call topic:	**FCH-02.2-2014** - Decentralized hydrogen production from clean CO_2-containing biogas
Project total costs:	**€3 396 640**
FCH JU max. contribution:	**€3 147 640**
Project start - end:	01/09/2015 - 31/12/2019
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bionicoproject.eu**

BENEFICIARIES: TECHNISCHE UNIVERSITEIT EINDHOVEN, JOHNSON MATTHEY PLC, FUNDACION TECNALIA RESEARCH & INNOVATION, I.C.I CALDAIE SPA, ABENGOA HIDROGENO SA, QUANTIS, RAUSCHERT KLOSTER VEILSDORF GMBH, ABENGOA RESEARCH SL, ENC POWER LDA, ENC ENERGY SGPS SA

PROJECT AND OBJECTIVES

BIONICO aimed to develop, build and demonstrate at a biogas plant a novel catalytic membrane reactor integrating H_2 production (100 kg/day) and separation in a single vessel. A significant increase of the overall efficiency (up to 72 %) and decrease of volumes and auxiliary heat management units is expected.

Within the project, new ceramic supported tubular membranes operating at 550 ºC and a new reforming catalyst for H_2 production from biogas have been developed. The membrane reactor has been manufactured and integrated in ICI's labs and is going through preliminary testing.

PROGRESS AND MAIN ACHIEVEMENTS

- Development and scale up of highly active, durable and stable reforming catalysts to produce H_2 from biogas
- Development and production of 120 Pd based ceramic supported tubular membranes able to work at high temperature (550 °C) for the BIONICO pilot reactor
- Manufacturing of the catalytic membrane reactor and integration in ICI's laboratory for testing.

FUTURE STEPS AND PLANS

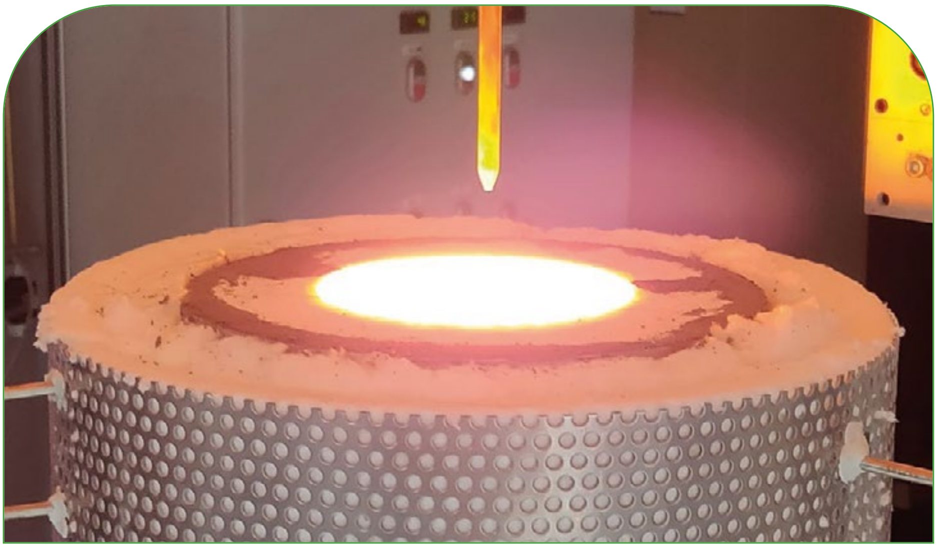
Testing of the BIONICO reactor in a real biogas plant in Portugal.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP (2014-2020)	Hydrogen production efficiency	%	72.0	71.9	✓	N/A	N/A
AWP 2014	Perform hydrogen production in a single step	step	1	1	✓	4	2016

BIOROBURplus

ADVANCED DIRECT BIOGAS FUEL PROCESSOR FOR ROBUST AND COST-EFFECTIVE DECENTRALISED HYDROGEN PRODUCTION



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:	**bioroburplus.org**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, JOHNSON MATTHEY PLC, SCUOLA UNIVERSITARIA PROFESSIONALE DELLA SVIZZERA ITALIANA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, UAB MODERNIOS E-TECHNOLOGIJOS, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, HYSYTECH SRL, KARLSRUHER INSTITUT FUER TECHNOLOGIE, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, ENGICER SA, ACEA PINEROLESE INDUSTRIALE SPA

PROJECT AND OBJECTIVES

The BioRoburplus project aimed to develop a pre-commercial oxidative steam reformer (OSR) for sustainable and decentralised hydrogen production from biogas with no preliminary removal of CO_2. The TRL6 demo-plant will deliver at least 50 Nm_3/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 objectives were reached by: i) high thermal integration, ii) PSA (pressure swing adsorption) off gas exploitation for reformer feed preheating, iii) power consumption minimisation through CO_2 removal prior to the PSA.

NON-QUANTITATIVE OBJECTIVES

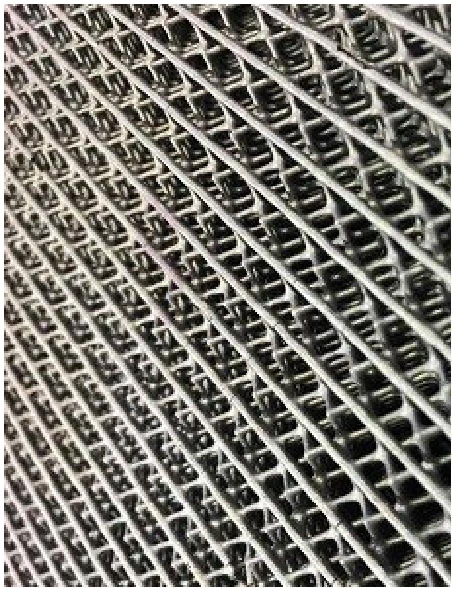
- Dissemination and training activities
- Participation in several conferences
- Improve the efficiency of hydrogen production through better heat integration of the components
- A preliminary LCA analysis of the general system has been carried out. REACH and HAZOP analysis of the BioRoburplus process has been completed. A first version of the exploitation plan has been drawn up. In addition, the development of decision support schemes for BioRoburplus system implementation is ongoing
- Coating and manufacturing process have been optimised.

PROGRESS AND MAIN ACHIEVEMENTS

- Structured nickel-based-catalyst and precious-metal-based catalyst delivered good results. The most promising process for H_2 purification was selected
- A dedicated innovative PSA-off-gas burner with structured components was developed
- Ceramic support structures as catalyst carriers with enhanced heat and mass transport properties were developed. LCA analysis are being performed.

FUTURE STEPS AND PLANS

- Optimisation of the catalyst-coating process
- To complete the testing campaign of the structured catalytic support on a pilot scale under more realistic conditions
- To finish the testing of the catalyst for WGS reactors
- Manufacturing and testing the overall plant
- LCA and PUEF final versions to be performed. Techno-economic analysis will be performed.

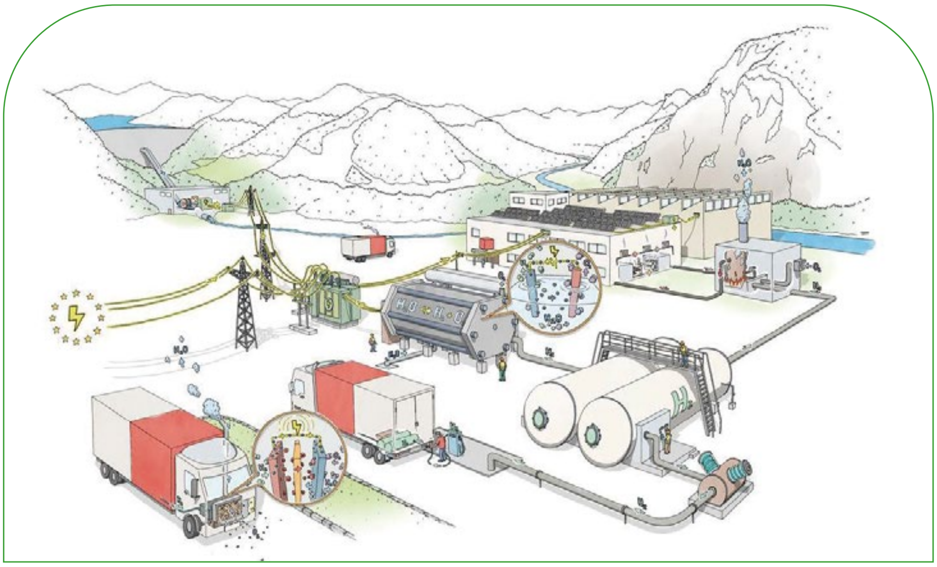


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Nominal H_2 production capacity	Nm^3/h	50		50 Nm^3/h	
	Overall plant efficiency based on HHV	%	≥80		Overall plant efficiency of 65 %	
	Reformer outlet CO concentration a dry-basis	%	<8		A value of 9.99 reached with the BioRobur	2016
AWP 2016	H_2 purity	%	99.99		BioRobur delivered 50 Nm^3/h of 99.9 % hydrogen from biogas	
	A cold start-up time of no more than	hours	2		BioRobur value 6 h	

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:	**€7 736 682.50**
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

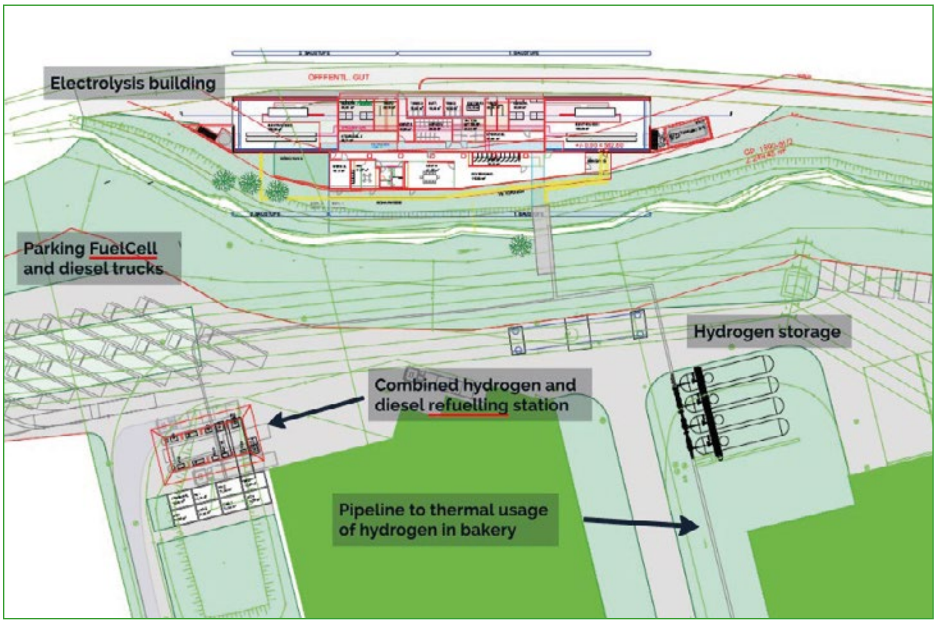
The main aim of project Demo4Grid is the commercial setup and demonstration of a technical solution utilising "above state of the art" Pressurised Alkaline Electrolyser (PAE) technology for providing grid balancing services in real operational and market conditions. The final goal is to provide grid balancing services to the transmission system operator (primary and secondary balancing services).
The electrolysis plant will be installed in Völs near Innsbruck.

PROGRESS AND MAIN ACHIEVEMENTS

- Engineering documents and analysis of RCS and Safety Requirements are in place
- A project specific business model has been updated
- A detailed market potential assessment on different business cases of hydrogen production through alkaline electrolysers has been developed.

FUTURE STEPS AND PLANS

- Permits procedures finalised by May 2020
- Building construction finished by August 2020
- Pae procurement and certification by May 2020
- Pae commissioning by December 2020
- Sat and test phase operation finished by March 2021.

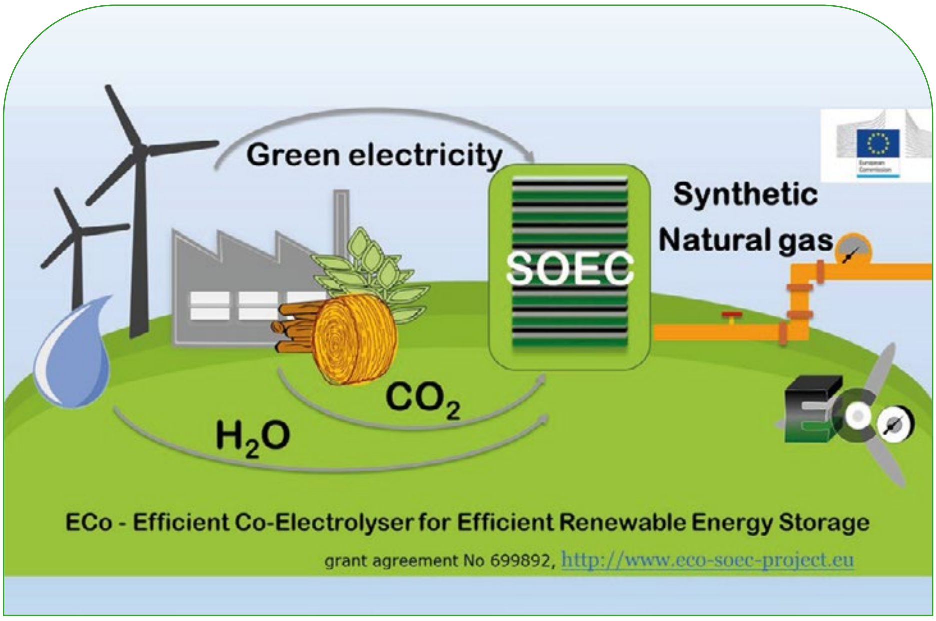


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	H_2 production electrolysis, hot start from min to max power	Seconds	2	🔧	60	2015
	Start-up time KPIs from cold to minimum part load for Alkaline Electrolysers	Minutes	20		20	
	Minimum part load operation targets for Alkaline Electrolysers	% (full load)	20		30	
	Ramp up	% (full load)/sec	7		7	
	Ramp down	% (full load)/sec	10		10	

ECo

EFFICIENT CO-ELECTROLYSER FOR EFFICIENT RENEWABLE ENERGY STORAGE - ECO



Project ID:	**699892**
Call topic:	**FCH-02.3-2015** - Development of co-electrolysis using CO_2 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: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, ENGIE, ENAGAS SA, BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE LABORELEC CVBA, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, SOLIDPOWER SA, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, VDZ GEMEINNUTZIGE GMBH

PROJECT AND OBJECTIVES

The overall goal of ECo was to develop and validate a highly efficient co-electrolysis process for conversion of renewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO_2 through Solid Oxide Electrolysis Cells.
The project provided multiple generations of cells with improved performance at cell and stack level. Degradation rates under realistic co-SOE conditions reached <1%/1 000 hr. Significant durability understanding was achieved. A co-SOE plant was designed and integrated into existing plants for techno-economic analysis and LCA.

NON-QUANTITATIVE OBJECTIVES

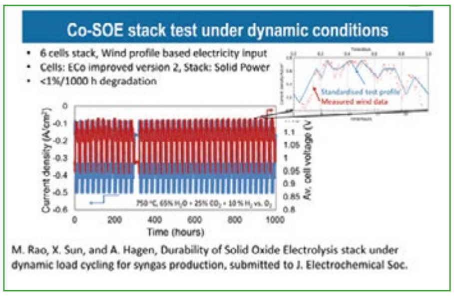
- The design of a co-SOE plant was achieved, yielding information about obtainable gas yields and efficiencies in correlation with operating conditions
- Techno-economic analysis of specific cases achieved and evaluated depending on geographic location, electricity mix, CO_2 availability, etc.
- LCA achieved based on realistic application cases and revealed benefits in case of availability of green electricity.

PROGRESS AND MAIN ACHIEVEMENTS

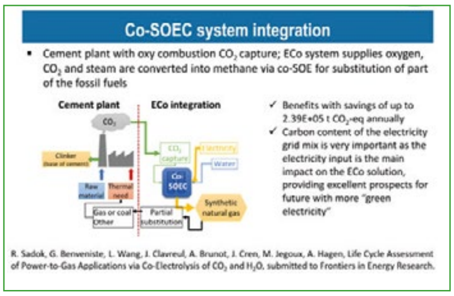
- Successful development of several cell versions to allow for a decrease of operating temperature by 50-100 °C and verification at cell and stack level
- Significant detailed durability understanding under relevant conditions (dynamic, pressure, impurities) gained and degradation rates of <1%/1 000 h achieved
- Co-SOEC plant designed and integrated with existing plants revealing environmental and economic benefits when green electricity is available.

FUTURE STEPS AND PLANS

Project is finished.



M. Rao, X. Sun, and A. Hagen, Durability of Solid Oxide Electrolysis stack under dynamic load cycling for syngas production, submitted to J. Electrochemical Soc.



R. Sadok, G. Benveniste, L. Wang, J. Clavreul, A. Brunot, J. Cren, M. Jegoux, A. Hagen, Life Cycle Assessment of Power-to-Gas Applications via Co-Electrolysis of CO_2 and H_2O, submitted to Frontiers in Energy Research.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Area specific resistance	Ohm*cm^2	0.2	0.2	✓
	Degradation rate	%/1 000 hr	1	<1	✓
	SOE performance at 10 bar, 750 °C, 1.3 V	A/cm^2	-1.3	-0.9	🛠

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:	**€2 315 217.50**
FCH JU max. contribution:	**€2 315 217.50**
Project start - end:	01/04/2016 - 31/09/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.ely4off.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 was 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.

NON-QUANTITATIVE OBJECTIVES

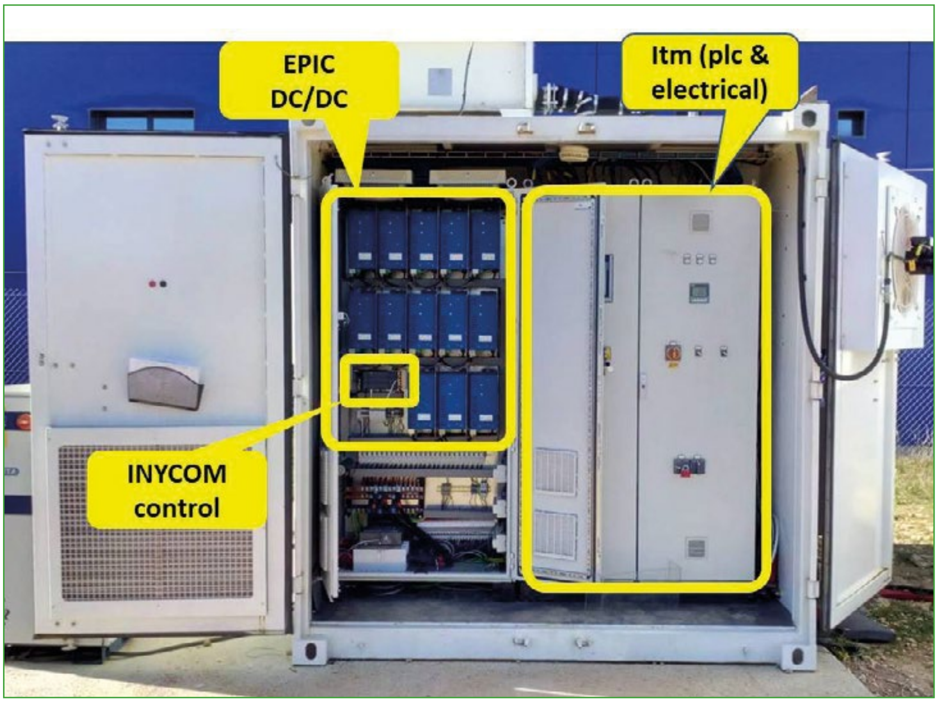
- Study covering specific national requirements and how to overcome barriers in four different countries (Denmark, Scotland, Sweden, France) has been elaborated
- Reveal under which conditions it is possible to utilise an off-grid hydrogen cycle instead of current technologies.

PROGRESS AND MAIN ACHIEVEMENTS

- First Hydrogen production on 13 September 2018
- Demonstration period started on 11 March 2019
- Quick and efficient response of the prototype DC/DC conversion and stack to solar variability.

FUTURE STEPS AND PLANS

Project is finished.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Efficiency at system level	kWh/kg	50	N/A	🔧	48 @ 100 kg/day	<48 @100 kg/day (Neptune)
	Efficiency degradation	%/8 000 h	2	Can not be measured until stack returns to lab conditions	🔧	1.5 %	1 % (Neptune)
	CAPEX	M€/(t/d)	6	4.5 @ 100 kW scale	✓ @ 100 kW scale	3 @ 1MW scale	2.4 @10MW scale
	H_2 production flexibility (degradation <2 %)	%	5-150	5-100	✓	20-300	10-400 (BEIS)
	Hot start (min to max power)	seconds	2	<2 seconds	✓	<1 second (for frequency control)	1 second

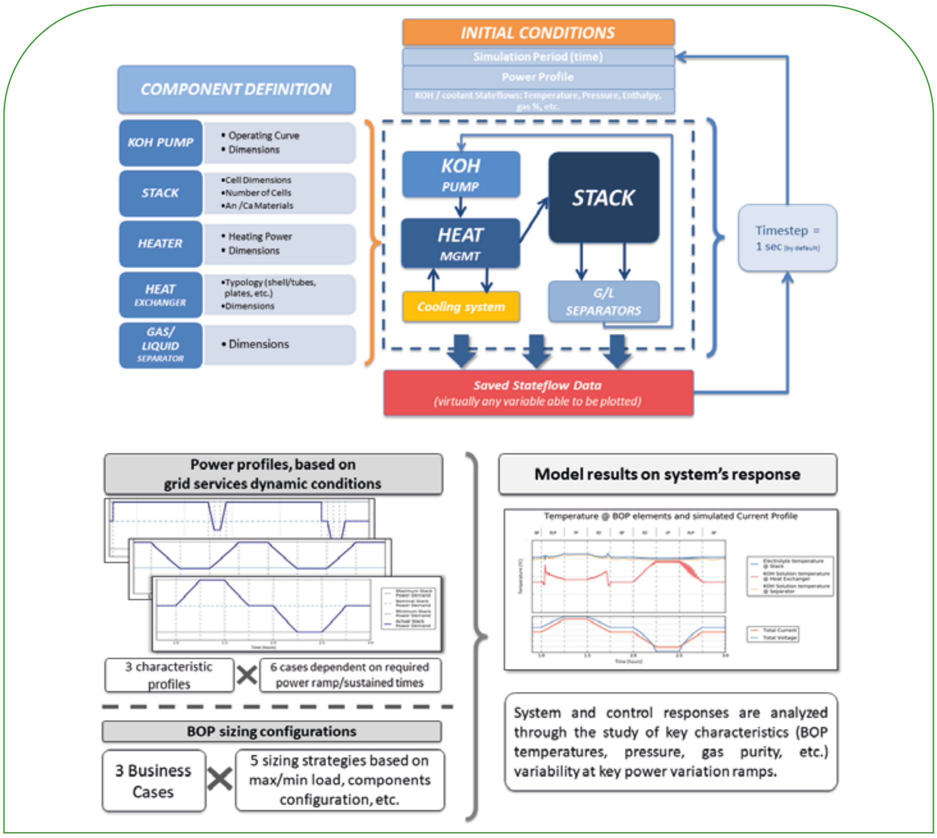
ELYntegration

GRID INTEGRATED MULTI MEGAWATT HIGH PRESSURE ALKALINE ELECTROLYSERS FOR ENERGY APPLICATIONS

elyntegration

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 - 31/05/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**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 focused on 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 H_2/day under highly dynamic power supplies, when high renewable energies shares are considered. The most attractive business models and an assessment on market potential have been implemented. Advanced new materials (membranes and electrodes) have been developed, tested and durability investigated by ASTs at pilot scale. The most promising materials have been tested at industrial scale.

NON-QUANTITATIVE OBJECTIVES

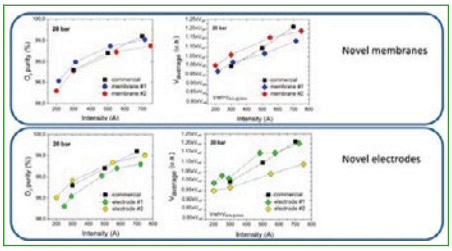
- Design and testing of Accelerated Stress Tests (AST) for AWE oriented to GS, 100 % accomplished
- An assessment of the requirements to provide GS was carried out and validated within WP5
- The regulatory frame work and end user requirements for an electrolyser providing grid services was carried out
- The most attractive business scenarios based on the utilization of the MW HP AWE for grid and energy storage devices was identified
- Dissemination was carried out through different channels, taking account of several target audiences. Several scientific publications were submitted.

PROGRESS AND MAIN ACHIEVEMENTS

- Demonstration of the capabilities of four industrial size electrolysers to provide grid services
- New materials (membranes and electrodes) developed and tested under AST conditions
- New cell assembly developed and tested.

FUTURE STEPS AND PLANS

Project is finished.

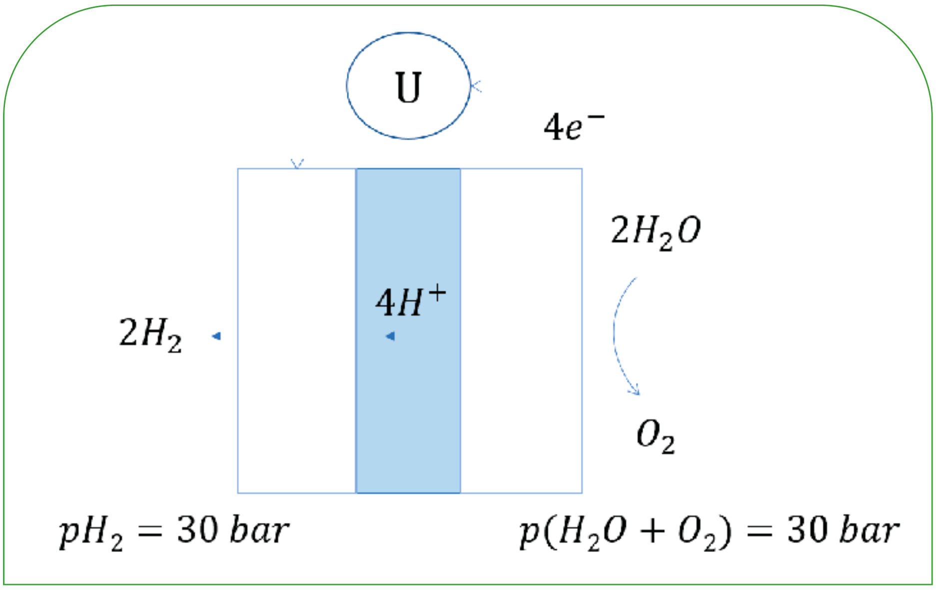


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
MAWP Addendum (2018-2020)	System efficiency	kWh/kg H_2	52	✓
	H_2 production flexibility with a degradation <2 %	Load spanning range (%)	0-200	(Partially, project's target was 15-130 %)
Project's own objectives	Increase of stack size	kW	9 700	✓
	Increase of stack capacity	t/d H_2	4.2	✓
Electrolysis Study FCH-JU 2014	Reduction of CAPEX	EUR/kW	<630	✓

GAMER

GAME CHANGER IN HIGH TEMPERATURE STEAM ELECTROLYSERS WITH NOVEL TUBULAR CELLS AND STACKS GEOMETRY FOR PRESSURIZED HYDROGEN PRODUCTION



Project ID:	**779486**
Call topic:	**FCH-02-2-2017** - Game changer High Temperature Steam Electrolysers
Project total costs:	**€2 998 951**
FCH JU max. contribution:	**€2 998 951**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**SINTEF AS, NO**
Website:	**www.sintef.no/projectweb/gamer**

BENEFICIARIES: AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS, STIFTELSEN SINTEF, UNIVERSITETET I OSLO, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, COORSTEK MEMBRANE SCIENCES AS, CRI EHF, MC2 INGENIERIA Y SISTEMAS SL

PROJECT AND OBJECTIVES

The GAMER project is developing a novel cost-effective tubular Proton Ceramic Electrolyser (PCE) stack that will produce pure dry pressurised hydrogen. The electrolyser system will be thermally coupled to renewable or waste heat sources in industrial plants to achieve higher AC electric efficiency. The project will establish the science and technology for high volume production of the novel tubular cells and will develop designs of system and balance of plant components supported by advanced modelling and simulation work, as well as flowsheets of integrated processes.

NON-QUANTITATIVE OBJECTIVES

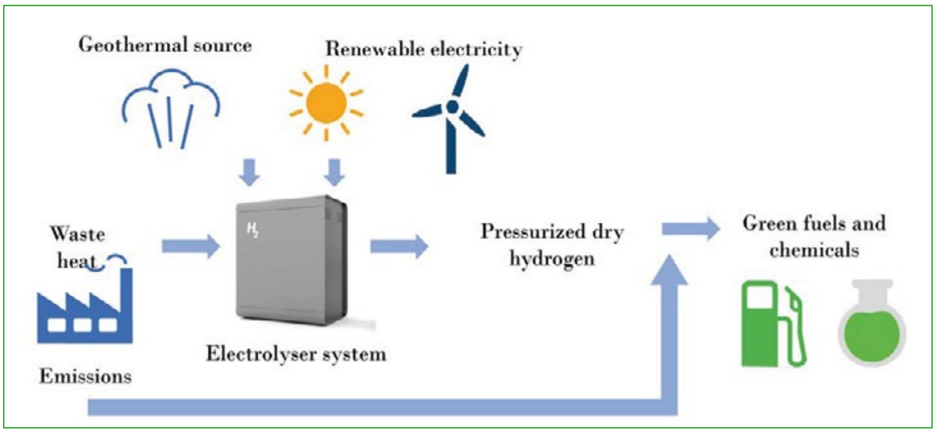
- Regular meetings are conducted with advisory board members to present the project's progress and define potential application scenarios for electrolyser integration
- In collaboration with industrial partners, the project has mapped relevant stakeholders for GAMER and prepared an action plan for interaction with them
- More than 11 presentations about the project have been delivered in open conferences. One flyer is also available for the project. One publication in a high-impact journal has been accepted
- The project is currently preparing a patent for the design of the single engineering unit.

PROGRESS AND MAIN ACHIEVEMENTS

- Stable operation of tubular cell at 3 bar total pressure with 1.5 bar steam on anode side measured over 700 hours at 600 °C
- Novel design of single engineering unit consisting of the electrochemical cell assembled with current collectors, seals and pressurised steel vessel
- Design of 10 kW electrolyser with balance of plant defined with the development of an integrated Excel design sheet.

FUTURE STEPS AND PLANS

- Experimental validation of SEU performance in relevant operating conditions
- Scaling up of SEU production for supply to electrolyser prototype
- Sub-contracting of electrolyser prototype engineering
- Installation and commissioning of electrolyser prototype at CSIC ITQ
- Testing of electrolyser system for at least 2 000 hr of operation.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Tubular electrochemical cell resistance	ohm * cm^2	2	4		4	2018
	Stability of cell = degradation of cell potential	% /500 hr	2	2	✓	Longest test period reported for tubular PCE: 700 hr	2019

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**

BENEFICIARIES: POLITECNICO DI TORINO, BOEING RESEARCH & TECHNOLOGY EUROPE S.L.U., EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, USTAV FYZIKY MATERIALU, AKADEMIE VED CESKE REPUBLIKY, V.V.I., SALZGITTER FLACHSTAHL GMBH, SUNFIRE GMBH, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

PROJECT AND OBJECTIVES

The central element of GrInHy was the manufacturing, integration and operation of the world's most powerful reversible HTE prototype at an integrated iron and steel works. Another focus was the technological improvement of robustness and durability on cell and stack level.
During the operation of about 10 000 hr in electrolysis, fuel cell or hot-standby mode, the prototype reached electrical efficiencies of 78 % LHV (without drying and compression) in electrolysis and 52 % LHV in fuel cell mode.
In total, about 90 000 Nm³ of hydrogen was produced during electrolysis operation.

NON-QUANTITATIVE OBJECTIVES

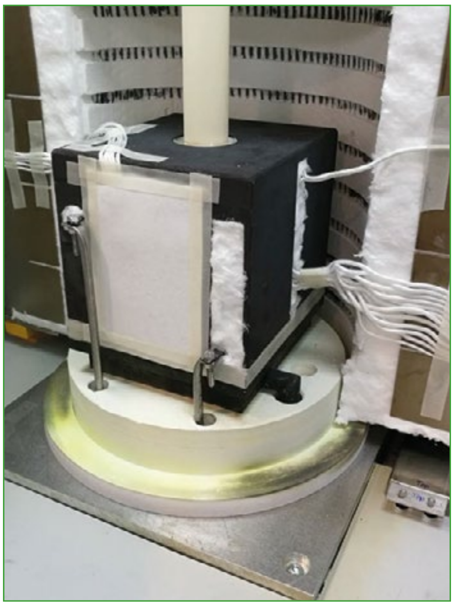
- Elaboration of an exploitation roadmap for cost reducing measures
- Development of dependable system cost data
- Integration of a reversible operation mode (fuel cell mode).

PROGRESS AND MAIN ACHIEVEMENTS

- Approximately 10 000 hr operation of the worldwide biggest reversible high-temperature electrolyser, fuel cell or hot-standby mode
- Production of about 90 000 Nm³ of hydrogen of which more than 41,000 Nm³ with a quality of 3.8 at 10 bar(g) were used for steel annealing processes
- Proof of electrical efficiencies of 78 % LHV (without drying and compression) in electrolysis and 52 % LHV in fuel cell mode.

FUTURE STEPS AND PLANS

Project is finished.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2015	Electrical efficiency	%HHV	68	92	✓	95	2017
	System capacity	kW_AC	70	150		75	2017
	Lifetime	hours	2 000	10 000		20 000	2017

H2Future

HYDROGEN MEETING FUTURE NEEDS OF LOW CARBON MANUFACTURING VALUE CHAINS

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:	**€17 852 540.38**
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**

BENEFICIARIES: NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND, SIEMENS AKTIENGESELLSCHAFT, SIEMENS AKTIENGESELLSCHAFT OESTERREICH, AUSTRIAN POWER GRID AG, VOESTALPINE STAHL GMBH, K1-MET GMBH, VERBUND TRADING GMBH

PROJECT AND OBJECTIVES

The EU flagship project "H2FUTURE – Hydrogen meeting future needs of low carbon manufacturing value chains" brings together energy suppliers, the steel industry, technology providers and research partners, all jointly working on the future of energy. With a capacity of 6 MW and a production of 1 200 m³ of green hydrogen per hour, H2FUTURE is currently the world's largest and most advanced hydrogen pilot facility using PEM (proton exchange membrane) electrolysis technology for producing green hydrogen from renewable electricity.

NON-QUANTITATIVE OBJECTIVES

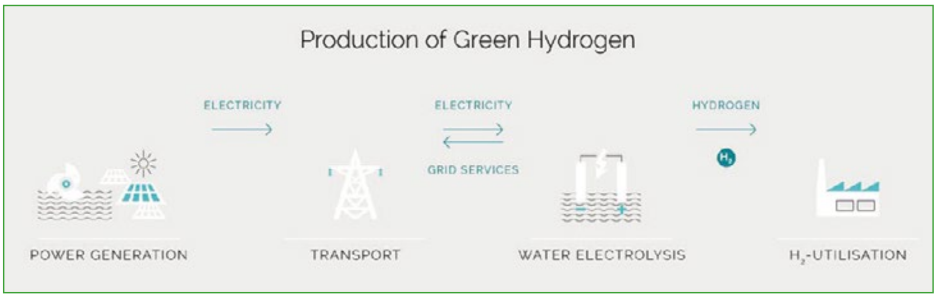
- Roll-out studies on steel and fertiliser industries
- KPIs and performance indicators grouped and defined
- Pilot tests and quasi-commercial operation planned
- Hardware tested in terms of prequalification for grid services.

PROGRESS AND MAIN ACHIEVEMENTS

- Construction permit obtained
- Electrolyser pilot plant building erected
- Optimisation tool for hydrogen/electricity markets developed.

FUTURE STEPS AND PLANS

- Commissioning of pilot plant
- Pilot test operation including testing of grid services
- Quasi-commercial operation and optimisation
- Roll-out and impact studies for steel and fertiliser industries.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Time to receive construction permit	months	24 months	12 months	✓
	Communication events	number	20	50	
	Awards won	number	0	1	

HAEOLUS

HYDROGEN-AEOLIC ENERGY WITH OPTIMISED ELECTROLYSERS UPSTREAM OF SUBSTATION

Project ID:	**779469**
Call topic:	**FCH-02-4-2017** - Highly flexible electrolysers balancing the energy output inside the fence of a wind park
Project total costs:	**€6 921 215**
FCH JU max. contribution:	**€4 997 738.63**
Project start - end:	01/01/2018 - 31/12/2021
Coordinator:	**SINTEF AS, NO**
Website:	**www.haeolus.eu**

BENEFICIARIES: STIFTELSEN SINTEF, UNIVERSITÉ DE FRANCHE-COMTE, FUNDACION TECNALIA RESEARCH & INNOVATION, UNIVERSITÉ DE TECHNOLOGIE DE BELFORT - MONTBELIARD, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, UNIVERSITÀ DEGLI STUDI DEL SANNIO, HYDROGENICS EUROPE NV, KES KNOWLEDGE ENVIRONMENT SECURITY SRL, NEW NEL HYDROGEN AS, COMMUNAUTE D´ UNIVERSITES ET ETABLISSEMENTS UNIVERSITÉ BOURGOGNE - FRANCHE - COMTE, VARANGER KRAFTVIND AS, VARANGER KRAFTNETT AS, VARANGER KRAFT AS, VARANGER KRAFTENTERPRENOR AS, VARANGER KRAFTMARKED AS, VARANGER KRAUFTUTVIKLING AS

PROJECT AND OBJECTIVES

Combining hydrogen production and wind power can allow greater uptake of wind power, as hydrogen production functions as a controllable buffer reducing the oscillations in wind power production.

Haeolus investigates several modes of operation (re-electrification, mini-grid, fuel production) and will demonstrate them in a plant being built in Berlevåg, Norway, in a remote area with a weak grid, which is representative of many good wind power sites in Europe.

NON-QUANTITATIVE OBJECTIVES

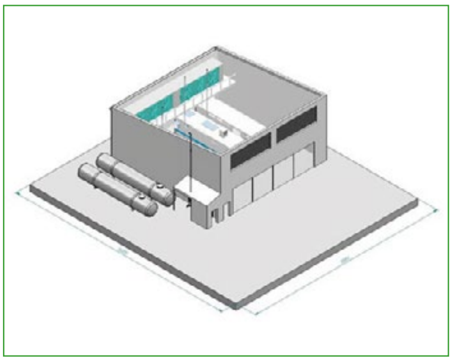
Valorisation of produced hydrogen as there is strong local interest in hydrogen projects, several exploitation actions are planned.

PROGRESS AND MAIN ACHIEVEMENTS

- Plant designed and site selected
- All authorisations and permits have been cleared, and construction is scheduled
- Local authorities are engaged in several spin-off projects.

FUTURE STEPS AND PLANS

- Construction and start-up of demonstration plant
- Spin-off of hydrogen exploitation actions (local initiatives, export, logistic chain)
- Testing of multiple operating modes
- Studies on LCA, business case, environmental performance, impact on energy systems & RCS.

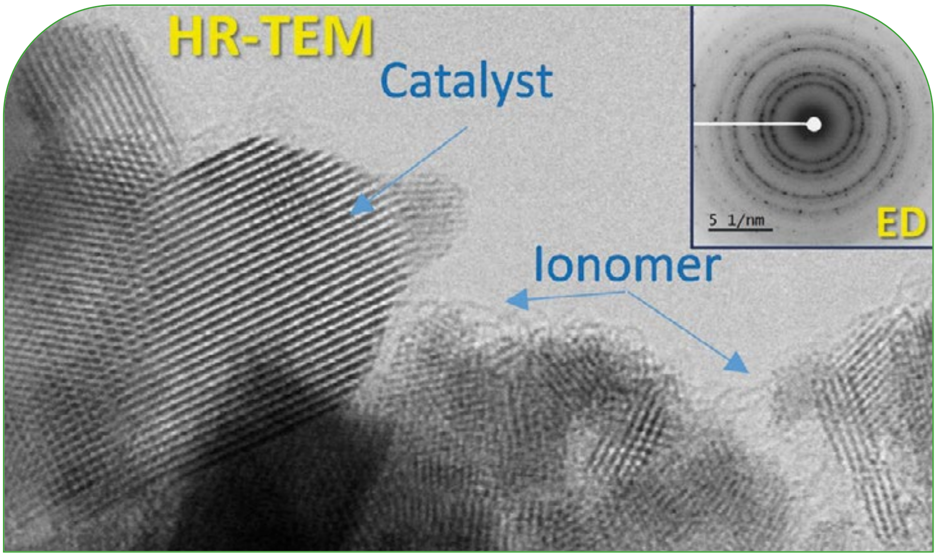


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AIP2012	Reactor production rate	kg/week	3	0.25		0.1	N/A
AWP 2017	Electrolyser CAPEX	M€/tpd	3	N/A		N/A	N/A
Project's Own Objectives	Demonstration	years	2.5	0		10	2018
MAWP Addendum (2018-2020)	Energy consumption	kWh/kg	52	N/A		45.6	2018
	Efficiency degradation	%/year	1.5	N/A		N/A	N/A

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:	**hpem2gas.eu**

BENEFICIARIES: JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, SOLVAY SPECIALTY POLYMERS ITALY SPA, UNIRESEARCH BV, IRD FUEL CELLS A/S, HOCHSCHULE EMDEN/LEER, ITM POWER (TRADING) LIMITED, STADTWERKE EMDEN GMBH

PROJECT AND OBJECTIVES

The HPEM2GAS project aimed to develop 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 aims to contribute significantly to reducing the electrolyser CAPEX and OPEX costs. HPEM2GAS develops key technologies to bring innovative solutions from TRL four to six 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 achieved; analysis of different test scenarios carried out and reported
- Successful demonstration of the electrolysis system in grid balancing
- Organisation of a workshop at the field testing site in Emden with participation of more than 60 stakeholders
- Participation at more than 20 conferences, publication of four open access papers in international journals, completion of radio interviews as well as publication of flyers, brochures and press releases
- Participation in about three joint workshops with other projects.

PROGRESS AND MAIN ACHIEVEMENTS

- Achievement of electrolysis current density of 3 A cm^{-2} at about 77 % (HHV) stack efficiency and 75 °C with reduced PGM catalyst loading (0.3 mg/W)
- Development of advanced stack components
- Integration of the developed components and the advanced electrolysis stack in a 180 kW electrolysis system validated in field testing at Emden (DE).

FUTURE STEPS AND PLANS

- Completion of field testing activities
- Completion of life cycle and cost analyses
- Preparation of dissemination and exploitation plans as follow up of the project.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Current density at cell voltage <1.8 V under nominal operation	A/cm^2	3.0	3.0	✓	2.0	2017
	Stack degradation in a 1000 h test at 3 A cm^{-2}	%/khrs	0.280	0.21	✓	0.250	2017
	Stack efficiency at 3 A cm^{-2}	% vs. HHV	82	77	🔧	N/A	N/A
	System energy consumption at 3 A cm^{-2}	kWh/kg H_2	48	54	🔧	58	2017
	System capacity	kg/d H_2	80	83.6	✓	N/A	N/A

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:	€15 803 441.25
FCH JU max. contribution:	€7 999 370.80
Project start - end:	01/10/2015 - 30/09/2020
Coordinator:	AIR LIQUIDE ADVANCED BUSINESS, FR
Website:	www.hybalance.eu

BENEFICIARIES: LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH, HYDROGENICS EUROPE NV, COPENHAGEN HYDROGEN NETWORK AS, FORDONSGAS SVERIGE AB, NEAS ENERGY AS, CEMTEC FONDEN, AIR LIQUIDE GLOBAL E&C SOLUTIONS FRANCE

PROJECT AND OBJECTIVES

HyBalance will demonstrate the link between energy storage in the form of hydrogen and the deployment of hydrogen mobility solutions. 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. Another goal of the project is to improve grid balancing efficiency in order to take benefit of wind turbine electricity production in excess by producing H_2.

PROGRESS AND MAIN ACHIEVEMENTS

- Successful delivery of hydrogen in challenging environment for industrial market and mobility applications
- Inauguration of the HyBalance facility on 3 September 2018
- Pipeline construction to supply a metallurgical plant through a direct connection with the HyBalance facility.

FUTURE STEPS AND PLANS

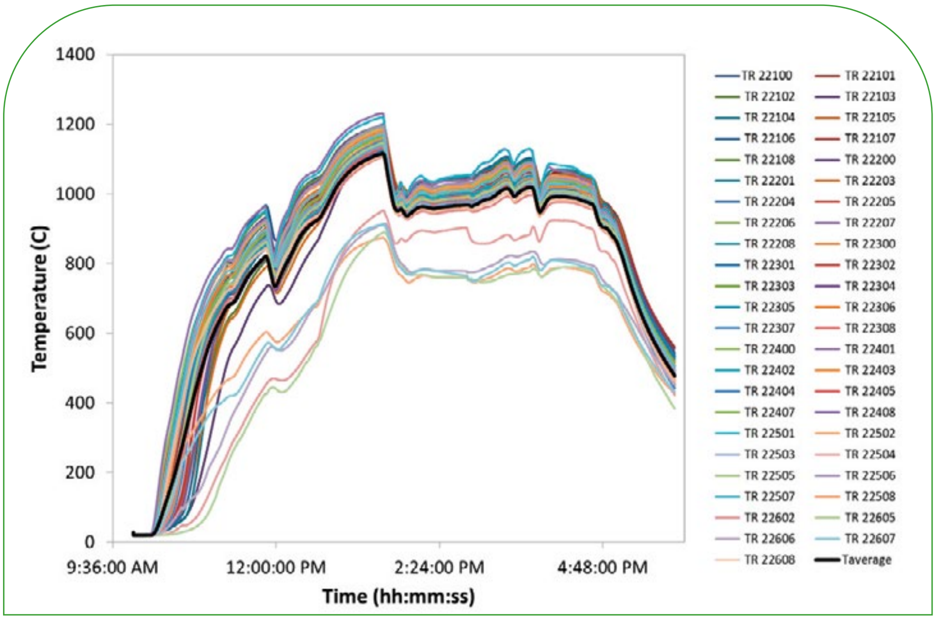
- Improve the hydrogen production efficiency to reach nominal capacity of the plant
- Implement and automate the grid balancing services over 2020
- Teething problems being solved in 2019. Close monitoring of system performance over 2019-2020.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP (2014-2020)	Cost goal	€/kW	1 570	1 810		1 200	2020
AIP 2014	Efficiency	$kWhel/kgH_2$	57.5	58.6	✓	55.3 - 52.2	2018 - 2019
	System lifetime	hours	20 000	4 000	✓	7 000	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:	**hydrosol-plant.certh.gr**

BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, HYGEAR B.V., ELLINIKA PETRELAIA AE

PROJECT AND OBJECTIVES

Within the HYDROSOL-PLANT project the development and operation of a plant for solar thermo-chemical hydrogen production from water was pursued.
The main objectives of HYDROSOL-PLANT were to achieve a material life-time of more than 1 000 operational hours and to construct a solar hydrogen production demo-plant in the 750 kWth range to verify the developed technology for solar thermochemical H_2O splitting and demonstrate hydrogen production and storage on site at levels >3 kg/week.

NON-QUANTITATIVE OBJECTIVES

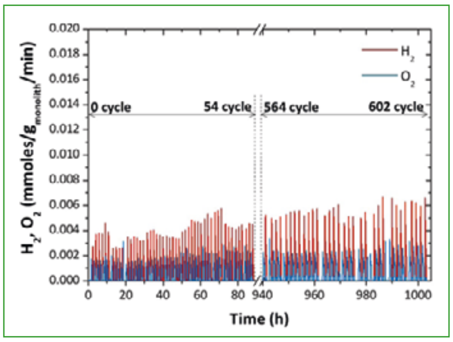
- Modelling and simulation of the plant and of key components
- Field tests of prototype plant completed via the installation of reactors and peripherals. Thermal experiments initiated. H_2 production experiments followed the thermal campaign
- Full-size reactor components and reactors was built.

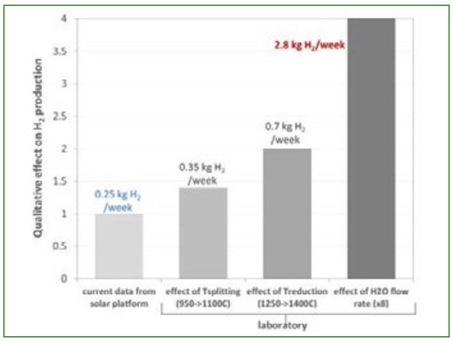
PROGRESS AND MAIN ACHIEVEMENTS

- Durability testing of structured redox material for over 1 000 hr of consecutive water splitting and thermal reduction
- Achieved hydrogen production from water based on redox thermochemical cycles exceeding 3 kg/week at the laboratory scale
- Construction, integration and operation of the 750 kWth solar reactors and peripherals on the solar platform. The largest solar redox reactors to date.

FUTURE STEPS AND PLANS

Project is finished.



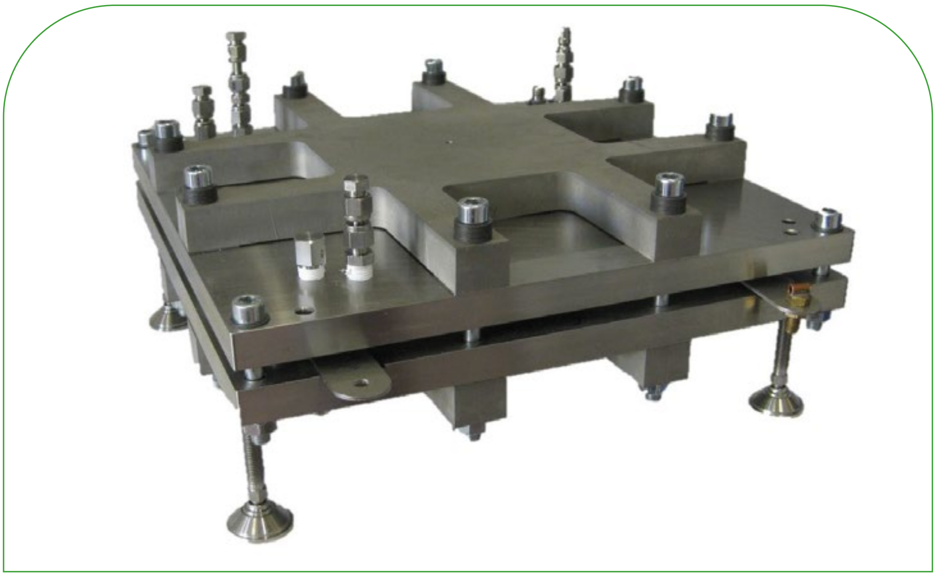


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AIP 2012	Material durability	hours	1 000	1 002	✓	283	2010
	Reactor production rate	kg/week	3	0.25		0.1	2012
	Solar hydrogen generator in a demonstration range @ 0.5-2 MW scale	MW	0.5-2	0.75	✓	0.10	2012
Project's own objectives	H_2 production	ml/g	4.6	7.35	✓	4.6	2010
	Maximum H_2 production rate	ml/min/g	0.1	0.45	✓	0.1	2014

HyGrid

FLEXIBLE HYBRID SEPARATION SYSTEM FOR H_2 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:	**€3 167 710**
FCH JU max. contribution:	**€2 527 710**
Project start - end:	01/05/2016 - 30/04/2020
Coordinator:	**TECHNISCHE UNIVERSITEIT EINDHOVEN, NL**
Website:	**www.hygrid-h2.eu**

BENEFICIARIES: FUNDACION TECNALIA RESEARCH & INNOVATION, SAES GETTERS S.P.A., HYGEAR BV, HYGEAR FUEL CELL SYSTEMS B.V., QUANTIS, HYET HYDROGEN BV, HYGEAR TECHNOLOGY AND SERVICES BV, NORTEGAS ENERGIA DISTRIBUCION SOCIEDAD ANONIMA

PROJECT AND OBJECTIVES

The key objective of the HyGrid project is the design, scale-up and demonstration 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 is on 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/kgH_2 and <1.5 €/kgH_2. A pilot designed for >25 kg/day of hydrogen.

NON-QUANTITATIVE OBJECTIVES

Young researchers trained.

PROGRESS AND MAIN ACHIEVEMENTS

- Patent for separation system submitted by TUE and TECNALIA
- Scale up of electrochemical compressor
- Patent on membranes to be submitted between TECNALIA and TUE.

FUTURE STEPS AND PLANS

- Finalising the prototype by 2019
- Testing of prototype by 2020.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2015	Pure hydrogen separation system with low power	kWh/kgH_2	5	4.69	✓
		€/kgH_2	1.5	1.6	🔧
	Pure hydrogen production	kg/day	25	0	🔧
	Prototype unit	TRL	5	5	✓

HySTOC

HYDROGEN SUPPLY AND TRANSPORTATION USING LIQUID ORGANIC HYDROGEN CARRIERS

Project ID:	**779694**
Call topic:	**FCH-02-6-2017** - Liquid organic hydrogen carrier
Project total costs:	**€2 499 921.25**
FCH JU max. contribution:	**€2 499 921.25**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**HYDROGENIOUS TECHNOLOGIES GMBH, DE**
Website:	**hystoc.eu**

BENEFICIARIES: FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN NUERNBERG, HYGEAR BV, HYGEAR FUEL CELL SYSTEMS B.V., OY WOIKOSKI AB, HYGEAR TECHNOLOGY AND SERVICES BV, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

PROJECT AND OBJECTIVES

The HySTOC project's primary objective is to demonstra the feasibility of the Liquid Organic Hydrogen Carrier (LOHC) technology for distribution and storage of hydrogen to supply Hydrogen Refuelling Stations (HRS) with hydrogen meeting all quality criteria defined in ISO 14687:2-2012. Definition of requirements, preliminary LCA, specification of the logistic concept as well as engineering of hydrogen storage, release and purification systems are completed. Current focus is on assembly of the systems, layout plan for the system setup, and LOHC logistics to prepare for field testing.

NON-QUANTITATIVE OBJECTIVES

- Development of a cost-efficient, fully automated LOHC hydrogen storage system (StorageBOX) and a release system (ReleaseBOX)
- Demonstration of full systems operation for HRS supply in Finland will follow 2020.

PROGRESS AND MAIN ACHIEVEMENTS

- Detail engineering of hydrogen storage, release and purification system is completed, meeting all project-specific requirements
- Successful completion of preliminary LCA, indicating the environmental impacts of the overall concept of LOHC-based hydrogen supply
- Development of LOHC-based logistic concept for hydrogen transportation between two locations in Finland.

FUTURE STEPS AND PLANS

- Delivery of LOHC-based hydrogen storage and release systems to Finland
- Demonstration of feasibility of LOHC-based hydrogen transport over long distance in Finland
- Proof that hydrogen released from LOHC meets the quality required according to ISO 14687:2-2012.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP Addendum (2018-2020)	H_2 Capacity of hydrogen trailer	kg	1 000	1 300	✓	850	2017
	Capital cost compressed gas tube trailer	€ /kg	350	85	✓	400	2017
Project's own objectives	H_2 Purity	%	ISO 14687:2	to be measured coming months	🔧	99.95 % purity of H_2 released from LOHC (before purification)	2019
	H_2 input pressure	bar	25	Design for 25 -30 bar	✓	50	2017

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:	**€3 656 756.20**
FCH JU max. contribution:	**€2 176 624.80**
Project start - end:	01/11/2014 - 31/10/2018
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE**
Website:	**inside-project.eu**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, ACTA SPA, HOCHSCHULE ESSLINGEN, NEW NEL HYDROGEN AS, ENAPTER SRL

PROJECT AND OBJECTIVES

The project developed a diagnostic tool for real-time monitoring of locally resolved current densities in water electrolysers. Involved Electrolyser technologies are proton exchange membrane based water electrolysis (PEMWE), alkaline water electrolysis (AWE), and anion exchange membrane based water electrolysis (AEMWE). Ex situ analyses accompanied the local deactivation that are visualised with the diagnostic tool. Accelerated stress tests were suggested and used and shared with FCH JU.

NON-QUANTITATIVE OBJECTIVES

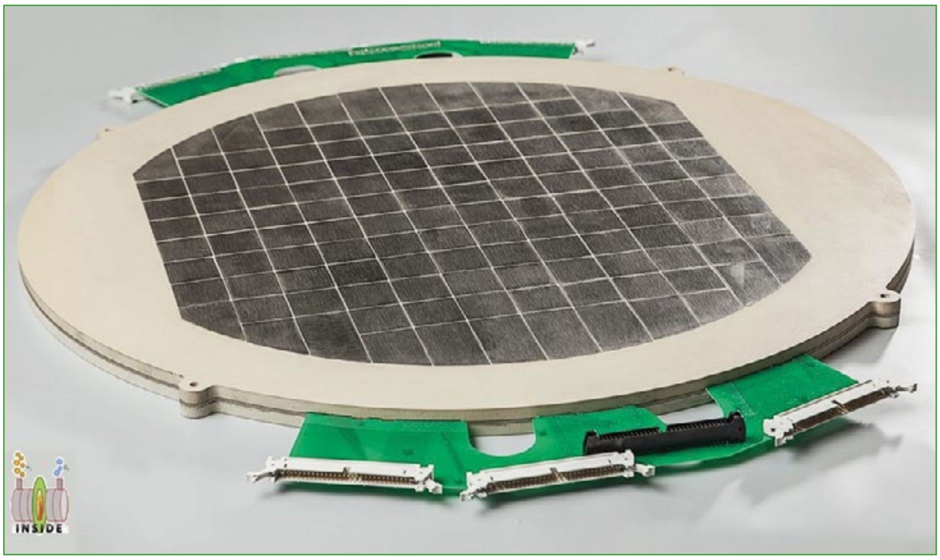
Testing protocols and ASTs for harmonised electrolyser testing. Contribution to basic harmonised electrolyser tests and testing methodology.

PROGRESS AND MAIN ACHIEVEMENTS

- Tools for real-time monitoring of locally resolved current density distribution were designed for PEMWE, AEMWE and AWE
- Correlation of local electrolyser activity/deactivation and local flow shortages/local contamination was demonstrated
- Partially harmonised accelerated stress tests for electrolysers were suggested and shared with FCH JU.

FUTURE STEPS AND PLANS

- Project is finished
- Reality test of diagnostics tool for AWE is planned (depending on the availability of the NEL testing site or an alternative).

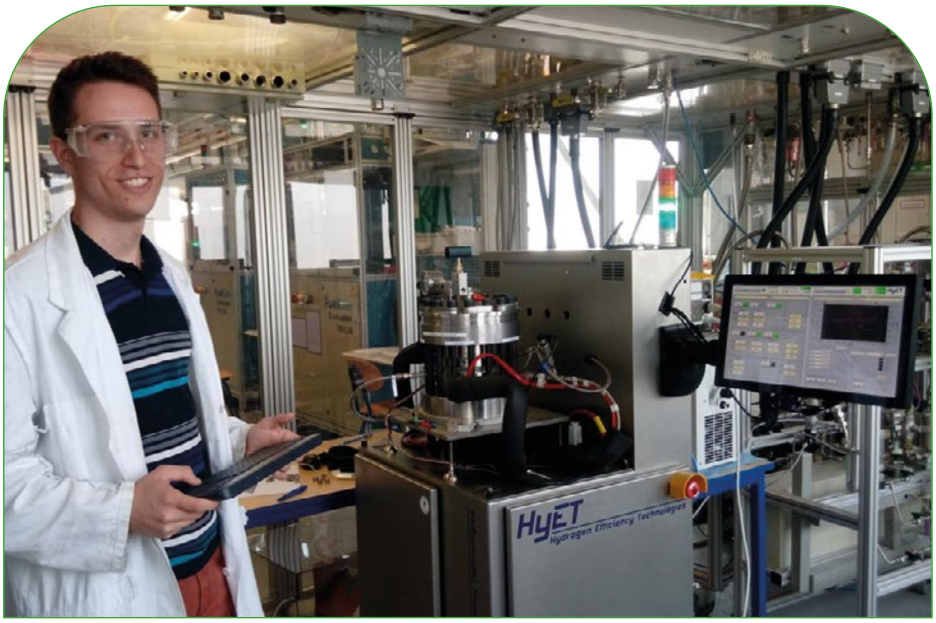


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET ACHIEVED?
MAIP (2008-2013)	Diagnosis/monitoring tool availability	✓
		✓
		✗

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:	INSTITUT JOZEF STEFAN, SI
Website:	www.memphys.eu

BENEFICIARIES: IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, FORSCHUNGSZENTRUM JULICH GMBH, BORIT NV, DUALE HOCHSCHULE BADEN-WURTTEMBERG, HYET HYDROGEN BV

PROJECT AND OBJECTIVES

Project MEMPHYS, targeted the development of a standalone hydrogen purification system based on an electrochemical hydrogen purification (EHP) system. The focus was on high contaminant tolerance at low system cost, making the system suitable for different applications. Project MEMPHYS aimed for a 5 kg H_2/day system with an energy consumption <5 kWh/kg H_2, a hydrogen recovery rate of >90 %, producing high purity hydrogen at a system cost of <1 500 €/kg H_2/day with a pressure of 200 bar.

PROGRESS AND MAIN ACHIEVEMENTS

- Targeted recovery rate was reached in short stack tests. Efficiency target was reached in short stack tests
- Comparable measurement results were achieved in the partners' laboratories at different institutions.

FUTURE STEPS AND PLANS

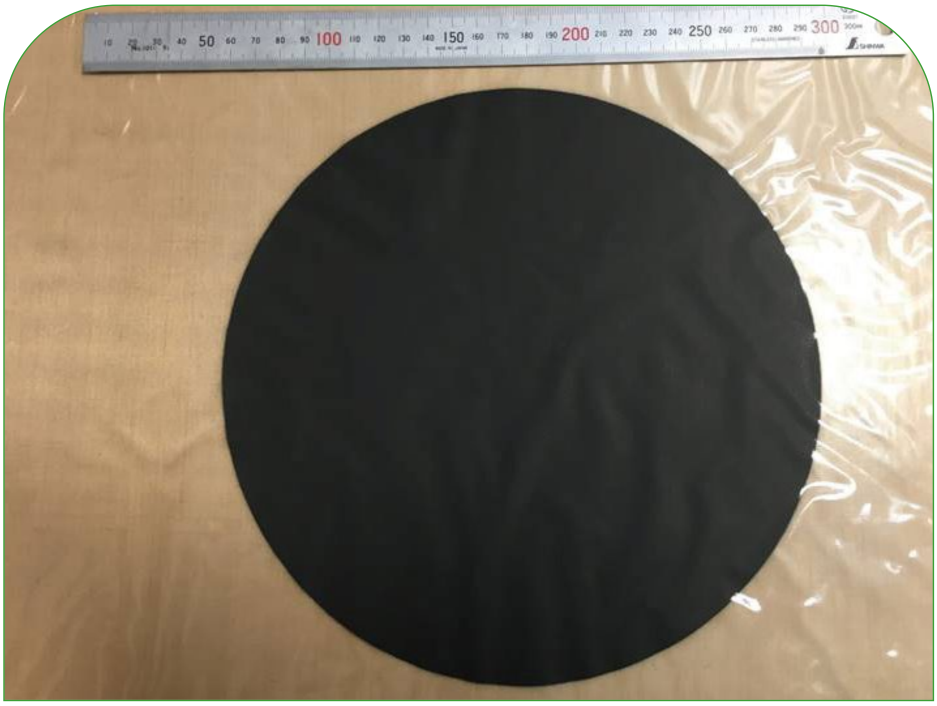
- 3-month duration test
- Building up of a 5 kg/day system in the fourth quarter of the running year.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Energy consumption of EHP stack	kWh/kg H_2	3	3	✓
	Recovery rate EHP short-stack	%	>90	90	
	Recovery rate single cell	%	>90	90	
	Energy consumption at targeted recovery rate	kWh/kg H_2	3	5	🛠

NEPTUNE

NEXT GENERATION PEM ELECTROLYSER UNDER NEW EXTREMES



Project ID:	**779540**
Call topic:	**FCH-02-1-2017** - Game changer Water Electrolysers
Project total costs:	**€1 927 335.43**
FCH JU max. contribution:	**€1 926 221.25**
Project start - end:	01/02/2018 - 31/01/2021
Coordinator:	**ITM POWER (TRADING) LIMITED, UK**
Website:	**www.neptune-pem.eu**

BENEFICIARIES: CONSIGLIO NAZIONALE DELLE RICERCHE, ENGIE, SOLVAY SPECIALTY POLYMERS ITALY SPA, IRD FUEL CELLS A/S, PRETEXO

PROJECT AND OBJECTIVES

The NEPTUNE project develops a set of breakthrough solutions at materials, stack and system levels to increase hydrogen pressure to 100 bar and current density to 4 A cm^{-2} for the base load, while keeping the nominal energy consumption <50 kWh/kg H_2. The rise in stack temperature at high current density will be managed by using Aquivion polymers for both membrane and ion exchange resin. Aquivion is characterised by enhanced conductivity, high glass transition temperature and increased crystallinity.

NON QUANTITATIVE OBJECTIVES

- Harmonised test protocols for assessing system components, stack and balance of plant over a wide range of operating temperature and pressure
- Website created during first three months of the project and accessible to the public
- Dissemination plan published.

PROGRESS AND MAIN ACHIEVEMENTS

- Manufacture of reinforced and non-reinforced membranes with a thickness of 50 μm and a series resistance reaching project target
- Operation of an electrolysis cell at 140 °C demonstrated
- Oxygen and hydrogen evolution over potentials target reached with an MEA having low noble metal loadings.

FUTURE STEPS AND PLANS

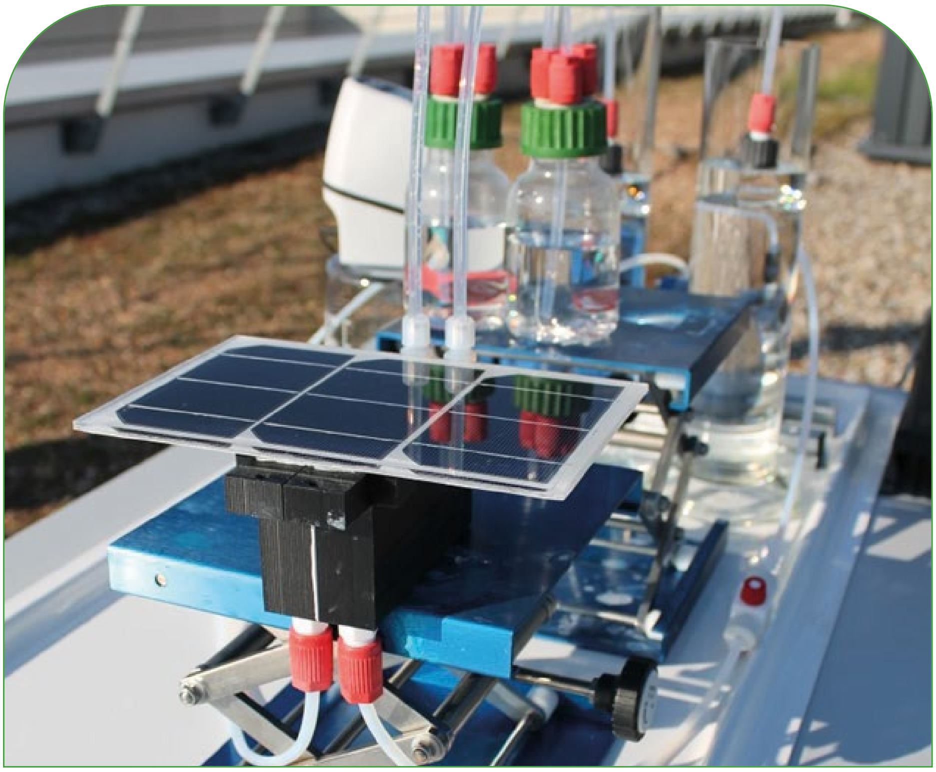
- Scaling-up and industrialisation of down-selected Aquivion membranes and ionomer dispersions
- Manufacturing of catalysts meeting the specifications and the demonstration of large-batch catalyst production
- Manufacture of enhanced MEAs for gas cross-over management at high pressure
- Advanced cost-effective PEM electrolysis stack operating at high temperature and high differential pressure
- Demonstration of advanced PEM electrolyser system for operation at high current density, temperature and pressure.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Anode catalyst loading	mg/W	0.05	0.047	✓	0.23	2018
	Cathode catalyst loading	mg/W	0.0071	0.014	🛠	0.035	
	Efficiency degradation per 1 000 hr for LT Electrolyser	%/1 000 hr	0.29	0.23	✓	0.2	

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:	**pecsys-horizon2020.eu**

BENEFICIARIES: UPPSALA UNIVERSITET, CONSIGLIO NAZIONALE DELLE RICERCHE, FORSCHUNGSZENTRUM JULICH GMBH, SOLIBRO RESEARCH AB, ENEL GREEN POWER SPA, 3SUN SRL

PROJECT AND OBJECTIVES

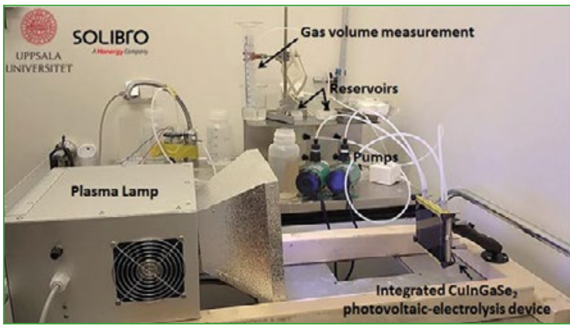
The PECSYS project is concerned with the demonstration of a solar driven electrochemical hydrogen generator using a solar collection area >10 m². Innovative device concepts for integrated photoelectrochemical devices with a solar collection area of at least 100 cm² have been implemented. Since TF Si was abandoned, only two approaches remain for consideration for deployment in the photovoltaic integrated electrolyser. Efforts are ongoing to increase the solar to hydrogen efficiency and device stability, as well as to upscale devices to ~ 1 m² modular units that will make up the demonstrator.

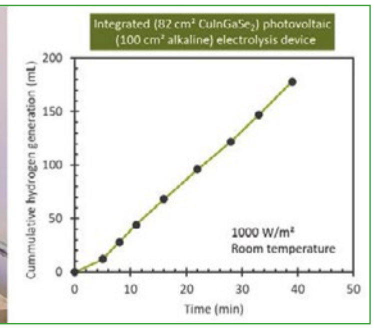
PROGRESS AND MAIN ACHIEVEMENTS

- Solar to H_2 efficiency of 8.5 % at a H_2 generation rate of 2.75 g/h/m² (ambient conditions 1 000 W/m², 25 °C) achieved for 100 cm² CIGS/NiO|NiMoV unit
- Solar to H_2 efficiency of 3.7 % at a H_2 generation rate of 1.1 g/h/m² (outdoor conditions 1000 W/m²) achieved for 294 cm² silicon/Ni|NiFeOx unit.

FUTURE STEPS AND PLANS

- Further improvement of electrolyser efficiency by optimising device design to reduce resistive and mass transport losses
- Further explore cost-effective alkaline resistant materials for long-term stability
- Further improvement in the activity, stability and electrical conductivity of non PGM catalysts.



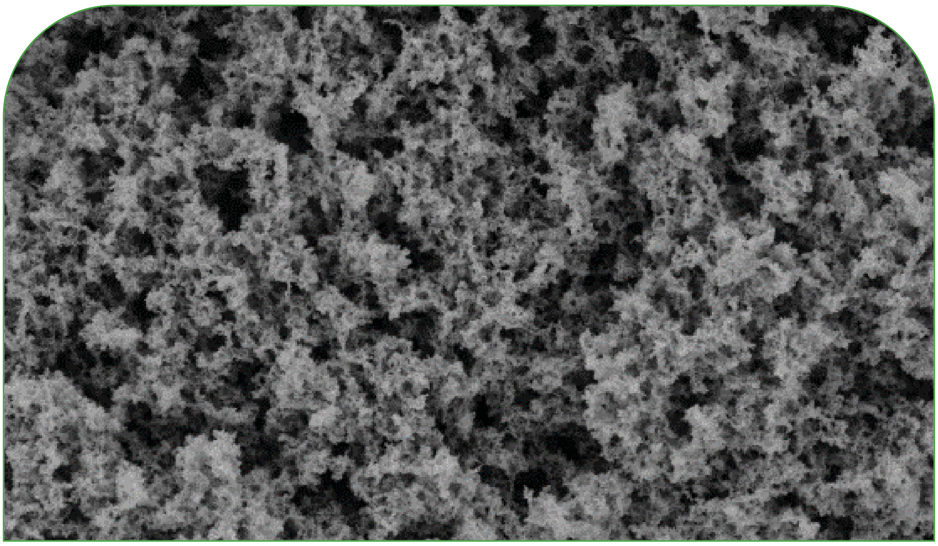


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
Project's own objectives	Hydrogen production rate	l/day	22		250 l/day
	Solar collection area	m²	10		1-2m²
	H_2 production cost	€/kg	5		
MAWP (2014- 2020)	System capital cost	€/(kg/d)	2 500		N/A
	System energy use	kWh/kg	100		

PRETZEL

NOVEL MODULAR STACK DESIGN FOR HIGH PRESSURE PEM WATER ELECTROLYSER TECHNOLOGY WITH WIDE OPERATION RANGE AND REDUCED COST



Project ID:	779478
Call topic:	**FCH-02-1-2017** - Game changer Water Electrolysers
Project total costs:	€1 999 088.75
FCH JU max. contribution:	€1 999 088.75
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE
Website:	pretzel-electrolyzer.eu

BENEFICIARIES: ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS, UNIVERSITATEA POLITEHNICA TIMISOARA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, ECOLE NATIONALE SUPERIEURE DES MINES DE PARIS, GKN SINTER METALS ENGINEERING GMBH, WESTFALISCHE HOCHSCHULE GELSENKIRCHEN, BOCHOLT, RECKLINGHAUSEN, GKN SINTER METALS FILTERS GMBH RADEVORMWALD, SOLUCIONES CATALITICAS IBERCAT SL, ADAMANT AERODIASTIMIKES EFARMOGES ETAIREIA PERIORISMENIS EFTHYNIS, IGAS ENERGY GMBH

PROJECT AND OBJECTIVES

The overall goal is to develop an innovative PEM electrolyser that provides significant increases in efficiency and operability to satisfy emerging market demands. PRETZEL is offering a breakthrough in the field of water electrolysers. A central objective of this project is the development of a novel PEM electrolyser system with a maximum 25 kW electrical power consumption that generates 4.5 m^3 h^{-1} H_2 at rated power, at an output pressure of 100 bar and feed water temperature of maximum 90 °C.

NON QUANTITATIVE OBJECTIVES

- Assessment of additional commercial opportunities that are available with the game changer electrolyser compared to current electrolysers
- Enabling additional commercial roll-out of electrolysers post 2025.

PROGRESS AND MAIN ACHIEVEMENTS

- Definition of compliance test protocols and analytics for corrosion, catalytic kinetic, physical property testing etc. and material characterisation
- Report on development of MEAs for 1-cell 25-100 cm^2 LP electrolysers with anode catalysts produced under task 3.3 for initial test cells
- Cell parts and CAD design of HP electrolyser stack are finalised.

FUTURE STEPS AND PLANS

- Report on catalyst synthesis procedure, physical characterisation of anode catalyst as well as performance and durability of components
- Component manufacture for 5-cell HP stack with 550 cm^2 (Catalyst, BPP, PCD, MEAs) and HP PEM electrolyser stack prototype
- Report on the manufacturing process
- Testing protocol for electrolyser operation and report on commissioning tests.

QUANTITATIVE TARGETS AND STATUS

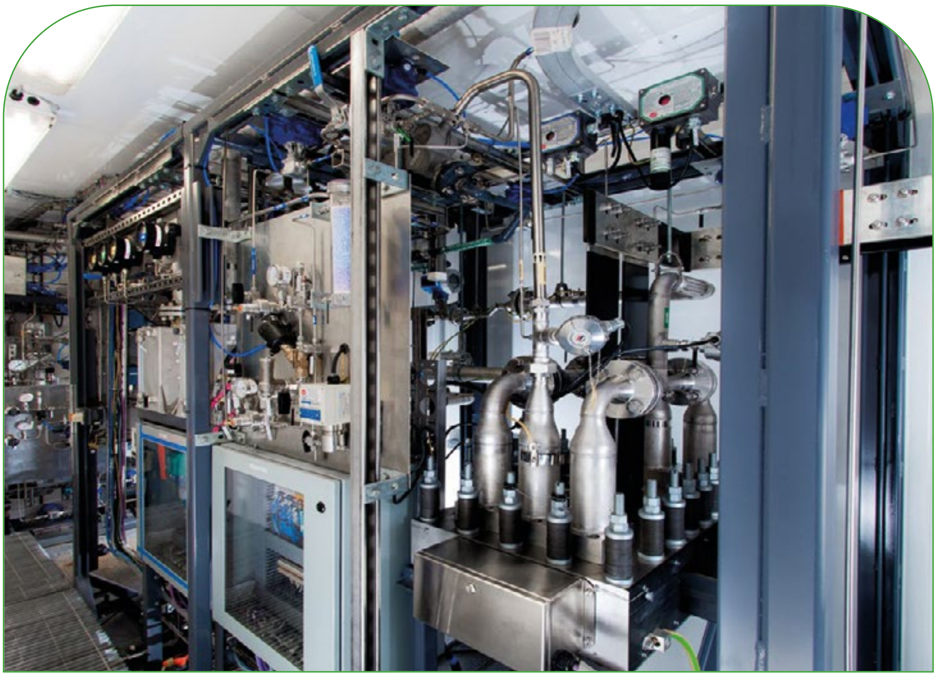
TARGET SOURCE	PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT
MAWP Addendum (2018-2020) and AWP 2017	New cost effective current collectors for PEM electrolysers	Reducing PEM electrolysers CAPEX costs	Initial PCD components are ready for testing in laboratory scale test devices
	25 cm^2 high pressure stack with all components tested	Development and validation of game-changer PEM electrolyser meeting the targets of 2023	Cell parts and CAD design of high pressure electrolyser stack are finalised
	Increase of catalyst activity and optimisation of supporting material	Increase energy efficiency of hydrogen production	Preliminary iridium supported material (Ir/SnO_2) has been prepared Development of catalyst and aerogel support for initial MEA production
	100bar, rapid response (<1s hot start), 4A cm^{-2} nominal current density and overload of 6A cm^{-2}, Temperature T>80°C	Step-change improvements	Initial cell test performing polarisation curve up to 6A/cm^2 at 90 °C was successful
	Cost consideration and market analysis from project results extrapolated to MW-scale	Enable additional commercial roll-out electrolyser	Not started yet

QualyGridS

STANDARDIZED QUALIFYING TESTS OF ELECTROLYSERS FOR GRID SERVICES

Project ID:	**735485 (735160 ???)**
Call topic:	**FCH-02-1-2016** - Establish testing protocols for electrolysers performing electricity grid services
Project total costs:	**€2 811 262.50**
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, IHT INDUSTRIE HAUTE TECHNOLOGIE SA, STICHTING NEDERLANDS NORMALISATIE - INSTITUUT, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, EUROPEAN FUEL CELL FORUM AG, ITM POWER (TRADING) LIMITED, NEW NEL HYDROGEN AS



PROJECT AND OBJECTIVES

The overall objective of the QualyGridS project was to establish standardised testing protocols for electrolysers to perform electricity grid services. Alkaline and PEM electrolysers were both considered within this project. A variety of different grid services were addressed as well as multiple hydrogen end users. The protocols developed were applied to alkaline and PEM electrolysers systems, using electrolyser sizes from 25 kW to 300 kW. Additionally, a techno-economic analysis of business cases was performed covering the grid and market situations in the most relevant regions of Europe.

NON-QUANTITATIVE OBJECTIVES

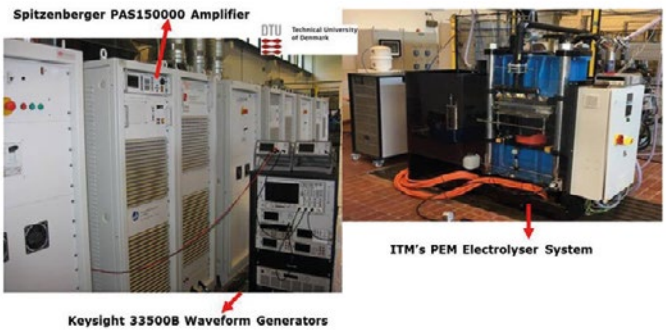
- Development of standardised protocols for electrolysers to provide grid services
- Definition of specific KPIs for dynamic operation to provide grid services
- Evaluation of business cases, sensitivities and a roadmap.

PROGRESS AND MAIN ACHIEVEMENTS

- First draft of testing protocols for electrolyser systems performing electricity grid services
- Report on definition of selected business cases and scenarios for electrolysers performing grid services finalised, some business evaluations completed
- Five electrolyser test benches have been set up to carry out the grid service tests, grid services protocols performed in parts on three electrolysers.

FUTURE STEPS AND PLANS

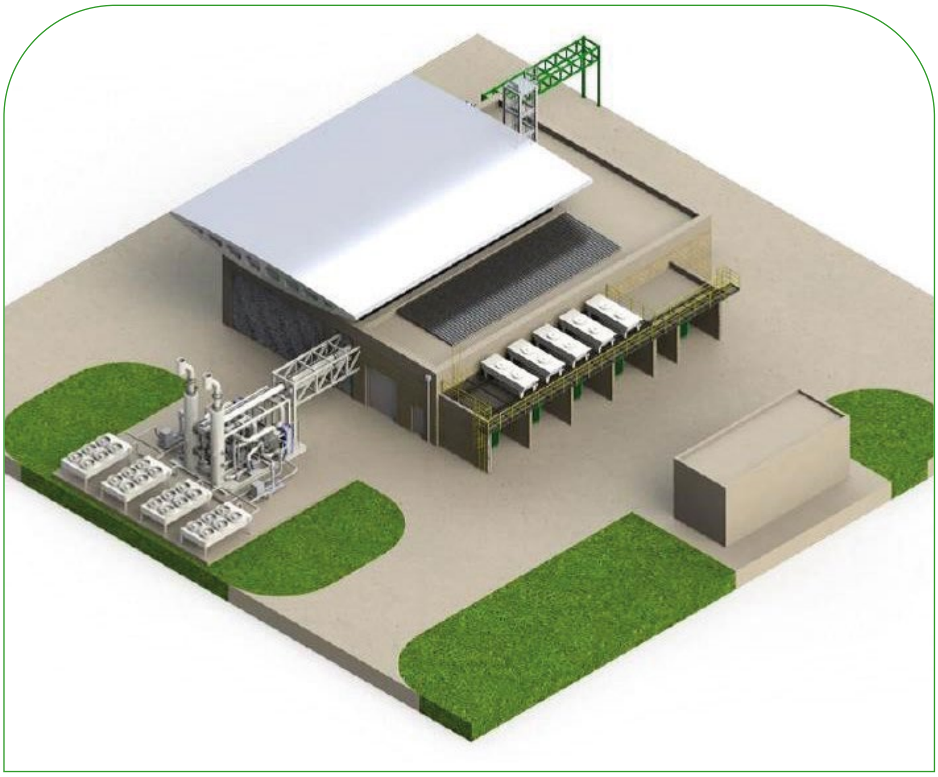
- Electrolyser testing protocols matching a selected grid service, ready for standardisation
- Electrolyser test run complying with developed testing protocol thus in principle being qualified for grid service operation
- Evaluation of business cases and a roadmap for the successful introduction of electrolyser technologies considering energy and grid service market.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Number of electrolysers having perfomed test run	N/A	5	Test runs with three electrolyser systems up to 300 kW		N/A	N/A
MAWP (2014-2020)	Cost of hydrogen	€/kg	4.5-7.0	Cost reduction by performing FCR for certain capacity utilisation scenarios can be as high as 10 %	N/A	Cost of hydrogen for mobility 6.70 €/kg status France 2017	2017
AWP 2016	Development of standardised protocols for electrolysers to provide grid Services covering EU countries	Number of drafts and reviews	3	1		N/A	N/A

REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE



Project ID:	779579
Call topic:	**FCH-02-5-2017** - Demonstration of large electrolysers for bulk renewable hydrogen production
Project total costs:	**€16 058 562.50**
FCH JU max. contribution:	**€9 998 043.50**
Project start - end:	01/01/2018 - 31/12/2022
Coordinator:	**SINTEF AS, NO**
Website:	**www.refhyne.eu**

BENEFICIARIES: STIFTELSEN SINTEF, ELEMENT ENERGY LIMITED, ITM POWER (TRADING) LIMITED, THINKSTEP AG, SHELL DEUTSCHLAND OIL GMBH, SHELL ENERGY EUROPE LIMITED

PROJECT AND OBJECTIVES

The overall objective of the REFHYNE project is to deploy and operate a 10 MW electrolyser in a power to refinery setting. In doing this, REFHYNE will validate the business model for using large scale electrolytic hydrogen as an input to refineries, prove the revenues available from primary and secondary grid balancing in today's markets and create an evidence base for the policy/regulatory changes needed to underpin the required development of this market. Commissioning of the system is expected to happen in 2020.

NON QUANTITATIVE OBJECTIVES

- One of the key outputs of the project is a suite of reports providing an evidence base for changes to existing policies. This will include specific analysis focused at policy makers recommending changes to existing policies
- REFHYNE will produce a detailed assessment of the consenting process for the system and any safety or codes and standards issues encountered.

PROGRESS AND MAIN ACHIEVEMENTS

- Finalised detailed engineering of the electrolyser system fulfilling the refinery requirements
- Finalised detailed design of the electrolyser building.

FUTURE STEPS AND PLANS

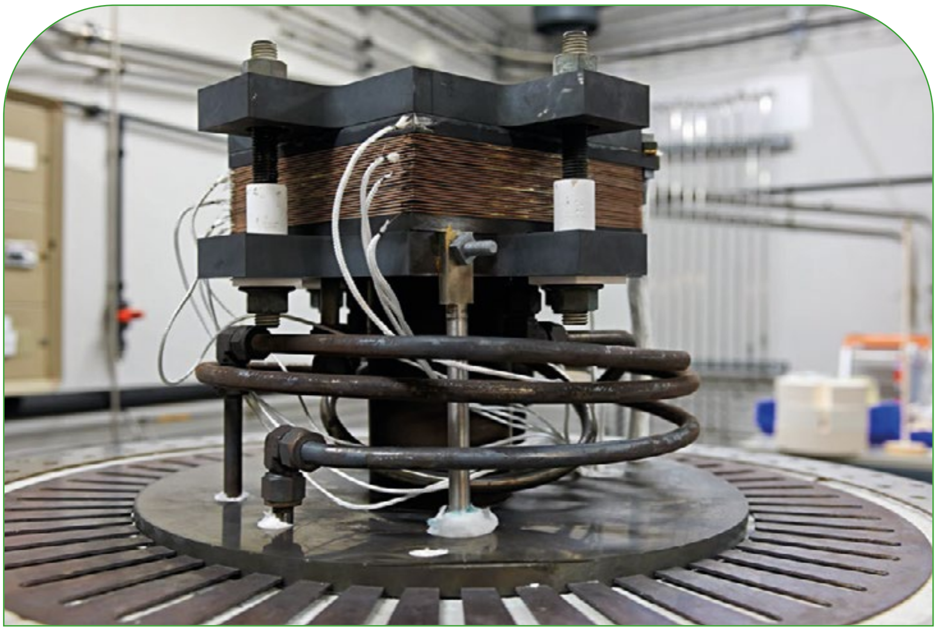
- Demonstration of the 10 MW PEM electrolyser in a refinery setting
- Techno-economic assessment of the electrolyser system and concept
- Environmental analysis of the electrolyser system and concept.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP Addendum (2018-2020)	Energy consumption @ rated power	kWh/kg	52	Not yet in operation, 54 kWh/kg is expected for the whole system		57-60	2017
	CAPEX, @rated power	M€/(t/d)	2	Not yet built, 2 M€(t/d) expected		8	
	Flexibility with degradation @rated power and considering 8 000 hours of operation/year	%	1.5	expected 0.54 %		2-4	
	Flexibility with degradation <2 % per year	%	0-200	expected 0-100 %		5-100	
	H_2 production electrolysis, hot start from min to max power	seconds	2	expected 1 sec		60	

REFLEX

REVERSIBLE SOLID OXIDE ELECTROLYZER AND FUEL CELL FOR OPTIMIZED LOCAL ENERGY MIX



Project ID:	**779577**
Call topic:	**FCH-02-3-2017** - Reversible Solid Oxide Electrolyser (rSOC) for resilient energy systems
Project total costs:	**€2 999 575.48**
FCH JU max. contribution:	**€2 999 575.25**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.reflex-energy.eu**

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, ENGIE, UNIVERSIDAD DE SEVILLA, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, GREEN POWER TECHNOLOGIES SL, AKTSIASELTS ELCOGEN, ENGIE SERVIZI SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SYLFEN

PROJECT AND OBJECTIVES

The REFLEX project aims at developing an innovative renewable energies storage solution based on reversible Solid Oxide Cell technology, able to operate either in electrolysis mode to store excess electricity to produce H_2, or in fuel cell mode when energy needs exceed local production, to produce electricity and heat again from H_2 or any other fuel locally available.
REFLEX integrates improvements of rSOC components (cells, stacks, power electronics, heat exchangers) and system, and the definition of advanced operation strategies. An in-field demonstration will be performed.

NON QUANTITATIVE OBJECTIVES

- Stack modified to achieve high performance in both SOEC and SOFC mode with project cells
- Among different topologies, the best electrical architecture has been selected.

PROGRESS AND MAIN ACHIEVEMENTS

- Optimisation of Solid Oxide Cell in order to improve the performance for rSOC operation, and the durability
- Optimisation of the stack design in order to increase the operating window and to include the modified cells
- System design definition and power electronics architecture for modules made of several stacks to reach the best overall efficiency.

FUTURE STEPS AND PLANS

- Assemble all components to build the system, manufacture the stacks for the demo system
- Perform long-term testing in rSOC operation in lab
- Finalise the site preparation
- Install and operate the system in-field
- Perform the techno-economic analysis and the upscaling study to 1 MWe.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Current density in SOEC mode	A/cm²	-1.2 at 700 °C in SOEC mode	-1.25	✓	-1.15 A/cm² at 750 °C - 1 A/cm² at 800 °C	2015-2016
	Current density in SOFC mode	A/cm²	0.6 at 700 °C	0.65	✓	0.4 A/cm² at 700 °C	2015
AWP 2017	Power	kW	50 in electrolysis	80 (at the stage of design)	✓ (at the design)	150	2018
	Fuel utilisation	%	80-85	85	✓	70	2015
	Cost	%	System cost increase due to addition hardware for MDLT less than 3 %	Evaluation in 2019		N/A	N/A

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, FORSCHUNGSZENTRUM JULICH GMBH, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, PYROGENESIS SA, PROTOTECH AS

PROJECT AND OBJECTIVES

SElySOs focused of understanding the degradation and lifetime fundamentals on both of the SOEC electrodes, for minimisation of their degradation and improvement of their performance and stability, mainly under H_2O electrolysis and in a certain extent under H_2O/CO_2 co-electrolysis conditions. The project investigated: modified SoA Ni-based cathode cements; alternative perovskite-type cathode materials; the O_2 electrode; and the development of a theoretical model to describe the performance and degradation of the SOEC H_2 electrode..

NON-QUANTITATIVE OBJECTIVES

- New materials and component design less prone to degradation. During the third year of SElySOs a series of modified Ni-based and Ni-free electrodes and a series of new air electrodes were investigated under various SOEC H_2O electrolysis and H_2O/CO_2 co-electrolysis conditions.
- Understanding of degradation mechanisms under dynamic operation. Mathematical modelling was under development for both of the SOEC H_2O electrolysis and H_2O/CO_2 co-electrolysis processes.

PROGRESS AND MAIN ACHIEVEMENTS

- Development of promising modified Ni-based and Ni-free cathodes and of new air electrodes with improved and tailored performance under SOEC operation
- Advanced "Operando" analysis of Ni-based and Ni-free electrodes, which provided useful insight on their surface state during SOEC operation
- Thermodynamic and electrochemical modelling of the H_2O and H_2 and CO_2 system by combining theoretical with experimental data, under SOEC operation.

FUTURE STEPS AND PLANS

- Understanding of the underlying operation and degradation mechanisms towards improved and stable SOEC performance
- Validation of the electrochemical model for the SOEC single cell operation
- Manufacture of large-sized cells, comprising the best performing fuel/air electrodes, and stability testing in SOE operation
- Manufacture of a short stack, comprising the best performing fuel/air electrodes as large-sized cells and stability testing under SOE operation.

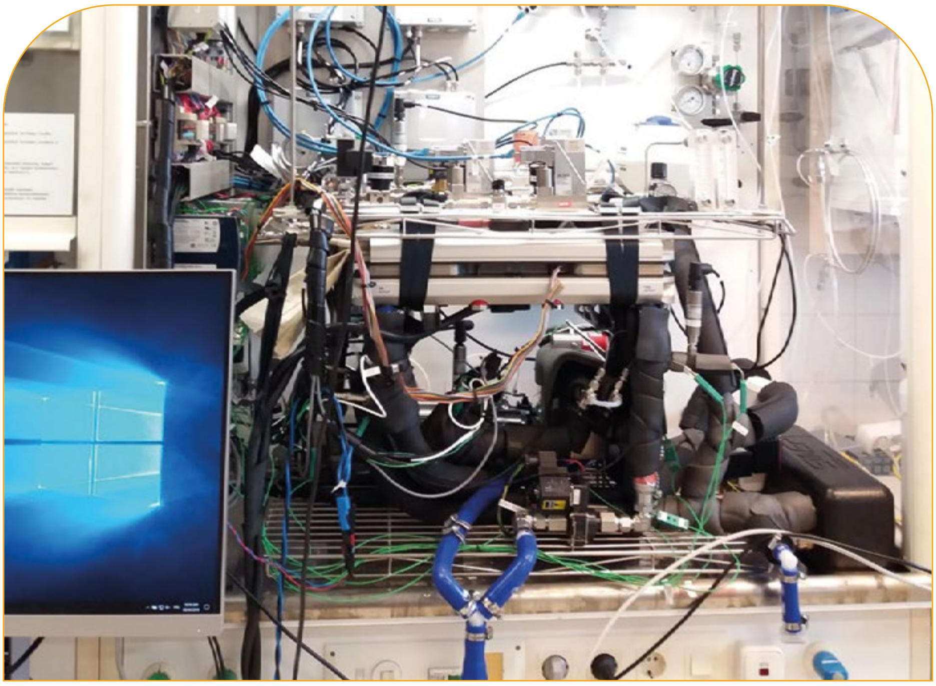
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Decrease the area specific resistance on the fuel electrode compared to the SoA	Ohm * cm^2	N/A	0.4 for a Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode	🔧	1.6	2019
	Increase in the current density	A/cm^2	1	0.59 for a Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode		0.22	
	Decrease of the catalyst (fuel electrode) loading per H_2 capacity	$g/(kgH_2/day)$	N/A	18.5 for a Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode		50.3	

PANEL 6
SUPPORT FOR MARKET UPTAKE

HYDRAITE

HYDROGEN DELIVERY RISK ASSESSMENT AND IMPURITY TOLERANCE EVALUATION



Project ID:	**779475**
Call topic:	**FCH-04-1-2017** - Limiting the impact of contaminants originating from the hydrogen supply chain
Project total costs:	**€3 499 867.50**
FCH JU max. contribution:	**€3 499 867.50**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**Teknologian tutkimuskeskus VTT Oy, FI**
Website:	**hydraite.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, STIFTELSEN SINTEF, NPL MANAGEMENT LIMITED, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, POWERCELL SWEDEN AB, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH, SINTEF AS

PROJECT AND OBJECTIVES

HYDRAITE project aims to solve the issue of hydrogen quality for transportation applications. Effects of contaminants, originating from the hydrogen supply chain, on the fuel cell systems in automotive applications are studied. An HRS sampling campaign has been conducted. In-line monitoring of hydrogen quality at the HRS as well as sampling strategy and methodology for new impurities, gas, particles and liquids have evolved. Two European H_2 laboratories have been established. Three laboratories will be established, capable of measuring all of the contaminants according to ISO 14687 standards.

NON-QUANTITATIVE OBJECTIVES

- Recommendations for revision of ISO standard 14687
- Recommendations for FC stack contaminant measurements in automotive-type operation will derive from the successful measurement campaigns
- 1st HRS measurement campaign completed, external analysis completed, internal analysis and inter-laboratory comparison ongoing
- Evaluation of existing methods has started and concept for PEM-based sensor has been established
- Two laboratories set up with ISO 14687 compliant analytical methods.

PROGRESS AND MAIN ACHIEVEMENTS

- Set up of six measurement systems from 6 different partners, according to the stack testing methodology
- 1st HRS sampling campaign, 10 gas and particle samples were collected from 8 different stations in Germany, Sweden and Norway
- Set up of two European hydrogen laboratories.

FUTURE STEPS AND PLANS

- FC measurements will run as planned in the DoA by six project partners and results reported
- Recommendations are formulated based on the experience and results from FC measurement campaigns
- 2nd HRS measurement campaign will be conducted
- Evaluation of the analytical solutions for in-line hydrogen fuel monitoring and development of new sensor for in-line hydrogen fuel monitoring
- Establishing three European H_2 laboratories and set up the first quality assurance network in Europe for hydrogen purity.

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 - 31/03/2019
Coordinator:	**HYDROGEN EUROPE, BE**
Website:	**www.hylaw.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, STIFTELSEN SINTEF, MAGYAR TUDOMANYOS AKADEMIA TERMESZETTUDOMANYI KUTATOKOZPONT, STICHTING NEDERLANDS NORMALISATIE - INSTITUUT, NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR CRYOGENICS AND ISOTOPIC TECHNOLOGIES ICSI RM VALCEA, INSTYTUT ENERGETYKI, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, VATGAS SVERIGE IDEELL FORENING, BULGARIAN ACADEMY OF SCIENCES, WATERSTOFNET VZW, GREATER LONDON AUTHORITY, OSTERREICHISCHE ENERGIEAGENTUR AUSTRIAN ENERGY AGENCY, BRINTBRANCHEN, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, STI - SISTEMAS E TECNICAS INDUSTRIAIS LDA, THE SCOTTISH HYDROGEN AND FUEL CELL ASSOCIATION LTD, DEUTSCHER WASSERSTOFF- UND BRENNSTOFFZELLENVERBAND EV, LATVIJAS UDENRAZA ASOCIACIJA, ASSOCIATION FRANCAISE POUR L'HYDROGENE ET LES PILES A COMBUSTIBLE, UK HYDROGEN AND FUEL CELL ASSOCIATION, DANSK GASTEKNISK CENTER AS, SINTEF AS

PROJECT AND OBJECTIVES

The project aimed to bring existing data into one place and combine it with rigorously acquired survey data.
It aimed to undertake a consistent quantitative and qualitative assessment of the impacts of each process studied in order to provide the facts and underlying evidence essential for discussions with regulatory agencies, policymakers and other stakeholders on how best to manage, simplify or/and modify or/and bring commonality to the lap process across the sector.
In this context, the HyLAW project set out to provide a comprehensive review of the typical barriers of FCH technologies.

NON-QUANTITATIVE OBJECTIVES

- Creating a comprehensive database with more than more 50 000 entries
- Identifying the most pressing legal and administrative barriers
- 18 well attended and well received workshops took place. They raised the profile of FCH technologies and helped create momentum in the HyLaw countries
- A strong network of partners across Europe has been formed that will continue to work together to promote FCH technologies.

PROGRESS AND MAIN ACHIEVEMENTS

- The development of the most comprehensive database of legal and administrative processes associated with FCH technologies
- The identification of the most pressing legal and administrative barriers faced by the sector, alongside well developed arguments and analysis
- High-profile dissemination events, raising awareness of FCH technologies and the barriers they face.

FUTURE STEPS AND PLANS

- Project is finished
- The database will be kept up to date.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2016	Countries	N/A	12	18	✓
Project's own objectives	Legal and Administrative Processes	N/A	55	55	
	Workshops	N/A	18	18	

HySEA

IMPROVING HYDROGEN SAFETY FOR ENERGY APPLICATIONS (HYSEA) THROUGH PRE-NORMATIVE RESEARCH ON VENTED DEFLAGRATIONS

a)
b)
c)
d)
e)
f)

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 HySEA project was 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

- Meetings in 2017, 2018 and 2019
- 29 presentations at conferences
- 19 journal publications.

PROGRESS AND MAIN ACHIEVEMENTS

- Completed experimental campaigns in 20-foot containers and smaller enclosures (GEXCON and UNIPI)
- Developed model based on semi-empirical correlations for vented hydrogen deflagrations (UWAR)
- Communicated project results top relevant RCS (CEN TC 305 WG 3 ad-hoc group on gas explosions).

FUTURE STEPS AND PLANS

Project is finished.

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:	**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 aimed to deliver reference documentation and studies about existing and new recycling and dismantling technologies and strategies applied to FCH technologies, paving the way for future demonstration actions and advances in legislation and business models.
Project results were a study on novel recycling technologies and strategies, a crade-to-grave LCA, a document of recommendations and guidelines for stakeholders in FCH life, and a business model with an implementation roadmap.
The project was completed in April 2019.

NON-QUANTITATIVE OBJECTIVES

- Deliver a reference document for the re-adaptation of the recycling centres considering the FCH technologies needs
- Document with recommendations and guidelines for the introduction of the circular economy in the FCH technologies, per actor involved
- Development of a business model that aims to consider all the previous work performed in the project, and an implementation roadmap
- Performing of a LCA of the whole life of the technologies.

PROGRESS AND MAIN ACHIEVEMENTS

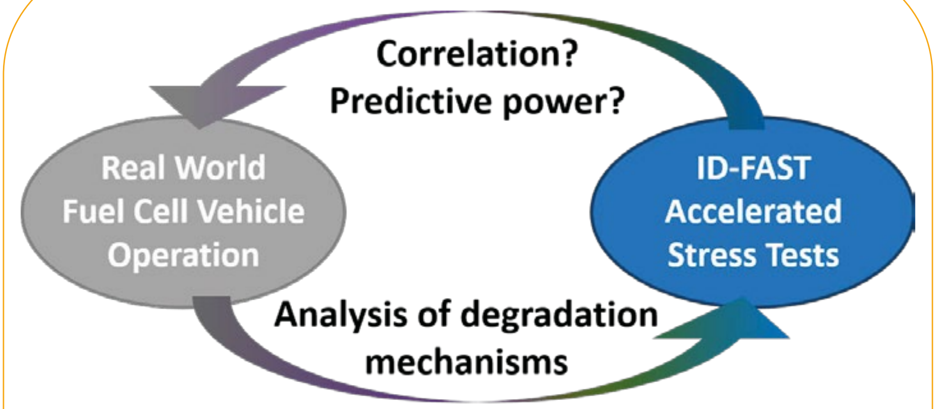
- Developing reference documentation for dismantling and recycling of the FCH, considering new technologies and the readapting of recycling processes
- A cradle-to-grave LCA has been completed per technology, considering the recycling strategies of the project
- A business model and its implementation roadmap have been developed considering future market trends and how the FCH technologies will evolve.

FUTURE STEPS AND PLANS

Project is finished.

ID-FAST

INVESTIGATIONS ON DEGRADATION MECHANISMS AND DEFINITION OF PROTOCOLS FOR PEM FUEL CELLS ACCELERATED STRESS TESTING



Project ID:	**779565**
Call topic:	**SFCH-04-5-2017** - Definition of Accelerated Stress Testing (AST) protocols deduced from understanding of degradation mechanisms of aged stack components in Fuel Cell systems
Project total costs:	**€2 748 195**
FCH JU max. contribution:	**€2 748 195**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**id-fast.eu**

BENEFICIARIES: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V., DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, POLITECNICO DI MILANO, ZENTRUM FUR SONNENENERGIE - UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, FREUDENBERG TECHNOLOGY INNOVATION SE & CO. KG, FREUDENBERG PERFORMANCE MATERIALS SE & CO KG, SYMBIOFCELL SA

PROJECT AND OBJECTIVES

ID-FAST aims at promoting the deployment of PEMFC technologies for automotive application thanks to specific combined Accelerated Stress Tests (AST) and a methodology allowing durability prediction. Core focus is on degradation mechanisms understanding and validation of representative ASTs relating in-situ, ex-situ and modelling investigations. Degradation analyses started on components aged in real conditions. Models of single degradation mechanisms are developed or improved, along with experiments and simulations on the impact of stressors. The next period will allow the coupling of mechanisms.

NON-QUANTITATIVE OBJECTIVES

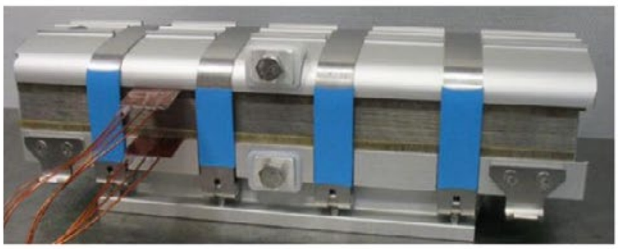
- Identification of real ageing mechanisms and quantification of their impact
- Development of performance degradation models integrating several mechanisms
- Application of degradation models for the simulation of accelerated ageing tests
- Development and validation of specific and combined AST protocols
- Proposal of transfer functions relating accelerated to real degradation.

PROGRESS AND MAIN ACHIEVEMENTS

- Real ageing database: new protocol based on fleet data adopted and several aged samples analysed post-mortem by physical and electrochemical methods
- Improved models for catalyst and membrane degradation and for carbon corrosion - Simulations showing the influence of ageing modes on Pt dissolution
- Approach for development of new ASTs launched successfully for Gas Diffusion Layer case or for start-up shut-down related ageing mechanisms.

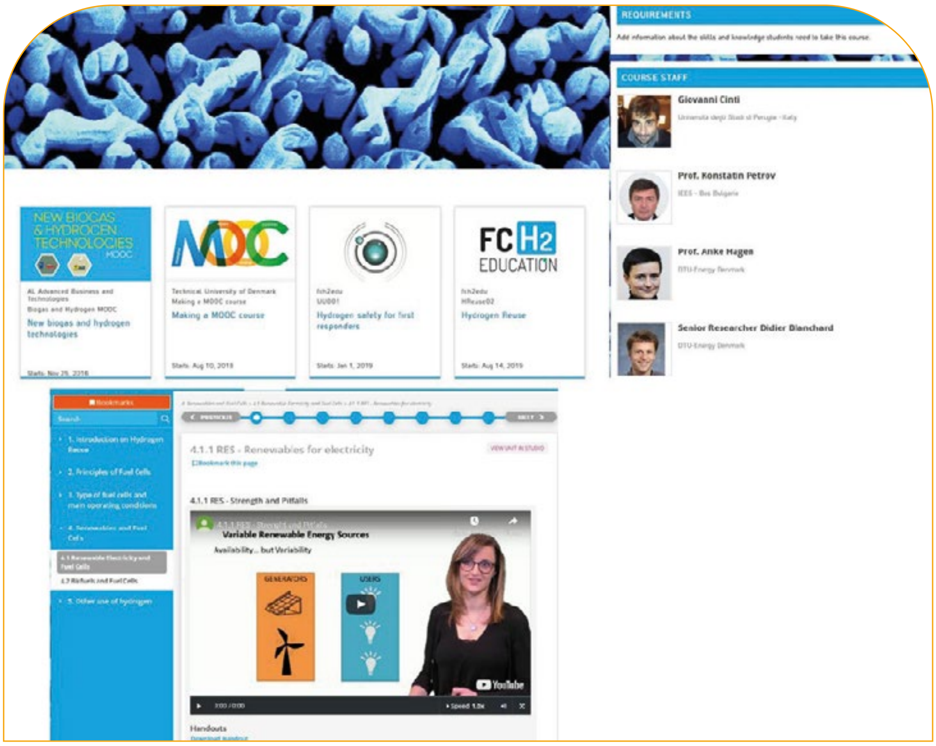
FUTURE STEPS AND PLANS

- Analysing real ageing data and post-mortem analyses results to define the major relevant stressors and their impact
- Validation of single mechanisms models and coupling of these models - Simulation and comparison of real / AST impact for single mechanisms
- Proposal of combined accelerated tests with several mechanisms and application in single cells to check their impact on performance losses
- Validation of the ASTs developed by comparing post-mortem data with real ageing case on MEA components
- Launching the ID-FAST approach on the bipolar plates with degradation analyses and relevance analysis.



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:	€1 596 007.50
FCH JU max. contribution:	€1 596 007.50
Project start - end:	01/03/2017 - 29/02/2020
Coordinator:	KARLSRUHER INSTITUT FUER TECHNOLOGIE, DE
Website:	www.h2fc-net.eu

BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS", UNIVERSITY OF ULSTER, UNIVERSITA DEGLI STUDI DI PERUGIA, INSTITUTE OF ELECTROCHEMISTRY AND ENERGY SYSTEMS, ELEMENT ENERGY LIMITED, PERSEE

PROJECT AND OBJECTIVES

NET-Tools aims to develop a functional e-platform which can operate as a gateway for the FCH community. The e-platform will provide FCH relevant information and content compiled under different categories. These categories are e-laboratory, e-learning and e-repository. While e-laboratory and e-learning are dedicated to FCH related education, the e-repository will offer additional opportunities to publish the outcome of FCH-projects or research results. Technical realisation has been completed as have most of the e-tools included in the e-laboratory, while examples of e-learning are under development.

NON-QUANTITATIVE OBJECTIVES

- Course executed based on NET-Tools e-learning. First course BAS Sofia 12 candidates, 10 certificates second course Buenos Ares
- Compilation of calculation e-tools based on peer reviewed publications
- Specific project events to introduce NET-Tools e-platform (Second educational school under preparation for 2020)
- First MOOCs of externals under preparation and development.

PROGRESS AND MAIN ACHIEVEMENTS

- Technical realisation and structuring of the e-platform and its categories e-laboratory, e-learning and e-repository
- The programming of a set of e-tools and inclusion into the e-laboratory
- The development of e-learning materials as a specific example on FCH related e-learning materials.

FUTURE STEPS AND PLANS

- Development of content to be added to the e-learning category in the e-platform
- Development of further e-tools for calculation and educational use
- Announcement and execution of second educational school and flying Teachers
- Dissemination of NET-Tools results and especially opportunities to motivate externals for direct collaboration on the development of content
- Structuring the whole content to each category included in the e-platform.

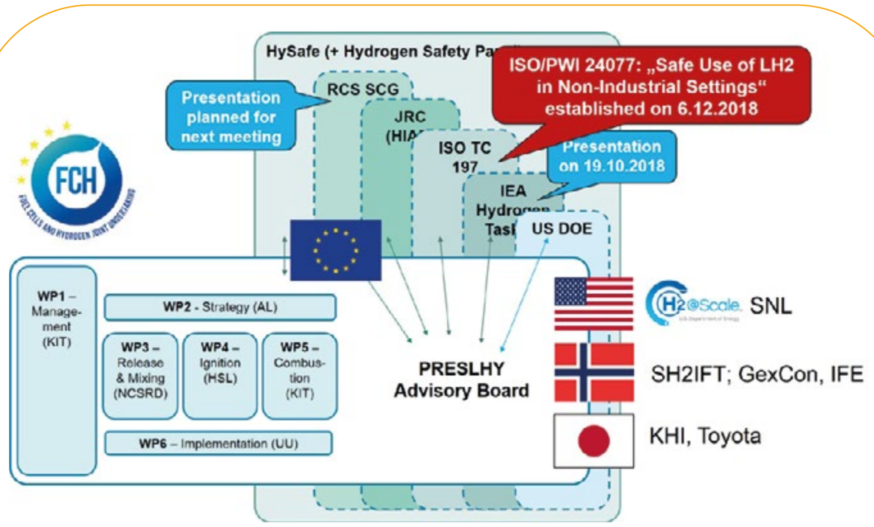
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	E-tools to be developed	35	24	
	Test courses	3	1.5	
	Public project events	5	3	
	E-newsletter	6	4	
	Persons in collaboration	100	20	

PRESLHY

PRE-NORMATIVE RESEARCH FOR SAFE USE OF LIQUIDE HYDROGEN

Project ID:	779613
Call topic:	**FCH-04-4-2017** - PNR for a safe use of liquid hydrogen
Project total costs:	€1 905 862.50
FCH JU max. contribution:	€1 724 277
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	KARLSRUHER INSTITUT FUER TECHNOLOGIE, DE
Website:	preslhy.eu



BENEFICIARIES: NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS", THE UNIVERSITY OF WARWICK, L AIR LIQUIDE SA, INSTITUT NATIONAL DE L ENVIRONNEMENT ET DES RISQUES INERIS, UNIVERSITY OF ULSTER, HEALTH AND SAFETY EXECUTIVE, PRO-SCIENCE - GESELLSCHAFT FUR WISSENSCHAFTLICHE UND TECHNISCHE DIENSTLEISTUNGEN MBH, INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

PROJECT AND OBJECTIVES

PRESLHY conducts pre-normative research for the safe use of cryogenic liquid hydrogen (LH2) in non-industrial settings. In the first phase the state of the art was summarised and the experimental programme was adjusted to the outcome of a research priorities workshop. The central part of the project consists of three phenomena oriented work packages addressing release, ignition and combustion with analytical approaches, experiments and simulations. The results will improve the general understanding of the behaviour of LH2 in accidents and suggest development or revision of standards.

NON-QUANTITATIVE OBJECTIVES

- Critical analysis of RCS in the field of LH2 safety
- Successfully initiated a preliminary working item on LH2 safety at ISO TC 197 initiation of standardisation process.

PROGRESS AND MAIN ACHIEVEMENTS

- Research Priorities Workshop on LH2 conducted. The workshop was accompanied with an RCS analysis and an advanced PIRT analysis
- First cold release experiments DISCHA combined with electrostatic measurements conducted. Hot surface ignition tests successfully accomplished
- Preliminary working item Nr 24077 at ISO TC 197 established.

FUTURE STEPS AND PLANS

Delay of KIT/PS experiments will be solved by combination of other related experiments in a more general set-up (e.g. DISCHA with electrostatics).

QUANTITATIVE TARGETS AND STATUS

PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Number of meetings with standards developing organisations	3	1	
Number of workshops with standards developing organisations	2	1	
Number of reports sent to standards developing organisations	2	0	

TeacHy

TEACHING FUEL CELL AND HYDROGEN SCIENCE AND ENGINEERING ACROSS EUROPE WITHIN HORIZON 2020

Project ID:	**779730**
Call topic:	**FCH-04-3-2017** - European Higher Training Network in Fuel Cells and Hydrogen
Project total costs:	**€1 248 528.75**
FCH JU max. contribution:	**€1 248 528.75**
Project start - end:	01/11/2017 - 31/10/2020
Coordinator:	**THE UNIVERSITY OF BIRMINGHAM, UK**
Website:	**www.teachy.eu**

BENEFICIARIES: DANMARKS TEKNISKE UNIVERSITET, UNIVERSITE LIBRE DE BRUXELLES, POLITECNICO DI TORINO, TECHNISCHE UNIVERSITEIT DELFT, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, UNIVERSITY OF ULSTER, INSTITUT POLYTECHNIQUE DE GRENOBLE, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, UNIVERSITATEA POLITEHNICA DIN BUCURESTI, NATIONAL TECHNICAL UNIVERSITY OF UKRAINE IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE, KARLSRUHER INSTITUT FUER TECHNOLOGIE

PROJECT AND OBJECTIVES

As the FCH industry gradually emerges into the markets, the need for trained staff becomes more pressing. TeacHy2020 specifically addresses the supply of undergraduate and graduate education (BEng/BSc, MEng/MSc, PhD etc.) in fuel cell and hydrogen technologies (FCHT) across Europe.
TeacHy 2020 will take a lead in building a repository of university grade educational material, and design and run an MSc course in FCHT accessible to students from all parts of Europe.
TeacHy2020 will be offering solutions to accreditation and quality control of courses, and support student and industry staff mobility by giving access to placements. Schemes of Continuous Professional Development (CPD) will be integrated into the project activities. TeacHy will offer educational material for the general public, build a business model to continue operations post-project, and as such act as a single-stop shop and representative for all matters of European university and vocational training in FCHT.

NON-QUANTITATIVE OBJECTIVES

- First draft of full course on e-learning platform implemented in full structure
- First test course accomplished in 2018-2019.

PROGRESS AND MAIN ACHIEVEMENTS

- Lecture material from partners collected
- Format and content of module delivery agreed
- First full course structured on e-learning platform.

FUTURE STEPS AND PLANS

- First full run of course in academic year 2019/20
- Run of several courses in parallel
- Translation of course content
- Implementation on the NET-Tools platform
- CPD courses added and performed

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JOINT UNDERTAKING

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