Programme review 2013

Fuel Cells and Hydrogen
Joint Undertaking (FCH JU)

New Energy World JU
fuel cells & hydrogen for sustainability

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Main acronyms and abbreviations used in this document

µCHP	micro combined heat and power
AA	application areas
AFC	alkaline fuel cells
AIP	annual implementation plan
APU	auxiliary power unit
AWP	annual work programme
BoP	balance of plant
CC	cross-cutting
CGH2	compressed gas hydrogen
CHP	combined heat and power
DC	direct current
DoE	United States Department of Energy
DMFC	direct methanol fuel cells
EC	European Community/Communities (replaced by EU in 2009)
EU	European Union
FC	fuel cell
FCH JU	Fuel Cell and Hydrogen Joint Undertaking
FP6	The sixth (2000-2006) RTD framework programme of the European Union
FP7	The seventh (2007-2013) RTD framework programme of the European Union
GDL	gas diffusion layers
H2	hydrogen
HRS	hydrogen refuelling system
HT	high temperature
IPHE	International Partnership for Hydrogen in the Economy
IPR	intellectual property rights
ISO	International Organisation for Standardisation
JRC	Joint Research Centre (a department or Directorate-General of the European Commission)

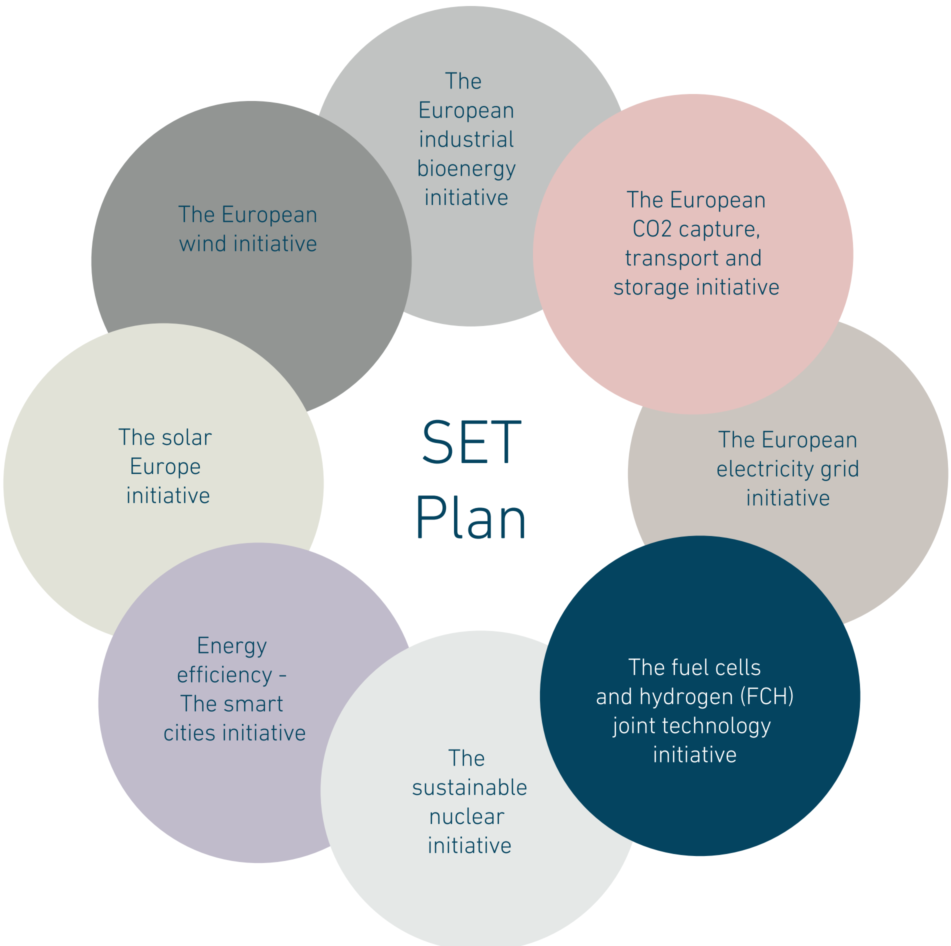
kW	kilowatt
LCA	life-cycle analysis
LT	low temperature
MAIP	multi-annual implementation plan
MAWP	multi-annual work programme
MCFC	molten carbonate fuel cells
MEA	membrane electrode assembly
MHV	materials handling vehicle
MW	megawatt
Nm3	normal cubic metre
OEM	original equipment manufacturer
PAFC	phosphorus acid fuel cell
PEM	proton exchange membrane
PEMFC	proton exchange membrane fuel cell
PFSA	perfluorosulfuric acid
PNR	pre-normative research
PPP	public-private partnership
Pt	platinium
R&D	research and development
RCS	regulations, codes and standards
RES	renewable energy sources
RTD	research and technological demonstration
SET-Plan	European Strategic Energy Technology Plan
SME	small and medium-sized enterprise
SOEC	solid oxide electrolyser cell
SOFC	solid oxide fuel cells
TMA	technology monitoring assessment
UAV	unmanned aerial vehicle
UK	United Kingdom
UPS	uninterrupted power supply
US	United States

1. Introduction

The European Union (EU) is committed to changing its energy system to meet the multiple environmental and economic challenges of the 21st century. To this end it has introduced a raft of measures to facilitate more cost-effective, efficient and sustainable energy use throughout the entire energy value chain. From energy production to infrastructure and utilisation, the EU has adopted a transition agenda for its energy system to meet the combined objectives of climate change mitigation through decarbonisation, energy security and economic growth.

Central to this agenda are the new technologies for making greater use of Europe's own renewable energy sources and for creating large-scale energy storage capacities and their integration into the wider energy economy for transport, power and heat. These ambitions are set out in the European Strategic Energy Technology Plan which identifies eight technology initiatives, including one for fuel cells and hydrogen.

Figure 1 –The SET Plan initiatives



The Member States, European Commission and European Parliament recognise the role fuel-cell and hydrogen technologies can play in the future energy system. Highly efficient, zero-emission-capable, and relevant across a range of transport, power and heat applications, these technologies are being developed by Europe's industry and research communities to meet environmental and climate change challenges, without sacrificing sustainable economic growth. North America (US and Canada), and Asia (Japan and South Korea) pursue similar goals.

Hydrogen and fuel-cell technologies constitute one of very few opportunities to deliver emissions-free transport, power and heat using renewable energy resources, coupled with large-scale storage. As a zero-emissions energy carrier, hydrogen can play a significant role in Europe's low-carbon future.The Fuel Cell and Hydrogen Joint Undertaking (FCH JU) was set up by the European Union to accelerate the commercial introduction of fuel-cell and hydrogen technologies in Europe. It was established in 2008 by Council Regulation (EC) 521/2008 as a public-private partnership (PPP) between the European Commission and Europe's fuel-cell and hydrogen industry and research communities.

A budget of about €1 billion, provided on a matched basis by the European Commission and industry, supports an industry-driven integrated multi-annual RTD programme carried out jointly with its stakeholders: industry (including SMEs), research centres and universities, Member States and EU regions and municipalities.

The FCH JU has, as a PPP with a large and secure budget, been able commit to a long-term and stable RTD programme, providing the European industry and research communities with a framework for investment and planning for the future.

The primary objective of the FCH JU RTD programme is to accelerate the commercialisation of fuel-cell and hydrogen technologies in the energy economy. It supports projects covering the range of RTD activities from basic and breakthrough research, through applied research to demonstrations of fuel cells and hydrogen in various applications, primarily transport and power and heat. Project activity is complemented by diverse cross-cutting activities relevant to all applications. These activities cover regulations, codes and standards (RCS) and safety, pre-normative research (PNR), socio-economic analysis, life-cycle analysis (LCA), market support, education and training, and public awareness.

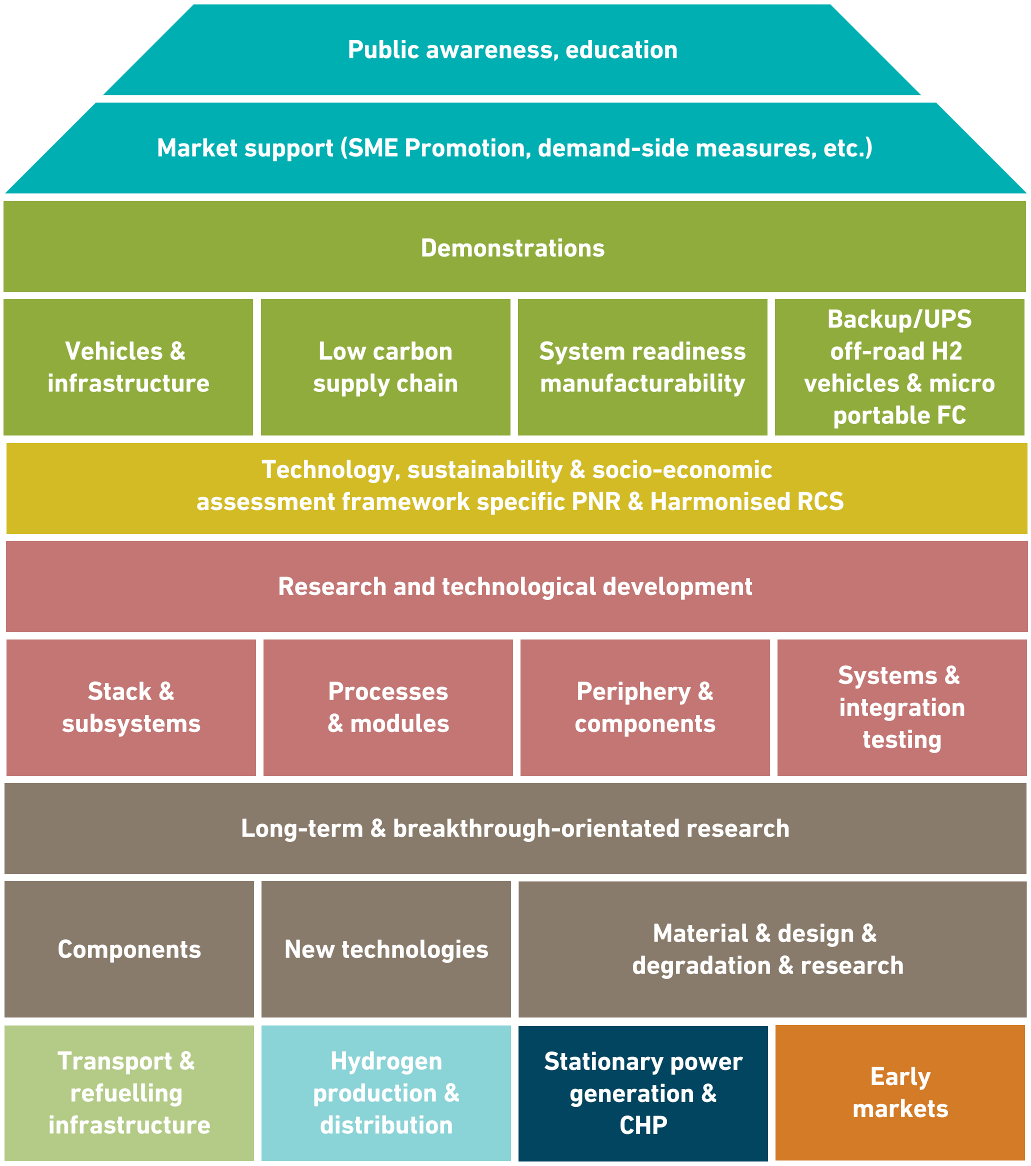
Projects are funded on a 50/50 basis by the FCH JU, through grants, and industry, through in-kind contributions. The FCH JU grants are awarded through competitive calls for proposals.

The primary strategy document of the FCH JU is the Multi-Annual Implementation Plan (MAIP). This sets out the detailed scope for basic, breakthrough and applied research and demonstrations over the life of the FCH JU for four application areas (AA) plus cross-cutting activities:

- transport and refuelling infrastructure
- hydrogen production and distribution
- stationary power generation and combined heat and power (CHP)
- early markets
- cross-cutting activities.

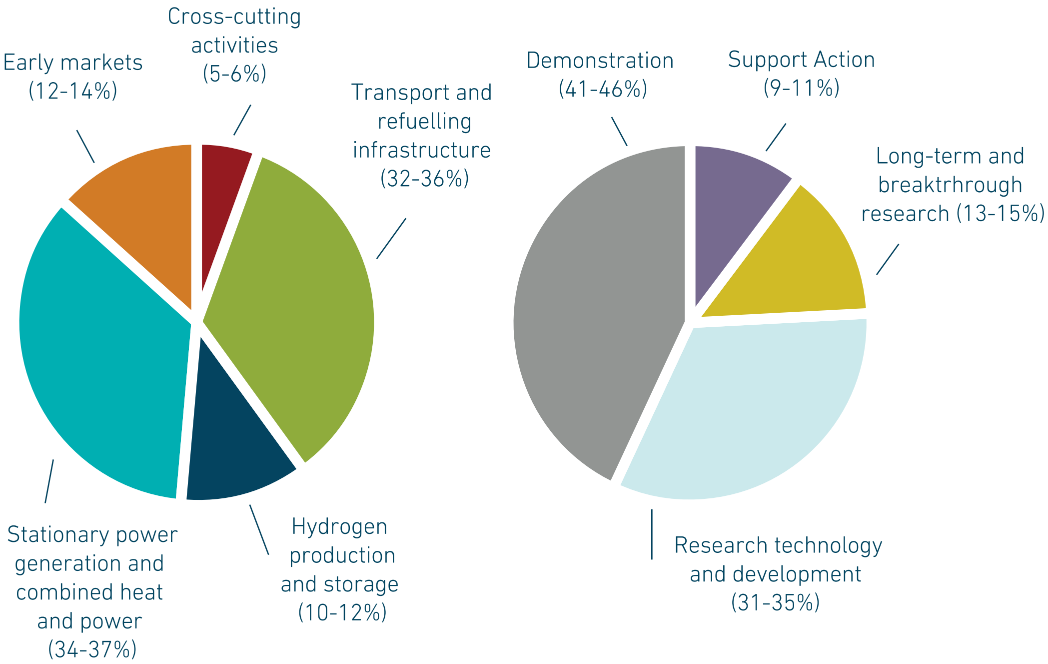
The structure of the MAIP is shown in Figure 2 below.

Figure 2 – FCH JU MAIP structure



The MAIP also provides an indicative budget breakdown according to AA and type of activity supported.

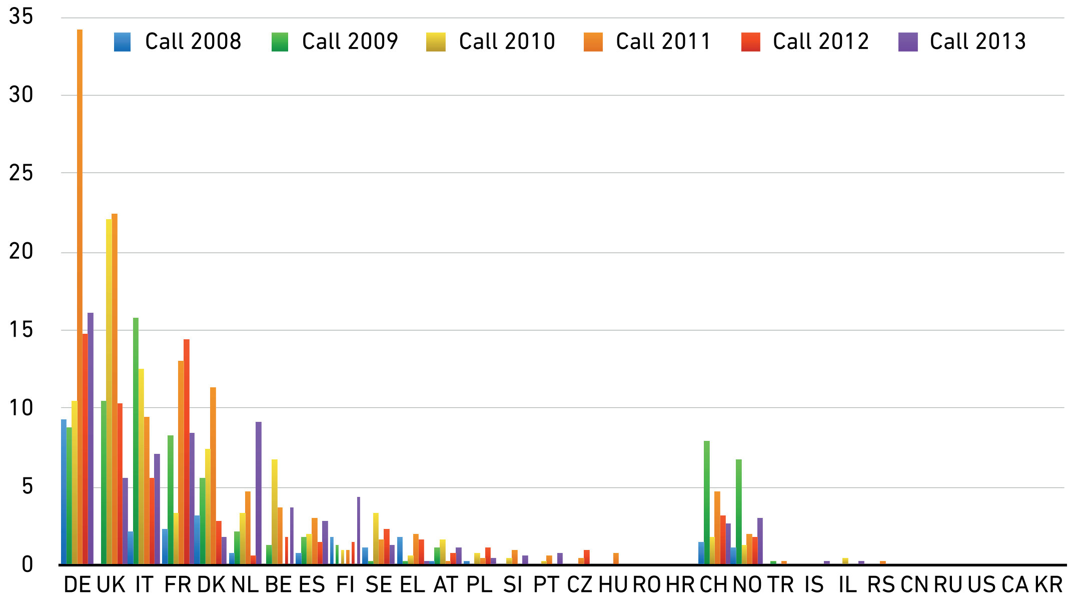
Figure 3 – FCH JU budget breakdown by application area and activity type



The strategy and objectives in the MAIP are translated into Annual Implementation Plans (AIP) which provide the basis for the annual calls for proposals, with each AA detailing a set of topics for which research and demonstration projects are sought.

The FCH JU has issued seven calls for proposals, one in each year from 2008 to 2012, and two in 2013. From 2008 to 2012, the FCH JU selected over 150 projects for support, all managed by the FCH JU Programme Office. In total, hundreds of organisations, from industry (including SMEs) and research sectors across 28 European countries, benefited from the FCH JU's support between 2008 and 2013.

Figure 4 – Distribution of FCH JU project funding across beneficiaries in EU Member States and countries associated with its research programmes.



1.1. The 2013 Review

The 2013 Review is the third annual review of the FCH JU portfolio. These reviews are part of the strategic management programme. They began in 2011, in line with the recommendation of the interim evaluation of the FHC JU. The review, conducted by an independent team of international experts, involves an assessment of the portfolio of FCH JU-supported projects. It is also tasked to evaluate the following.

- The achievements of the portfolio against the strategic objectives and content of the FCH JU's MAIP and the AIPs as set out for each AA and cross-cutting category;
- The extent to which the portfolio meets the FCH JU's remit for promoting the horizontal activities of RCS, PNR, safety, life-cycle and socio-economic analysis, education and training, and public awareness;
- The portfolio's effectiveness in promoting linkages and cooperation between its projects, and between FCH JU-supported projects and those supported by other European instruments, the Member States or third countries.

The 2013 Review was undertaken by a team of 21 experts from Europe and the US, on 11 and 12 November 2013 in Brussels. A total of 101 projects were reviewed on the basis of written information (provided by project coordinators); some of these were also assessed on the basis of presentations made during the two review days. Each project also prepared a poster, outlining its objectives, targets and achievements to-date. These were on display during the review days. Central to the review was the FCH JU's Scientific Committee, which acted as rapporteur for the various panel sessions.

1.1.1. Revised structure

One major difference from the 2011 and 2012 reviews is the structure of the groups of projects. In 2011 and 2012, the projects were reviewed according to the structure of the FCH JU activities during the period 2008-2013, which consisted of four AAs and the cross-cutting category. The 2013 Review adopted the proposed new structure for the next phase of the FCH JU under Europe's Horizon 2020 programme. This structure has two primary innovation pillars: i) energy, and ii) transport, with cross-cutting as a third group. The relationship between the AAs and the innovation pillars is shown in Figure 5.

Figure 5 –Relationship between application areas and RTD pillars

Application Area	Innovation Pillar		
	Transportation	Energy	Cross-cutting
Transport and refuelling infrastructure	●		
Hydrogen production and distribution		●	
Stationary power generation and CHP		●	
Early markets	Part	Part	
Cross-cutting			●

The portfolio of projects was grouped in 11 panels, according to thematic area. The panels are shown in Table 1 below, with the third column indicating the relevant innovation pillar.

For each panel a team of experts reviewed the portfolio of projects in the panel and produced a consensus report which was submitted to the FCH JU after the review days. The mandate was to assess projects within each panel as a portfolio (within the FCH JU portfolio) and not as individual projects, although examples of individual projects representing good practice were highlighted.

Table 1: List of review panels for the 2013 Review and relevant innovation pillar

Panel Number	Title	Innovation Pillar
1	Demonstration activities in transport	Transportation
2	Demonstration activities in energy	Energy
3	Research and demonstration for portable applications	Energy
4	Fuel-cell degradation aspects for CHP applications	Energy
5	Research on hydrogen production and distribution	Energy
6	Research on hydrogen storage	Energy
7	New materials and stacks for transport applications	Transportation
8	New materials and stacks for CHP	Energy
9	Proof-of-concept, components and diagnostics for CHP applications	Energy
10	PNR issues, including safety aspects	Cross-cutting
11	Socio-economic aspects including LCA and training aspects	Cross-cutting

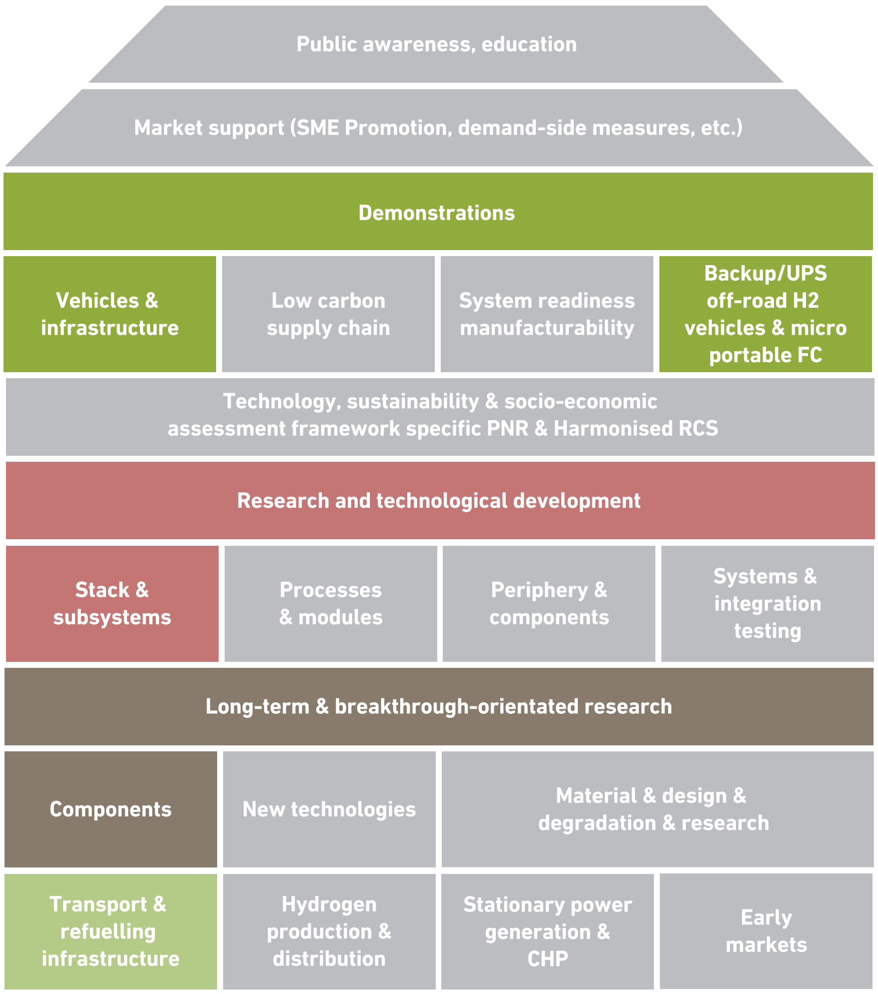
The present report is a general synthesis of the panel reports organised into the two pillars of energy and transport, plus the cross-cutting activities. An initial oral report was made by the Chair of the Scientific Committee to the FCH JU's Stakeholder Assembly on 13 November 2013 in Brussels.

2. Transport

2.1. Objectives

The strategic objectives of the transport pillar are to fast-track the commercialisation of hydrogen and fuel cells for clean transport, primarily road transport. With transport responsible for an estimated quarter of carbon emissions Europe-wide, decarbonisation is a major policy priority. Hydrogen as an energy carrier and fuel cells as energy conversion devices, deliver zero emissions at the tail-pipe, and potentially zero fuel source emissions when utilising 'green' hydrogen.

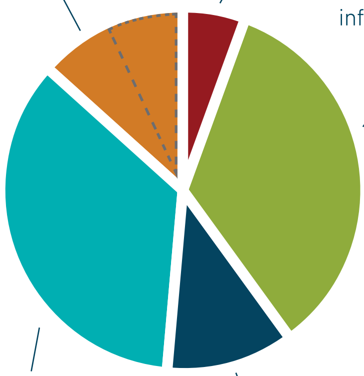
Figure 6 – Transportation activities



2.2. Funding

The Multi-Annual Implementation Plan 2008-2013 set a budget for transport and refuelling infrastructure activities (excluding off-road vehicles) of between 32% and 36% of total spend.

Figure 7 – Budget breakdown by application area



In the pie-chart, the Transport pillar also includes a portion (outlined in gray) of the application area "Early markets". This is the section of Early markets covering off-road vehicles.

2.3. Demonstration – focus areas and achievements

2.3.1. Focus areas

The MAIP 2008-2013 identifies five areas of focus for demonstration projects:

- cars – build up the number of demonstration vehicles on the road in Europe
- buses – reduce vehicle cost and improve fuel economy
- materials handling vehicles (MHV) – demonstrate the business case for these applications
- auxiliary power units (APUs) – validate the technology and identify markets
- refuelling infrastructure – develop the necessary infrastructure at a competitive cost.

The focus is to demonstrate and test the durability, robustness, reliability, efficiency and sustainability of technologies, and ease of customer use, with a view to taking the technology to full commercialisation.

2.3.2. Achievements

The FCH JU has supported 16 transport demonstration projects in five calls from 2008 to 2012. In addition, at the time of the 2013 Review, one project had been selected from the first of the 2013 calls[1].

Table 2: Transport demonstration projects supported by the FCH JU

	Number of projects			
Category	**Finished**	**Live**	**Cross-cutting**	**Total**
Cars	1	2	1	4
Buses		3		3
Materials handling vehicles[2]		4		4
Auxiliary power units (APUs)		6		6
Refuelling infrastructure[3]	Integrated within other categories of demonstration projects			
Total	**1**	**15**	**1**	**17**

Substantial progress has been made towards large-scale deployment of fuel-cell vehicles in Europe, with the achievements shown in Figure 8.

Figure 8 – Achievements of FCH JU demonstration projects from 2008 to 2012

> 150 cars | **> 45 buses** | **> 400 MHV** | **4 APU applications**

> 20 filling points

- More than 150 cars are being demonstrated on Europe's roads in a number of Member States via three projects: H2MOVES, HYTEC and SWARM. A fourth project has been selected for support from the 2013 call;

1 Two calls for proposals were launched in 2013. Projects from the first call have been selected for negotiation. Projects from the second call were due to be evaluated in March 2014.
2 These figures exclude the SHEL project which was terminated early due to under-performance.
3 Refuelling infrastructure has typically been developed as part of demonstration projects rather than as projects in their own right.

- More than 45 buses are being deployed across Europe by three projects: CHIC, HIGH V.LO.City and HyTransit. In addition, a commercialisation bus study was commissioned by the FCH JU and published in December 2012;
- More than 400 MHVs are being used across Member States in four projects: HyLIFT-DEMO, MobyPost, HyLIFT-Europe and HAWL;
- Four APU applications are being developed and validated over six projects: FCGEN, DESTA, SAPIENS, PURE, HYCARUS and SAFARI;
- More than 20 hydrogen filling points are being installed and operated in association with demonstration projects.

2.4. Research and development – focus areas and achievements

2.4.1. Focus areas

The MAIP identifies the following areas of focus for research and development in fuel-cell and hydrogen transportation technologies:

- Membranes – develop and improve membranes for transportation cells and stacks;
- Catalysts – raise performance levels and reduce costs;
- Bipolar plates – develop and improve materials for better performing components;
- Manufacturing and process development – support the near-term production of components and sub-systems;
- Methodology and tools – create and develop modelling and other tools to assist industry to undertake projects;
- BoP (balance of plant) components – develop and improve components for better performance and/or reduced cost;
- Advanced hydrogen refuelling station – develop the hydrogen refuelling process.

The area of gas diffusion layers (GDL) was added post hoc to the FCH JU R&D programme. The aim is to advance research and technological development of fuel-cell stacks and sub-systems, while conducting longer-term, breakthrough-oriented, research on fuel-cell components.

2.4.2. Achievements

Transport-focused R&D projects are addressing the key MAIP R&D areas described above, together with GDL although not part of the original MAIP. The R&D area coverage is shown in Table 3.

- Membrane electrode assemblies (MEAs) are investigated in a broad range of approaches, within nine projects: PEMICAN, ARTEMIS, IMPACT, IMMEDIATE, IMPALA, CATHCAT, CATAPULT, NANOCAT and SMARTCAT
- Bipolar plates are the focus of two projects: STAMPEM and COBRA;
- Stack R&D is being undertaken in two projects with the objective of establishing a global leading European stack platform: AUTOSTACK and AUTOSTACK-CORE;
- One modelling project, PUMAMIND, is being undertaken
- H2 storage R&D is the object of two projects, dealing separately with solid-state and CGH2 storage: SSH2S and COPERNIC;
- One advanced hydrogen refuelling system (HRS) project, PHAEDRUS, is under way.

The majority of these projects originated from the 2011 and 2012 AIPs; the majority of impacts are expected post-2015.

Table 3: Distribution of FCH JU transport R&D projects across the various MAIP areas

	MEA									Bipolar Plates		Stacks & Subsystems		Modelling & simulation	H2 storage		HRS
MAIP R&D areas	PEMICAN	ARTEMIS	CATHCAT	IMMEDIATE	IMPACT	IMPALA	CATAPULT	SMARTCAT	NANOCAT	STAMPEM	COBRA	AUTOSTACK	AUTOSTACK CORE	PUMAMIND	SSH2S	COPERNIC	PHAEDERUS
Membranes	•	•	•	•	•			•				•	•				
Catalysts	•	•	•	•	•		•	•	•			•	•				
GDL				•	•	•						•	•				
Bipolar Plates										•	•	•	•				
Manufacturing & process development										•		•	•			•	
Methodology & Tools	•	•			•	•	•							•			
BoP components															•	•	
HRS (adv.)																	•

2.5. Review findings – demonstration

The review of the demonstration project portfolio covered the 11 projects shown in Table 4.

Table 4: Reviewed projects in the area of transport demonstration

Project name	Description
CHIC	Deployment of fuel-cell hybrid buses, plus H2 refuelling infrastructure in five Phase 1 cities; together with learning from Phase 0 cities
DESTA	Demonstration of European SOFC auxiliary power unit for trucks
FCGEN	Development and demonstration of proof-of-concept fuel-cell auxiliary unit on-board a truck
High V.LO City	Implementation of a fleet of 14 fuel-cell hybrid buses in three regions across Europe, plus H2 production and refuelling infrastructure
HyCARUS	Design of generic PEM hydrogen-air fuel-cell systems for use in aircraft
HyLIFT-DEMO	Deployment of fuel-cell H2 systems for materials handling vehicles, notably fork lifts
HyLIFT-EUROPE	Expansion of deployment of fuel-cell H2 systems for materials handling vehicles
HyTEC Review	Demonstration of up to 30 new H2 vehicles in Denmark and the UK in three classes: taxis, passenger cars and scooters
PURE	Development of fuel-cell auxiliary power units for recreational marine applications
SAPIENS	Development and deployment of SOFC auxiliary power unit for recreational vehicles
SWARM	Deployment and operation of 100 fuel-cell vehicles and three refuelling stations across three Member States

2.5.1. Relevance to MAIP and AIP objectives

The distribution of projects across the four demonstration areas (cars, buses, MHVs and APUs) is consistent with the FCH JU MAIP and the individual AIPs. Infrastructure development has invariably been part of these projects, rather than a stand-alone activity. Reviewers found projects to be relevant to the MAIP objectives.

Buses

Reviewers noted that bus projects, such as CUTE and HyFLEET CUTE, are building on prior experience gained under FP6 and FP7 (the EU's sixth and seventh RTD framework programmes). CHIC and High V.Lo.City projects both benefit from this previous experience, while also providing lessons for other cities in Europe interested in deploying fuel-cell buses.

Recommended improvements include: make bus deployment easier by increasing the level and consistency of vehicle availability, which currently ranges from 40% to 80%. Thought should be given to separating bus deployment projects from those on hydrogen refuelling infrastructure, because the latter increase the challenges and risks already associated with bus demonstration projects. Reviewers recommended that bus demonstration projects run in parallel with R&D projects focused on cost reductions, as this is the 'most prominent hurdle for large bus deployment'. Projects should also focus on deploying the lowest-cost and most reliable technology to accelerate progress, rather than dispersing efforts and resources across different technologies. Furthermore, as part of the overall FCH JU approach to transport, it is worth assessing the potential of a strategic EU infrastructure deployment. Finally, reviewers identified the need for an R&D project on reducing refuelling infrastructure costs.

Cars, MHVs and APUs

Car projects, such as H2MOVES Scandinavia, have been successful. However, reviewers did query how some projects will achieve the ambitious demonstration targets for total number of vehicles deployed.

MHV projects demonstrate continuity and complementarity as in the case of HyLIFT-Europe which expands on HyLIFT-DEMO.

APU projects cover both SOFC and PEM technologies in a range of applications. Reviewers felt that projects were supporting a range of technologies (SOFC, LT-PEM and HT-PEM) with no apparent underlying rationale. Projects appear to be falling short on some of their original objectives like volume, weight and start-up time targets. Reviewers recommended that more work be done on the underlying technologies prior to demonstrations. This includes the further development of advanced BoP components. More specifically the reviewers noted the challenge of on-board H2 storage for flight systems, and asked whether and how certification of the technologies can be achieved. More research will be needed to understand the issues affecting certification of compressed hydrogen in aircraft.

2.5.2. Horizontal and dissemination activities/exploitation plan

There is good evidence that progress made by the projects in the portfolio is being actively disseminated. Reviewers found the workshops held on specific aspects of demonstration particularly relevant, such as the international bus workshop in Hamburg held by CHIC. Projects, such as HYLIFT-DEMO and HYLIFT Europe were seen as highly active disseminators, and reviewers would like to see similar levels of activity from all projects in the portfolio. One area of concern is the reliance on project websites for dissemination. This is a passive method, and difficult to evaluate in terms of impact, since there is no record of how visitors to such sites react.

Horizontal activities like training, risk assessment, and regulations, codes and standards vary considerably from one project to another. CHIC states that training is part of the project. HYCARUS says it covers safety issues, and HyLIFT-Europe says it aims to prepare best-practice guidelines for H2 refuelling infrastructure. Reviewers were not able to determine, on the basis of the project reports, whether APU projects are investigating these issues.

Plans for commercial exploitation are most advanced for bus and car demonstration projects while for MHV demonstrations projects the technology 'is far from being commercial'. Reviewers recommended additional efforts for demonstration activities, and market-introduction mechanisms, together with more financial and regulatory support. Reviewers noted that few projects refer to possible patents arising from their work, but this is not surprising given that these are essentially demonstration rather than development projects.

2.5.3. Relationship/complementarity with other projects/programmes

All projects have linkages with other projects and programmes. Linkages with national programmes include High V.Lo.City in the UK and FCGEN in Slovenia. Equally important, complementarity and continuity between projects exist, as in the way HyLIFT-Europe follows on from HyLIFT-DEMO, with all four partners common to both. CHIC and High.V.Lo. City work together while building on experience from their forerunner, the CUTE project. On the other hand, the portfolio of projects did not identify the extent to which linkages led to cross-fertilisation of ideas and lessons learnt.

The APU sector was highlighted as an area where joint workshops would enable teams from FCH JU-supported projects and those in the Member States to learn from each other for their mutual benefit.

In terms of networking, HyLIFT-Europe intends to establish a network for MHV demonstrations, whilst CHIC is active in networking across localities interested in fuel-cell bus demonstrations.

2.6. Review findings – research and development

The review of the R&D project portfolio covered the 13 projects shown in Table 5.

Table 5: Projects reviewed in the area of transport R&D

Project name	Description
CATAPULT	New catalyst structures and concepts for automotive power trains using ultra-thin film coatings on novel nano-structured supports
IMMEDIATE	High-performance MEA with thermal stability up to 160^{0}C through materials development and process optimisation
IMPALA	Improvement of MEA performance through four levels and durability via development of improved GDL
NANO-CAT	Reducing platinum (Pt) loading of catalyst structures by developing Pt alloys as well as innovative Pt free (bio-inspired) structures
PUMA-MIND	Development of predictive durability modelling tool as a function of component composition and operating conditions
SMARTCAT	Development of new and innovative electrodes using tri-metallic low-Pt content-based catalyst nano-structured layers
ARTEMIS	Development of new MEA based on phosphoric acid doped alternative polybenzimidazole-type polymers
CATHCAT	Development of new MEA, operating at 100^{0}C with an emphasis on the cathode side
IMPACT	Development of MEA with ultra-low Pt loading and improvement of lifetime combined with investigation of degradation phenomena and mechanisms
LIQUIDPOWER	Fuel-cell systems and hydrogen supply for early markets
PEMICAN	Development and manufacture of MEAs with reduced platinum costs
STAMPEN	Research and development of improved stability and reduced costs of bi-polar plates through use of durable coatings materials
AUTOSTACK-CORE	Development of best-in-class automotive stack hardware with superior power density and performance whilst meeting commercial target costs

2.6.1. Relevance to MAIP and AIP objectives

Reviewers found the 13 projects examined as part of the review to be in line with the objectives of the MAIP and the individual AIPS. The strong and diverse portfolio supports one of the basic MAIP objectives. This is the 'integration of the fragmented PEMFC stack research and development in Europe and establishment of European leadership in the transportation fuel-cell stack industry'. In general, the projects were found to have relevant targets, and to have achieved a balance between basic and applied R&D activities.

Ten of the projects concerned efforts to optimise MEA and other components in the stack. They ranged from development and optimisation of PEMFC electrodes and GDLs in PEMICAN, or new catalyst structures and concepts for automotive PEMFCs in CATAPULT and SMARTCAT, to modelling in PUMA-MIND. The collective objectives include:

- increasing operating temperatures
- reducing precious metal catalyst loading or replacement with non-precious metal catalyst
- optimisation of catalyst-layer composition and loading
- optimisation of gas-diffusion layer
- increased power density.

The expected outcome is to reduce costs and increase lifetimes to 5,000 hours.

Reviewers found the portfolio of projects lacked a coordinated approach towards technology progress and achievement of targets, and recommended careful analysis of final achievements so as to identify possible shortfalls and define updated targets, as needed, for the next phase of the FCH JU (2014-2020).

The remaining projects in the portfolio addressed other aspects of transport fuel-cell technology, including the development of a globally leading European stack technology: AUTOSTACK and AUTOSTACK-CORE.

When evaluating the project portfolio against cost-reduction targets, reviewers highlighted the need for projects to set out quantified cost targets and a clear plan for achieving them. At present there are too few projects with specific targets against which to measure performance and achievements. In contrast, risk assessment, understanding of bottlenecks, and assessment of the likelihood of success were found to be good.

The typical three-year project duration is, however, seen as too short to be able to generate 'breakthrough' approaches or to take project outcomes forward into the next stage. Reviewers believe that such a relatively short duration encourages projects to focus on less risky aspects, rather than the 'breakthroughs' which may be necessary to overcome obstacles and challenges.

Reviewers also believe that, where possible, modelling projects in the portfolio should have access to experimental data from demonstration projects so as to validate and improve models, and hence add greater value to the portfolio as a whole. Reviewers recommended that these issues be addressed in the next phase of the FCH JU.

2.6.2. Horizontal and dissemination activities/exploitation plan

With many projects still only partly through their work programmes, reviewers were unable to reach a conclusion as to the adequacy of the portfolio's dissemination efforts. Nonetheless evidence of progress is provided by participation at conferences and the publication of papers. Projects also intend to make significant use of websites for dissemination. Planned dissemination activities, such as coming workshops by CATHCAT, PUMA-MIND and PEMICAN, were viewed positively.

The exploitation of results is planned by most projects, although it is not apparent that all have the intention to do so. Plans include further research and development, scaling up and demonstration of results. In this context, AUTOSTACK-CORE foresees a need for a further project to incorporate results in OEM vehicle platforms.

2.6.3. Relationship/complementarity with other projects/programmes

There is good evidence that projects cooperate with each other and also participate in joint activities at European level. For example, a number of projects are involved in the discussions on the 'harmonisation of test protocols' led by the European Commission's Joint Research Centre (JRC). Elsewhere it is clear that projects are benefiting from previous ones implemented under FP6 and FP7. IMMEDIATE is, for instance, a continuation of two previous EU-supported projects while PEMICAN builds on achievements from DECODE and AUTOSTACK. For cases where projects overlap, reviewers propose joint workshops to encourage knowledge-sharing and the discussion of results, thus reinforcing the learning process.

Synergies with national programmes exist, but tend to be on the level of partner organisations. Even so, it is less developed than expected. Instances include IMPACT which is connected with a German-funded project, and NANO-CAT which has contacts with two French-funded projects.

Reviewers also advise greater efforts in coordinating R&D project activities at the portfolio level and harnessing overall results to ensure that PEMFC stack research is integrated and future fragmentation avoided.

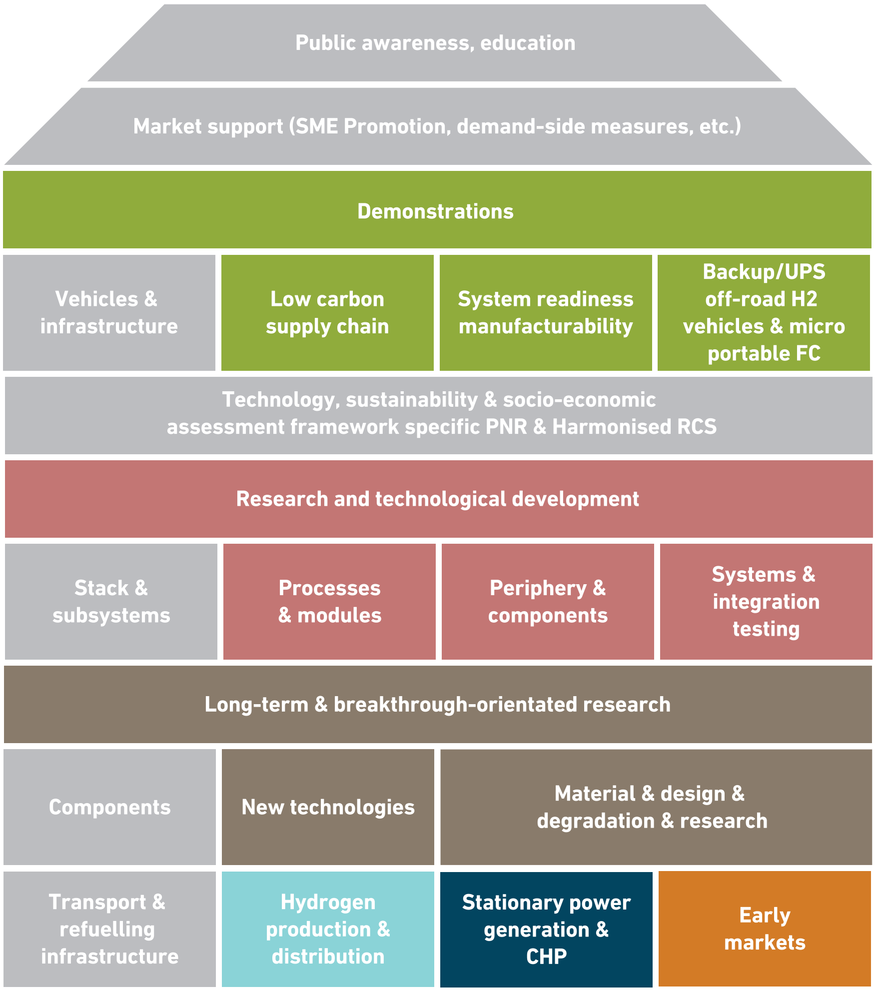
3. Energy

3.1. Objectives

The strategy of the energy pillar is to accelerate commercialisation in two fields. One is fuel-cell technologies for stationary power, including combined heat and power and small-scale back-up and micro and portable fuel-cell systems. The second covers technologies for hydrogen production, distribution and storage.

Specifically, for stationary power and CHP technologies, the objective is to improve the technology for fuel-cell stacks and balance of plant for fuel-cell systems, so as to compete with incumbent and alternative power and heat generation technologies. For hydrogen production, distribution and storage technologies, the objective is sustainable cost-competitive hydrogen production and delivery (no- and low-carbon supply chains) for use in the transport and stationary power and heat sectors.

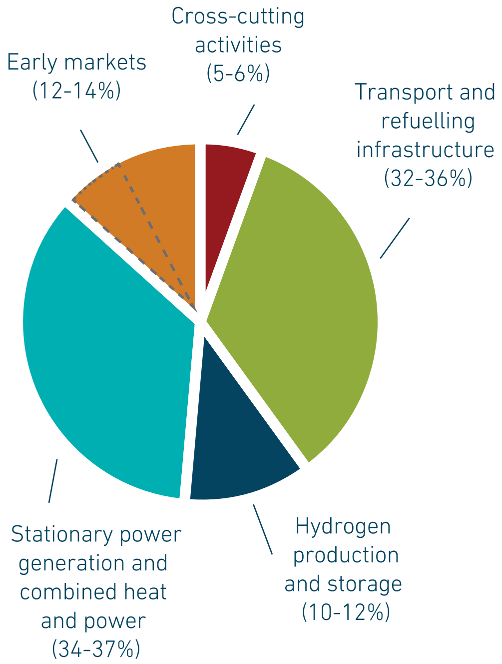
Figure 9 – Activities of the energy pillar



3.2. Funding

The 2008-2013 MAIP of the FCH JU set a budget of 34-37% of total expenditure for stationary power and CHP applications; 10-12% for hydrogen generation, distribution and storage projects; and 12-14% for early markets, where a portion is dedicated to projects with an energy focus (e.g. back-up power, off-grid power generators etc.).

Figure 10 – FCH JU budget distribution (2008-2013)



Note: The Energy pillar includes the application areas "Stationary power generation and combined heat and power", "Hydrogen production and storage", and a portion of "Early markets".

3.3. Demonstration – focus areas and achievements

3.3.1. Focus areas

FCH JU-supported demonstration activities have been in the following areas:

- Field demonstrations of micro-CHP and larger-scale power and CHP units – to establish a European demonstration programme, alongside programmes supported by Member States;
- Proof-of-concept of whole fuel-cell systems and balance of plant components, plus diagnostics and monitoring sub-systems – supporting technologies through a programme of activities for proof-of-concept and validation projects;
- Demonstration of small-scale fuel-cell systems for power for a range of back-up and remote locations;
- Demonstrations of hydrogen production and distribution technologies – supporting both the development of existing electrolyser-based production, but also more innovative renewable energy-based technologies capable of producing 'green' hydrogen at both large and smaller (distributed) scales;

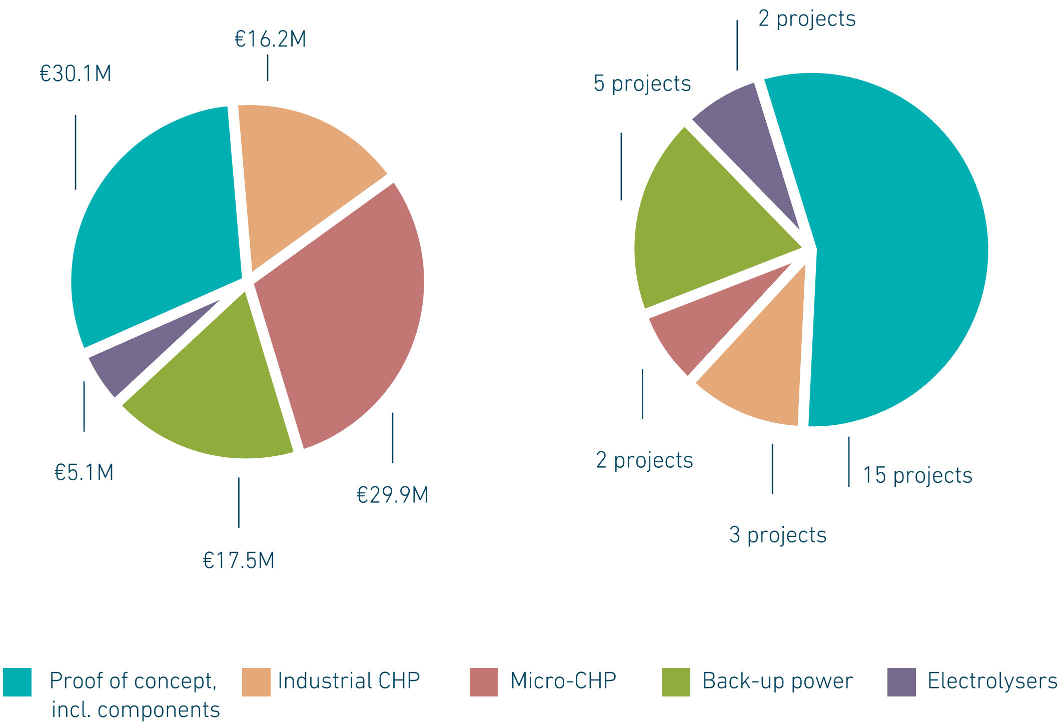
- Demonstration of hydrogen storage technologies – supporting technologies capable of storing hydrogen from small-tank storage to large-scale underground storage, and in a variety of forms: gaseous, liquid and solid.

3.3.2. Achievements

The FCH JU supported 27 energy demonstration projects in five calls from 2008 to 2012.

The portfolio addresses all of the issues and targets set out in the MAIP. The value and number of projects by area is shown below.

Figure 11 – Energy demonstration projects by value (€) and number



- More than 1,000 fuel-cell CHP units are being deployed across 12 Member States in two micro-CHP projects (ene.field and SOFT-PACT), representing a major achievement in terms of volume against the MAIP target of 1,000 CHP units by 2015;
- Three industrial CHP projects (including CLEARGEN DEMO and POWER-UP), totalling more than 1.5MW in capacity, are ongoing – a positive step towards achieving the MAIP cost-reduction targets through economies of scale;
- Five back-up power projects (including FIT-UP, FCPoweredRBS) are being supported, with at least 37 fuel-cell systems deployed;
- Two electrolyser projects are receiving support, one with 1MW of capacity connected to wind generation (ELYGRID);
- Finally, 15 proof-of-concept, components and diagnostic projects over a number of fuel-cell technologies and systems are active (including ASSENT, CATION, RE4CELL, LOTUS, SAPPHIRE, SOFCOM, FLUMABACK, DECODE, TRI-SOFC, Reforcell).

For all projects there have been notable improvements in the performance and cost of components and whole systems, together with advances in manufacturing capabilities.

The FCH JU has also commissioned a study on the development of water electrolysis in the EU, and is planning similar studies for distributed generation and energy storage.

3.4. Research and development – focus areas and achievements

3.4.1. Focus areas

FCH JU-supported R&D activities have focused on the following areas:

- Materials: materials for fuel cells, components and storage devices;
- FCH performance phenomena: improved understanding of phenomena affecting performance of FCH technologies (e.g. degradation);
- Cell and stack design and production: manufacturing and process development for cells and stacks;
- Hydrogen storage issues: materials, designs and development of hydrogen storage capability, and hydrogen state changes (e.g. liquefaction);
- Electrolysers: development of electrolysis technologies;
- Innovative hydrogen production: development of sustainable hydrogen production technologies.

R&D activities for the energy sector involve 62 projects.

3.4.2. Achievements

The primary achievements to-date include:

- Materials: improved performance of existing materials, and development of new materials for fuel cells and stacks in five projects – e.g. membranes and MEAs with improved mechanical properties (LOLIPEM, MAESTRO), and new materials for low-temperature SOFC (SCOTAS-SOFC);
- FCH performance phenomena: improved understanding of degradation and lifetime fundamentals through eight projects - e.g. PEM stacks with lifetimes of 20,000 hours or more (KEEPEMALIVE, STAYERS), development of accelerated testing regimes for PEMFC and SOFC cells and stacks (ROBANODE, SOFC-Life, PREMIUM ACT);
- Cell and stack design: next generation cell and stack design – eight projects developing new cell and stack designs for SOFC, alkaline and PEMFC technologies (LASER-CELL, METSAPP, METPROCELL, T-CELL, DEMSTACK, RAMSES, CISTEM);
- Hydrogen storage issues: improved design and testing for pressurised H2 tanks (HYCOMP); 5% weight H2 in metal-hydride based tanks integrated with a fuel cell (SSH2S); H2 delivery with 400 bar composite tanks (DELIVERHY); 50% energy reduction for liquefaction of H2 (IDEALHY);
- Electrolysers: development of alkaline electrolysers with advanced membranes (RESelyser); development of PEM electrolysers aiming for MW scale commercial units (NOVEL); SOEC electrode operating at 700°C, with 15% increase in performance (ADEL);
- Innovative H2 production: 1-10kg H2 per day with thermophilic fermentation processes (HYTIME); a pilot-scale demonstration of thermochemical water-splitting using solar energy (HYDROSOL-3D); advanced catalysts for steam reforming at 400-500°C (COMETHY);

3.5. Organisation of energy review sections

The Energy portfolio was reviewed across seven panels, grouped, for the purposes of the discussion, into four sections:

1. Demonstrations, proof-of-concept, components and diagnostics
    - demonstrations
    - proof-of-concept, components and diagnostics
2. R&D combined heat and power
    - degradation
    - materials and stacks
3. R&D hydrogen
    - hydrogen production
    - storage
4. Early markets: R&D and demonstrations

3.6. Review findings – demonstrations, proof-of-concept, components and diagnostics

The review of the demonstration portfolio covered six projects shown in Table 6.

Table 6: Projects reviewed in the area of energy demonstration

Project name	Description
Don Quichote	Demonstration of new qualitative innovative concept of hydrogen out of wind turbine electricity
ELYGRID	Improvements to integrate high-pressure alkaline electrolysers for electricity/H2 production from renewable energies to balance the grid
ene.field	Europe-wide field trials for residential fuel-cell micro-CHP
FCpoweredRBS	Demonstration project for power supply to telecom stations through fuel-cell technology
FITUP	Fuel-cell field test demonstration of economic and environmental viability for portable generators, back-up and UPS power system applications
FLUMABACK	Fluid management component improvement for back-up fuel-cell systems

A further 11 projects were reviewed under the category of proof-of-concept, components and diagnostics as shown in Table 7.

Table 7: Projects reviewed in the area of proof-of-concept, components and diagnostics

Project name	Description
ASSENT	Anode sub-systems development and optimisation for SOFC systems
Asterix3	Assessment of SOFC CHP systems built on the technology of HTCERAMIX 3
CATION	Cathode sub-system development and optimisation
D-CODE	DC/DC converter-based diagnostics for PEM systems
DESIGN	Degradation signature identification for stack operation diagnostics
FC-EuroGrid	Evaluating the performance of fuel cells in European energy supply grids
GENIUS	Generic diagnostic instrument for SOFC systems
LOTUS	Low-temperature SOFC for micro-CHP application
ReforCELL	Advanced multi-fuel reformer for CHP fuel-cell systems
SAPPHIRE	System automation of PEMFC systems with prognostics and health management for improved reliability and economy
TriSOFC	Durable SOFC tri-generation system for low-carbon buildings

3.6.1. Relevance to MAIP and AIP objectives

3.6.1.1. Demonstrations

All projects were deemed relevant to the FCH JU MAIP and AIPs, and no gaps were identified in the project portfolio. There was significant industry involvement in all projects. Reviewers expressed the need for an improved definition of state-of-the-art technology so as to assess better the advanced nature of the projects and ensure that they are not duplicating activities elsewhere.

3.6.1.2. Proof-of-concept, components and diagnostics

Reviewers found the portfolio of projects to be in line with the MAIP and relevant AIPs, with few, if any, overlaps or gaps.

Reviewers identified as good projects those with significant industry involvement and an awareness of the technical state-of-the-art on the part of project proponents. These were good indicators of project relevance to industry needs, and therefore increased the likelihood of contributing to FCH JU commercialisation efforts. Reviewers recommended that all projects be in a position to compare their activities with state-of-the-art technology, and that the FCH JU should also gain a better understanding of the state-of-the-art of the portfolio as a whole.

3.6.2. Horizontal and dissemination activities/exploitation plan

Horizontal and dissemination activities and exploitation plans of the project portfolios were found to be satisfactory, with some projects undertaking a variety of dissemination activities, including workshops, conference presentations and publications. There was also some evidence of training, as, for example, in the employment of Master's and PhD students, as well as consideration of RCS issues. Projects showing little in the way of dissemination activities were primarily those still in their first phase. In these cases, dissemination activities are planned and will be performed later during the project. These include publications and conference contributions, workshops and seminars.

Efforts to exploit project outcomes were found to be mixed: satisfactory in some projects, but very weak in others. Reviewers recommended that project consortia 'think more about deployment'. It is, however, worth noting that some of these projects are well advanced in terms of commercialisation, and market exploitation, but these are either not sufficiently documented or are commercially sensitive.

3.6.3. Relationship/complementarity with other projects/programmes

The existence of linkages was recognised, but they were judged not to be extensive enough. There is evidence of linkages between projects and Member State programmes, and to some extent international programmes. There are additional opportunities of linkages with similar projects elsewhere in Europe and in the Member States, and thus for joint learning and sharing of experiences.

3.7. Review findings – research and development – combined heat and power

The review of this element of the FCH JU project portfolio was in two parts: one for degradation projects and the other for materials for cells and stacks. Eight degradation projects were reviewed as shown in table 8.

Table 8: Projects reviewed in the area of degradation

Project name	Description
LOLIPEM	Long life PEM FCH and CHP systems at temperatures above 100^0C
DEMMEA	Understanding degradation mechanisms of MEA for high-temperature PEMFCs and optimisation of individual components
KEEPEMALIVE	Knowledge to enhance the endurance of PEM fuel cells by accelerated lifetime verification experiments
PREMIUM ACT	Predictive modelling for innovative unit management and accelerated testing procedures of PEMFC
STAYERS	Stationary PEM fuel cells with lifetimes beyond five years
MCFC CONTEX	MCFC catalyst and stack component degradation and lifetime, fuel-gas contaminant effects and extraction strategies
ROBANODE	Understanding and minimising anode degradation in hydrogen and natural gas-fuelled SOFCs
SOFC LIFE	Solid oxide fuel cells – integrating degradation effects into lifetime prediction models

Another 16 materials, cell and stack development projects were reviewed, covering various fuel-cell technologies. These are shown in Table 9.

Table 9: Projects reviewed in the area of materials, cell and stack development

Project name	Description
ALKAMONIA	Proof-of-concept of ammonia-fuelled alkaline fuel cells for remote power applications
CISTEM	Construction of improved high-temperature PEM MEAs and stacks for long-term stable modular CHP units
DEMSTACK	Understanding the degradation mechanisms of a high-temperature PEMFC stack and optimisation of the individual components
EURECA	Development of next generation of micro-CHP systems based on advanced PEM stack technology
EVOLVE	Evolved materials and innovative design for high-performance, durable and reliable SOFC cell and stack
LASERCELL	Innovative cell and stack design for stationary industrial applications using novel laser processing techniques
MAESTRO	Improve mechanical properties of low-equivalent weight state-of-the-art perfluorosulfonic acid membranes with chemical and thermal processing
METSAPP	Development of novel cells and stacks based on a robust and reliable scalable metal-supported technology for stationary and mobile applications
MMLCR-SOFC	Working towards mass-manufactured, low-cost and robust SOFC stacks
ONSITE	Operation of a novel SOFC-battery integrated hybrid for telecommunication energy systems
PROSOFC	Production and reliability-oriented SOFC cell and stack design
RAMSES	Developing an innovative, high-performance, robust, durable and cost-effective SOFC based on metal-supported cell concept
SCORED 2.0	Steel coatings for reducing degradation
SCOTAS SOFC	Sulphur, carbon, and re-oxidation-tolerant anodes and anode supports for solid oxide fuel cells

Project name	Description
T-CELL	Innovative SOFC architecture based on triode operation
METPROCELL	Innovative fabrication routes and materials for metal and anode-supported proton-conducting fuel cell

3.7.1. Relevance to MAIP and AIP objectives

3.7.1.1. Degradation

Understanding and improving degradation rates for fuel-cell systems for CHP applications is critical for achieving target stack lifetimes of 40,000 hours (about five years). The topic therefore features prominently in the MAIP and individual AIPs. The portfolio of projects was found to be highly relevant to the MAIP and AIPs, covering fundamental research through to overall technology development. However, reviewers recommended that efforts should 'shift more towards technology development with the goal of developing improved fuel-cell technologies that industry can adapt and adopt'; i.e. research with a short- to medium- term focus, rather than long-term, breakthrough-oriented research. Specific technical recommendations include:

- A need to understand state-of-the-art for the subject in general and modelling in particular;
- Requirement for future SOFC project(s) to include at least a single repeatable unit or fuel-cell stack;
- Requirement for PEM projects to include work on sealing, housing and flow fields.

A number of issues were judged to be less than satisfactory.

- The virtual absence of targets (apart from stack lifetime) against which to measure project progress;
- The basic and fundamental nature of research on SOFC projects and hence their possible irrelevance for the short- to medium-term needs of industry;
- A lack of PAFC and AFC projects (which probably reflects the limited European industry interest in these two technologies);
- General lack of overall coherence/coordination between PEM-related projects. The five PEM projects seem to exist in 'separate bubbles', with each developing its testing methodologies, data analysis and lifetime prediction tools. Reviewers believe that, despite some differences in the projects, these development efforts are highly duplicative and that opportunities for cooperation are being missed. Moreover, four of the eight projects were explorative in nature rather than targeted on specific issues of interest to industry. This issue was emphasised by the lack of evidence that projects have access to field experience and the absence of plans for demonstration activities in subsequent stages.

Reviewers did highlight the positive evolution of the FCH JU programme in prioritising industry-relevant (short- to medium- term) R&D, with better industry involvement and access by the research community to industrial activities. They recommended that this, together with enhanced feedback from demonstrations, feature prominently in the forthcoming Multi-Annual Work Programme (MAWP) and Annual Work programmes (AWPs). Continued R&D efforts (both basic and applied) in degradation are seen as critical and, in the absence of substantive breakthroughs, they must be the object of a long-term effort.

3.7.1.2. New materials, cells and stacks for CHP

Projects involving new and improved materials and cells and stacks for CHP represent the largest single section in the FCH portfolio, reflecting their importance in the commercialisation effort. Reviewers found that the projects in this category are largely centred on improved durability, but also touch on cost and manufacturing issues, reflecting concerns of industry in this area.

Overall the portfolio was found to be in line with MAIP and AIP objectives, with a balance in favour of basic and applied research. Some bias in projects, towards high-risk, longer-term (more than five years) and breakthrough activities was noted. While this is consistent with part of the MAIP objectives, the timescales were felt to be too long and the risks too high to impact positively on the FCH JU's commercialisation efforts. Reviewers also noted that although projects had been running long enough to generate results, even the successful ones were still a long way from commercial exploitation. This applied primarily to projects approved in the early years of the FCH JU. More recent projects showed a sharper focus on near-term commercialisation needs.

Reviewers felt clearer targets were needed for materials research and the link to the high-level system targets contained in the MAIP such as the impact on cost-reduction targets and thus on the future commercial success of fuel-cell CHP systems. They recommended that the future MAWP should also set component-level targets, in addition to those at system-level. Assessment of projects against state-of-the-art technology shows that some are competitive internationally and others apparently not. Reviewers recommended that the FCH JU assess project proposals more rigorously in terms of state-of-the-art to identify and support technically-advanced activities. They also called on the FCH JU to develop a more coherent strategy for longer-term, breakthrough research in this area and draw up a plan for effective implementation. Examples of such future research include PFSA-type or non-phosphoric acid-doped PEM membranes, which may be more beneficial in the long term, as well as solid proton-conducting fuel cells which are also a long-term focus.

3.7.2. Horizontal and dissemination activities/exploitation plan

In the portfolio of degradation projects, the reviewers found significant ongoing dissemination activity in terms of publications, conference participation and workshops. LOLIPEM had, for example, held three workshops and published 21 journal papers, while DEMMEA reported 15 journal papers. The portfolio of new materials projects noted a total of 13 journal papers and 47 conference contributions. Reviewers were not convinced of the value of the websites set up by each project, citing very little evidence that non-project participants were making use of this resource.

The project portfolio revealed only limited activity in terms of formal training and education, possibly because of the research nature of the topics, although there was evidence of student exchanges, the employment of PhDs and involvement of technical schools.

Exploitation plans are in place for most projects and are credible. STAYERS, for example, with a strong industry involvement, had convincing plans for the exploitation of results, as did SOFC LIFE. Reviewers also noted that some projects biased towards longer-term basic and high-risk research would take a long time, in some cases a very long time, and considerable additional work, to deliver commercial benefits. However, it is expected that much of this research work will be carried forward into new projects. On this point, reviewers noted that more recently-approved projects tended to have a lower risk level with much clearer and near-term exploitation potential, perhaps reflecting the changes made to AIPs by the FCH JU.

3.7.3. Relationship/complementarity with other projects/programmes

Both degradation and new material projects showed interaction with other projects and programmes although its effectiveness was not always clear. There are opportunities for projects within the portfolio to benefit from interaction with each other and with projects in other European, Member State and international programmes. Indeed reviewers noted that bilateral contacts were evident in most projects and that there were links with Member State programmes, where Danish and French participants appear to have useful interactions. There was also considerable evidence of projects benefiting from their predecessors: SOFC LIFE is based on REAL SOFC from FP6 and STAYERS builds on the Dutch EOS project. Linkages beyond Europe to the international community were identified as an area for improvement.

The reviewers noted that there were clear opportunities for collaboration and learning amongst FCH JU projects working on similar issues such as high-temperature PEM or low nickel content SOFC supports. There is also scope for greater linkages with other European programmes which are, or could be, relevant to the FCH JU's commercialisation objectives. This could include the materials activities of the FP7 and Horizon 2020 programmes, especially in relation to nanotechnologies. It was recommended that basic and applied research projects have access to demonstration projects so that they can work on real field-trials, improving the relevance and hence value of current and future FCH JU projects. However, preservation of confidentiality was acknowledged to be an issue, in particular for commercially-sensitive items, which may impede the sharing of results.

3.8. Review findings – research and development – hydrogen

The review of the hydrogen R&D projects was divided into two parts. The first looked at projects focused on hydrogen production and distribution, and the second at aspects of hydrogen storage. There were 14 hydrogen production and distribution projects, as shown in Table 10. These include electrolyser, renewable hydrogen production, hydrogen purification and hydrogen distribution projects.

Table 10: Projects reviewed in the area of hydrogen production and distribution

Project name	Description
ARTIPHYCTION	Development and improvement of novel nano-structured materials for photo-activated processes as well as chemical systems for highly efficient low-temperature water splitting using solar radiation
BIOROBUR	Biogas robust processing with combined catalytic reformer and trap
COMETHY	Intensification of hydrogen production processes, developing innovative compact and modular steam reformer to convert reformable fuels to pure hydrogen and adaptable to several heat sources
DELIVERHY	Assessing high-capacity trailers composed of composite tanks with respect to weight, safety, energy efficiency and greenhouse gas emissions
ELECTROHYPEM	Development of cost-effective components for PEM electrolysers with enhanced activity and stability to reduce stack and system costs and improve efficiency
HY2SEPS-2	Design and testing of hybrid separation schemes that combine membrane and pressure swing adsorption technology for the purification of H2 from a reformate stream
HYDROSOL – 3D	Demonstration of a CO2-free hydrogen production and provision process and related technology, using a two-step thermochemical water-splitting cycle, harnessing concentrated solar radiation
HYTIME	Construction of a prototype process based on fermentation of biomass for delivering 1-10kg hydrogen per day and development of a bio-hydrogen production system
NEMESIS2+	Development of small-scale hydrogen generation prototype capable of producing 50Nm3 per hour from diesel and biodiesel at refuelling stations
NOVEL	Novel materials and system designs for low-cost, efficient and durable PEM electrolysers
RESELYSER	Development of high-pressure, highly efficient, low-cost alkaline water electrolyser that can be integrated with electricity from renewable energy sources using an advanced membrane concept, highly efficient electrodes and a new cell design
SOL2HY2	Solar-to-hydrogen hybrid cycles

Project name	Description
PRIMOLYZER	Development, construction and test of cost-minimised highly efficient and durable PEM-electrolyser stack aimed for integration with domestic micro-CHPs
UNIFHY	UNIQUE gasifier for hydrogen production

Nine projects were reviewed as part of the H2 storage portfolio covering solid-state storage, underground hydrogen storage, hydrogen-tank design, manufacturing and testing and liquefaction, production and refuelling, and hydrogen transfer (see Table 11).

Table 11: Projects reviewed in the area of hydrogen storage

Project name	Description
BOR4STORE	Fast, reliable and cost-effective boron hydride-based high storage capacity solid-state hydrogen storage materials
COPERNIC	Increasing the maturity and competitiveness of CGH2 manufacturing processes
EDEN	Realisation of high-density H2 storage system in solid-state material for stationary and portable applications
HYCOMP	Definition of design requirements and testing procedures of composite cylinders
HYTRANSFER	Avoiding cooling and overheating during all hydrogen transfer processes
HYUNDER	Assessment of potential actors and relevant business cases for hydrogen underground storage
IDEALHY	Integrated design for demonstration of efficient liquefaction of hydrogen
PHAEDRUS	High-pressure hydrogen for electro-chemical decentralised refuelling station
SSH2S	Development of solid-state hydrogen storage coupled with HT-PEMFC for a car application

3.8.1. Relevance to MAIP and AIP objectives

3.8.1.1. H2 production and distribution

The reviewers found the hydrogen production and distribution group of projects to be in line with MAIP and AIP objectives, with a mix of activities in basic and applied research. The lack of demonstration activities for these technologies was, however, identified as a weakness in the portfolio, in particular for hydrogen production from renewable energy sources. Reviewers recommended that a higher budget be allocated to demonstrations, with a view to developing cost-effective hydrogen production for the future. They also recommended that projects on innovative hydrogen production technologies be supported by the FCH JU with a view to longer-term technological development.

Finally reviewers recommended improvements in understanding the international state-of-the-art by the FCH JU so that projects selected for support are technically advanced and do not duplicate activities already undertaken elsewhere in Europe or the rest of the world.

3.8.1.2. H2 storage

The hydrogen storage portfolio was deemed highly relevant to the objectives of the MAIP and individual AIPs, with consistently good achievements to-date, and competitive in terms of state-of-the-art. As with H2 production, reviewers would like to see R&D activities carried forward into demonstration projects.

Reviewers assessed the projects' contribution to future FCH JU activities as ranging from moderate to very strong. Of note were the potential contributions to hydrogen tank design, manufacture and testing, underground storage of hydrogen and solid-state storage.

3.8.2. Horizontal and dissemination activities/exploitation plan

Reviewers were generally satisfied with the horizontal and dissemination activities of both groups of projects, although these could be strengthened further. Dissemination activities include websites, traditional journal and conference contributions, and some involvement with workshops and summer schools. Reviewers recommended a more systematic approach to knowledge dissemination, via European summer schools and other networks like those of Erasmus Mundus.

RCS development was found to be weak across all projects and in need of greater emphasis. Aspects such as safety analysis, risk assessment methodologies, and database development should be accelerated and made a mandatory part of the FCH JU portfolio.

Activities and plans for exploitation and utilisation of results appear well-developed, but should continue to be monitored up to completion. Some projects were found to lack a credible business-oriented approach to exploitation.

3.8.3. Relationship/complementarity with other projects/programmes

Linkages and relationships with other projects and programmes in the field are mixed. Some were exemplary, like BORASTOR, EDEN, HYTRANSFER, SSH2S and PHAEDRUS, and others much less so. As similar programmes and projects are being undertaken in Member States and internationally, with substantial opportunities for cross-fertilisation and learning from sharing of results and experiences, the FCH JU should ensure greater efforts are made to establish linkages. In addition, there is limited evidence of projects actively engaging and collaborating with the RES community in Europe and the Member States. The FCH JU should ensure that this is addressed in future projects in this portfolio, given the importance of renewables in 'green' hydrogen production.

3.9. Review findings – research and development – early markets

Seven projects were reviewed. All involved applied research and development activities, as well as some element of demonstration, reflecting in part their early market nature. This portfolio (see Table 12) included micro-fuel cells, internal reforming activities and low-temperature steam reforming.

Table 12: Projects reviewed in the area of early markets

Project name	Description
BeingEnergy	Integrated low-temperature methanol steam reforming and high-temperature polymer electrolyte membrane fuel cell
DURAMET	Improved durability and cost-effective components for new generation solid polymer electrolyte direct methanol fuel cells
HYPER	Integrated hydrogen power-packs for portable and other autonomous applications
IRAFC	Development of internal reforming alcohol high-temperature PEM fuel-cell stack
IRMFC	Development of portable internal reforming methanol high-temperature PEM fuel-cell system
ISH2SUP	In-situ H2 supply technology for micro-fuel cells powering mobile electronics applications
SUAV	Micro-tubular solid oxide fuel-cell power system development and integration into a mini-UAV

3.9.1. Relevance to MAIP and AIP objectives

All projects were found to be in line, to varying degrees, with the objectives of the MAIP and relevant AIPs. However, reviewers found it hard to assess the projects against specific targets and state-of-the-art technology because of the lack of information provided by the projects and the absence of targets for this sector in the MAIP. The exceptions were the DURAMET and HYPER projects. This area needs to be addressed by the FCH JU in future versions of the MAWP and AWPs.

SMEs were found to be well represented in the consortia undertaking these projects.

Reviewers believe that projects should more closely examine external factors – especially competing technologies – and undertake basic techno-economic comparisons to complement market knowledge and business plans.

Reviewers noted that there were similarities between this portfolio of projects and those of H2 production and storage, with opportunities for grouping projects across these portfolios for the benefit of joint learning and workshops. They also recommended that information/results from demonstrations should be fed back to the research community, to ensure more effective R&D activities for the FCH JU.

3.9.2. Horizontal and dissemination activities/exploitation plan

All projects were found to be active in dissemination, although information on detailed activities was lacking. Public awareness may not be sufficiently addressed, especially with regard to future deployment of FCH technologies.

A good example of dissemination was the joint workshop organised by three hydrogen storage projects and the HYPER project. This example could be followed by other projects, to benefit from experience and expertise and joint learning. Such workshops could be enhanced through the participation of end-users, as well as 'experts' and students and early-career engineers. The latter would improve the horizontal benefits of training and education, which all projects are undertaking to a degree, but not to the extent that the reviewers believe is possible.

Exploitation plans of the seven projects were assessed as being clear, with the DURAMET project in particular having 'a comprehensive and convincing commercialisation strategy'.

3.9.3. Relationship/complementarity with other projects/programmes

All projects have some form of interaction with relevant projects and programmes in Member States and internationally. There is, however, a lack of specific and detailed information about activities in this area.

Reviewers believe more can be done to foster cooperation amongst projects. For a start, the FCH JU can encourage or organise more interactions through activities like workshops, and project clustering. Additionally the FCH JU might be able to work with other European programmes and Member States to formalise linkages, *inter alia* through joint calls. Finally, it was emphasised that project/programme linkages and collaboration should go beyond Europe to partners like the US, Australia, Japan, China and South Korea.

4. Cross-cutting activities

4.1. Objectives

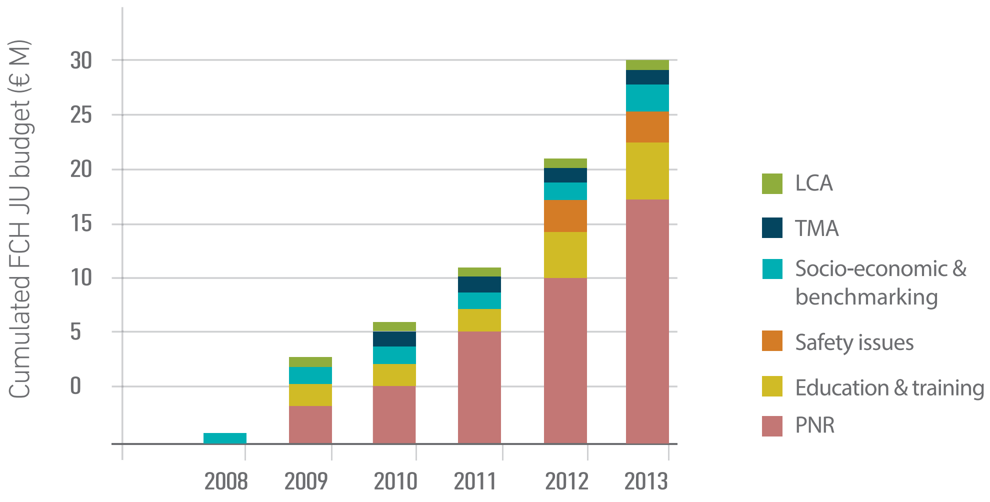
Cross-cutting activities support the commercialisation component in the two innovation pillars for transport and energy, and thus represent a fundamental element of the overall FCH JU programme. The primary goals are to:

- Support commercialisation through market-support measures, including pre-normative research and harmonised RCS and safety;
- Raise public awareness and support education activities in the field of fuel cells and hydrogen technology;
- Undertake technology, environmental, energy and socio-economic assessments;
- Develop tools to assist in monitoring the RTD programme implementation.

4.2. Funding

Total funding allocated to all stand-alone cross-cutting activities from the FCH JU budget was set at between 5% and 6%. In addition to these stand-alone activities, CC projects have been undertaken and supported under the transport and energy pillars. The cumulative annual costs per CC activity are shown below.

Figure 12 – Cumulative FCH JU spend by cross-cutting project type (2008-2013)



Note: RCS activities are included under other categories

Figure 12 shows that the vast majority of CC funds have been used to support PNR projects. These projects have the most support from, and greatest involvement with, industry, as opposed to research organisations. CC activities have also been funded within the energy and transport pillars as part of their internal cross-cutting activities, including PNR. The FCH JU has also worked to ensure that projects in the portfolio address the issue of life-cycle analysis to enhance the understanding of environmental and sustainability benefits and issues. Similarly the issue of RCS is covered both as separate projects and within projects in the energy and transport portfolio.

4.3. Focus areas and achievements

4.3.1. Focus areas

A range of projects supporting FCH technology commercialisation has been commissioned by the FCH in conjunction with the European FCH industry and research communities. These fall into seven categories:

- Pre-normative research – research into aspects of FCH technologies which are of essential strategic interest to the industry as a whole. It is primarily pre-competitive;
- Education and training – developing FCH technology-specific education and training tools for use in the wider European Union and Member State education and training systems, including (non-FCH) professionals and students;
- Regulations, codes and standards – projects to develop the RCS necessary for the deployment of FCH technologies within society;
- Safety issues – understanding the safety issues associated with the application of FCH technologies in various application types e.g. transport and stationary CHP;
- Socio-economic and benchmarking studies – studies to improve understanding of FCH technologies from economic and societal perspectives, including benchmarking against other technologies;
- Technology monitoring and assessment (TMA) – tools to assist FCH JU monitoring and assessment activities;
- Life-cycle analysis – processes and tools to assess the impact of FCH technologies on the environment, including end-of-life issues.

Information and knowledge generated by cross-cutting projects are for the benefit of the European fuel cell and hydrogen industry and research communities, and a range of other current and potential stakeholders. For instance, education and training projects assist health and safety regulators involved in assessing applications for FCH technologies. Socio-economic and energy impact studies are used by decision-makers responsible for developing policies at the European, Member State and local levels. Information as a whole is valuable for investors and end-users. Cross-cutting projects also support general public education and awareness, vital for increasing understanding of FCH technologies.

4.3.2. Achievements

The FCH JU has supported 26 cross-cutting projects in five calls from 2008 to 2012. In addition, at the time of the 2013 Review, a number of projects had been selected from the first of the 2013 calls for negotiation. The projects cover six categories as shown in Table 13.

PNR projects are the most numerous, representing 11 of the 26, followed by education and training, safety and socio-economic and benchmarking studies, with one project for TMA and two for life-cycle analysis.

Table 13: Cross-cutting projects supported by the FCH JU

	Project (number)			
Category	Finished	Live	Under negotiation	Total
Pre-normative research		8	3	11
Education and training	3	1	1	5
Safety		3		3
Socio-economic and benchmarking studies	3		1	4
Technology monitoring and assessment	1			1
Life-cycle analysis	2			2
Total	**9**	**12**	**5**	**26**

4.4. Organisation of cross-cutting review sections

The 2013 Review divided cross-cutting projects between two panels: PNR, including safety aspects, and socio-economic aspects, including LCA and training activities.

4.5. Review findings – PNR, including safety aspects

4.5.1. Relevance to MAIP and AIP objectives

Seven 'live' (or running) projects were reviewed. The majority focused on safety issues associated with the hydrogen value chain, either safety of components or applications, or generic safety tools or sensors. The reviewers found the portfolio of projects to be relevant to the needs of FCH technology development and commercialisation, and in line with the MAIP and AIP objectives. The portfolio contains primarily applied research projects providing technical support to the transport and energy sectors as shown below.

Figure 13 – Projects in the PNR portfolio

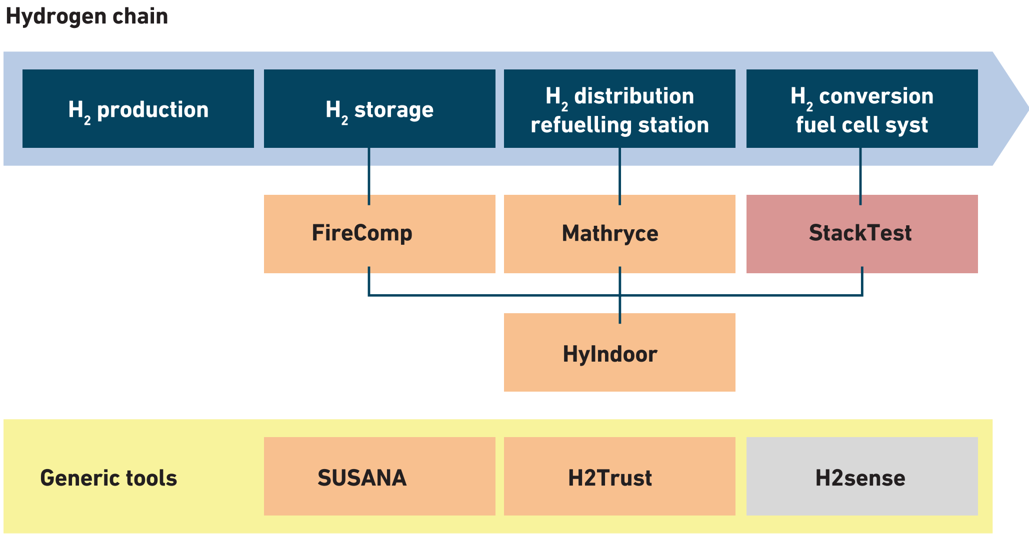


Table 14: Projects reviewed in the area of PNR

Project name	Description
Safety projects	
HYINDOOR	PNR for safe indoor use of fuel cells and hydrogen systems
MATHRYCE	PNR for metallic components exposed to hydrogen-enhanced fatigue
STACKTEST	Development of PEM fuel-cell stack reference test procedures for industry
Generic H2 safety tools	
H2TRUST	Development of H2 safety expert groups and due diligence tools for public awareness and trust
SUSANA	Support for safety analysis of hydrogen and fuel-cell technologies
H2 Sensor Project	
H2SENSE	Cost-effective and reliable sensors for facilitating the safe use of hydrogen

4.5.2. Horizontal and dissemination activities/exploitation plan

The reviewers found that the portfolio of projects satisfactorily addressed the transfer of information and knowledge gained in the projects to the stakeholder community, especially in training and education, safety, and regulation codes and standards. Workshops and conferences are being used to engage with stakeholders – for example FIRECOMP is setting up an expert networking group on safety issues, while MATHRYCE intends to present its findings to a dedicated ISO working group as part of standards improvements.

Workshops and networks are critical tools for cross-cutting projects to engage with and disseminate information to the stakeholder community, and provide opportunities for the community to assist in the design of regulations, codes and standards for common technical and safety issues. It can be argued that presentations at specialist FCH conferences do not reach all the stakeholder community; projects should therefore include as much networking and workshop activity as possible.

More traditional passive means of dissemination are also being pursued by projects. H2TRUST, for instance, intends to develop an information pack on hydrogen safety for use with stakeholders, while most projects have developed websites which reviewers found to be valuable in providing information on safety issues. Also noteworthy is H2SENSE's intention to develop a hydrogen sensor knowledge hub for gathering and disseminating information.

4.5.3. Relationship/complementarity with other projects/programmes

The portfolio of seven projects shows numerous linkages to others within the FCH JU portfolio as well as to projects from previous EU framework programmes, and FCH programmes operated by Member States.

A number of projects are related to previous projects: STACKTEST is based in part on FCTESTNET and FCTESQA, while H2TRUST carries forward work undertaken in HYSAFE and HYFACTS. This continuation of activities from earlier projects is an encouraging indication that learning and knowledge-generation build on prior developments, and are thus complementary rather than duplicative. There are clear linkages between these cross-cutting activities and other projects in the transport and energy sectors. Moreover, linkages to Member State programmes and projects is evident in HYINDOOR and MATHRYCE, both of which have links to French projects, whilst SUSANA has links with the UK's SUPERGEN programme.

Most significant in terms of relationships beyond Europe is the fact that H2SENSE was set up specifically to coordinate with similar activities in the US. Similar international cooperation initiatives are encouraged given that CC activities are mostly non-competitive.

Review findings on networking within the FCH stakeholder community are encouraging, but reviewers argued that further strengthening of this area will be necessary as technologies move closer to commercialisation.

4.6. Review findings – socio-economic aspects, including LCA and training activities

Four projects were involved in the 2013 Review; the balance between research and demonstration was appropriate for these projects.

Table 15: Portfolio of cross-cutting projects reviewed

Project name	Description
Training and Education	
TRAINHY	Building training programmes for young professionals in the hydrogen and fuel-cell field
HYPROFESSIONALS	Development of educational programmes and training initiatives related to hydrogen technologies and fuel cells in Europe
Monitoring and Assessment	
TEMONAS	Technology monitoring and assessment
Life Cycle Assessment	
FC-HYGUIDE	Guidance document for performing LCAs on hydrogen and fuel-cell technologies

4.6.1. Relevance to MAIP and AIP objectives

No significant gaps were identified in the portfolio of cross-cutting projects. While there is some overlap in subject matter between TRAINHY and HYPROFESSIONAL, duplication is avoided because the projects target different groups for training. Indeed the reviewers believe that both projects deliver added value. Reviewers nonetheless emphasised the need for the FCH JU portfolio to address the training and education needs of stakeholders, specifically in standardisation and regulation.

Reviewers believed more needs to be done on technology monitoring both to assess projects in general, and also to contribute to the 'planning of future AIPs and MAIPs'. The TEMONAS tool is a positive step and should assist the FCH JU in making 'a much stronger effort' in technology monitoring.

4.6.2. Horizontal and dissemination activities/exploitation plan

The dissemination activities were found to be good, including participation in and presentations at conferences, workshops and summer schools. How much more can be done in this area deserves consideration given the importance of these projects, especially education and training activities.

Reviewers noted the lack of quantitative or operational targets in the MAIP/AIPs against which the portfolio of projects could be evaluated. The inclusion of measurable outcomes in the MAIP for cross-cutting projects would be a valuable addition to the FCH JU framework for its portfolio. Such comments have been made in previous FCH JU portfolio reviews.

The reviewers recommended that LCA be mandatory for projects in the application areas/pillars, and that these should be improved and developed where possible. In addition, TMA tools should be used to monitor individual projects within the portfolio.

Reviewers recommended that cross-cutting projects include a sustainability plan for continuation of activities after the end of a project. This raises an issue noted in previous reviews regarding continuity of funding for CC projects, especially on education and training, where the need and demand will increase as FCH technologies move closer to commercialisation. Such projects would also benefit from access to up-to-date results from the FCH JU transport and energy projects, to ensure that they remain relevant in a changing sector. They also need to work on a means to integrate education and training project activities into the mainstream European education and training structures, which is an ongoing task.

4.6.3. Relationship/complementarity with other projects/programmes

Cross-cutting projects by their very nature should have a high degree of linkages and relationships with other projects and programmes at the EU, Member State and local levels. Interactions with a larger stakeholder community will usually lead to better project activity and outcomes, through cross-fertilisation of ideas, sharing of findings and results, and more critical assessments. The portfolio of projects reviewed demonstrates an element of linkages with other projects and programmes. Thus TRAINHY and HYPROFESSIONALS are linked to other education and training activities, and elements of their work are likely to be carried forward by successor projects funded by the FCH JU such as HYRESPONSE.

The reviewers emphasised the importance of linkages with other programmes in Europe and beyond. They noted that some projects had 'few interfaces to regional, national and international organisations'. They called for linkages to be considered with other relevant EU-level educational activities like the Leonardo programme and for international linkages to be strengthened (e.g. via IPHE education and training activities). They also recommended that relations with programmes in partner countries like Japan and the US be developed.

5. Conclusions

5.1. Overview

The 2013 Review has concluded that the portfolio of projects across the energy and transport pillars, and within the cross-cutting category is a strong one. The portfolio lines up with the FCH JU's strategic objectives as set out in the MAIP, with some limited gaps. Good progress has been demonstrated since the 2011 Review.

Of the more than 150 projects supported during 2008-2012, the majority are well run and are on track to achieve most of their objectives. There are many exemplary projects where state-of-the-art RTD is under way, with exciting possibilities for the future application of fuel-cell and hydrogen technologies.

Inevitably within a large RTD programme like that of the FCH JU, there are projects which struggle to attain their original objectives. This generally reflects the degree of the RTD challenge involved, or even the excessive ambition of projects, rather than poor management. There are, nonetheless, learning opportunities for the FCH JU, industry and research communities.

5.2. Participation

All FCH JU-funded projects have some form of industry involvement, either leading projects or supporting them, as well as participation from research organisations, often performing the role of basic and breakthrough researchers. This industry-research collaboration represents a significant achievement of the FCH JU: bringing together Europe's most innovative organisations to collaborate around a RTD-structured programme addressing the challenge of commercialisation.

It is notable that the 2013 Review identified very good levels of industry and research collaboration, with much greater emphasis on the commercialisation challenge than was apparent in previous reviews.

Industry accounts for about 60% of participants in the FCH JU portfolio. Within this category, the FCH JU programme is supporting the efforts of a very large number of SMEs, who make up about 30% of total participants. These are innovative and potentially high-growth businesses.

In addition, the FCH JU portfolio of projects includes public sector participation through either Member State RTD programmes, or through Europe's municipalities and regions. The latter are often involved in the critical role of providing locations for demonstrations. What is clear from this wider public sector involvement is the degree to which the FCH JU has been able to leverage its own funds with further contributions from elsewhere: another key achievement.

5.3. Overall portfolio of activities

The FCH JU portfolio comprises a balanced range of projects from basic and breakthrough research to applied research and demonstrations. It covers the entire fuel-cell and hydrogen value chain, from projects focusing on materials, fuel cells and stack development, through to components and sub-systems, and demonstrations of complete fuel-cell and hydrogen systems. For hydrogen in particular the portfolio has been strengthened with the addition of large-scale storage RTD.

This focus on commercialisation is evident from the expansion of the demonstration activities in both the energy and transport pillars. The transport demonstration projects like CHIC, High V.LO City and FCGEN have been joined by HyTransit, with a further project in the pipeline from the 2013 call. Similarly, the POWERUP project joins the Ene.field, SOFC-PACT and ELYGRID projects in the energy sector.

At the same time, the FCH JU continues to support basic and breakthrough research with good examples in both innovation pillars. In the transport pillar IMPALA, CATAPULT and PUMA-MIND have started in the past 12 months, while in the energy pillar, new projects include NOVEL, SOL2HY, SCORED and CISTEM.

The cross-cutting project portfolio has seen the addition of a number of different projects: those aimed at testing protocols such as STACKTEST; hydrogen-vessel design and development, MATHRYCE; and the development of hydrogen sensors under H2SENSE. This last project is very significant as it includes a high degree of coordination with similar efforts in the US.

5.4. Learning and improvements

The 2013 Review identified, as did previous reviews, areas where lessons can be learnt and improvements made. Any portfolio as large as that of the FCH JU will include well-functioning projects displaying good practice across all their activities, alongside those that require improvement.

Reviewers have identified a general need for more technical targets against which project progress can be measured. This is extremely important for the basic and breakthrough research efforts where such targets would help focus the FCH JU portfolio. As the FCH JU moves into its second phase under the Horizon 2020 programme, this is an opportune time to revisit the targets set out in the MAIP.

In terms of horizontal activities, there are in general good efforts in the fields of safety and RCS, especially amongst demonstration projects, while dissemination is being achieved through the use of websites, conference presentations and journal publications. However, the reviewers were keen to see more active and targeted dissemination, especially to the wider European industry and potential end-users. They identified the workshops and networks run by exemplar projects as good practice that should be encouraged by the FCH JU.

Sustained and expanded efforts are also required in the area of education and training and public awareness. Reviewers argued that as fuel-cell and hydrogen technologies move towards larger-scale deployment the demand for skills and expertise will only grow. FCH JU must make sure that it expands its support of projects which address the creation of training and education materials, and which link to the mainstream education systems of EU Member States. The FCH JU also has a role in raising public awareness, especially by publicising the activities of demonstration projects.

Although there is a much-improved focus on the need to move towards the commercial application of fuel-cell and hydrogen technologies, it is evident that more can be done. A stronger and more credible approach to address the challenges and identify ways to speed up the exploitation of project results is required for a number of projects.

Reviewers also focused on the benefits to be gained from FCH JU projects collaborating with each other within the portfolio as a whole, but also with projects and programmes operated at the European, Member State and local levels. Significant benefits are possible through learning from each other, from the exchange of experiences and information, and through developing common protocols and approaches to challenges. The reviewers recommend further efforts by the FCH JU to promote such cooperation, subject to issues of intellectual property rights (IPR) and commercial sensitivity. They also encourage more cooperation at the international level.

5.5. Future of the FCH JU

Fuel-cell and hydrogen technologies have made significant advances in Europe over the past six years. This is in no small part due to the activities of the FCH JU. Fuel-cell and hydrogen technologies are clearly part of the future technical solutions for ensuring a secure and sustainable energy supply for Europe, supporting economic growth while protecting the environment. However, there remain substantive challenges ahead: mobilising private-sector investment to commercialise the technologies in the market place, tackling the barriers to market entry, understanding RCS and safety issues, training a skilled and qualified workforce, raising public awareness and preparing consumer acceptance.

The second phase of the FCH JU gives it a role in addressing these challenges. By focusing on improving further still its overall portfolio of projects, the FCH JU can ensure that these directly contribute to the future success of fuel-cell and hydrogen technologies, and thus unlock the environmental, energy and economic benefits for the European Union, its Member States and its citizens.

Projects funded by the FCH JU

New Energy World JU
fuel cells & hydrogen for sustainability

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* Of the 116 projects implicated by the review process, 107 submitted posters for the Programme Review 2013. Projects indicated with an asterisk (*) are those for which no poster is available

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Guide to projects by application area

Cross-cutting activities

Early markets

Hydrogen production and distribution

Stationary power generation and CHP

* Of the 116 projects implicated by the review process, 107 submitted posters for the Programme Review 2013. Projects indicated with an asterisk (*) are those for which no poster is available

Transport and refuelling infrastructure

ADEL

Advanced Electrolyser for Hydrogen Production with Renewable Energy Sources

Duration

Start and end date: January 2011 - December 2013

Application area

Hydrogen production and distribution

Budget

Total budget €4,155,776
FCH contribution €2,043,518

Partnership/consortium list

HTceramix (coordinator), accelopment AG (administration), Commissariat à l'énergie atomique et aux énergies alternatives, Deutsches Zentrum für Luft- und Raumfahrt eV, European Institute for Energy Research, Eidgenössische Materialprüfungs- und Forschungsanstalt, Abengoa Hidrógeno SA, HyGear BV, Fundacion IMDEA Energia, Joint Research Center, SOFCpower Srl, Topsoe Fuel Cell AS, Empresarios Agrupados.

Summary/main objectives of the project

Extend the solid-oxide electrolyser (SOE) durability. Decrease the operating temperature of the SOE to increase the overall system efficiency and reduce the cost of the electrolysis system. Optimise the cells, interconnects and contact layers for operation temperatures below 750°C. Develop countermeasures against phenomena such as interdiffusion, corrosion or vaporisation responsible for cell and stack degradation. The aim is to decrease the degradation rate to less than 1%/1000hrs. Limit the cell ASR and allow current densities across the cell as high as 2A/cm2, interconnect/coating associations are searched.

Technical accomplishment/progress/results

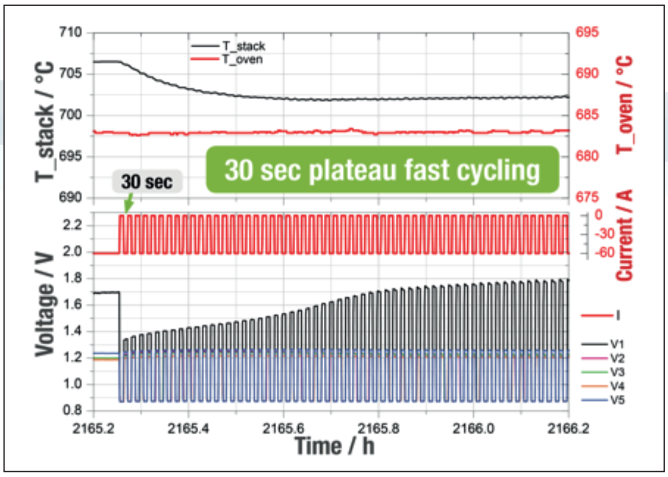
Advanced methods where utilised to understand the degradation phenomena in the different cell layers. A new air electrode for lower temperatures on the basis of LSC has been tested at T = 700°C with 15% increased performance at 0.9A/cm^2. Extensive tests have been performed on cell and stack level. On the basis of an advanced SOE model different system designs have been simulated to study the influence of different heat sources, like thermal solar power plants or nuclear reactors.

Contribution to the programme objectives

Electrolysis systems to produce H2 with more than 90% efficiency have been identified, benefiting from low-grade heat sources. Intermittent electrolyser stack operation has been proven without additional stack degradation.

Future steps

1 – Define the concept for a demonstration in kW scale for the electrolyser coupled to renewable heat and electricity sources
2 – Complete the work on the understanding of degradation mechanisms in SOE



Conclusions, major findings and perspectives

High temperature electrolysis can achieve H2 production with higher than 90% efficiency using heat sources at relatively moderate temperature levels (150°C).
SOE stacks can be operated under strong cycling conditions and are therefore suitable to convert intermittent power sources to H2 for storage.
The absolute temperature level of the electrolyser has hardly an effect on the system efficiency; the system operation temperature can be optimised to achieve lowest cost resulting in an optimisation of high performance and low degradation. SOE temperature reduction towards 600°C is not an objective as such; 700°C seems to be a reasonable operating temperature. The underlying mechanisms of degradation have not been sufficiently understood and require further efforts.

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adel Advanced Electrolysers

ALKAMMONIA

Ammonia-Fuelled Alkaline Fuel Cells for Remote Power Applications

Duration

Start and end date: 1 January 2012 - 31 December 2014

Application area

Stationary power generation and CHP

Budget

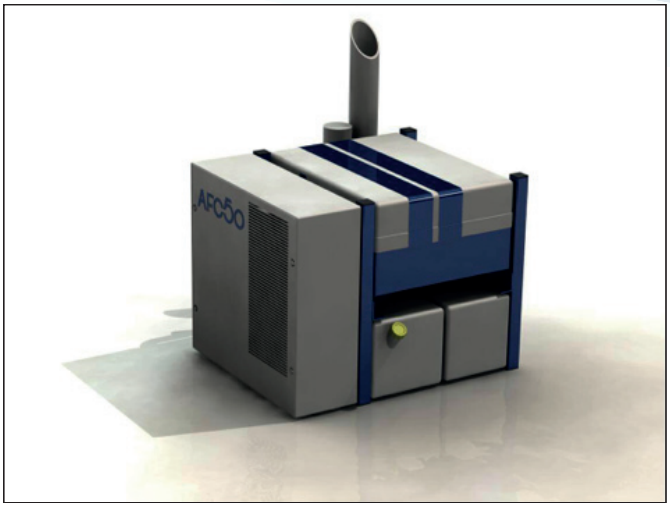
Total budget €2,870,896
FCH contribution €1,962,548

Partnership/consortium list

AFC Energy plc (UK)
ACTA SPA (Italy)
Universität Duisburg-Essen (Germany)
Zentrum für Brennstoffzellentechnik ZBT GMBH (Germany)
UPS Systems plc (UK)
PAUL SCHERRER INSTITUT (Switzerland)
European Hydrogen Association (Italy)

Summary/main objectives of the project

Seamless integration of the cracker and the alkaline fuel-cell technologies into a flawlessly functioning proof-of-concept system, which complies with all relevant fuel-cell regulation and CE marking directives.
Demonstrate cost competitiveness of the integrated 3-5kW proof-of-concept system against other technologies competing in the same target market(s).
Three months continuous operation of the system using liquid ammonia.
A detailed analysis of the environmental and socio-economic impacts of the proof-of-concept system that addresses, in particular, ammonia supply chains and public perception of ammonia as a fuel.



Contribution to the programme objectives

CRACKER TECHNOLOGY: Project ALKAMMONIA will advance the state-of-the-art in cracking technology and deliver a highly efficient hydrogen generator. The high efficiency of the cracker makes the technology a possible key component in the energy carrier chain for the growing hydrogen economy.
AMMONIA STORAGE TECHNOLOGY: This project will advance the state-of-the-art with respect to the temperature range in which ammonia can be utilised as a fuel by thermally integrating the ammonia storage and the fuel cell and the cracker.
ALKALINE FUEL-CELL TECHNOLOGY: This project will deliver a small-scale alkaline fuel-cell system (3-5kW) which will be ideally suited for application in the remote power and back-up power markets.

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ALKAMMONIA

ARTEMIS

Automotive PEMFC Range Extender with High-Temperature Improved MEAs and Stacks

Duration

Start and end date: 1 October 2012 - 30 September 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €2,948,202
FCH contribution €1,747,884

Partnership/consortium list

Centre National de la Recherche Scientifique (CNRS) (France), Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA) (France), Nedstack Fuel Cell Technology BV (Netherlands); Fundation CIDETEC (Spain), Centro Ricerche Fiat (CRF) (Italy), Politecnico Di Torino (Italy)

Summary/main objectives of the project

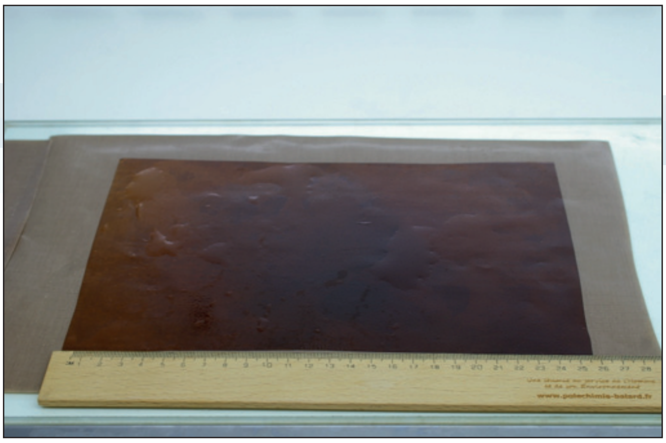
- Develop and optimise alternative materials (membrane, catalysts, bipolar plates) for high temperature (160-180°C) PEMFC stack
- 3kWe stack operation as a range extender on an electric vehicle; increase kilometric range
- Understanding of degradation mechanisms by multiscale modeling tools
- HT MEA manufacture at pilot scale

Technical accomplishment/progress/results

- Baseline materials developed and characterised ex-situ
- First MEA materials ready to be tested (membrane, catalyst)
- Bipolar plate materials properties investigation (electrical resistance/ wettability vs. H_3PO_4 acid)

Contribution to the programme objectives

- Complete state-of-the-art European materials for MEA fabrication
- Introduction to the automotive market of HT stack suitable for range extender application
- Overall cost reduction as developed materials exhibit low cost and high efficiency



Future steps

- First generation MEA elaboration and testing
- Development of the second generation materials
- HT stack manufacturing (0.3 kWe then 3 kWe)

Conclusions, major findings and perspectives

- Early stage of materials development but very promising results
- If the goal is reached, ARTEMIS will produce and propose state-of-the-art materials, MEAs and top-of-the-line HT stack products
- Potential for upscale materials production
- HT stack implementation as a range-extender
- High potential for commercialisation
- First publication of results

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Artemis

ASSENT

Anode sub-system development for SOFC systems

Duration

Start and end date: 1 October 2012 - 30 September 2013

Application area

Stationary power generation and CHP

Contribution to the programme objectives

Budget

Total budget €4,496,501
FCH contribution €1,819,133

Partnership/consortium list

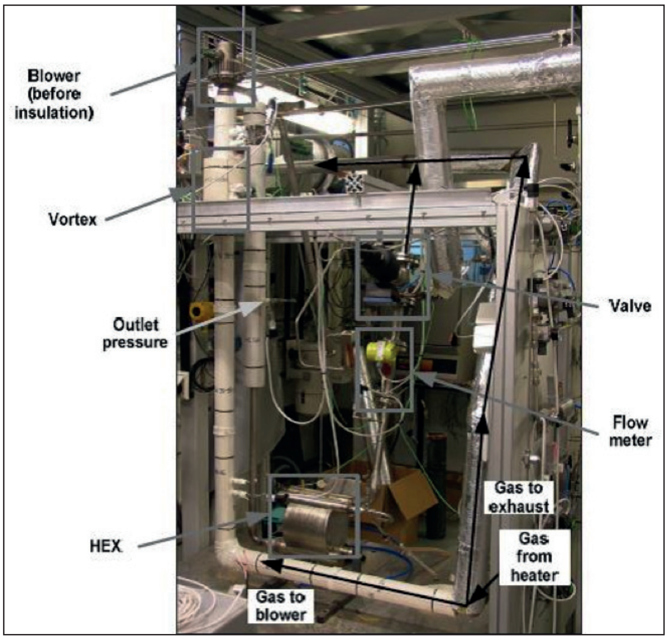
VTT Technical Research Centre of Finland, HTceramix SA, EBZ Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH, Wärtsilä Finland Oy, Hexis AG, Forschungszentrum Jülich GmbH

Summary/main objectives of the project

The objective of this project was to find optimal anode subsystem concepts that are validated for small-scale and large-scale SOFC systems to be implementable into a real system to fulfil performance, lifetime and cost targets for stationary applications technology but some of the results might also support development of MCFC technology.

Technical accomplishment/progress/results

Four different optimised subsystems were validated successfully: two in large-scale and two in small-scale. These subsystems solution are implementable into a pre-commercial system after the project.



Contribution to the programme objectives

	Objectives of the call	Objectives of theproject	Current Status
Power unit efficiency (%)	>40	>40	achieved
CHP unit efficiency (%)	>80	>80	achieved
FC system life time (h)	>40,000	40,000	<40,000
Cost (€/kW)(excl. stacks) Large scale	1,500	1,500-2,000	2,000
Cost (€/kW) (excl. stacks) Small scale	3,000	3,000-4,000	>>4,000

Future steps

This project has ended.

Conclusions, major findings and perspectives

Dedicated cost analysis (DtC) was conducted within ASSENT and parallel CATION projects to support the understanding of overall commercial feasibility of different process approaches. Based on this analysis, a good understanding on the economies of scale was achieved. As a result, it can be concluded that with certain additional stack related development steps a commercially feasible system having investment cost (excl. stacks) of less than €2,000/kW can be achieved.

Asterix3

Assessment of SOFC CHP Systems Built on the Technology of HTcerarmix 3

Duration

Start and end date: 1 January 2011 - 31 December 2014

Application area

Stationary power generation and CHP

Budget

Total budget €3,096,000
FCH contribution €1,361,000

Partnership/consortium list

Dantherm Power (Denmark), HTceramix (Switzerland), EIFER (Germany), CNR-ITAE (Italy).

Summary/main objectives of the project

The Asterix3 project aims to develop a proof-of-concept micro CHP system based on SOFC technology with progress beyond state of the art towards market requirements.

Technical accomplishment/progress/results

The SOFC-based µCHP have been simulated as integrated units in a single family house, based on data for France, Germany and Denmark with different operational strategies:
Based on these inputs the design of the sub-system "HoTbox™" has been modified in some crucial points;
Dantherm Power has designed and built the total system including all BoP components

Contribution to the programme objectives

As a minimum we will build, test and validate a fully integrated and autonomous CHP system meeting the following requirements.

- Electrical efficiency (peak) 35% net AC efficiency
- Electrical efficiency (nominal avg.) 30% net AC efficiency
- Total efficiency of the system reached values up to 90%

Future steps

The outcome of this project will hopefully enable us to demonstrate a concept fulfilling market requirements and to move to the next steps of field test readiness. This development path also implies a large number of demonstration units in field trials.

Conclusions, major findings and perspectives

- Modification of inverter software in order to supply power to the grid according to the rules
- Finishing the HoTbox™", integrating it and testing it in the system
- Building three more systems and do further tests at EIFER and CNR-ITAE

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Asterix3

Auto-Stack

Automotive Fuel-Cell Stack Cluster Initiative for Europe

Duration

Start and end date: 1 January 2010 - 30 September 2011

Application area

Transportat and refuelling infrastructure

Budget

Total budget €2,728,689
FCH contribution €1,193,016

Partnership/consortium list

ZSW (Coordinator), CEA, Daimler, DANA, CRF, Freudenberg FCCT, JRC, PSI, SNECMA, Solvay, Solvicore, Umicore, Volvo, VW.

Summary/main objectives of the project

- Make a proposal for establishing a competitive automotive fuel-cell stack industry
- Assess the European component supply industry
- Provide a fuel-cell stack cost-analysis tool
- Develop a technical and cost road map for fuel cell stacks for FC-EV in a mass market including component road maps
- Explore the synergies between fuel-cell applications in transport-oriented markets
- Develop a business plan for a European fuel-cell stack integrator

Technical accomplishment/progress/results

Agreed high-level stack specification

- Stack power 95kW, scaleable 10-95kW.
- Operating conditions:
    - Hight power: 1.5 A cm^2 @ 0.675 V $cell^{-1}$.
    - Low power: 0.2 A cm^2 @ 0.8 V $cell^{-1}$.
- Operating temperature < 95°C.
- Operating pressure < 2 bar_a.
- Voltage: 220 - 430 V
- Volume and weight limits for a 95kW-stack: < 60 l, < 75 kg.
- Cost: €101/kW @ 10,000 95kW stacks.
- Durability: > 5,000 operating hours.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Key technical targets	assessment	Agreed high-level stack specifications.	Document available
Expertise of relevant players	assessment	Assessment of European supply industry	Document available
Commercial and social targets	assessment	Business plan for a European stack integrator	Document available
Implementation of the concept	assessment	Road map	Document available

Future steps

The project was completed in September 2011
A follow-up project for hardware development was started in May 2013

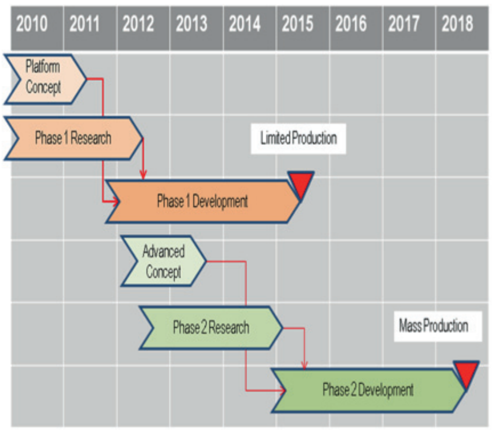
Conclusions, major findings and perspectives

- A common stack specification and platform concept across several OEMs has been agreed upon.
- High power density is critical for the stack platform concept.
- Metallic bipolar plates are the sole option to match volumetric and gravimetric power densities and cost.
- Ultra-low Pt-loadings are in conflict with power density requirements in the foreseeable future.
- The platform concept offers technical synergies with other industrial applications.
- The stack platform can substantially improve economies of scale.

Annual production rate	1000	10000	50000	100000	500000
Total stack cost - mBPP	16 187 €	9 608 €	6 781 €	5 853 €	4 187 €
Cost/kW gross - mBPP	170 €	101 €	71 €	62 €	44 €
Total stack cost - cBPP	18 971 €	11 791 €	8 508 €	7 398 €	5 359 €
Cost/kW gross - cBPP	200 €	124 €	90 €	78 €	56 €

Power density 1 W/cm^2
Pt-price @ 21,16€/g
Stack power 95 kW
Total Pt-loading 0,85 mg/cm^2

Cost benefits of metallic BPP vs. Carbon BPP = 27 % @ optimum production volumes



New Energy World JU
fuel cells & hydrogen for sustainability

autostack moves

Auto-Stack CORE

Automotive Fuel-Cell Stack Cluster Initiative for Europe II

Duration

Start and end date: 1 May 2013 - 30 September 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €14,715,530
FCH contribution €7,757,273

Partnership/consortium list

ZSW (Coordinator), Belenos Clean Power Holding, BMW AG, CEA, Reinz Dichtungs GmbH, Fraunhofer ISE, JRC-IET, FFCCT, Powercell Sweden AB, Solvicore, SymbioFCell, Volkswagen AG, VOLVO.

Summary/main objectives of the project

- Development of a European automotive PEM fuel cell stack platform in three evolutions that can be accessed and shared by several OEMs.
- Design and use advanced components which can be manufactured at an industrial level.
  - Development of a low-cost, high-performance MEA adapted to metallic bipolar plate design including industrial manufacturing concept.
  - Development of metallic bipolar plates allowing a cell pitch << 1.5 mm at production cost < €10/kW.
- Cost engineering to help select the most efficient design options using established automotive cost assessment methodology.
- Manufacturing and testing of automotive fuel cell stacks having a nominal power of 95kW.

Technical accomplishment/progress/results

- Review of stack and component specifications based on the Auto-Stack project (GA 245142).
- Design and modeling work on stack, bipolar plate and MEA started.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Stack gross power	95kW	95 kW (continuous)	Design point at 95kW continuous
Specific power (stack)	> 2kW/kg	2.1 (Evolution 3)	Design in progress
Power density (stack)	> 2kW/l	2,3 (Evolution 3)	Design in progress
Lifetime hours	> 5,000	5,500	To be confirmed

Future steps

1. Continuation of design work
2. Manufacturing of components
3. Stack assembly and testing
4. Design review and improvements
5. Cost analysis

Conclusions, major findings and perspectives

Specifications of Auto-Stack could be confirmed.

- Simulation of different channel geometries and header sizes to achieve desired pressure drops and flow distribution.
- Development targets for components (MEA, BPP) refined and confirmed by flow modeling.
- Initial flow models available.
- Initial designs for bipolar plates and MEAs available.
- Overall development on schedule.

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fuel cells & hydrogen for sustainability

autostack core

BioRobur

Biogas Robust Processing with Combined Catalytic Reformer and Trap

Duration

Start and end date: 1 May 2013 - 30 April 2016

Application area

Hydrogen production and distribution

Budget

Total budget €3,909,726
FCH contribution €2,486,180

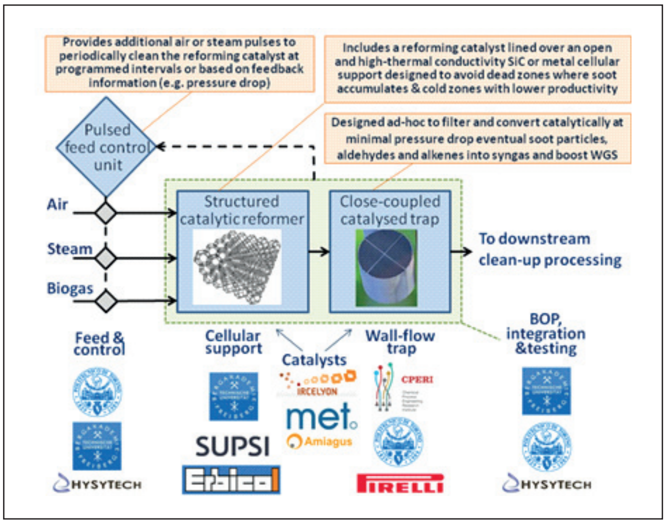
Partnership/consortium list

- Politecnico di Torino: Coordinator (Italy)
- Technische Universität Bergakademie Freiberg (Germany)
- Scuola universitaria professionale della Svizzera italiana (Switzerland)
- Institut de recherches sur la catalyse et l'environnement de Lyon (France)
- Chemical Process Engineering Research Institute/Centre for Research and Technology Hellas (Greece)
- Erbicol SA (Switzerland)
- HySyTech srl (Italy)
- UAB Modernios E-Technologijos (Lithuania)
- Pirelli Eco Technology SpA (Romania)

Summary/main objectives of the project

BioRobur project will develop a robust and efficient biogas reformer aimed at covering a wide span of potential applications, from fuel cells feed (both high-temperature SOFC or MCFC fuel cells and low temperature PEM ones, requiring a significantly lower inlet CO concentration) up to the production of pure, PEM-grade hydrogen.

Technical accomplishment/progress/results



Scheme of the BioRobur reformer core innovations and partners' roles

The project started last May. At the moment some preliminary possible Si-SiC structures designs have been selected for the Biorobur reformer.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current Status
H2 production (kg/day)	50-250	100	N/A (test not started)
CO concentration (vol%)	<10	<10	N/A (test not finalised)
Materials cost of 50 Nm3/hr H2 (€)	<250,000	150,000	N/A (test not finalised)

Future steps

1. Definition of BioRobur specifications to properly design all the components
2. Setup for steady-state screening and transient regeneration experiments optimised
3. Definition of optimal design for the reformer and the trap.
4. Dissemination plan issued

Conclusions, major findings and perspectives

The consortium started to work together a few months ago. We expect to reach some important milestones during the next year in terms of the major constraints to build the future test rig.

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fuel cells & hydrogen for sustainability

BioRobur

BOR4STORE

Fast, Reliable and Cost-Effective Boron Hydride-Based High-Capacity Solid-State Hydrogen Storage Materials

Duration

Start and end date: 1 April 2012 - 31 March 2015

Application area

Hydrogen production and distribution

Budget

Total budget €4.07 million
FCH contribution €2.30 million

Partnership/consortium list

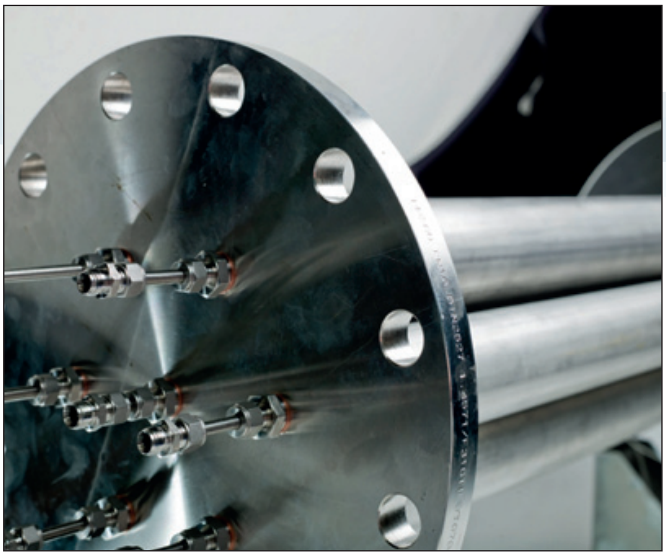
Helmholtz-Zentrum Geesthacht GmbH, Abengoa Hidrógeno SA, Zoz GmbH, Katchem spol. s.r.o., Aarhus Universitet, Institutt for Energieteknikk, Università degli Studi di Torino, Eidgenössische Materialprüfungs- und Forschungsanstalt, National Centre for Scientific Research "Demokritos"

Summary/main objectives of the project

Integrated approach for development and testing of novel, optimised and cost-efficient boron hydride-based hydrogen storage materials with superior performance (materials capacity more than 8 wt.% and 80 kg H2/m3) for SOFC applications.

Technical accomplishment/progress/results

- Investigation of a range of different high-capacity boron hydride-based hydrogen storage materials.
- Characterisation of thermodynamic, kinetic and cycling properties. Scientific understanding of solid-state reactions during hydrogenation.
- Down selection of most promising candidates for storage tank: LiBH4/MgH2 RHC, EMC.
- Establishment of simulation model of integrated SOFC– metal hydride tank systems.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Volumetric capacity	> 60 kg H_2/ m^3 materials level	> 80 kg H_2/m^3 materials level	> 80 kg H_2/ m^3 material level
Gravimetric capacity	> 6 wt.% materials level	> 8 wt.% materials level	8 - 10 wt.% material level
Loss of capacity	-	> 500 cycles / < 2%	n.a.
Cost of tank systems	<€500/kg H_2	Demonstration of potential for < €500/kg H_2	n.a.

Future steps

1. Further investigation of rate-limiting steps and cyclability of storage materials with a focus on in situ techniques
2. Optimisation of additives and nanoscaffolds
3. In silico optimisation of thermal integration
4. Construction and testing of prototype SOFC–metal hydride tank system

Conclusions, major findings and perspectives

- Promising borohydride based materials systems exist, suitable for construction of solid state hydrogen storage integrated with SOFC.
- Simulation of material in storage tank and thermal integration with SOFC developed.
- Optimisation of thermal integration can be achieved by simulation.

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BOR 4 STORE

CATAPULT

Novel Catalyst Structures Employing Pt at Ultra Low and Zero Loadings for Automotive MEAs

Duration

Start and end date: 1 June 2013 - 31 May 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €4.68 million
FCH contribution €2.26 million

Partnership/consortium list

Université Montpellier 2 (France), Johnson Matthey Fuel Cells Ltd (UK), Volkswagen (Germany), Beneq (Finland), Technical University of Munich (Germany), VTT (Finland), University of Ulm (Germany), Pretexo (France).

Summary/main objectives of the project

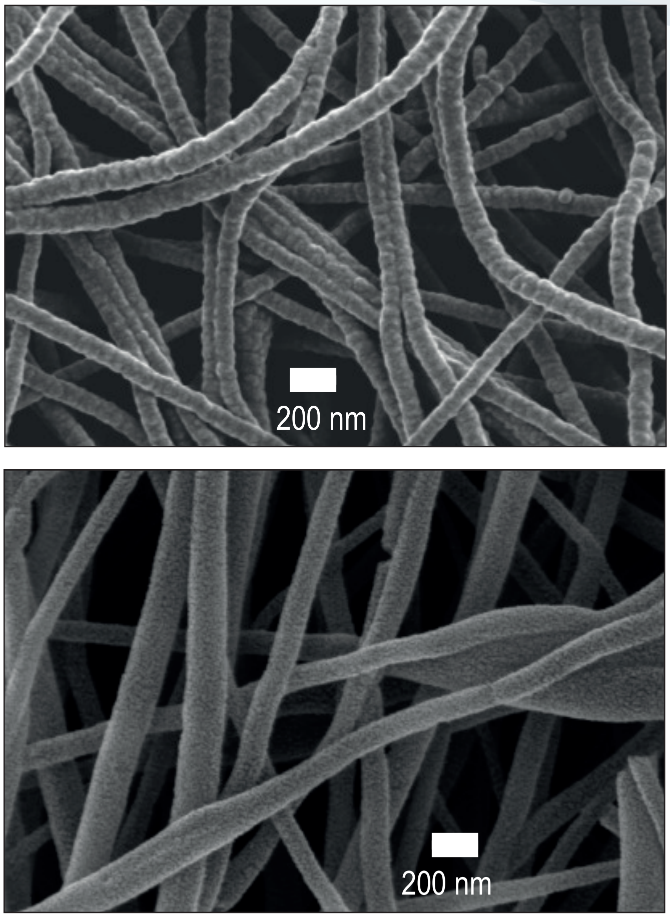
To develop ultra-low Pt loading MEAs using ultra-thin extended film coatings on novel nanostructured supports, and non-PGM catalysts and catalyst layers, to achieve a platinum specific power density of ≤ 0.1 g/kW Pt, providing ≥ 2 kW/l in a short stack, demonstrated for complete MEAs on representative power train profiles.

Technical accomplishment/progress/results

- Technical work in all work packages has commenced, in particular on novel nanofibrous support materials in WP3, novel low Pt deposition studies in WP4 and non-Pt precursor materials in WP5.
- CATAPULT has contributed to the «Harmonisation of Automotive Test Protocols».

Contribution to the programme objectives

2012 Call for proposals
Topic SP1 JTI FCH.2012.1.5: «New catalyst structures and concepts for automotive PEMFCs».
Expected scope of project activities:
The objective ... new catalyst structures and concepts ... reaching the long-term cost and durability targets for PEMFCs in automotive applications. Proposals can include...highly novel catalyst structures having high mass activity and durability, platinum saving approaches or non-precious metal catalysts. Research leading to corrosion resistant catalyst supports should be included. Increase in the temperature of operation should be addressed.... Supporting theoretical modeling efforts to develop of a fundamental understanding of catalytic processes and catalyst support interactions....
...catalyst mass activity of 0.44 A/mg Pt (at 900 mVIR-free) contributing to an MEA power density of ≥ 1.0 W/cm2 at 0.67 V (1.5 A/cm2, single cell) at beginning of life, and ≥ 0.9 W/cm2 at 0.64 V (1.4 A/cm2, single cell) at end of life, key enabling metrics for the platinum specific power density of ≤ 0.1 g/kW Pt, providing ≥ 2kW/l in a short stack, demonstrated for complete MEAs on representative power train profiles including temperature excursions to 120°C.



Continuous Pt films (above) and non-continuous, connected rafts (below) on thin, fibrous supports

Future steps

CATAPULT is in an early stage (M3) and the immediate future steps are to pursue the project plans

Conclusions, major findings and perspectives

CATAPULT only kicked-off in June 2013. If the project reaches its objectives, the potential for commercial exploitation is very high, and it is expected that results will be integrated rapidly into commercial product offerings.

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fuel cells & hydrogen for sustainability

CathCat

Novel Catalyst Materials for the Cathode Side of MEAs Suitable for Transportation Applications

Duration

Start and end date: 1 January 2013 - 31 December 2015

Application area

Transport and refuelling infrastructure

Budget

Total Budget €3,088,327
FCH contribution €1,895,862

Partnership/consortium list

TU München, JRC, Université de Poitiers, DTU, Chalmers UT, University of Padova, Ion Power, Forth Institute, Toyota Motor Europe

Summary/main objectives of the project

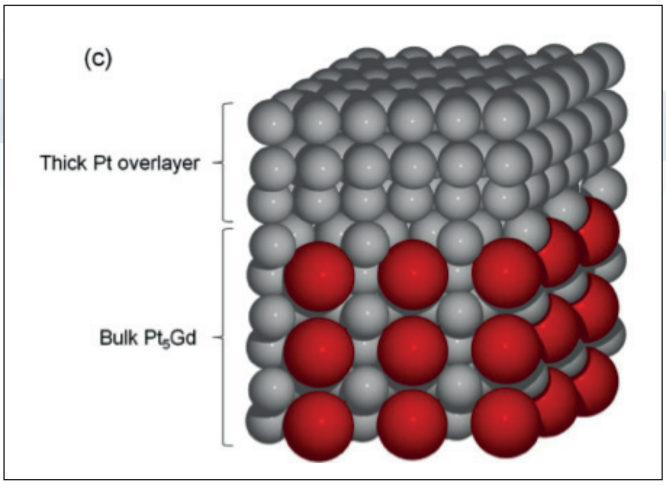
The major objective of Cathcat is to develop improved MEAs for low- and intermediate- temperature PEM, based on binary alloy catalysts with reduced Pt loading for the oxygen reduction reaction (ORR), and advanced carbon and oxide-based support materials.

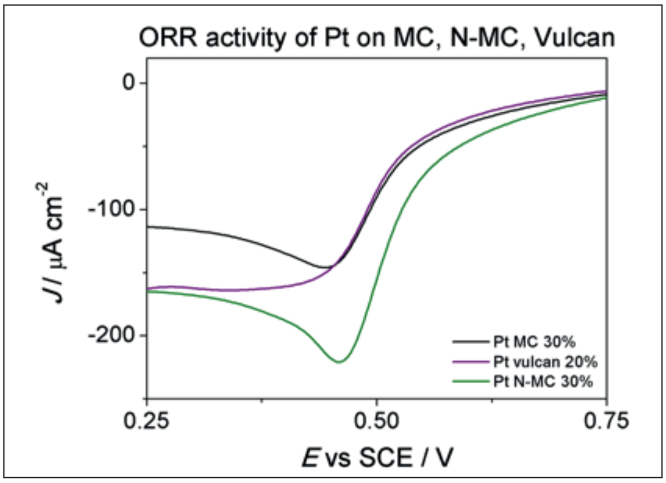
Technical accomplishment/progress/results

Theoretical studies for Pt and Pd alloys regarding activity and stability have been performed; alloys with enhanced activity were identified. Experimental confirmation was obtained for Pt-Gd and other alloys. Nanoparticle synthesis is underway. Experiments on N-doped HOPG and their influence on catalytic activity have been carried out.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Pt loading	<0.15g/kW	<0.1g/kW	-
BOL efficiency	>55%	>55%	-
BOL power	>1 W cm^{-2} @ 1.5 A cm^{-2}	>>1 W cm^{-2} @ 1.5 A cm^{-2}	-
Lifetime	>5,000h	>5,000h	-





Future steps

1. Chemical nanoparticle synthesis
2. MEA fabrication and testing

Conclusions, major findings and perspectives

Several interesting target catalyst compositions have been identified, and computational methods have been developed. First studies on model catalysts and on model support materials have been carried out. Alloy nanoparticle synthesis in underway, followed by MEA fabrication and testing.

CATION

Cathode Subsystem Development and Optimisation

Duration

Start and end date: 1 January 2011 - 30 June 2014

Application area

Stationary power generation and CHP

Budget

Total budget €7,108,505
FCH contribution €2,625,788

Partnership/consortium list

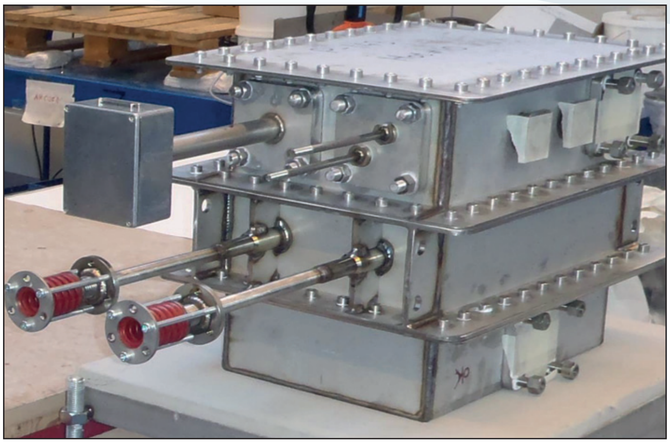
VTT Technical Research Centre of Finland, Wärtsilä Finland Oy, AVL List GmbH, Topsoe Fuel Cells A/S, Bosal Research NV, Centro per lo Sviluppo della Sostenibilità dei Prodotti

Summary/main objectives of the project

The main objectives are to evaluate different process alternatives and find optimal process and mechanical solutions for the cathode and stack subsystems with the aim of having commercially feasible and technologically optimised subsystem solutions ready for future ~ 250 kWe atmospheric SOFC systems. The aspects taken into account in the development are mainly electrical efficiency, controllability, reliability, mass-production and cost-effectiveness of developed subsystems and individual components.

Technical accomplishment/progress/results

- The most important achievements during the first reporting period were the following:
- To provide modeling input for optimal cathode subsystem layout and choosing the best ones for further analysis. (WP1).
- To develop components which are optimal for the cathode subsystem and evaluate their feasibility and manufacturing technologies (WP2).
- To develop a compact and cost-effective stack subsystem solution where the stack/system interface and related solutions are optimised (WP3).
- To design and evaluate the overall cathode subsystem solution which will be developed within this project (WP4).



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Power unit effciency (%)	> 40	> 40	achieved
CHP unit efficiency (%)	> 80	> 80	achieved
FC system life time (h)	> 40,000	40,000	< 40,000
Cost (€/kW) (excl. stacks) Large scale	1,500	1,500 - 2,000	2,000
Cost (€/kW) (excl. stacks) Small scale	3,000	3,000 - 4,000	>> 4,000

Future steps

- Validation testing of designed subsystem solution done by AVL (WP4)
- More efforts and RTD are needed to the final commercial breakthroughs and special attention has to be paid for costs and reliability issues.

Conclusions, major findings and perspectives

As a result from Cation (and ASSENT) project, it can be concluded that with certain additional stack-related development steps a commercially feasible large-scale system (> 250 kWe) having investment cost (excl. stacks) of less than €2,000/kW can be achieved.

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Cation

CHIC

Clean Hydrogen in European Cities

Duration

Start and end date: April 2010 - December 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €81.8 million
FCH contribution €26 million

Partnership/consortium list

10 cities across Europe
16 industrial partners
7 research and consultancy partners

Summary/main objectives of the project

- Implementation of clean urban mobility in five major EU regions through the deployment of 26 hydrogen fuel-cell powered buses and the enlargement of H2 infrastructure systems
- Facilitation of the development of clean urban public transport systems into at least 14 new EU regions
- Collaboration, transfer and securing of significant key learning from previous fuel-cell projects into the CHIC stakeholders
- Greater community understanding of "green" H2 powered fuel-cell buses, leading to increased political acceptance and commitment.

Technical accomplishment/progress/results

- 49 fuel-cell buses are on the road in day-to-day passenger duty
- The vehicles are able to satisfy the daily demands of urban bus routes without returning to the depot
- The high throughput 350 bar H2 stations deployed in the project have performed availabilities over 98% and fill times < 10 min.

Contribution to the programme objectives

Hydrogen Infrastructure Goals	Fuel Cell Bus Goals
• H2 fueling station capacity of 200 kg/day • Average availability of fueling station 98% • Production efficiency for H2 between 50% and 70% • H2 OPEX costs €10/kg	• Fuel cell lifetime greater than 6,000 h • Average availability of all fuel-cell buses greater than 85% • Average fuel consumption less than 13 kg/100 km

Future steps

- Operation of all 26 buses in the "Phase 1 Cities" by the end of 2013
- Completion of the hydrogen infrastructure in the "Phase 1 Cities" by the end of 2013
- Showing reliability and availability of this technology during day-to-day operation
- Dissemination of the project results in workshops for interested "Phase 2 Cities"

Conclusions, major findings and perspectives

The CHIC-Project is a demonstration project where buses from a number of different bus manufacturers are evaluated with different fuel cell suppliers and an appropriate H2 infrastructure. The buses and the hydrogen refuelling stations are integrated in the daily public service to show their reliability, availability and also the possible need of technical improvement. This technology is well accepted by the bus drivers and passengers.

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CHIC

CISTEM

Construction of Improved HT-PEM MEAs and Stacks for Long-Term Stable Modular CHP-Units

Duration

Start and end date: 1 June 2013 - 31 May 2016

Application area

Stationary power generation and CHP

Budget

Budget: €6,097,180
FCH contribution €3,989,723

Partnership/consortium list

Coordinator: NEXT ENERGY, Danish Power Systems, inhouse-engineering, Eisenhuth, CLM, ICTP, ICI Caldaie, Oel- Waerme-Institute

Summary/main objectives of the project

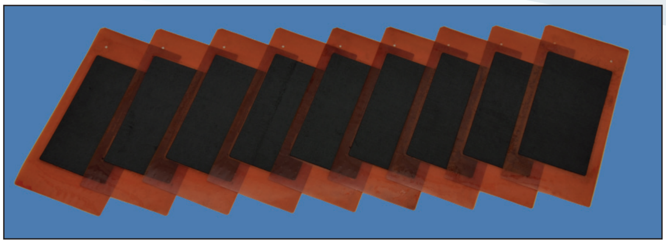
Key issue of CISTEM is the development of long lifetime HT- PEM based 5kW stack modules (reformer included) that are suitable for larger CHP systems up to 100kWel. The modular concept will be investigated in an H-i-L test bench.

Technical accomplishment/progress/results

An efficiency improvement of ~18% has already been achieved with a backpressure increase to 3 bara (at 0.3 A/cm^2). Durability testing is in progress under new operational conditions.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Modularity 5 to 100 kW	Operational CHP unit	10kW in H-i-L bench	Design in progress
Lifetime (h)	> 20,000	Up to 40,000	N/A (ASTs not finalised)
Efficiency (%)	> 40	> 45	N/A (tests in progress)
Increase of operational hours	-	>8,000	Simulations in progress



Large Area MEAs for HT-PEM Stacks

Future steps

1. Manufacture 200 cm^2 MEAs
2. Construction of 5kW HT-PEM stacks and CHP
3. Testing of new materials for HT-PEMFCs
4. Investigate operational scenarios for CHP unit

Conclusions, major findings and perspectives

Project progress is currently on time. Efficiency targets seem to be achievable but need further investigation. HT-PEM stack durability under new operational conditions will be the key question to be answered within the next project periods. Modular stack design will improve flexibility for CHP customers and increase annual operating hours.

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CISTEM

CoMETHy

Compact Multifuel Energy-to-Hydrogen Converter

Duration

Start and end date: 1 December 2011 - 30 November 2014

Application area

Hydrogen production and distribution

Budget

Total budget €4,927,884
FCH contribution €2,484,095

Partnership/consortium list

ENEA (Coordinator, Italy), Processi Innovativi Srl. (Italy), Acktar Ltd. (Israel), Technion (Israel), Fraunhofer IKTS (Germany), University of Salerno (Italy), CERTH (Greece), Aristotle University of Thessaloniki (Greece), University "La Sapienza" (Italy), ECN (the Netherlands), GKN Sinter Metals Engineering GmbH (Germany), University "Campus Bio-medico" of Rome (Italy)

Summary/main objectives of the project

Development of a flexible membrane reformer operating at "low temperatures" (<550°C) to convert different fuels (methane, ethanol, etc.) and adaptable to different heat sources (solar, biomass, fossil, etc.), using molten salts as heating fluid.

Technical accomplishment/progress/results

Advanced catalysts for methane/biogas and ethanol steam reforming at 400-550°C have been developed, with satisfactory catalytic performance, enhanced heat transfer and low pressure drops. Suitable Pd-based hydrogen selective membranes have also been identified. Starting from these basic components, innovative membrane reformer concepts have been designed, to be experimentally tested and evaluated in the coming months.

Contribution to the programme objectives

FCH JU implementation plan objective	CoMETHy project objective/solution
Up to 50% of the H_2 energy from renewable sources (RES), decarbonisation of transport, CO_2 lean/free H_2	CoMETHy solar steam methane reforming allows CO_2 reduction rate by > 40%
Combine carbon capture and storage and distributed production from RES	CCS is enhanced with CoMETHy membrane reformer
High-performance materials (e.g. membranes), reactor compactness, centralised (CCS-ready) efficiency > 72%, decentralised biogas SMR efficiency > 67%	High efficiency for centralised/decentralised hydrogen production achievable with CoMETHy compact reformer
Distributed plants taking advantage of locally available sources	CoMETHy technology has twofold flexibility: primary feedstock and external heat source
Reforming catalysts with shift activity to reduce CO concentration below 10 vol% to reduce shift catalyst quantity	Outlet CO content < 5 vol% is already achieved with the developed catalyst system

Conclusions, major findings and perspectives

The promising results obtained on catalyst and membrane development/selection, and on reactor design, will support the pilot and bench proof-of-concept of the CoMETHy reformer during the next year.

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CoMETHy

COPERNIC

Cost & Performances Improvement for CGH2 Composite Tanks

Duration

Start and end date: June 2013 - May 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €3.4 million
FCH contribution €2 million

Partnership/consortium list

Coordinator: CEA
An interdisciplinary team of European research institutes (CEA, WRUT) and industrials (SFC, RAIGI, SSA, GHR, H2Logic) with strong expertise in material and pressure component design, manufacturing processes, numerical modeling, FCEV integration, and H2 refilling.

Summary/main objectives of the project

- Increasing the maturity and competitiveness of innovative CGH2 manufacturing processes evolving from classical automotive manufacturing technologies or concepts.
- Decreasing costs while improving composite quality and/or manufacturing productivity using optimised composite design, materials and components.
- All-in-one innovative high-pressure on-tank valve development and certification (benchmark, price and normative requirement analysis)

Technical accomplishment/progress/results

- First tanks market survey (benchmark, price and normative requirement analysis)
- First set of performances, durability and cost targets defined
- First set of enhanced material and reference tank design have been identified
- First comparative assessment of conventional vs robot-assisted filament winding equipment started
- First protocol evaluation in progress

Future steps

- Final performances, durability & cost specifications
- Progress on enhanced material characterisation
- Tanks using selected enhanced materials & designs
- Pressure component definition
- Multi-scale modeling of composite lay-ups
- Conception and Modeling of optimised tanks

Contribution to the programme objectives

	State-of-the-art	Expected progress
Enhanced materials	• Toray carbon T700 Epoxy resin • Metal insert SS or Al	• Performance/cost efficient design using innovative materials and design • Decrease cost of inserts by 5
Optimised composite design	• Bottle geometries • Non representative modeling for thick composite	• Quantification of ultimate accessible performance on model cylinders • Improved composite design (target 15% weight carbon fibre saving)
Manufacturing process	• Wet winding • High human operation Perf. variability • Environmental Issues	• Highly repeatable automated winding • Increase quality, consistency and productivity • Quantify wet winding/ repreg winding performance and cost achievements
Tank components	• Std proprietary valve • Separate P regulators HP piping	• Innovative all-in-one compact lightweight pressure device • No high-pressure piping, pressure outlet 10bar
Structural health monitoring	• Not existing or on devpmt • Normative destructive testing	• Develop and embed/ integrate OFS strain transducers to monitor on/ off board the integrity of high pressure composite cylinders
Test method	• R79/2009 (EC406/2010)	• Contribution to the advancement of relevant test methods by generation of accurate data

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COPERNIC

D-CODE

DC/DC COnverter-Based Diagnostics for PEM Systems

Duration

Start and end date: 1 March 2011 - 28 February 2014

Application area

Stationary Power Generation and CHP

Budget

Total budget €2,215,000
FCH contribution €1,173,000

Partnership/consortium list

University of Salerno (I) Univ.; European Inst. For Energy Research (D) Res.; Université de Franche-Comté (F) Univ.; Dantherm Power A/S (Dk) SME; CIRTEM (F) SME; Bitron S.p.A (I) Ind; Inno TSD (F) SME.

Summary/main objectives of the project

- Transpose electrochemical impedance spectroscopy from lab scale to on-field applications for PEM FC.
- Perform EIS-based on-board monitoring and diagnosis of low & high temperature PEM FC (1-2).
- Develop a DC/DC converter to measure the stack impedance spectrum on-board.

Technical accomplishment/progress/results

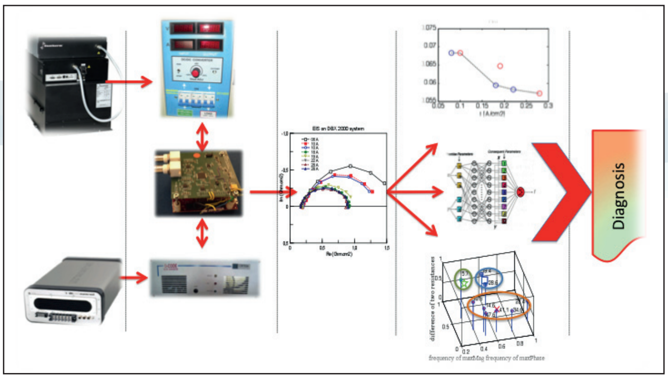
- Two converters (low & high voltage, 3-4) for EIS spectrum measurement have been manufactured.
- One electronic board has been built and tested to drive the converters for EIS measurement (5).
- More than 350 spectra have been collected (6).
- Three diagnosis algorithms (RLC circuit model, Fuzzy, Neuro-Fuzzy) have been developed and tested (7-9).

Future steps

1. Customise and optimise HW and algorithms.
2. On-field testing of several FCs with EIS.
3. Improve/adapt control strategies.
4. Industrial exploitation of project outcomes.
5. Apply the D-CODE concept to SOFC.

Conclusions, major findings and perspectives

The results obtained confirmed the possibility to perform the EIS on-field. Status detection of PEM FC is possible via dedicated algorithms, which are potentially applicable to other FC technologies.
Many challenging problems have been faced and a deep experience has been consolidated on components (EIS board, converters), algorithms (parameters identifications, model generalisation) and hardware integration.



Contribution to the programme objectives

Topic 2009.3.3: Operation diagnostics and control for stationary power applications

Objectives of the call	Objectives of the project
Effective control of stationary FC stacks for optimum operation	Stack status knowledge (EIS) may improve control via feedback
Better understanding of critical operating conditions	On-line EIS carries meaningful information on cell electrochemistry
Utilisation of diagnostic techniques to reveal potential failures	Diagnostic algorithms can detect and isolate faults from EIS
Optimise run parameters and recovery methods in stacks and FC-units	Use actual FC state information for control adaptation and recovery

DeliverHy

Optimisation of Transport Solutions for Compressed Hydrogen

Duration

Start and end date: 1 January 2012 - 31 December 2013

Application area

Hydrogen production and distribution

Budget

Total budget €1,247,773
FCH contribution €719,501

Partnership/consortium list

Ludwig-Bölkow-Systemtechnik GmbH, Air Liquide Advanced Business, CCS Global Group, H2 Logic A/S, Raufoss Fuel Systems, Norwegian University of Science and Technology.

Summary/main objectives of the project

- Evaluation of safety and cost-related effects caused by the introduction of composite materials trailers
- Safety factors for well-built pressure vessels can be reduced compared to current requirements while maintaining adequate risk levels
- Identification and rationale of needed changes in regulations, codes & standards (RCS) and preparation of an action plan
- Initiation of a dialogue with selected national authorities about these changes

Technical accomplishment/progress/results

Delivery frequencies of CGH_2 truck trailers can be reduced threefold, transport related CO_2 emissions can drop by 75% and delivery costs for new CGH_2 trailers are competitive with LH_2 delivery costs

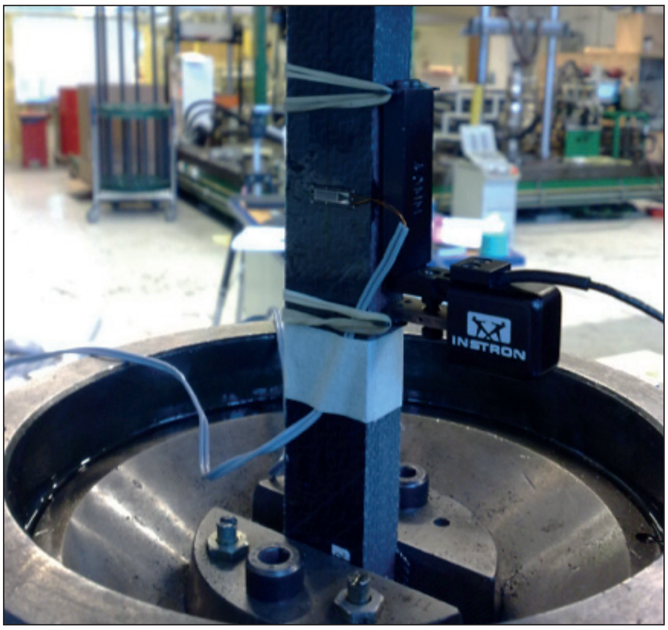
Contribution to the programme objectives

- Assessment of safety implications using composite material and higher storage pressure
- Comparison of state-of-the-art 20 MPa infrastructure with 40 MPa+ equipment in order to determine strengths/weaknesses of 40 MPa+ truck delivery technology
- Assessment of technical and cost issues for such trailers including impact on energy efficiency and GHG emissions
- Identification of issues regarding RCS and way-forward for facilitating the use of high-pressure trucks

Future steps

To improve the chance of better uptake in the market, to explore a better understanding and approach, on the basis of testing (RTD) to back up the scientific principles described by DeliverHy could be the subject of further study.

Conclusions, major findings and perspectives



DeliverHy will have been successful, when probabilistic qualification approaches as described in DeliverHy are implemented into international RCS. This can be between 2-3 years after substantiated recommendations from the DeliverHy project have been published.

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DeliverHy

DEMMEA

Understanding the Degradation Mechanisms of Membrane-Electrode-Assembly for High-Temperature PEMFCs and Optimisation of the Individual Components

Duration

Start and end date: 1 January 2010 - 31 December 2012

Application area

Stationary power generation and CHP

Budget

Total budget €3,189,918
FCH contribution €1,638,986

Partnership/consortium list

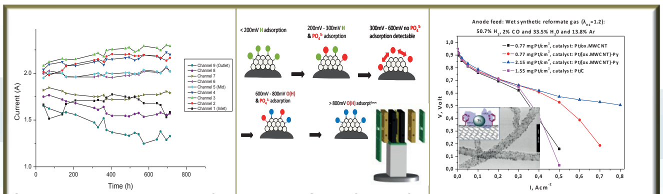
Coordinator: Advent Technologies S.A., Greece
Partners: Institute of Chemical Engineering Sciences (Greece), Paul Scherrer Institute (Switzerland), Centre National de la Recherché Scientifique (France), FUMATECH GmbH (Germany), Institute of Chemical Technology Prague (Czech Republic), Next Energy - EWE- Forschungszentrum fur Energietechnologie e.V. (Germany), Technical University of Darmstadt (Germany)

Summary/main objectives of the project

The objective of the DEMMEA project was to understand the functional operation and degradation mechanisms of a high-temperature H_3PO_4 imbibed PEM and its electrochemical interface. This can enable the tailor-made optimisation of the MEA into a commercially reliable product for stack manufacturers. The milestone of the project was the combined use of advanced experimental techniques that can lead to the development of prediction tools for performance and stability

Technical accomplishment/progress/results

Some failure mechanisms of the current technology MEAs were identified using a series of ex-situ and in-situ experimental techniques including techniques adopted for the first time for this purpose, i.e. in situ XANES and APPES spectroscopy and HT segmented cell.



Segmented cell - The degradation of the outlet segments can be observed | In situ XANES- Identification of Pt coverage | The new developed electrocatalyst can operate under harsh reformate conditions

Conclusions, major findings and perspectives

- Improved high-temperature polymer electrolytes were prepared and successfully tested.
- By means of in-situ spectroscopy, Pt coverage from H_2, PO_4- and O(H) species was identified.
- The HT segmented cell helped to identify the most vulnerable parts of the MEA.
- A mathematical model was developed describing the degradation in terms of Pt dissolution and dispersion within the membrane.
- Above 0,7 V at 0,2 A/cm^2 for H_2/O_2 feed at 180°C was achieved.
- The severe degradation of the anode under harsh reformate conditions (low H_2<50% and high H_2O>20% content) was studied.
- Novel electrode structures were developed in order to overcome certain limitations as well as increase the catalyst utilisation that result in reduced Pt loads on the electrodes. The catalysts were successfully tested depicting high performance and possibility to operate under harsh reformate conditions.

DeMStack

Understanding the Degradation Mechanisms of a High-Temperature PEMFC Stack and Optimisation of the Individual Components

Duration

Start and end date: 1 May 2013 - 30 April 2016

Application area

Stationary power generation and CHP

Budget

Total budget €2,576,615
FCH contribution €1,495,680

Partnership/consortium list

Coordinator: Institute of Chemical Engineering Sciences (Greece).
Partners: Fundación CIDETEC (Spain), Institute of Chemical Technology Prague (Czech Republic), Advent Technologies S.A. (Greece), Joint Research Centre, Institute for Energy (Belgium), Helbio S.A. (Greece) and Prototech AS (Norway)

Summary/main objectives of the project

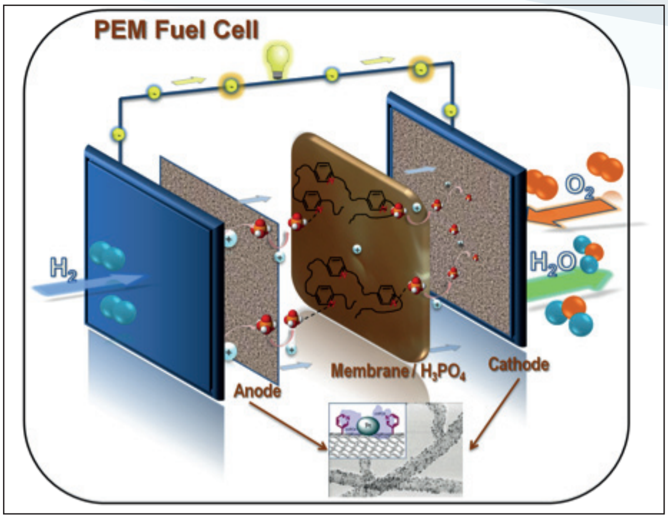
The activities of DeMStack will be on the stack optimisation and construction based on the high temperature MEA technology of Advent S.A. and its long-term stability testing in combination with a fuel processor. The aim is to enhance the lifetime and reduce the cost of the HT PEMFC technology.

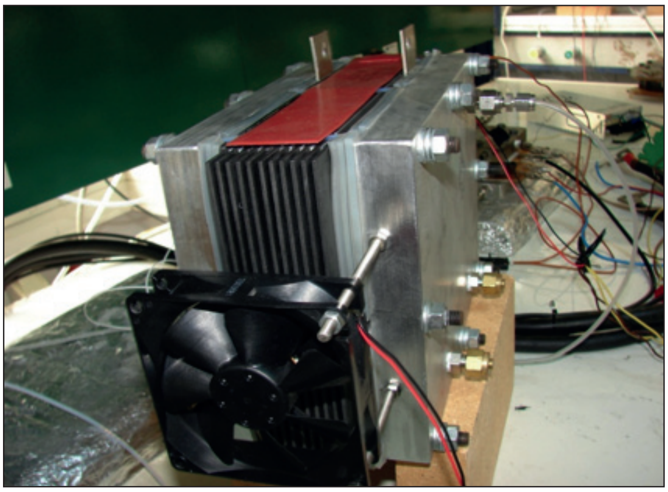
Technical accomplishment/progress/results

Scaling up of the component materials of the MEAs (PEMS and electrocatalysts) and design of the bipolar plates are attempted

Future steps

DeMStack aims at a wider temperature operating window (160-200°C) through the incorporation and optimisation of the most promising, efficient, robust materials and architectures for the challenging components of the stack: the high temperature polymer electrolyte, the catalytic layers as well as the bipolar plates and stack design.





Conclusions, major findings and perspectives

DeMStack project will work towards the construction of a HT PEMFC prototype stack with the following operating features.

1. Power of 0.2 W/cm2 at 0.65 V (single cell).
2. Specific (0.1 kW/kg) and volumetric (100 kW/m3) power density.
3. Operation over a wide range of reformates.
4. Overall cost reduction by a factor of 2 (reduction of the MEA's cost due to the lower Pt loading and the cheaper membranes).

The successful implementation of the DeMStack product into the hydrogen existing and future infrastructure will open new perspectives in fuel cell technology, a fact that will contribute to the objectives of the European Platform to gain world leadership and offer substantial scientific, economic, energy and environmental benefits.

DESIGN

Degradation Signature Identification for Stack Operation Diagnostic

Duration

Start and end date: January 2011 - December 2013

Application area

Stationary power generation and CHP

Budget

Total budget €3,266,000
FCH contribution €1,746,000

Partnership/consortium list

CEA Coordinator	France	R&D
VTT	Finland	R&D
Eifer	Germany	R&D
UNISA	Italy	University
EPFL	Switzerland	University
HFCS	Netherlands	Industry/SME
HTc	Switzerland	Industry/SME
EBZ	Germany	Industry/SME

Summary/main objectives of the project

DESIGN objective is to provide a sound diagnostic method for insidious phenomena that slowly accelerate the degradation at the stack level, through the understanding of the local responses of sub-stack elements.

- Identification of specific signatures at the local cell/SRU/small stack level
- Transposition from local signatures to full stack with limited instrumentation

Technical accomplishment/progress/results

- Focus on high fuel utilisation fault in hydrogen and reformate
- Development of data analysis method
- Identification of signature mechanisms
- Recommendations for operation recovery, once a degradation condition is identified at the cell, SRU or stack level

Contribution to the programme objectives

	Objectives of thecall	Objectives of the project	Current status
Lifetime	up to 40,000h	Early detection of identified degradation mechanisms	Degradation signature identified
	Improved prediction and avoidance of failure mechanisms	Early detection to allow minimising degradation by optimising system operating parameters	Validated for high fuel utilisation fault
Competitiveness versus other technologies	Development of strategies for recovery of cell and stack performance	Recommendations for recovery strategies	In progress: cell and stack level
Fuel	Use of multiple fuels	Hydrogen and reformate	Done in hydrogen, almost finished in reformate

Future steps

- At this stage most of the project objectives have been achieved at cell and short-stack level
- Next step is validation of tools and methodology at larger stack and at system level

Conclusions, major findings and perspectives

An original methodology has been developed based on identification of signatures and data analysis of cell/stack operation upon specific defaults in particular high fuel utilisation, in hydrogen and reformate. Impact of these defaults on performances and durability has been studied and recovery strategy has been proposed and experimented.
This methodology has to be validated at larger stack and system level and could be experimented for other type of faults.
Papers have been published and patenting process is in progress. Follow up projects will be beneficial to confirm the potential of the methodology.

DESTA

Demonstration of First European SOFC Truck APU

Duration

Start and end date: 1 January 2012 - 31 December 2014

Application area

Transport and refuelling infrastructure

Budget

Total budget €9,841,007
FCH contribution €3,874,272

Partnership/consortium list

AVL List GmbH, Eberspächer Climate Control Systems GmbH & Co KG, Topsoe Fuel Cell A/S, Volvo Technology AB, Forschungszentrum Jülich

Summary/main objectives of the project

Demonstration of the first European SOFC APU on a Volvo HD truck, one-year testing of six APU systems (3 of Eberspächer and 3 of AVL); development and assembly of the final DESTA SOFC APU system, merging the most promising approaches of AVL and Eberspächer SOFC APU concepts; significant improvements of SOFC stacks operated on diesel fuel

Technical accomplishment/progress/results

Requirement specification for truck application performed, ongoing optimisation and testing of Eberspächer and AVL systems, electrical efficiency of 30% and net power of 3kW reached, significant stack improvements, benchmark result available, packaging size reduction for truck integration

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Electric System Efficiency	35%	35%	30%
Anticipated lifetime	> 20,000	> 10,000	N/A (test not finalised)
Emission reduction	Less than current	75%	N/A (test not finalised)

Future steps

1 – Build-up of optimised SOFC-APU for truck integration
2 – Ongoing system tests incl. vibration & salt spray
3 – Truck integration and testing

Conclusions, major findings and perspectives

So far very promising results during the tests of six APU systems have been achieved. Major breakthroughs towards operation on sulfur containing US diesel fuel and packaging size have been reached. Operation of SOFC APUs for a few 1,000 hours with high efficiency on real diesel fuel has been shown. Based on the progress of the project and the results achieved so far, the consortium is confidently looking forward to the truck integration scheduled for 2nd half of 2014

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DESTA

Don Quichote

Demonstration of New Qualitative Innovative Concept for Hydrogen out of Wind Turbine Electricity

Duration

Start and end date: October 2012 - October 2017

Application area

Hydrogen production and storage

Budget

Total budget €4,946,134
FCH contribution €2,954,846

Partnership/consortium list

Etablissementen Franz Colruyt NV, FAST- Federazione Delle Associazioni Scientifiche e Tecniche, Hydrogenics Europe NV, Hydrogen Efficiency Technologies (HYET) BV, Icelandic New Energy Ltd, European Commission (JRC), PE International, TUV Rheinland Industrie Service GmbH, WaterstofNet vzw.

Summary/main objectives of the project

- Demonstrate the technical and economical viability of hydrogen as large-scale renewable energy storage solution
- Connection to a refuelling facility to investigate the commercial opportunity connecting intermittent renewable electricity to transport applications
- Grid balancing using a fuel-cell system
- Demonstrate and validate the technology readiness
- Generate facts-based data for the exploitation of RE to H2.

Technical accomplishment/progress/results

- The project is in its development stage.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Efficiency	> 55%	> 58%	N/A (test not finalised)
Cost of H_2 delivered	ST: < €15/kg LT: €7/kg	ST: < €13/kg LT: < €7/kg	N/A (test not finalised)
H_2 production turnkey CAPEX	€3.5m	< €3.5m	N/A (test not finalised)
H_2 quality	ISO/DIS 14786-2 Compliant <12		N/A (test not finalised)
Availability	> 95%	> 95%	N/A (test not finalised)
Operation within the project	25,000 hours	> 25,000 hours	N/A (test not finalised)
Expected durability	> 10 years	> 10 years	N/A (test not finalised)

Future steps

- Phase 1 (until M18): testing of existing already installed technology (alkaline electrolyser, mechanical compressor, storage and forklifts)
- Phase 2 (until M36): research, develop and build a new generation PEM electrolyser + storage + PEM fuel-cell + testing of entire system
- Phase 3 (until M57): research, develop and build a new electrochemical compressor, expansion system + testing of entire system

Conclusions, major findings and perspectives

The project is in its development stage.

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DON QUICHOTE

DURAMET

Improved Durability and Cost-Effective Components for New-Generation Solid Polymer Electrolyte Direct Methanol Fuel Cells

Duration

Start and end date: 1 December 2011 - 30 November 2014

Application area

Early markets

Budget

Total budget €2,956,874
FCH contribution €1,496,617

Partnership/consortium list

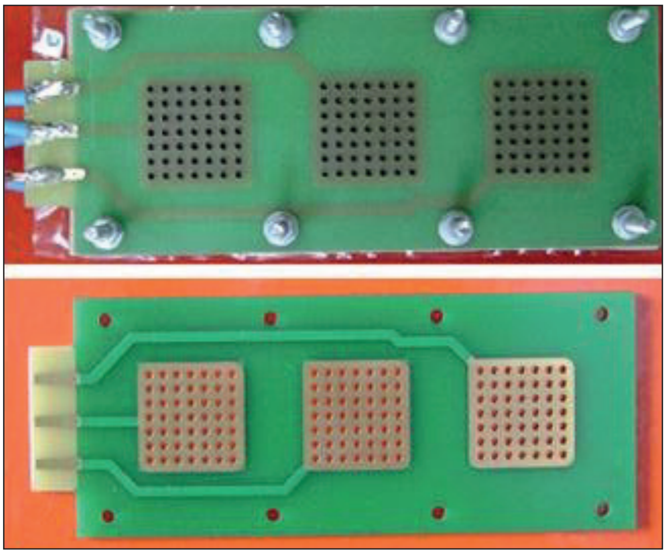
Coordinator A.S. Aricò (CNR-ITAE Messina, Italy)
CNR-ITAE, CNRS, FUMA-TECH, CRF, TUM, IRD, POLITO, PRETEXO, JRC-IET.

Summary/main objectives of the project

The clear focus of the project is on the demonstration of the enhanced performance and durability of newly-developed or optimised DMFC components, i.e. catalysts, membranes and MEAs, in single cells and in appropriate short stacks under practical operation.

Technical accomplishment/progress/results

Cost-effective membranes with improved conductivity and reduced methanol cross-over have been developed. The focus was also on the reduction of total noble metal loading. Novel materials have been assessed in MEA showing performances approaching project targets. Two types of stacks have been designed for portable and APU applications (http://www.duramet.eu).



Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current status
Proof-of-concept on the component level	Membrane conductivity > 50 mS/cm & MeOH cross-over lower < 5 mA cm^{-2}	Proton Conductivity ~ 50-70 $mScm^{-1}$ at 60 °C & cross-over 6-20 mA cm^{-2}
New components for DMFCs with improved durability, efficiency	Performance > 50-250mW cm^{-2} for LT, HT operation; Degradation: two times < benchmark MEAs	Performance > 70-210mW cm^{-2} LT, HT operation; N/A
Integration in at least one DMFC stack solution	Validation in short stacks (150W active, and 1W passive mode); 500 hrs durability test	Passive mode stack operation validated; N/A
New components for DMFCs with superior cost efficiency	PGM loading < 0.5-1 mg cm^{-2}; Novel hydrocarbon membranes	PGM loading < 0.5-1 mg cm^{-2}; polysulfone, PEEK membranes

Future steps

1. Scaling-up of the newly developed components
2. Validation of components in DMFC stacks
3. Dissemination of the project results
4. Exploitation of the project results

Conclusions, major findings and perspectives

The DMFCs devices developed in the project are amenable to be integrated in auxiliary power units, for portable powers sources and in general for applications related to energy supply systems for micro-distributed and remote generation.
The novel materials show promising properties in terms of cost reduction and increase of durability.

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DURAMET Methanol fuel Cells

EDEN

High Energy Density Mg-Based metal hydrides storage system

Duration

Start and end date: 1 October 2012 - 30 September 2015

Application area

Hydrogen Production, Distribution and Storage

Budget

Total budget: €2,653,574
FCH Contribution: €1,524,900

Partnership/consortium list

Fondazione Bruno Kessler, project coordinator (Italy), MBN Nanomaterialia SpA (Italy), Cidete Ingenieros SL (Spain), MATRES Scrl (Italy), PANCO GmbH (Germany), Universidad de la Laguna (Spain), Joint Research Centre – Institute for Energy and Transport

Summary/main objectives of the project

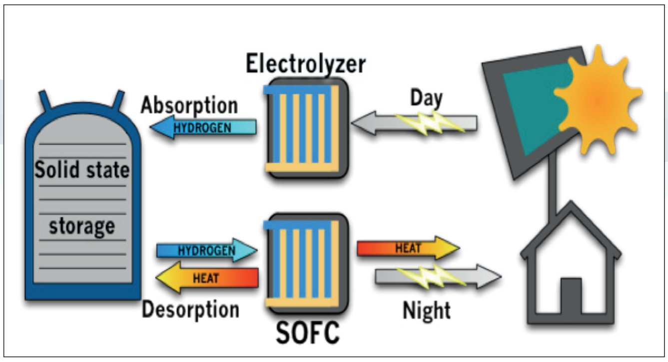
EDEN is developing an integrated system for stationary solid state H2 storage realised through: 1) an optimised fast reacting Mg-based hydride, 2) a newly designed tank with 3) full thermal and hydrogen management in connection and integration with a SOFC.

Technical accomplishment/progress/results

The development of basic Mg-based material has been realised. The modeling tool for the design of the tank is going to be validated. The major elements for system integration have been identified, comprised of components for thermal exchange and hydrogen management and fuel-cell system (SOFC).

Future Steps:

1 – Finalise the design and realisation of the tank
2 – Obtain catalyst addition on MgH2 powders directly with PVD deposition technique to enhance reaction kinetics
3 – Design thermal and hydrogen management for tank-SOFC coupling
4 – Realise the full system and run demonstration activities



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Hydrogen storage capacity	>6% w	>6% w	6,8% w
System storage capacity	>4% w	4% w	N/A (test not finalised)
Compatibility with FC systems	Any FC	SOFC	confirmed
Long term run cost	<500€/kg	300€/kg	N/A (test not finalised)

Conclusions, major findings and perspectives

EDEN is in line with indicated objectives. After one year, most part of the subcomponents to be developed and realised have been designed or identified. The storage-FC system has been designed to fully manage intermittent and variable sources towards end-user demand management. The project has a real perspective to realise a small-to-medium scale system to allow a wide penetration of distributed energy generation.

Electra

High-Temperature Electrolyser with Novel Proton Ceramic Modules of Superior Efficiency, Robustness and Lifetime Economy

Duration

Start and end date: 1 March 2014 - 28 February 2017

Application area

Hydrogen production and storage

Budget

Total budget €3,790,000
FCH contribution €2,240,000

Partnership/consortium list

Coordinator: University of Oslo
Partners: SINTEF, UP Valencia ITQ CSIC, Marion Technology, Protia AS, Abengoa Hidrogeno SA, Carbon Recycling International

Summary/main objectives of the project

The main objective of ELECTRA is to develop scalable fabrication of robust tubular HTE cells with proton conducting electrolytes. The tubular cells will be assembled in a multi-tube module to produce pure dry pressurised H2 more efficiently than competing technologies. The cells will operate at temperatures up to 600°C in steam electrolysis mode to promote efficient integration of the electrolyser in geothermal and solar heat power plants. ELECTRA will also perform proof-of-concept test of CO2 and steam co-electrolysis enabling novel system concepts for economic production of DME.

Technical accomplishment/progress/results

The project will start in March 2014.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Cells with high current	> 1 $A.cm^{-2}$	1 $A.cm^{-2}$	-
Cells with low degradation rate	< 1% per 1,000 hrs	< 1% per 1,000 hrs	-
Lifetime (years)	> 5	> 5	-
Total efficiency of integrated process	85-95%	> 85	-

Conclusions, major findings and perspectives

None at present. The project starts in March 2014

ELECTROHYPEM

Improved Durability and Cost-Effective Components for New Generation Solid Polymer Electrolyte Direct Methanol Fuel Cells

Duration

Start and end date: 1 July 2012 - 30 June 2015

Application area

Early markets

Budget

Total budget €2,842,312
FCH contribution €1,352,771

Partnership/consortium list

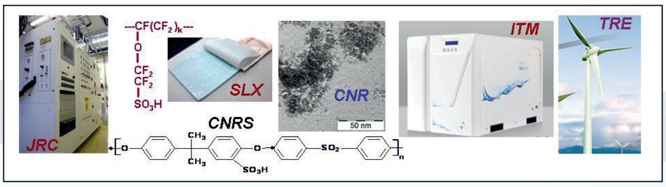
CNR-ITAE, JRC-IET, CNRS, SSPI-SLX, ITM, TRE.
Coordinator A.S. Aricò (CNR-ITAE Messina, Italy)

Summary/main objectives of the project

The project deals with cost-effective and enhanced durability components for PEM electrolysers amenable to be integrated with renewable energy sources. The approaches are oriented towards both short- and long-term innovation. (http://www.electrohypem.eu).

Technical accomplishment/progress/results

Novel chemically stabilised ionomers and hydrocarbon membranes and improved cost-effective electrocatalysts have been developed. These components are validated in a PEM electrolyser prototype. The stack is integrated in a system and assessed in terms of durability in the presence of current profiles simulating intermittent operation of a renewable power source.



Contribution to the programme objectives

Objectives Of the call	Objectives of the project	Current status
hydrogen production capacity > 1 Nm^3/h	Rated capacity > 1 Nm^3/h	Small laboratory prototypes tested
Efficiency of 75% (LHV)	Energy consumption < 4 kWh/Nm^3 H at 1 Nm^3 h^{-1}	Voltage efficiency vs. thermoneutral potential 86% at 1 A cm^{-2}
Voltage increase < 15 μV/h at constant load	Voltage increase < 15 μV/h at 1 A cm^{-2}	Oxide supported catalysts with high resilience to corrosion prepared; N/A
Stack cost <€2,500/Nm^3 H_2 in series production	Stack cost << €2,500 /Nm^3 H_2	Low-cost membranes and low PGM content electrocatalysts produced; N/A

Future steps

1. Scaling-up of the newly develop components
2. Validation of components in PEMWE stacks and systems in combination with RES
3. Dissemination of the project results
4. Exploitation of the project results

Conclusions, major findings and perspectives

The project addresses the development of PEM electrolysers based on innovative components for residential applications with the perspective of a suitable integration with renewable power sources. Promising results in terms of performance and durability have been achieved and preliminary tests on the stack/system and renewable power sources have been initiated.

ELYGRID

Improvements to Integrate High-Pressure Alkaline Electrolysers for Electricity/H2 Production from Renewable Energies to Balance the Grid

Duration

Start and end date:
1 November 2011 - 31 October 2014

Application area

Hydrogen production and distribution

Budget

Total budget €3,752,760
FCH Contribution €2,105,017

Partnership/consortium list

Coordinator: Foundation for Hydrogen in Aragon (FHA). Partners: Industrie Haute Technologie (IHT), Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA), AREVA Stockage Energie SAS (AREVA), Forschungszentrum Jülich GmbH (FZJ), Vlaamse Instelling voor Technologisch Onderzoek N.V. (VITO), Lapesa Grupo Empresarial, Instrumentación y Componentes, S.A. (INYCOM or I&C), INGETEAM Power Technology S.A., Commissariat à l'energie atomique et aux energies alternatives (CEA).

Summary/main objectives of the project

ELYGRID project aims at contributing to the reduction of the total cost of hydrogen produced via electrolysis coupled to RES, mainly wind turbines, and focusing on megawatt-size electrolyses (from 0.5MW and up).

Technical accomplishment/progress/results

- New membranes development: different materials have been tested under several conditions (corrosion experiments, ionic resistance, bubble point, water permeability, U/I curves). Tests at lab scale (30-130 mm) in order to select the best materials.
- Power electronics: new unit developed in order to work properly coupled to renewable energies
- BoP: mechanical redesign, cost reduction, new control system and improvements in safety and maintenance operations
- Field testing: real scale tests (1,600 mm) have started at FHA facilities

Figure: Electrolyser of IHT at FHA facilities

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
unit capacity (Ton/d)	3 (2020)	>3	3.5 (last value obtained)
Efficiency (70%)	70 (2020)	>85	≈75 (last value obtained)
Cost (M€/(T/d))	1.9 (2020)	25% CAPEX reduction	M36 (end project)
Field trials with RES>25kW	1 demo	Demo at FHA (70kW)	In progress

Conclusions, major findings and perspectives

The consortium has a well oriented market approach and therefore if the project achieves the goals described, the results could be exploited in short-term or when the market grows up. Specially, it is important to remark that if a free asbestos membrane is found suitable during the project, IHT can produce big electrolysers with high production capacities at 33 bar. These big units are not available in the market and they could have a significant impact if the P2G applications continue growing up.

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ELYGRID

ene.field

Europe-Wide Field Trials for Residential Fuel-Cell Micro-CHP

Duration

Start and end date: September 2012 - September 2017

Application area

Stationary power generation and CHP

Budget

Total budget €53 million
FCH contribution €26 million

Partnership/consortium list

The European Association for the promotion of Cogeneration (COGEN Europe), Belgium (Coordinator), Baxi Innotech, Bosch Thermotechnik, Ceres Power Limited, Dantherm Power, Elcore, Hexis , Riesaer Brennstoffzellentechnik (RBZ), SOFCpower, Vaillant, Dolomiti Energia, British Gas, Element Energy, GDF SUEZ, ITHO Daalderop, Hydrogen, Fuel Cells and Electro-mobility in European Regions (HyER), Imperial College of Science, Technology and Medicine, Development Centre for Hydrogen Technologies (DCHT), Parco scientifico e tecnologico per L'ambiente - ENVIRONMENT PARK , Politecnico di Torino, DBI Gastechnologisches Institut (DBI-GTI), Energy Saving Trust (EST), Gas- und Wärme-Institut Essen (GWI), Danmarks Tekniske Universitet (DTU), European Institute for Energy Research (EIFER), DONG Energy.

Summary/main objectives of the project

Ene.field will deploy up to 1,000 residential fuel cell micro-CHP installations, across 12 key Member States, and bring nine European micro FC-CHP manufacturers into a common analysis framework to deliver trials across all major micro FC-CHP technologies. This represents a change in the volume of fuel-cell micro-CHP deployment in Europe and a meaningful step towards the commercialisation of the technology.

Technical accomplishment/progress/results

- The field trials started in September 2013
- The first two micro fuel cell-based combined heat and power units were installed in Germany
- Information packs for householders in 12 different languages
- First regional workshop in Spain in September 2013
- Field support report of the state of the art with regard to field support arrangements, training and certification
- Tracking system for trials in place
- Utility working group established
- Regulations codes and standards working group established

Contribution to the programme objectives

	JTI Target	Current State of the Art**	ene.field expected performance
Technical targets for FC CHP	Efficiency minimum of 35% (electrical)	30%	The products will meet and exceed the targets with a range of 35–50% electrical efficiency
	Overall efficiency >85% (LHV)	70–85%	Up to 90%
	Lifetimes of 8-10 years	3 years	Up to 8 years
	Cost below €20,000/unit (Assumed to refer to the capital cost of the system per kWe)	€50,000/kW	€13,000-€27,000/kW for the trial – excludes 300W outlier potential for <€10,000/kW after the trial.
	Cost reduction to meet targets in the MAIP including a 2015 target cost of €4,000-€5,000/kW for micro CHP.	Manufacture, hand made	Pre-serial to serial production

**Inputs from discussions with suppliers and the Callux Programme

Future steps

- 2011-2014 - Deployment of field trials in Austria, Belgium, Denmark, France, Germany, Luxembourg, Ireland, Italy, Netherlands, Slovenia, Spain and the UK
- 2013-2014 - Regional workshops in Germany, Italy, Norway, Latvia and the UK
- 2015 - Data analysis – aggregation of the data from the trials first report
- 2015 - Analysis of the field support and barriers.
- 2015 - Development of an environmental life-cycle and costs assessment
- 2016 - Establish a commercialisation framework

Conclusions, major findings and perspectives

Aims of the project

- Create real-world learning – demonstration of market potential, segmentation, cost and environmental benefits of micro FC-CHP
- Develop market-oriented product specifications and harmonised codes and standards
- Set up a more mature supply chain, readied for deployment of micro FC-CHP in 12 Member States
- Provide evidence-base on cost and environmental performance that can be used to accelerate policy support from governments and adoption by channels to market.

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EURECA

Efficient Use of Resources in Energy Converting Applications

Duration

Start and end date: July 2012 - June 2015

Application area

Stationary power generation and CHP

Budget

Total budget €6,314,505
FCH contribution €3,557,293

Partnership/consortium list

Next Energy · EWE Research Centre for Energy Technology (coordinator), Eisenhuth GmbH & Co. KG, Univerzitet u Beogradu, Commissariat a l'energie atomique et aux energies alternatives, Foundation for Research and Technology Hellas, Inhouse Engineering gmbh, Celaya, Emparanza y Galdos Internacional, s.a., Fundacion CIDETEC, Fraunhofer-Gesellschaft zur Foerderung der angewandten Forschung e.v

Summary/main objectives of the project

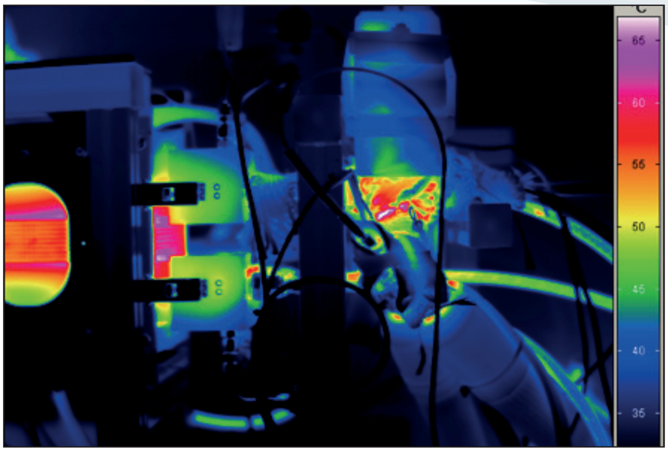
The objective of this project will be to propose, evaluate and qualify stacks in the µ-CHP application trying to combine advantages of the two previous technologies (low- and high-temperature proton exchange membrane fuel cells). To develop the next stack generation based on new materials, the consortium intends to work on several tasks in parallel. In different work packages we will develop new membranes, catalysts (< 0.2 g/kW), MEAs and bipolar plates for a next generation MT PEM stack (90-120°C) to gain favourable power densities.

Technical accomplishment/progress/results

New membrane materials and catalysts have been developed which operate at 90°C as planned in description of work. Bipolar plate materials could be improved and a material with rated conductivity stated in the internal deliverables for the first project stack has been chosen for the MT project stack. Performance of single cells with new materials fulfilled the expected power densities at 90°C working temperature. All proposed goals for the project have been achieved so far.

Contribution to the programme objectives

To achieve the goals of the MAIP and the AIP 2011 an important part of the project is the validation of the design targets. The µ-CHP system – including the reformer – is expected to operate at an electrical efficiency of 40%. Lifetime tests with defined test procedures on single cells and short stacks will indicate a stack lifetime of approx. 12,000 h. In all development processes the partners have agreed to a design-to-cost approach. This includes the producibility in series production processes. A cost assessment will indicate the cost savings by the less complicated system.



Future steps

- Prototype MEA and bipolar plates and gaskets
- Delivery of prototype middle temperature PEM FC stack
- Mid-term report
- Cost assessment
- Laboratory µ-CHP FC system will be installed

Conclusions, major findings and perspectives

With the new generation of stacks a cost-effective product for stationary fuel cell application will be developed. The new approach of middle temperature PEMFCs will help to simplify the CHP-system and lead to a more robust and less expensive product to supply heat and power efficiently. During the project the stack development will be proven by applying adapted protocols of the FCTESQA project. A higher durability and longer lifetime will be expected by enhanced testing procedures and use of application dependent load profiles.

EVOLVE

Evolved Materials and Innovative Design for High-Performance, Durable and Reliable SOFC Cell and Stack

Duration

Start and end date: 1 November 2012 - 31 October 2016

Application area

Stationary power generation and CHP

Budget

Total budget €5,805,373
FCH contribution €3,105,093

Partnership/consortium list

Coordinator: Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany), Alantum Europe GmbH (Germany), ARMINES (France), Ceramic Powder Technology AS (Norway), Consiglio Nazionale delle Ricerche (Italy), Institut Polytechnique de Grenoble (France), Saan Energi AB (Sweden), Ceraco Ceramic Coating GmbH (Germany).

Summary/main objectives of the project

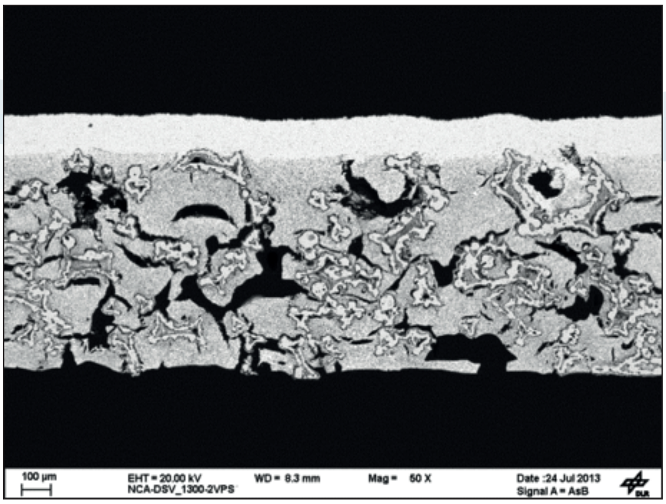
Development of an innovative SOFC, particularly the anode compartment, without nickel as structural component, addressing the issues of redox non-cyclability and sulfur poisoning observed with conventional nickel-zirconia cermet. The anode compartment is made of a metal alloy able to form a protective alumina layer and an electronic conducting perovskite, allowing operation in hydrogen or syngas. A power density of 550mW/cm^2 with hydrogen as fuel is targeted at 750°C.

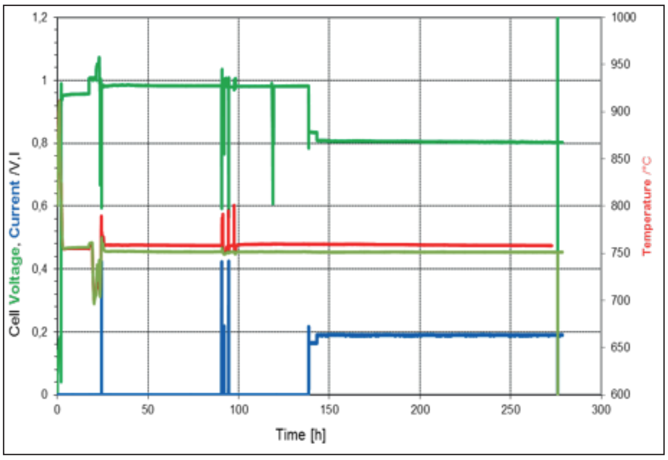
Technical accomplishment/progress/results

Prototype with a 50x50mm^2 footprint has been produced on the basis of a standard NiCrAl foam, $La_{0,1}Sr_{0,9}TiO_3$ as anode, and a zirconia-based electrolyte produced by vacuum plasma spraying (see picture 1). Power density was measured at 20mW/cm^2 at 750°C. The prototype exhibited a stable behaviour over 100h without loading and a degradation limited below 0,6%/100h under loading (see picture 2).

Contribution to the programme objectives

The EVOLVE cell concept proposes a concrete technological alternative to existing technologies, addressing their challenges and issues which have been identified. The expected results target a more robust, durable, reliable and efficient cell technology, which should ultimately result in a simplification of the system and thus in a reduction of the total cost of the technology. The involvement of three growing SMEs and a company in the consortium as well as the dissemination and the promotion of the results toward a large audience will help in the promotion and establishment of hydrogen as energy source





Future steps

1. Implementation of LSCF-based composite cathode
2. Addition of catalysts at the anode compartment
3. Reduction of the electrolyte thickness
4. Implementation of a full PVD electrolyte

Conclusions, major findings and perspectives

A first cell prototype has been manufactured demonstrating the feasibility of the EVOLVE cell architecture and the possibility of a full cell manufacturing in air. Achievements are in line with the planned milestones. The observed stability with or without loading of the cell highlighted the stability of the system in tested conditions and open the opportunity to the implementation of further improvement on each active layer. The potential of development of the EVOLVE cell remains intact after one year of development.

FC-EuroGrid

Evaluating the Performance of Fuel Cells in European Energy Supply Grids

Duration

Start and end date: 1 October 2010 - 31 December 2012

Application area

Stationary power generation and CHP

Budget

Total budget €805,927
FCH contribution €588,982

Partnership/consortium list

- University of Birmingham (coordinator)
- Forschungszentrum Jülich GmbH
- European Institute for Energy Research
- E.ON Ruhrgas
- Valtion Teknillinen Tutkimuskeskus (Technical Research Centre of Finland)
- Agenzia nazionale per le nuove tecnologie, l´energia e lo sviluppo economico sostenibile
- Grontmij AB
- Instytut Energetyki (Institute of Power Engineering)
- EBZ Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH

Summary/main objectives of the project

The project reviewed the current situation of electricity grids in the EU. It established a methodology for determining primary energy and CO_2 savings, especially of residential CHP units.

Technical accomplishment/progress/results

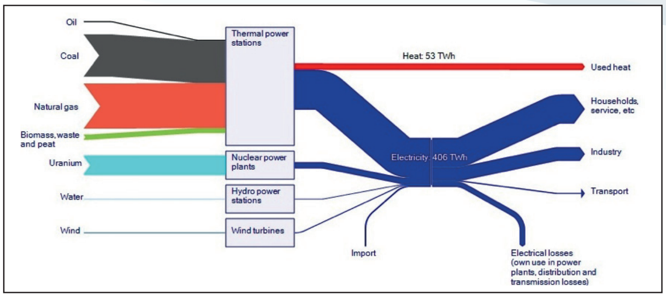
The project established tools in order to determine targets and benchmarks for stationary fuel-cell employment.

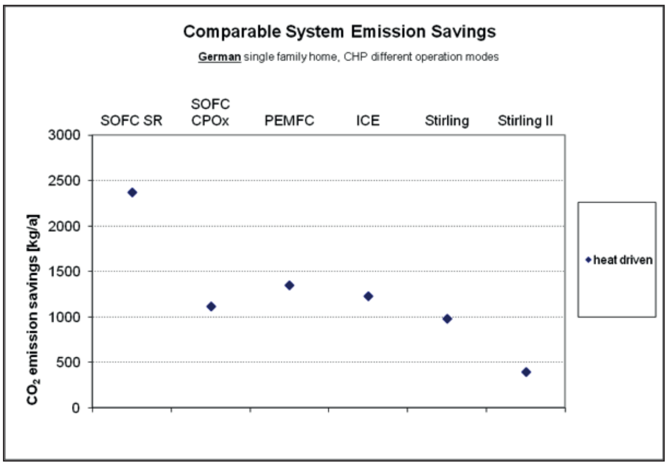
Contribution to the programme objectives

Setting target performance goals for stationary fuel-cell applications; providing input to updating of the MAIP target KPI.

Future steps

- contribution to discussion of MAWP
- setting targets for stationary fuel cell development

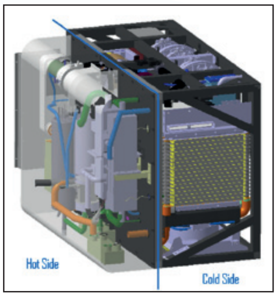




Conclusions, major findings and perspectives

Electrical and overall (total) efficiency of stationary fuel cells are the major factors determining their potential to contribute to increasing the primary energy efficiency and CO_2 abatement. Especially at low carbon footprints of the electricity grid, a high efficiency of small-scale CHP systems gains utmost importance.

FCGEN



Fuel-Cell Based On-board Power Generation

Duration

Start and end date: 1 November 2011 - 31 October 2014

Application area

Transport and refuelling infrastructure

Budget

Total budget €10,338,414
FCH contribution €4,342,854

Partnership/consortium list

Volvo Technology (coordinator), Powercell Sweden AB, Forschungszentrum Jülich GMBH, Institut Jozef Stefan, Centro Ricerche Fiat SCPA, Institut fuer Mikrotechnik Mainz GmbH, Johnson Matthey PLC., Modelon AB

Summary/main objectives of the project

To develop and demonstrate a proof-of-concept complete fuel cell based 3kW (net el.) auxiliary power unit in a real application, on-board a truck. Another objective is to further develop key components and subsystem technologies that have been advanced by the project partners in previous collaborations and move them closer towards commercially viable solutions.
The quantitative targets for the auxiliary power unit to be developed in the FCGEN project are:
System cost (€/kW) ≤ 1,000
Efficiency = 30%
Weight (kg) = 125
Volume (L) = 300

Technical accomplishment/progress/results

- Design, manufacturing and successful testing of fuel processor sub-components (ATR, WGS, PrOx).
- Definition of the electrical layout, communication requirement and mechanical constraints for the APU integration on-board the demonstration vehicle.
- BoP components have been identified and tested according to design specifications.
- Development of control system and complete electric hardware for the FCGEN APU. Hardware development includes FC-specific DC/DC power converter, complete electric APU design, power supply system for BoP components and on-going work on the APU control unit - ECU.
- Packing model for integration of the four main systems (fuel processor, BoP components, fuel cell and control/power components), In addition, Finite element analysis was performed to study the influence of the thermal and vibration effects on the system.

Contribution to the programme objectives

Objective of the call	Objective of the project	Current status
Demonstrations of increased efficiency of on-board power generation and reduce CO_2 emissions and local pollutions	80% reduction in fuel consumption compared to conventional idling. Reduce the emission of toxic components (NOx, PM, NMHC and CO) to < 1 ppm.	• Improved system efficiency measures have been considered during system design, component development and selection of BoP components. • Fuel processor component testing show evidence for levels of toxic emissions < 1 ppm.
Research, development and proof-of-concept demonstration of APU systems for on-board power generation.	Development of functional and mature components and sub-systems that can withstand the on-board conditions.	• System components are ready for system integration according to a well considered packaging model.
Demonstrated feasibility of using logistic fuels.	Run the system on low sulphur diesel (EN590).	The FCGEN developed reformer has shown the ability to generate the required quality reformate from reforming logistic low sulphur diesel.

Conclusions, major findings and perspectives

For the time being, APU system integration has not started yet. However, all system components are tested and seem to meet the defined targets on component levels.
Further RTD and demonstration activities after the FCGEN project will be needed. The FCGEN APU system, which is going to be tested under real operation conditions on-board a vehicle, contains several 1st gen. units and some BoP components that need further optimisation. During the FCGEN project time, two more cost effective 2nd gen. reactors will be developed. The project will not reach the defined size and cost targets completely, but will provide guidelines for further size and cost reduction at the end of the project.

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FCGEN

FCpoweredRBS

Demo Project for Power Supply to TLC Stations through FC Technology

Duration

Start and end date:
1 January 2012 - 31 December 2014

Application area

Early markets

Budget

Total budget €10,591,649
FCH contribution €4,221,270

Partnership/consortium list

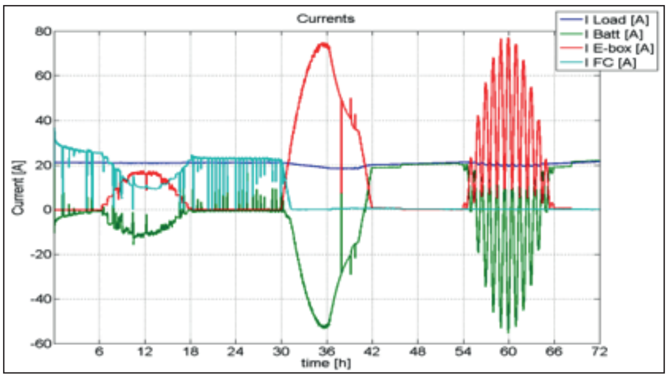
Coordinator:	Ericsson Telecommunication Italy
Partners:	Dantherm Power AS
	GreenHydrogen DK APS
	MES SA
	Joint Research Centre
	University of Rome Tor Vergata

Summary/main objectives of the project

Field trials in 18 live radio base station sites and lab test in two research centres. Demonstrate to the TLC operators the possible advantage, in terms of TCO, associated to power off-grid RBS with a new system combining renewable sources to replace diesel gensets.

Technical accomplishment/progress/results

- Solution successfully integrated in laboratory definition of a three-day benchmark profile
- Benchmark tests performed in the laboratory
- Provisional TCO calculated
- TLC operators agreements signed and radio sites identified for live trials
- Legal authorisation process started
- Training and dissemination activities started



Contribution to the programme objectives

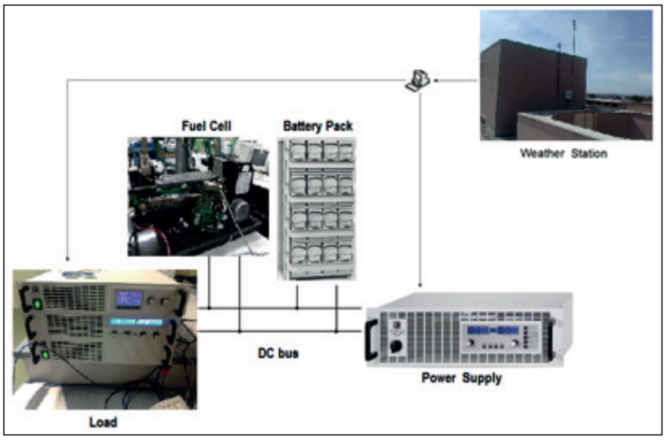
	Objectives of the call	Objectives of the project	Current status
Number of RBS sites	20	20	7
Total cost of ownership (TCO)	<= Diesel gensets	<= Diesel gensets	Lab tests: in progress and in line. Field tests: to be evaluated
System lifetime [h]	N/A	>5,000 h	Lab tests: in progress and in line. Field tests: to be evaluated

Future steps

1. Field installations and solution commissioning
2. Safety procedures for TLC and O&M processes
3. Field tests and TCO consolidation
4. Dissemination in TLC industry
5. FC certification procedures TLC compliant

Conclusions, major findings and perspectives

The project results will give an immediate answer as to the market readiness of the proposed solution. The partners expect that if the TCO demonstration matches expectation, a proper market proposition may already be available. Only standard product development activities would be needed and an appreciable commercial impact is foreseen.



FireComp

Modeling the Thermo-Mechanical Behaviour of High-Pressure Vessel in Composite Materials when Exposed to Fire Conditions

Duration

Start and end date: 1 June 2013 - 31 May 2016

Application area

Cross-cutting activities

Budget

Total budget €3,543,498
FCH contribution €1,877,552

Partnership/consortium list

- Air Liquide, CNRS
- University of Edinburgh
- Raufoss Fuel Systems
- Ineris, Health and Safety Laboratory
- IMS Samtech, Alma CG

Summary/main objectives of the project

The main objective of FireComp is to better characterise the conditions to be fulfilled to avoid composite cylinders bursting in case of fire.

- Experimental work will be carried out to improve the understanding of heat transfer mechanisms and the loss of strength of composite high-pressure vessels in fire conditions.
- Then the modeling of the thermo-mechanical behaviour of these vessels will be set up. The model will be validated by full-scale fire tests

Technical accomplishment/progress/results

- Risk analysis of hydrogen systems the partners are working on
- Production of samples for fire and mechanical performance laboratory tests
- Definition of experimental conditions for fire tests of high-pressure vessels

Contribution to the programme objectives

- Development of an understanding of the evolution of the composite material when exposed to fire conditions
- Development of a model for predicting the loss of strength of the composite pressure vessel due to fire conditions and for identifying the conditions that need to be achieved to avoid burst.
- Validation of this model by an experimental programme where pressure vessels are subject to fire conditions with application of a specified pressure relief curve.

Future steps

1. Tests will be carried out to better understand the influence of different parameters on the mechanical behaviour (February 2014)
2. Definition of reference fires for composite reservoirs (June 2014)
3. Preliminary thermal properties of the material and preliminary model of thermal degradation (November 2014)

Conclusions, major findings and perspectives

Expected outcomes of the project are recommendations for regulations, codes and standards regarding the qualification of high-pressure composite storage and sizing of its protections.

FITUP

Fuel-Cell Field Test Demonstration of Economic and Environmental Viability for Portable Generators, Back-Up and UPS Power System Applications

Duration

Start and end date: 1 November 2010 - 30 April 2014

Application area

Early markets

Budget

Total budget €5,289,900
FCH contribution €2,475,825

Partnership/consortium list

Electro Power Systems (coordinator), FutureE, Environment Park, Lucerne University of Applied Sciences and Arts, Joint Research Centre,TÜV SÜD, Wind, Swisscom Betriebskommission Polycom Nidwalden, Bilgi University, Università di Roma Tor Vergata

Summary/main objectives of the project

FITUP will demonstrate the technical viability and economic maturity of back-up power systems based on fuel-cell technology. Thirteen market-ready systems from two suppliers are installed in selected sites across Europe for field trials, and six systems are in testing at R&D centres for benchmarking.

Technical accomplishment/progress/results

More than 50% of foreseen tests have been performed at both final user sites and research centres according to the developed test protocol. Results are summarised in the table. Fuel cell demonstrated operational capability within extreme weather conditions during field tests and within climate chamber.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Number of FC back-up systems	5-10	19	19
Reliability	100%	>95%	99.4%
Response time	<5 ms	<5 ms	Satisfied so far
Lifetime	5 years	1,500 h	1000 operating hours are demonstrated so far
Number of start-stop cycles	1,000	1,000	835 start-stop cycles are demonstrated so far
Target system cost	€5,000/ kW	€5,000/kW	€5,500/kW (including hydrogen generators)

Future steps

1. Completion of foreseen tests
2. Completion of LCA and proposal for a uniform certification procedure for fuel-cell systems installation and use

Conclusions, major findings and perspectives

FITUP project will increase the visibility of fuel cells as a potential alternative to conventional backup power sources (batteries and diesel generators) and prove to potential telecommunication customers in real conditions their advantages.
Lesson learned from project on installation and operation of fuel cell-based UPS systems to avoid obstacles or hurdles for up-coming projects.
Need of public incentives/tax rebates for mass adoption of fuel cell back-up systems.

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fitup

FluMaBack

Fluid Management Component Improvement for Back-Up Fuel-Cell Systems

Duration

Start and end date: 1 July 2012 - 30 June 2015

Application area

Stationary power generation and CHP

Budget

Total budget €4,440,464
FCH contribution €2,773,700

Partnership/consortium list

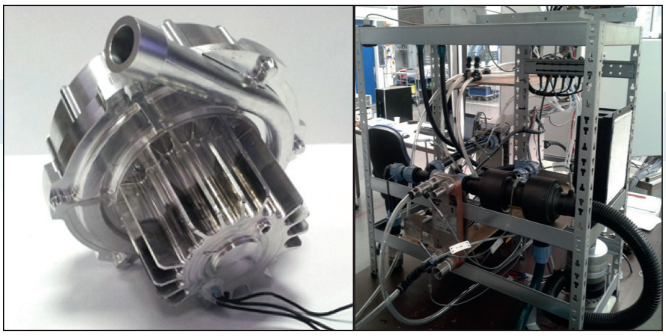
Electro Power Systems (coordinator), Domel, Tubiflex, Environment Park, Institut Jožef Stefan, Fundacion para el desarrolo de nuevas tecnologias del hidrogeno en Aragon, Nedstack, Onda, University of Ljubljana, European Commission (JRC).

Summary/main objectives of the project

Main objectives of the project are improvements of key balance of plant components for back-up fuel-cell systems – air blower, hydrogen recirculation pump, air humidifier and heat exchangers. The improvements are in terms of components' performance, extended lifetime, simplified production and lower production costs.

Technical accomplishment/progress/results

Definition of technical and economic specifications of each BoP component to be developed has been performed based on functional requirement of both fuel-cell stack and fuel-cell system. First release of prototypes of blower, recirculation pump and heat exchangers have been developed and delivered.
Detailed test protocol to validate performance and lifetime has been defined.



Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current status
Heat exchangers/thermal management	Heat exchangers	Specs defined first prototypes delivered
Air and fluid flow equipment	Blower	Specs defined first prototypes delivered
Fluid supply and management including pumps, turbines, compressors, valves, flow meters, desulphurisation, humidification	Hydrogen recirculation pump humidifier	Specs defined first prototype (pump) delivered
Manufacturing processes and quality control techniques for high performance and cost-effective components	The same	In progress
Validation of lifetime, durability/robustness (System life>10 years)	Validation of 20,000 h lifetime for BoP components	To be started

Future steps

1. Tests of first BoP prototypes
2. Development of second release of BoP components

Conclusions, major findings and perspectives

The main project results will be four BoP components improved both in technical performance and lifetime as well as in cost-efficient production. Primary goal is to include these components in fuel-cell based back-up power systems, but the components could be used for any other stationary fuel-cell system. The full achievement of cost target for each BoP component to be developed is primary objective. Very short timescale are therefore foreseen to have commercial ad hoc BoP components for stationary applications.

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FLUMABACK
Fluid Management component improvement for Back up fuel cell systems

H2moves Scandinavia

Lighthouse Project for the Demonstration of Hydrogen Fuel-Cell Vehicles and Refuelling Infrastructure in Scandinavia

Duration

Start and end date: 1 January 2010 - 31 December 2012

Application area

Transport and refuelling infrastructure

Budget

Total budget €19.5 million
FCH contribution €7.8 million

Partnership/consortium list

LBST, Daimler, H2Logic, SP, TÜV SÜD Industry Services, Hydrogen Sweden, Hydrogen Link Denmark, SINTEF, Hyundai Motor Europe

Summary/main objectives of the project

Acceleration of market introduction and commercialisation of hydrogen-powered fuel-cell electric cars and hydrogen refuelling infrastructure; launch of the latest state-of-the-art hydrogen fuel-cell vehicles and consolidation of the existing hydrogen fuelling network in the south of Norway and in Denmark by adding a new refuelling station in Oslo and delivering 19 fuel-cell city and sedan cars in total. Understanding the status of certification and need to adapt them across all of Scandinavia

Technical accomplishment/progress/results

- 10 Daimler B-Class F-CELL (drivetrain power 100kW,range 380 km (NEDC), H2 capacity 3.7 kg @ 70 MPa);
- 4 Hyundai ix35 FCEV (drivetrain power 100kW, range 525 km (NEDC), H2 capacity 5.6 kg @ 70 MPa);
- 5 Th!nk FC city cars (fuel-cell range extender 10kW, range 250 km, H2 capacity 1.5 kg @ 70 MPa). FCEVs drove 213,641 km in total within 13.5 months covering an ordinary annual driving distance of about 10,000 km each saving 24.5 tonnes of CO2 in this period as compared to conventional cars.
- Avg. refuelling time: 2.8 minutes
- Avg. distance between refuellings: 150-200 km
- Cold climate no problem for driving
- Performance over time: realistic perspective of reaching 200,000 km lifetime with one stack (Hyundai)
- Grand avg. availability of FCEVs: 98%
- No safety relevant incident
- High visibility in Denmark and Norway and in EU during 4 weeks road tour 2012 (3,050 individuals reached during European Road Tour 2012 alone).
- Vehicles close to market readiness.
- HRS infrastructure to be improved to avoid range anxiety. Overwhelming public acceptance.

Contribution to the programme objectives

Issue	AIP/MAIP	Accomplished
Number of FCEV	5	19
Number of HRS	1 HRS	1 HRS 1 moveable HRS
Number of public ride-and-drives	5	More than 10
H2 price at pump (€/kg)	10	8.96 NOK/100g

Future steps

HyOP has acquired all Norwegian hydrogen refuelling stations from Statoil and the one in Gaustad with the plan to extend the network over time (Oslo: 3*70 MPa stations, one with 35 MPa, Copenhagen is extending the HRS network through HyTEC and the HIT activity).
All 17 cars continue to operate for at least one more year in Oslo, The Copenhagen fleet is extended by the HyTEC project and the HIT activity. Negotiations are ongoing to further enlarge the FCEV fleets in Denmark and Norway.

Conclusions, major findings and perspectives

- Demonstrating performance of latest fuel-cell vehicle and hydrogen refuelling technology
- Gaining customer acceptance
- Establishing partnerships amongst stakeholders
- Build up of hydrogen infrastructure
- Most project goals were outperformed at €1 million under budget, due to good hardware performance

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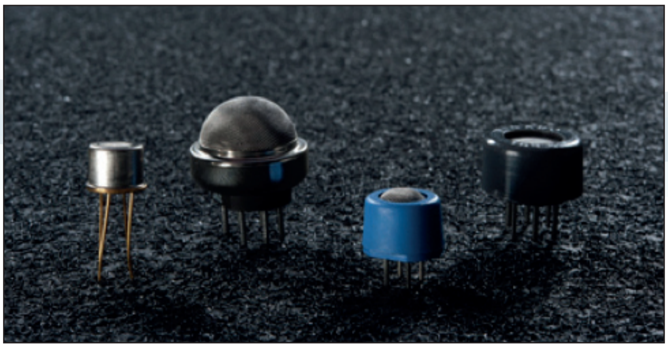
H2Sense

Cost-Effective and Reliable Hydrogen Sensors for Facilitating the Safe Use of Hydrogen



Duration

Start and end date: 1 June 2013 - 31 May 2014

Application area

Cross-cutting activities

Budget

Total budget €785,290
FCH contribution €380,348

Partnership/consortium list

BAM (Coordinator), | Joint Research Centre – IET, AppliedSensor GmbH, Sensitron Srl, UST Umweltsensortechnik GmbH, ZSW

Summary/main objectives of the project

The main objective of H2Sense is to promote the effective deployment and safe use of reliable hydrogen sensors, primarily but not exclusively for applications of hydrogen as an alternative fuel.

Technical accomplishment/progress/results

- Organisation of workshop "Hydrogen Sensors – The right one in the right place at the right time" with EU stakeholders and US government representatives in Brussels
- Implementation of the stakeholder questionnaire "Application and use of hydrogen sensors"
- Dissemination activities at the International Conference on Hydrogen Safety (ICHS2013) and on the H2Sense website

Contribution to the programme objectives

Objectives Of the call	Objectives of the project	Current status
Assessment of hydrogen sensor technologies; recommen-dations for deployment and near-term applications	Evaluation of existing and anticipated sensor technologies; identification of existing and key near-term hydrogen applications and sensor performance requirements	In progress; first paper published at ICHS2013
Recommenda-tions for sensor requirements on regulations, codes and standards	Identification of commercialisation barriers and approaches in R&D, regulation and standardisation to overcome these barriers	In progress
Testing and validation	Performance tests and validation of promising commercial off-the-shelf hydrogen sensors	Sensors to be tested have been identified; testing to be started
Compendium of applications, feedback on performance, experiences and best practices	Soliciting of specific external stakeholder input to foster hydrogen sensor commercialisation	Workshop and stakeholder questionnaire implemented
Coordination with US proposal submitted to the US DoE	Interaction and knowledge transfer on state-of-the-art hydrogen sensors, technology developments and deployment strategies	In progress; workshop with participation of US delegation was organised

Future steps

1. Evaluation of stakeholder input at the workshop and in the questionnaires
2. Compendium of existing hydrogen sensors, their applications and expected future trends
3. Recommendation for sensor requirements
4. Sensor testing and validation

Conclusions, major findings and perspectives

- Sensitive, selective, fast and safe hydrogen sensors of different types are available
- R&D for sensor quality improvement in specific applications is needed
- Application-specific standards are required
- Further activities to overcome barriers for application are suggested

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H2Sense

H2TRUST

Development of H_2 Safety Expert Groups and Due Diligence Tools for Public Awareness and Trust in Hydrogen Technologies and Applications

Duration

Start and end date: 1 June 2013 - 30 November 2014

Application area

Cross-cutting activities

Budget

Total budget €1,208,416
FCH contribution €796,678

Partnership/consortium list

MATGAS 2000 AIE, Air Products PLC, European Hydrogen Association, Solvay Specialty Polymers (Italy) SPA, Politecnico di Milano, McPhy Energy SA, SOL SPA, Ciaotech Srl, Technische Universiteit Eindhoven.

Summary/main objectives of the project

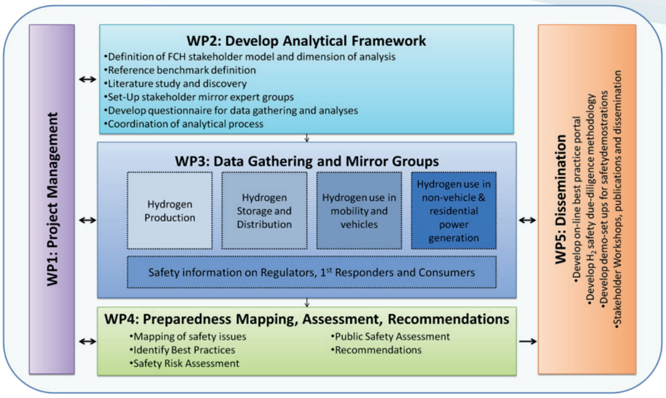
This project has been created by a team of highly experienced and qualified industry and academic experts to assess industry efforts to assure FCH technology is safe and that there is adequate regulation. The main objective is to guarantee maximum level of safety for an accelerated deployment of the H_2 economy.

Technical accomplishment/progress/results

We have already developed the framework and methodology, which will guide the whole project.
Ongoing tasks include the reference benchmark for H_2 production-storage-distribution technologies, the online literature database and dissemination of the project.

Contribution to the programme objectives

Objectives of the project	Current status
Development of analytical framework (%)	60
Data-gathering and mirror groups (%)	0
Mapping, assessment and recomendations (%)	0
Dissemination (%)	5



Future steps

1. Develop questionnaires for data gathering
2. Set up stakeholder mirror expert groups
3. Collect safety data for the different H_2 applications
4. Mapping, assessment and recommendations

Conclusions, major findings and perspectives

The H_2TRUST project proceeds according to the description of work of the grant agreement.
The deliverable corresponding to the framework and methodology, as well as the others related to project management, have been finished and submitted.
It is expected that dissemination actions will be intensified in the second part of the project, through conferences, workshops, publications, exhibitions, fairs and website (h2trust.eu/). The aim is to maximise the diffusion of this knowledge to the widest possible audience, including stakeholders, industries and the general public.
We have contacted the PNNL, the coordinators of the project "SCS006- Hydrogen safety Knowledge Tools", supported by the US DoE. The objective is to explore the synergies between the H_2TRUST project and the Hydrogen Safety Panel in the US.

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H_2TRUST

High V.LO City

Cities Speeding up the Integration of Hydrogen Buses in Public Fleets

Duration

Start and end date: 1 January 2012 - 31 December 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €31.5 million
FCH contribution €13.4 million

Partnership/consortium list

Van Hool (Belgium), Riviera Trasporti (Italy), Aberdeen City Council (UK), Dantherm Power (Denmark), DITEN (Italy), Solvay (Belgium), Ballast Nedam (Netherlands), Waterstofenet (Belgium), Regione Liguria (Italy), HyER (Belgium), FIT Consulting (Italy), VVM - De Lijn (Belgium).

Summary/main objectives of the project

High V.LO City facilitates the rapid deployment of the latest generation FCH buses in public transport operations by addressing key environmental and operational concerns. The project envisions broad dissemination of actual FCH bus performance.

Technical accomplishment/progress/results

The project is in its construction phase. Five FC buses for Sanremo are produced and delivered, the other nine buses are in production. The refuelling infrastructures are put in place as well. Start of the operational phase is foreseen for January 2014.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
FC Buses in operation	5	14	5
FC Bus fuel consumption		7-9kg/100km	9.62kg/100km
FC Module warranty	>4,000 hours	>12,000 hours	15,000 hours
Refuelling stations		3	0
Capacity	200kg H_2/day	300kg H_2/day	

Future steps

1. Finalisation of the project's infrastructure (buses and refuelling infrastructure)
2. Put in place the 'Clean Hydrogen Bus Centres of Excellence'
3. Launch the operations at the three sites with a local workshop, included bus monitoring system and dissemination tools
4. Monitor the operations and report them in a clear way

Conclusions, major findings and perspectives

Although the project is still in its initiation phase, the lessons already learnt are:

- The introduction of novel hydrogen technology in a classic operational diesel bus environment is challenging, on both technical and administrative level
- Next generation will require further optimisation (and cost reduction) between battery and fuel-cell technology

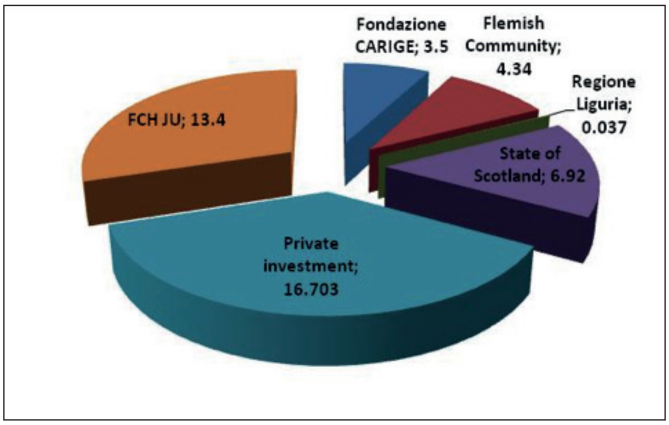


Figure 1: Contributions of private and public investors in the High V.LO City budget.

Hy2Seps-2

Hybrid Membrane - Pressure Swing Adsorption (PSA) Hydrogen Purification Systems

Duration

Start and end date: 1 November 2011 - 31 October 2013

Application area

Hydrogen production and distribution

Budget

Total budget €1,606,279
FCH contribution €825,321

Partnership/consortium list

FORTH/ICE-HT (Greece, Coordinator), University of Porto (Portugal), PSE Ltd (UK), HyGear b.v. (Netherlands), CTI s.a. (France).

Summary/main objectives of the project

Design and testing of hybrid separation schemes that combine membrane and pressure swing adsorption (PSA) technology for the purification of H2 from a reformate stream that also contains CO2, CO, CH4, and N2. Focus is on small-scale systems at pressures < 10 bar

Technical approach:

- Membrane & adsorbent development
- Process modeling & optimisation
- Pilot unit testing

Technical accomplishment/progress/results

- Detailed study of carbon membrane synthesis on ceramic supports
- Screening of new candidate adsorbents and modeling of their performance
- Development of dynamic models for the membrane and PSA units
- Adaptation and operation of a pilot membrane-PSA system employing a hollow-fibre polymeric membrane module (operation of hybrid system is currently in progress)

Contribution to the programme objectives

"A development objective for most decentralised production technologies is scale-up to cost-effective capacity, as well more cost-efficient, high-performance materials (e.g. membranes) to meet the overall cost targets."
MAIP 2008-2013, Document FCH JU 2011 D708.
Project target: hydrogen recovery improvement by 10%.

Future steps

1. Commercial toolkit for membrane-PSA processes
2. Incorporation of hybrid system in small-scale hydrogen generator
3. Investigation of new membrane materials

Conclusions, major findings and perspectives

- H2/CO2 separation not feasible with carbon membranes
- Improved CO2 adsorbents based on metal-organic-framework (MOF) materials have been identified
- The developed modeling toolkit can be applied in the optimisation of stand-alone or hybrid PSA systems for hydrogen purification
- There is need for cost-efficient membranes for hydrogen purification at room temperature

HYCARUS

Hydrogen Cells for Airborne Usage

Duration

Start and end date: 1 May 2013 - 30 April 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €10,057,617
FCH contribution €5,219,265

Partnership/consortium list

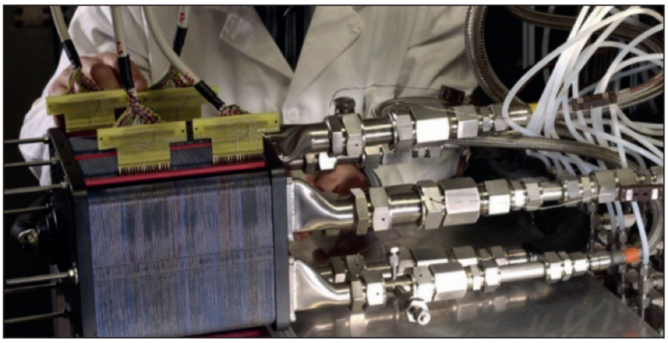
Zodiac Cabin & Controls (Coordinator), Commissariat à l'énergie atomique et aux énergies alternatives, Dassault Aviation, Air Liquide, JRC (Institute for Energy and Transport), Spanish National Institute for Aerospace Technology, ARTTIC, Zodiac Electrical Power Systems, Zodiac Galleys Europe.

Summary/main objectives of the project

- To design a generic fuel-cell system which is compatible with the non-essential aircraft applications such as galleys, lavatory or crew rest compartment in a large commercial aircraft or secondary power sources on-board a business jet.
- To assess and exploit the by-products in different airborne applications – galleys, lavatories, warmers, chillers or inerting functions such as fuel tank...

Technical accomplishment/progress/results

It is planned to finalise WP1 with the deliverable "Specification and sizing" in November 2013.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Fuel-cell system efficiency (LHV)	25% of rated power: 55%	25% of rated power: 55%	45%
Durability with cycling hours	2,500 hours under flight represen-tative load profiles	performing durability tests under flight representative load profiles	N/A (not finalised)
Fuel-cell system power density (EOL) kW/L	0,40 kW/L	0,40 kW/L based on the fuel cell stack value 1,7 kW/L	0,40 kW/L
Fuel-cell system specific power (EOL) kW/kg	0,65 kW/kg	0,65 kW/kg based on the fuel cell stack value 1,2 kW/kg	0,60 kW/kg
Demonstrator	TRL 6	Demonstration of a TRL 6 FC-system under typical aircraft standard operating conditions	

Future steps

1. Finalise the "Specifications and sizing" in November 2013
2. Continue with the safety assessment
3. Prepare system integration

Conclusions, major findings and perspectives

The HYCARUS project is one of the first fuel-cell system applications in aircraft use, covering all requirements in order to bring fuel-cell system in operation. HYCARUS has now started to select all relevant aircraft specifications, especially the use of hydrogen on the aircraft. This will also influence the supply chain of fuel for fuel cells.

HyCOMP

Enhanced Design Requirements and Testing Procedures for Composite Cylinders Intended for the Safe Storage of Hydrogen

Duration

Start and end date: 1 January 2011 - 31 March 2014

Application area

Transport and refuelling infrastructure

Budget

Total budget €3,802,542
FCH contribution €1,380,728

Partnership/consortium list

Coordinator: Air Liquide SA
Partners: Armines, Bundesanstalt für Materialforschung und Prüfung, CCS Global Group, Commissariat à l'Energie Atomique (CEA), EADS Composites Aquitaine, Faber Industrie, Hexagon Composites (HEX), Wroclaw University of Technology, European Commission (JRC-IET), Alma Consulting Group (ALMA).

Summary/main objectives of the project

Pre-Normative Research (PNR) project to:

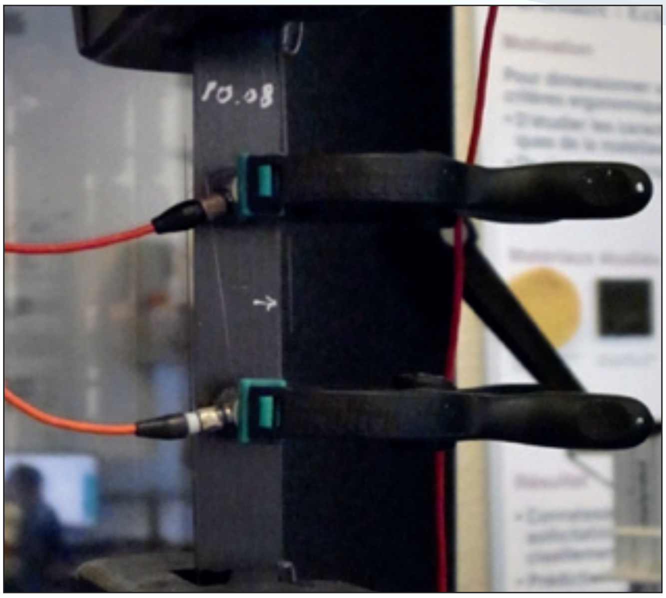
- Define new design requirements and testing procedures for composite pressure vessels used for the storage of compressed hydrogen.
- Demonstrate a possible reduction of the safety factor, without compromising high safety levels.
- Propose recommendations intended to RCS & industry covering design requirements, testing procedures for type-approval, manufacturing quality assurance and in-service inspection.

Technical accomplishment/progress/results

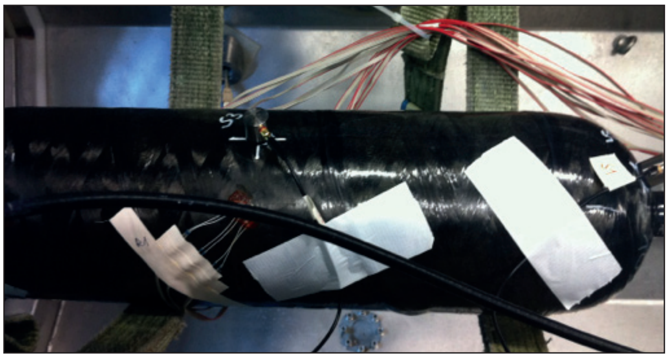
- Experimental and numerical approach to assess the minimal safety factor required to cover intrinsic materials properties of CF composite materials
- Testing of cylinders with intentional big variations in process parameters to quantify the effect on cylinder performance
- Development of a NDT procedure based on acoustic emission for manufacturing control

Contribution to the programme objectives

- Objectives of the project - current status (in %)
- Enhance design requirements for CPV – reduction of the SF value: 90%
- Improve the full set of requirements, for different type of testing:
  - Design type approval: 60%
  - Manufacturing quality assurance: 80%
  - In-service inspection: 10%
- Dissemination to RCS and Industry: to be done in 2014



Acoustic Emission sensors applied on plate specimens to measure damage accumulation rate



T3 cylinder (9L) especially designed for HyCOMP, with acoustic emission sensors and strain gauges

Future steps

1. Deep analysis of scientific results
2. Extraction of valuable recommendations
3. Dissemination of recommendations to RCS & industry

Conclusions, major findings and perspectives

This new approach will provide the scientific data necessary to improve and adapt the requirements defined for composite cylinders.
A document gathering recommendations for enhanced design requirements and testing procedures will be proposed to new and ongoing RCS activities.
Possible perspective: include accidental conditions in the approach (effect of mechanical impacts, such as cylinder fall or shocks between cylinders).

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HyCOMP

HYDROSOL 3D

Scale Up of Thermochemical hydrogen Production in a solar Monolithic Reactor: a 3rd Generation Design Study

Duration

Start and end date: 1 January 2010 - 31 December 2012

Application area

Hydrogren production and distribution

Budget

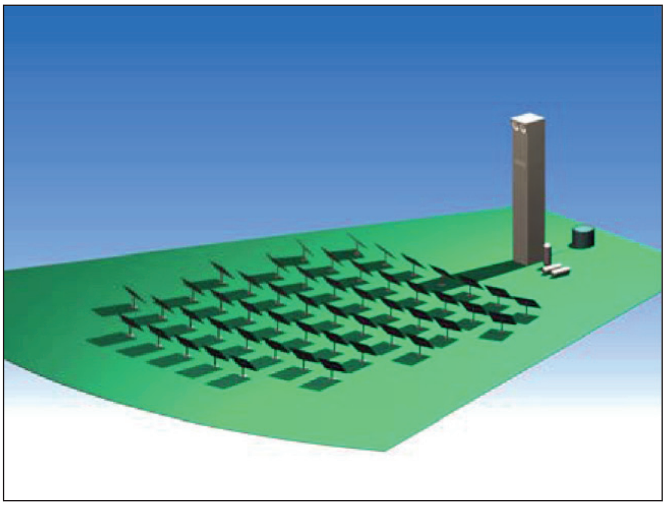
Total budget €1.73 million
FCH contribution €0.98 million

Partnership/consortium list

APTL/CPERI/CERTH (Coordinator), DLR, Ciemat, Total S.A. ,HYGEAR

Summary/main objectives of the project

HYDROSOL-3D aims at the preparation of a demonstration of a CO_2-free H_2 production and provision process and related technology, using two-step thermochemical water splitting cycles by concentrated solar radiation. This process has been developed in the framework of HYDROSOL and HYDROSOL-II (FP5 and FP6).
HYDROSOL-3D focuses on the next step towards commercialization carrying out all activities necessary to prepare the erection of a 1MWth solar demonstration plant and concerns the pre-design and design of the whole plant including the solar H_2 reactor and all necessary upstream and downstream units needed to feed in the reactants and separate and bottle the products. Two alternative options were analysed: adapting the H_2 production plant to an already available solar facility or developing a new, completely optimised H_2 production/solar plant. Validation of pre-design components and process strategies by experiments (in laboratory, solar furnace, solar simulator and solar tower facilities) and a detailed techno-economic analysis covering market introduction complemented the project.



Technical accomplishment/progress/results

Redox reactor with long-term cyclic operation stability (a total of over 70 cycles) under operation at high temperature solar irradiation (up to 1200°C). Ability to construct monolithic porous structures consisting entirely of the redox material.
Ability to construct a redox reactor with increased thermal uniformity. A software tool for process engineering simulation at the MW scale. Complete layouts of the whole plant and design of all specific components

Contribution to the programme objectives

AIP expected outcome	Project objectives	Status	M
Development of new high temperature reactors, component improvements	Design of a reactor integrated with a solar tower	V	12
Simulation of the components and systems	Simulation of the pilot plant	V	24
	Simulation of core components and of the process as a whole	V	33
Design study of a scaled up reactor	Design of 1 MW reactor for high-temperature H2O-splitting	V	33
	Integrated process concept	V	33
	Automation and control concept	V	33
	Techno-economic study to determine the feasibility of the scale up of the process to industrial application	V	36

Future steps

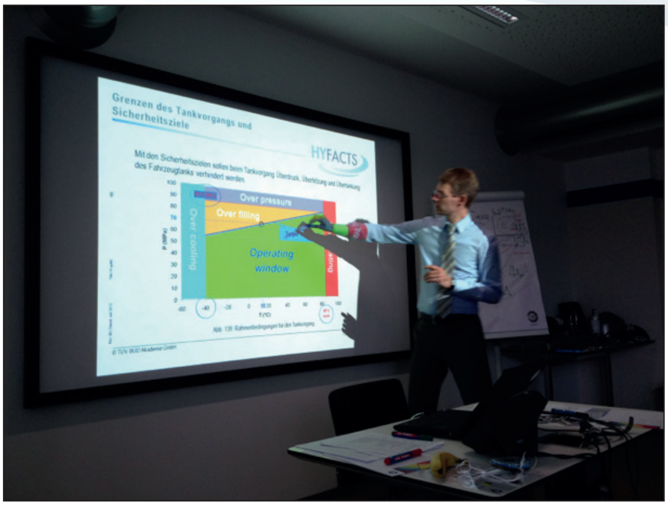
The realisation of a demonstration plant for solar H_2 production at the MW scale. Partners of the consortium have proceeded with the submission of the HYDROSOL-PLANT proposal which is the natural evolutionary step after HYDROSOL-3D.

Conclusions, major findings and perspectives

A significant number of H_2 production cycles was realised/optimisation of operational parameters at pilot scale is viable.
New redox coated monoliths with indication of long-term cyclic operation stability at high temperature solar irradiation. Adaptation of an already existing solar facility: reduction of direct and indirect costs related to site installation and plant operation. The estimated H_2 production cost: within a factor of 2-2.5 of the cost of non-renewable routes without considering taxes/benefits. Improvements in solar technology, heliostat's tracking system and solar field optimisation would reduce cost.
The HYDROSOL technology could take a visible share of the H_2 market in the long-term, especially alongside fuel-cell vehicles deployment.

HyFacts

Identification, Preparation and Dissemination of Hydrogen Safety Facts to Regulators and Safety Officials



Duration

Start and end date: 1 February 2011 - 31 July 2013

Application area

Cross-cutting activities

Budget

Total budget €1.40 million
FCH contribution €1.04 million

Partnership/consortium list

TÜV SÜD Akademie GmbH
TÜV SÜD Industrie Service GmbH
Air Liquide Hydrogen Solutions
CCS Global Group
FAST/EHA
Health and Safety Laboratory (HSE)
University of Ulster

Summary/main objectives of the project

The project aims to develop and disseminate fully up-to-date contemporary material in the form of customised training packages for regulators and public safety experts providing accurate information on the safe and environmentally friendly use of hydrogen as an energy carrier for stationary and transport applications under real conditions.

Technical accomplishment/progress/results

Teaching material

Contribution to the programme objectives

The HyFacts project has contributed to the call by supplying up-to-date and complete teaching material for regulators and safety officials.

Future steps

Public will use the teaching material

Conclusions, major findings and perspectives

Project was successful but more work needs to be done in the area of specific training for all kinds of persons involved in hydrogen technologies.

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HYFACTS

HyGuide

Guidance Document for Performing LCAs on Hydrogen and Fuel-Cell Technologies

Duration

Start and end date: October 2010 - September 2011

Application area

Cross-cutting activities

Budget

Total budget €366,318

Partnership/consortium list

PE International ag
Universität Stuttgart
Karlsruher Institute of Technology (KIT)
European Hydrogen Association (EHA), represented by FAST
European Commission (JRC)

Summary/main objectives of the project

- Development of a specific life-cycle assessment (LCA) guidance document for application to hydrogen and fuel-cell technologies (based on and in line with the International Reference Life Cycle Data System (ILCD) Handbook).
- Broad dissemination among LCA practitioners and industry,
- Provision of a website, as a central information point and as fully integrated component of the ILCD data network.

Technical accomplishment/progress/results

The output of HyGuide is a set of information, developed, reviewed and ready-to-use:

- LCA guidance document on fuel cells and hydrogen production technologies
- Templates: data collection, data documentation, reporting
- Examples (LCA data sets incl. reporting template) from case studies
- Training courses

Contribution to the programme objectives

"Sustainability is a key driver of the FCH JU activities and it is necessary to assess the new developments towards these goals. Life-cycle assessment will therefore be applied throughout the FCH JU on a programme level." (FCH JU, AIP 2009, SP1-JTI-FCH.2009.5.5 Life-Cycle Assessment (LCA))

Conclusions, major findings and perspectives

The HyGuide project is completed and all objectives and targets were achieved The LCA guidance documents were developed in a multi-stage stakeholder approach. The outcome of the project can be used in all hydrogen and fuel-cell application areas within the FCH JU asking for LCA.

Hyindoor

Pre-Normative Research on the Indoor Use of Fuel Cells and Hydrogen Systems

Duration

Start and end date: January 2012 - December 2014

Application area

Hydrogen production and distribution

Budget

Total budget €3.6 million
FCH contribution €1.5 million

Partnership/consortium list

Air Liquide SA, Commissariat à l'Energie Atomique et aux énergies alternatives (CEA), Karslruhe Institute of Technology (KIT), University of Ulster, The CCS Global group Ltd, Joint Research Center (JRC), Hygear Fuel Cell Systems, Health and Safety Laboratory, National Center for Scientific Research Demokritos (NCSRD), LGI Consulting.

Summary/main objectives of the project

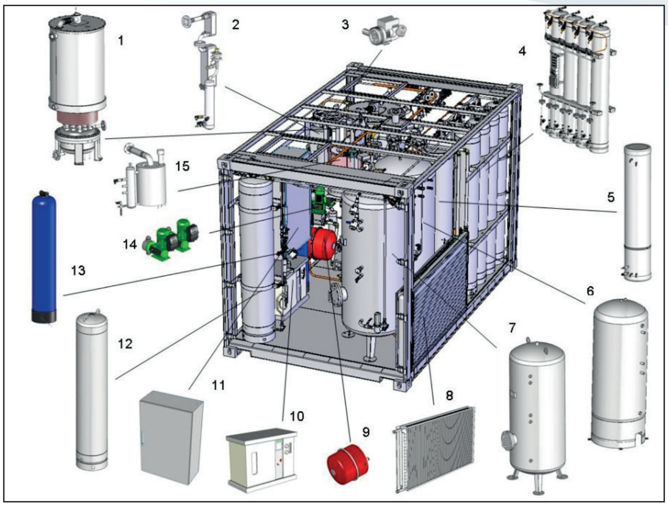
Providing scientific and engineering knowledge for the specification of cost-effective means to control hazards, and to develop state-of-the-art guidelines

Technical accomplishment/progress/results

- Finalise CEA, KIT and HSL experiments
- Exp. data processing, analysis for CFD validation
- Prepare next workshops
- Prepare inputs for safety guidelines
- Recommendations for implementation in international regulations, codes and standards

Contribution to the programme objectives

Objectives of the call and of the project	Current Status
Analytical, CFD, and experimental results on dispersion and accumulation of H_2 in a confined space	End in Q2/2014
Analytical, CFD, and experimental results on vented deflagrations	End in Q2/2014
Analytical, CFD, and experimental results on jet fire	End in Q2/2014
Advanced Industrial and final workshop	Q1 and Q4/2014
Safety guidelines and RCS inputs	End in Q4/2014



Conclusions, major findings and perspectives

Test and numerical programmes have been launched, planned or are to be analysed. When first results are available. They will be reviewed as inputs into possible RCS recommendations for requirements that apply to equipment or to installation.

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Hyindoor

HyLIFT-DEMO

Demonstration of Hydrogen-Powered Fuel-Cell Materials Handling Vehicles

Duration

Start and end date: January 2011 - December 2013

Application area

Early markets

Budget

Total budget €7.3 million
FCH contribution €2.9 million

Partnership/consortium list

Ludwig-Bölkow-Systemtechnik GmbH (Coordinator), H2 Logic A/S, DanTruck A/S, Technical University of Denmark, Linde AG, European Commission (JRC), Stiftelsen SINTEF), European Regions and Municipalities Partnership for Hydrogen and Fuel Cells, and European Hydrogen Association (HyRaMP-EHA), TÜV SÜD Industrieservice GmbH

Summary/main objectives of the project

- Demonstration of >30 hydrogen-powered fuel-cell materials handling vehicles
- Ensuring commercial market deployment from 2013 on

Technical accomplishment/progress/results

- HyLIFT-DEMO is one of the leading projects in Europe
- 11 vehicles in operation (10 forklifts & one airport tow tractor)
- Tests, trials and demo operations helped to overcome teething problems
- Batch production of fuel-cell systems in place, series production under preparation
- Several vehicles clocked >1,500h of operation at real end-user sites
- >2,000 refuelling procedures at corresponding hydrogen refuelling station
- Further large-scale demos already started or under preparation

Contribution to the programme objectives

Objectives of the call		Objectives of the project	Current status
Number of vehicles	10	30	11
Total cost of fuel cell system (€/kW)	< €4,000	< €3,100*	< €3,100*
System life time (with service/stack refurbishment) h	> 5,000	> 5,000	Test not finalised
System efficiency (tank to wheel) (%)	>40%	>48% (@10kW)	49% (last value obtained)
Refuelling time (min)	< 5	3-4	< 3 min
H_2 price at pump (€/kg)	< €13	< €9	€14.2 (average)

* Price after public support when reaching stated volume

Future steps

- The next step is to raise figures to hundreds of units as envisaged e.g. in the HyLIFT-EUROPE project (200 units)
- Authorities at all levels are asked to implement dedicated support mechanisms enabling a rapid market uptake in time
- The project enables the key partners to establish contacts to potential end-users which are currently not ready to enter into a contract

Conclusions, major findings and perspectives

Already a number of lessons have been learned. One is that test trials for potential customers are inevitable. An initial success of the project is that hydrogen-powered fuel-cell materials handling vehicles have clocked over 1,500h of operation at a real end-user site in Europe while the number of hydrogen refuelling procedures at the corresponding refuelling station has to date exceeded 2,000

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HyLIFT Clean Efficient Power For Materials Handling www.hylift.eu

HyLIFT-EUROPE

Large-Scale Demonstration of Fuel Cell-Powered Materials Handling Vehicles

Duration

Start and end date:
1 January 2013 - 31 December 2016

Application area

Early markets

Budget

Total budget €20,331,983
FCH contribution €9,263,194

Partnership/consortium list

Ludwig-Bölkow-Systemtechnik GmbH (Coordinator), STILL GmbH, MULAG Fahrzeugwerk Heinz Wössner GmbH, Air Products GmbH, Copenhagen Hydrogen Network A/S, Element Energy Ltd., Federazione delle Associazioni Scientifiche e Tecniche/European Hydrogen Association (FAST/EHA), European Commission (JRC), Heathrow Airport Ltd., H2 Logic A/S.

Summary/main objectives of the project

- Demonstration of up to 200 units of fuel cell-powered materials handling vehicles at vehicle-user sites across Europe
- Demonstration of state-of-the-art supporting hydrogen refuelling infrastructure at 10-20 vehicle-user demonstration sites throughout Europe
- Validate total cost of ownership (TCO) & path towards commercial targets
- Plan and ensure initiation of supported market deployment beyond 2013
- Best practice guide for HRS installation
- European dissemination and supporting European industry

Technical accomplishment/progress/results

- HyLIFT-EUROPE will become one of the leading projects in Europe
- As the project started only in 2013 no vehicles are in demonstration yet
- Several contacts to potential vehicle users are established and discussions are ongoing
- Tests, trials and demo operations are under preparation

Contribution to the programme objectives

Objectives of the call		Objectives of the project
Number of FC-systems	<50 units	Up to 200 units
FC system lifetime (h)	>7,500 hours	10,000 hours
FC system efficiency (%)	<45%	45-50%
FC-systems sales price	<€3,000/kW	<€2,300/kW
Refuelling time	3 minutes	~3 minutes
HRS availability	--	98%
H2 price at pump	<€10/kg	<€7-9/kg

Future steps

- As one of the first steps test trials for potential customers will be performed
- The consortium will prepare a package comprising vehicles, hydrogen refuelling station and hydrogen supply to be offered to potential customers
- Focus will be on customers with large fleets, three-shift operation and cheap hydrogen available
- As soon as demonstration has started total costs of ownership (TCO) calculations will be performed to identify the real TCO in comparison with conventional technology

Conclusions, major findings and perspectives

- In the US the number of fuel cell-powered materials handling vehicles has reached 4,000 units
- The US success factors are not easily transferred to Europe
- Substantial financial support will be required until supply chains are fully established and enable cost structures to compete with conventional technology

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HyLIFT Clean Efficient Power For Materials Handling www.hylift.eu

HYPER

Integrated Hydrogen Power Packs for Portable and Other Autonomous Applications

Duration

Start and end date:
September 2012 - August 2015

Application area

Early markets

Budget

Total budget €3.9 million
FCH contribution €2.2 million

Partnership/consortium list

Orion Innovations, EADS IW, Institute of Power Engineering, Joint Research Centre, McPhy Energy, PaxiTech, University of Glasgow.

Summary/main objectives of the project

Development and demonstration of a market-ready, portable power pack comprising an integrated modular fuel-cell and hydrogen storage system that is flexible in design, cost-effective and readily customised for application across multiple low-power markets.

Technical accomplishment/progress/results

- System engineering task complete - to ensure system specifications meet end-user needs
- Fuel-cell component evaluation complete
- Selection of promising candidate solid-state storage materials
- Design of bench-top scale storage tank for materials testing
- Suitable lightweight, high-pressure gas cylinders have been identified

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Volume and weight	< 35 kg/kW and 50 l/kW	20 kg/kW and 20 l/kW for 500 W system	On track
Final system cost (€k)	>€5,000	>€5,000	Cost at volume tbd
FC system efficiency	>30%	50%	Potential for 50%
Lifetime	1,000h, 100 start/stop cycles	1,000h 100 start/stop cycles	On track

Future steps

1. PoP of 50W fuel cell and scale up to 100W and 500W stacks
2. Integrate with gaseous and solid-state storage modules
3. Demonstrate 100W and 500W system prototypes (battery charger, portable power pack, and UAV range extender)
4. Finalise commercialisation strategy for rapid market diffusion

Conclusions, major findings and perspectives

Fuel-cell component evaluation phase has significantly improved the electrochemical performance of the fuel cell. MgH2 + catalysts and LiOH + LiH have been identified as promising novel materials for solid-state storage. Modeling of these and other materials to determine whole system performance is now underway. Gaseous storage represents a fast-track route to complete system integration and field demonstration.

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HYPER

Hyprofessionals

Development of Educational Programmes and Training Initiatives Related to Hydrogen Technologies and Fuel Cells in Europe

Duration

Start and end date: 1 January 2011 - 31December 2012

Application area

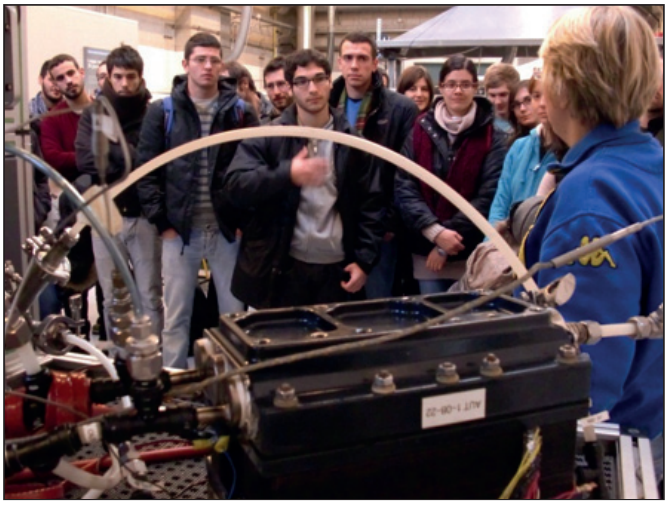
Cross-cutting activities

Budget

Total budget €432,116
FCH Contribution €373,537

Partnership/consortium list

Coordinator: Foundation for Hydrogen in Aragon (Spain)
Partners: FAST - Federation of Scientific and Technical Association (Italy), San Valero Foundation (Spain), UNIDO-ICHET (Austria), Joint Research Centre (JRC), Institute for Energy (Belgium), WeiterBildungsZentrum Ulm (Germany), Association PHYRENEES (France), Environment Park (Italy), Centre for Process Innovation (UK).



Summary/main objectives of the project

Today's technicians and students are the next generation of potential fuel-cell users and designers, so education becomes a critical step towards the widespread acceptance and implementation of hydrogen fuel-cell technology in the near future. The development of training initiatives for technical professionals should start aiming to secure the required mid- and long-term availability of human resources for hydrogen technologies.

Technical accomplishment/progress/results

Mapping of existing training initiatives, materials and funding programmes.

- Proposals for new initiatives, by way of a gap analysis (current training offer vs. industry expectations)
- Test or implement initiatives, through four pilot actions with 353 trainees (253 person-week trained)
- Dissemination (two dedicated workshops)

Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current status
Suitable existing programmes should be identified and concrete proposals	Mapping of existing training programmes in the EU	Completed
The initiatives shall be tested and implemented during the project	Two pilot actions and > 200 person-week of training	Completed. Four pilot actions and >250 person-week of training

Conclusions, major findings and perspectives

The "gap and need analysis" for automotive market has highlighted the need of workforce trained in hydrogen and fuel-cell technologies between five and 10 years for the sector (hydrogen mobility). For this application the hydrogen demand by 2015 will be very small (a few thousand vehicles per year). So technician training could be done incrementally: first in-house training (short course) and then from 2020 (when demand is greatest) integrate training for technicians as part of their initial vocational training. The pilot actions were delivered by a number of different mechanisms such as instructor-led training and E-learning. One positive opportunity with E-learning is the ability to train a large number of people in more convenient timescales to suit the student. If supplemented with some practical training (i.e. attendance at a facility) this helps further in the training and development.

HyResponse

Hydrogen Emergency Response Training Programme for First Responders

Duration

Start and end date: June 2013 - 31 May 2016

Application area

Cross-cutting activities

Budget

Total budget €2,640,284
FCH contribution €1,858,453

Partnership/consortium list

Project Coordinator: Marc Lopez (ENSOSP)
Leader : ENSOSP (France) : French academy for fire, rescue and civil protection officers
Partner 2 : Air Liquide Business (France)
Partner 3 : University of Ulster (UK)
Partner 4 : AREVA Energy Storage (France)
Partner 5 : FAST (Italy)
Partner 6 : CCS group (UK)
Partner 7 : CRISIS simulation engineering (France)

Summary/main objectives of the project

1. Build a European hydrogen training platform with mock-up real scale transport and hydrogen stationary installations on which full-scale operational exercises will be carried out.
2. Create a virtual reality platform reproducing entire accident scenarios
3. Disseminate knowledge into the first responders community through a website and produce a European emergency response guide

Technical accomplishment/progress/results

Constitution of an advisory and consultative panel emergency scenarios and first response strategies.

Future steps

- Emergency scenarios and first response strategies
- Educational training material
- Operational training facility
- Virtual reality training platform
- Pilot training sessions
- Recommendations and dissemination

Conclusions, major findings and perspectives

Support the successful implementation of hydrogen and fuel-cell demonstration projects and market transformation by providing educational and practical hydrogen safety training to first responders, who must know how to handle potential incidents to protect the public without putting in jeopardy their own life. Their understanding can also facilitate local project approval.

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HyResponse

HyTEC

Hydrogen Transport in European Cities

Duration

Start and end date:
1 September 2011 - 31 December 2014

Application area

Transport and refuelling infrastructure

Budget

Total budget €29.1 million
FCH contribution €11.95 million

Partnership/consortium list

Air Products, UK (Coordinator)
Cenex, UK
LBST, Germany
Intelligent Energy, UK
Element Energy, UK
Greater London Authority, UK
Copenhagen Hydrogen Network, Denmark
Heathrow Airport Ltd, UK
HyER, Belgium
hySOLUTIONS, Germany
Kobenhaven Kommune, Denmark
London Bus Services Ltd, UK
LTI, UK[1]
Matgas, Spain
Foreningen Hydrogen Link, Denmark
Fraunhofer Gesellschaft, Germany

Summary/main objectives of the project

HyTEC brings together a European consortium to:

- Demonstrate new hydrogen vehicles in three vehicle classes: taxis, passenger cars and scooters.
- Deliver new hydrogen refuelling facilities to London and Copenhagen. Copenhagen is based on on-site production and London based on hydrogen delivery, allowing different pathways to be tested and compared.
- Analyse the results of the project, considering the full well to wheels life-cycle impact of the vehicles and associated fuelling networks, demonstrating the technical performance of the vehicles and uncovering non-technical barriers to wider implementation.
- Plan for future commercialisation of the vehicles, as well as providing an approach for the rollout of vehicles and infrastructure, building on the demonstration projects.
- Disseminate the results to the public to improve hydrogen awareness. Carry out targeted dissemination to key industrial stakeholders and policy makers at local, regional, national and European level.

[1] Note that LTI is no longer part of HyTEC. However, the organisation contributed greatly to the first half of the project.

Technical accomplishment/progress/results

London:

- Installation and operation of the UK's first public accessible hydrogen fuelling station at Heathrow airport. Vehicle test and shakedown, driver training and certification of five fuel-cell taxis and creation of their operations base in London.
- Operation of the fuel-cell taxis during the London 2012 Olympics & Paralympics for the carriage of VIP guests of the London Mayor to/from Olympics venues, with operational data collected and reported.
- Tendering process for procurement of fuel-cell passenger cars underway

Copenhagen:

- Completion of the tendering process for the procurement of FCEVs, resulting in the delivery of 15 Hyundai ix35 FCEVs (nine of these vehicles are supported by HyTEC, with six coming via another project).
- Completion of the first edition of the hydrogen infrastructure expansion analysis for Denmark, which provided input into a new energy plan for the country.

Future steps

- Continued operation and data collection from hydrogen vehicle fleets in Copenhagen and London.
- Delivery of fuel-cell passenger cars into London.
- Upgrade to the London Hydrogen fuelling station to allow for 350 & 700 bar fuelling.
- Final design specification, installation and operation of the remaining Copenhagen fuelling station.

Conclusions, major findings and perspectives

HyTEC's work will lead to the creation of networks in each country to coordinate the process leading to hydrogen vehicle rollout.
These networks will be used to generate policy, industrial and administrative action towards hydrogen vehicle rollout. This work will be coordinated with the FCH JU to ensure the networks work within an overarching European vision for hydrogen vehicle deployment.

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HYTEC

HyTIME

Low-Temperature Hydrogen Production from 2nd Generation Biomass

Duration

Start and end date: 1 January 2012 - 1 January 2015

Application area

Hydrogen production and distribution

Budget

Total budget €2.92 million
FCH contribution €1.61 million

Partnership/consortium list

Wageningen UR Food & Biobased Research, Awite, ENVIRONMENT PARK, Heijmans, RWTH Aachen, TU WIEN, Wiedemann-Polska Projekt, HyGear and Veolia.

Summary/main objectives of the project

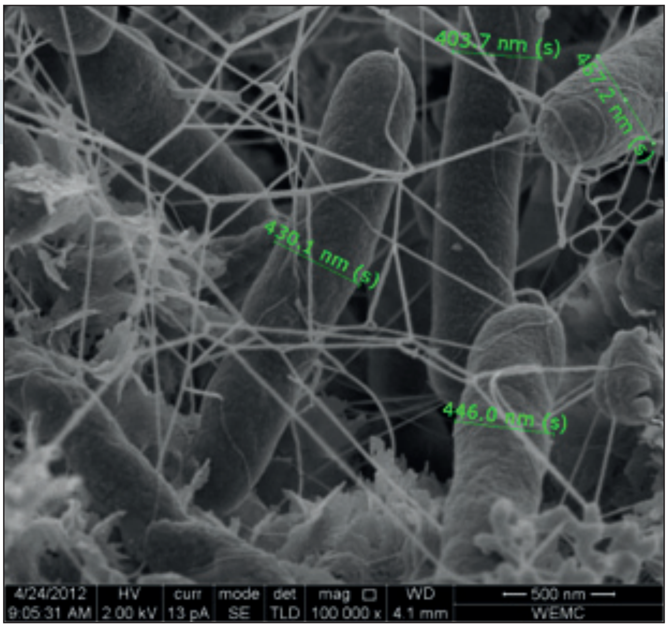
The objective of HyTIME is to construct a prototype process for delivering 1-10 kg H_2/day based on the unique strategy of a combination of extreme thermophilic dark fermentation with anaerobic digestion (Fig. 1). HyTIME builds on previous results from FP 5 (EU BIOHYDROGEN) and FP 6 (HYVOLUTION). The acquired knowledge on biomass availability, logistics and pretreatment and on gas upgrading technology will be fully exploited to develop dedicated systems for an easy-to-handle biohydrogen production system.

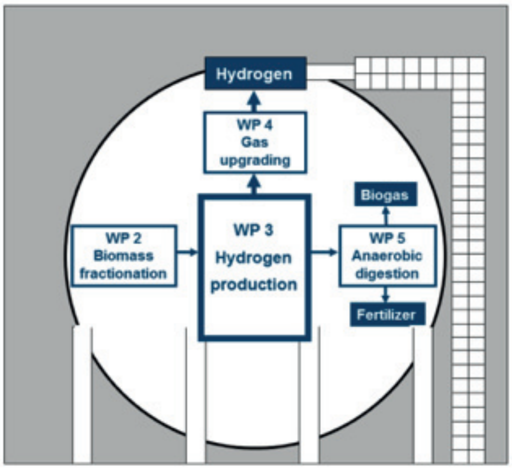
Technical accomplishment/progress/results

Designed co-cultures of Caldicellulosiruptor sp. showed stable hydrogen production during continuous fermentation of over 40 days. In a prototype packed bed bioreactor with a gas disengager hydrogen production from sugars was 9.1 g/day with 25% H_2 in the off-gas. Using verge grass hydrolysate, 6 g H_2/day with 19% H_2 in the off-gas was achieved at a much higher retention time of 10h. The effluent from the hydrogen fermenter has been successfully used for anaerobic digestion. Hydrolysate production from straw and kitchen waste has been optimised. Membrane contacters for gas upgrading have been selected. Desk studies for system integration have been started. An up-scaled bioreactor of 50 L has been designed and delivered.

Contribution to the programme objectives

Objectives of the call	Objectives of the project (500 L bioreactor)	Current status (5 L bioreactor)
1-10 kg H_2/day	1-10 kg H_2/day	6-9 g H_2/day





Future steps

Operation of the 50 L bioreactor. Construction and commissioning of the 500 L bioreactor for the production of 1-10 kg H_2/day from molasses. Testing of organic residues from biomass production or food processing for hydrogen production. Fermentation off-gas will be upgraded to 98% H_2 using low energy demanding protocols. Heat and energy balances will be finalised for optimal system integration.

Conclusions, major findings and perspectives

Verge grass hydrolysate representing a 2^{nd} generation biomass can be converted to hydrogen in a stable fermentation process. Fermentation at 70°C warrants high yield and protection against contamination. The production of biogas using the effluent of the hydrogen fermenter can contribute significantly to reduce external energy demand.

Hy Transfer

Pre-Normative Research on Gaseous Hydrogen Transfer

Duration

Start and end date: June 2013 - November 2015

Application area

Hydrogen production and distribution

Budget

Total budget €3.1 million
FCH contribution €1.6 million

Partnership/consortium list

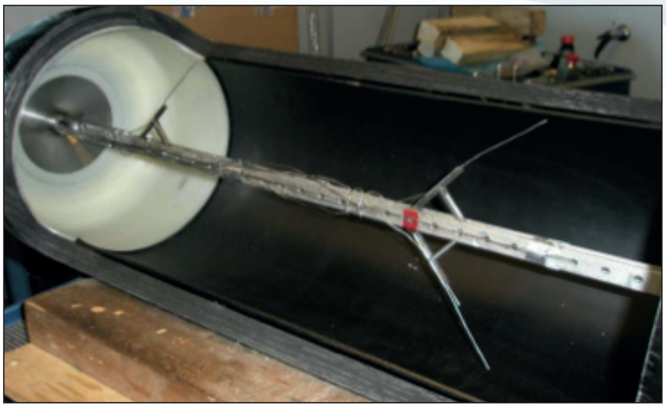
Ludwig-Bölkow-Systemtechnik GmbH (LBST), Raufoss Fuel Systems AS, Air Liquide SA, Honda R&D Europe (Deutschland) GmbH, European Commission (JRC), Centre National de la Recherche Scientifique (CNRS), TesTneT Engineering GmbH, The CSS Global Group Ltd

Summary/main objectives of the project

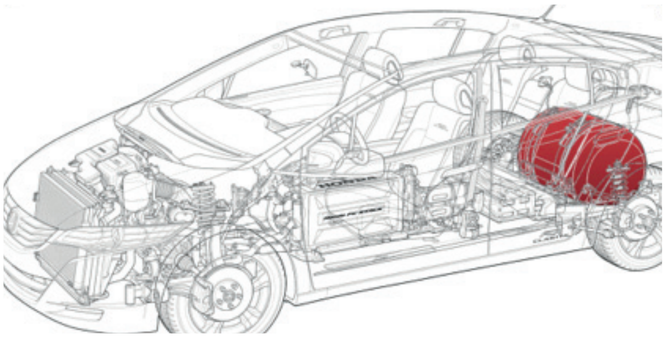
HyTransfer aims to develop and experimentally validate a practical approach for optimising means of temperature control during fast transfers of compressed hydrogen to meet the specified temperature limit (gas or material) taking into account the container and system's thermal behaviour.
This project aims to create conditions for an uptake of the approach by international standards, for wide-scale implementation into refuelling protocols.

Contribution to the programme objectives

Objectives of the call and project	Current status
Evaluation of potential benefits with regards to refuelling performance	To be started in 2014
Proposed approach for standardisation	To be started in 2014
Improved approaches for carrying out the transfer with less pre-cooling	To be started in 2014
Recommendations for implementation in international regulations, codes and standards	2015



Source: JRC



Source: Honda

Future steps

1 - Development of simple thermodynamic model
2 - Experimental validation
3 - Techno-economic analysis
4 - Recommendations for regulations, codes and standards

Conclusions, major findings and perspectives

The new approach to be developed within HyTransfer will allow a hydrogen station to directly and accurately calculate an end-of-fill temperature in a hydrogen tank and thereby maximise the fill quantity and minimise the refuelling time.

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HyTransfer

HyUnder

Assessment of the Potential, the Actors and Relevant Business Cases for Large-Scale and Seasonal Storage of Renewable Electricity by Hydrogen Underground Storage in Europe

Duration

Start and end date: 18 June 2012 - 17June 2014

Application area

Cross-cutting activities

Budget

Total budget €1,766,516
FCH Contribution €1,193,273

Partnership/consortium list

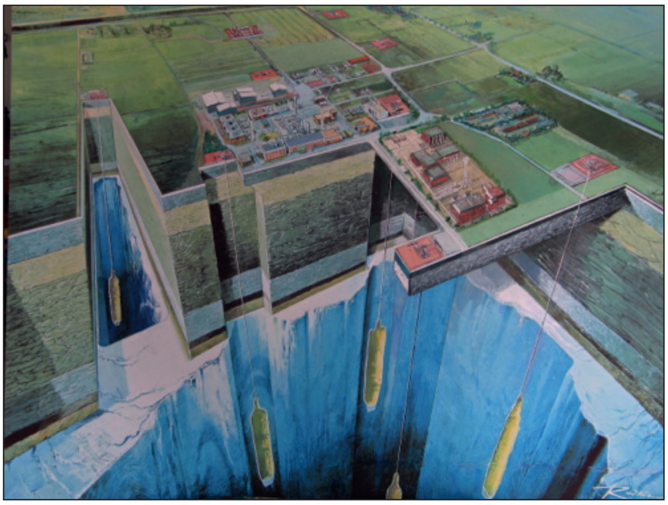
Coordinator: Foundation for Hydrogen in Aragón. Partners: Ludwig-Bölkow-Systemtechnik, Hinicio, KBB Underground Technologies, National Center for Hydrogen & Fuel Cells Romania, DEEP Underground Engineering, E.ON Gas Storage, Energy Research Centre of the Netherlands, Shell Global Solutions, Centre of Excellence for Low Carbon and Fuel Cell Technologies, Solvay Chemicals, Commissariat à l'énergie atomique et aux énergies alternatives (CEA).

Summary/main objectives of the project

The objective of the HyUnder project is to establish a European initiative supporting the deployment of hydrogen energy storage in underground storage caverns at large scale, benchmark their storage potential in relation to the energy market and competing storage technologies, and identify and assess application areas, stakeholders, safety, regulatory framework and public acceptance.

Technical accomplishment/progress/results

Benchmark study of large-scale hydrogen underground storage and other energy buffering alternatives valid for GWh scale. An evaluation of each geological storage option was also completed. Salt caverns are established as the best option. A mapping and semi-quantitative assessment of the potential in the six HyUnder project countries (Spain, France, UK, Netherlands, Germany, Bulgaria) to store hydrogen in geological formations was also defined. A description of below-ground and above-ground components of the system and safety issues was undertaken. All case studies are running to date.



Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current satus
Benchmark study of ESS valid for large scale (GWh scale)	Benchmark study of ESS valid for large scale (GWh scale)	Completed
Assess storage options in geological formations	Assess storage options in geological formations	Completed. Salt caverns best option
Evaluate availability of suitable geological formations for the recommended storage options all over Europe	Mapping geological formations (DE,FR,NL,SP,RO,UK)	Running. Almost finished
Potential business cases (management by modeling)	Case studies (DE,FR,NL,SP,RO,UK)	Running
Set recommendations on future projects for technology evaluation, demonstration or pilot scale. Identify the interest groups, establish a communication plan and execute it.	Implementation plan	Month 24

Future steps

1. Case studies comparison
2. Conclusions

Conclusions, major findings and perspectives

There is ample potential to develop relevant cavern sites in the selected locations. Salt caverns represent the most interesting geological option. Hydrogen could serve for all energy sectors in need of large-scale energy storage. Initially it seems that in the short term the industry sector and PtG appear as first business cases. Medium- to long-term, the transport sector is the more relevant business case. PtP systems have low efficiencies. Final results will give us the final business models.

IDEALHY

Integrated Design for Efficient Liquefaction of Hydrogen

Duration

Start and end date: November 2011 - October 2013

Application area

Hydrogen production and distribution

Budget

Total budget €2.5 million
FCH contribution €1.3 million

Partnership/consortium list

Shell (Netherlands), SINTEF (Norway), WEKA (Switzerland), Linde Kryotechnik (Switzerland), Technical University of Dresden (Germany), Loughborough University (UK), North Energy (UK), PLANET (Germany), Kawasaki (Japan).

Summary/main objectives of the project

The aim of IDEALHY is to enable liquid hydrogen (LH2) as an efficient low-carbon energy carrier, by designing a process for efficient hydrogen liquefaction at a scale of up to 200 tonnes per day and developing plans for a demonstration plant.

Technical accomplishment/progress/results

IDEALHY has achieved the 50% energy reduction target:

- Novel process design with efficient components that are within capabilities of supplier
- Energy consumption for plant size 40 - 200 tpd is only 13% of the hydrogen energy content (6.4kWh/kg LH2: compare current best in class 12-15kWh/kg LH2)
- Safety and risk management considered at all stages of the LH2 chain Roadmap drafted of route to commercial operation

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Hydrogen production and distribution	Technology readiness in 2020 for expansion of H2 infrastructure	Enable efficient transport of low-CO2 energy from resource to demand areas	Energy-efficient liquefaction enables transport of hydrogen from renewables or from fossil+CCS
Long-term MAIP target on hydrogen refuelling stations	Over 2,000 stations with cost from €0.6m-€1.6m	Enable liquid supply to larger hydrogen stations, to reduce station equipment cost	LH2 storage more compact/cheaper than gaseous; compression equipment also lower cost
Reduce cost of delivered hydrogen	Cost of hydrogen production and delivery below €5/kg	Efficient hydrogen liquefaction enables distribution cost reductions	4x fewer trucks than gaseous H2; faster loading/offloading times. Plus: liquefaction cost minimised
Centralised hydrogen production by electrolysis	50 tonnes per day capacity of electrolyser	LH2 transport permits efficient transport away from production facility by road or barge (isocontainers)	Liquefaction plant process design complete for 50 tonnes per day/plant

Future steps

- Further process optimisation, prioritising feasibility and availability of relevant equipment
- Development of appropriate components through collaboration with manufacturers
- Growing of LH2 market through cooperation with Europe-wide hydrogen initiatives
- Assessment of options for pilot plant location, including supply of and market for LH2

Conclusions, major findings and perspectives

IDEALHY demonstrates that liquefaction energy requirement is no barrier to an efficient liquid hydrogen distribution chain, thus enabling transport in larger volumes and over longer distances. Life-cycle analysis shows that cost and overall greenhouse gas emissions can be competitive with compressed gaseous hydrogen.

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idealhy

IMMEDIATE

Innovative Automotive MEA Development – Implementation of IPHE-genie Achievements Targeted at Excellence

Duration

Start and end date: 1 January 2013 - 31 December 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €3,823,504
FCH contribution €2,229,172

Partnership/consortium list

IRD (Coordinator), ICPF, CNRS, FUMA-TECH, Shanghai Jiao Tong University, Volvo Technology, SGL Carbon, JRC, TIMCAL.

Summary/main objectives of the project

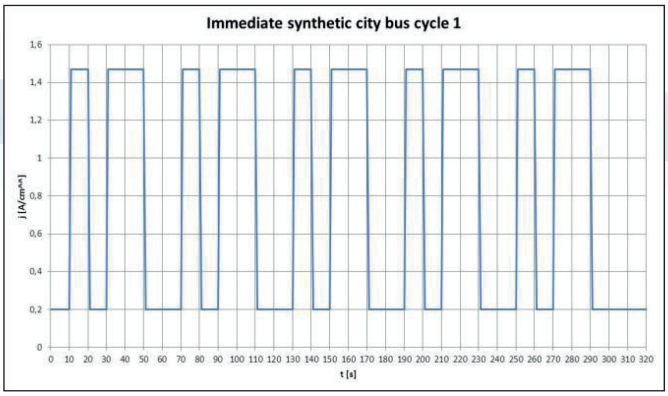
The prime focus of Immediate is to develop high performing MEAs aimed for automotive applications through material R&D and process optimisation.

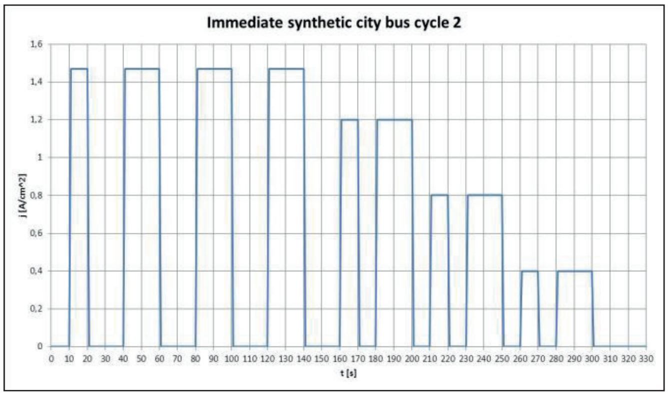
Technical accomplishment/progress/results

The main objectives during the first phase of the project have been the definition of test protocols, establishment of website (www.immediate.ird.dk), and review of state-of-the-art materials. Initial batches of new precursor materials have been distributed among the partners.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Pt usage	<0.15 g/kW	<0.15 g/kW	N/A (test not finalised)
Lifetime (h)	>5,000	>5,000	N/A (test not finalised)
Proton conductivity	>100 mS/cm at ≤25% RH, 120°C	>100 mS/cm at ≤25% RH, 120°C	N/A (test not finalised)
BoI power density	>1W/cm^2	>1W/cm^2	N/A (test not finalised





Future steps

1. Test of precursor materials
2. Fabrication and test of 1G MEAs
3. Fabrication of next generation precursor materials.

Conclusions, major findings and perspectives

The objectives in the first part of the project have been met and in addition an input has been given to the "Harmonisation of PEFC testing protocols for automotive applications" initiative.

IMPACT

Improved Lifetime of Automotive Application Fuel Cells with Ultra-Low Pt-Loading

Duration

Start and end date: November 2012 - April 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €8,837,294
FCH contribution €3,902,403

Partnership/consortium list

German Aerospace Center, Germany (coordinator); Commissariat à l'Energie Atomique (France), European Commission (JRC), Consiglio Nazionale di Ricerche (Italy), ITM-Power (UK), Johnson-Matthey Fuel Cells (UK), Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Germany), University of Applied Sciences Esslingen (Germany), Technische Universität Berlin (Germany), Institut National Polytechnique de Toulouse (France), Gwangjiu Institute of Science and Technology (South Korea), Solvay Specialty Polymers (Italy).

Summary/main objectives of the project

Improvement of lifetime and performance-cost ratio by reduction of platinum loading.

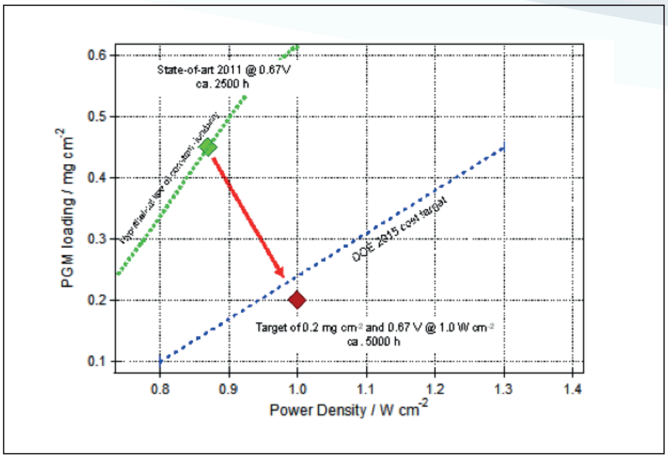
Technical accomplishment/progress/results

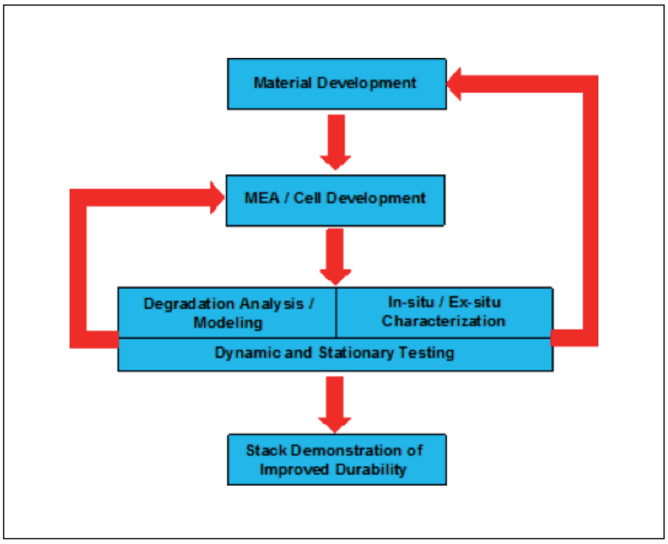
- Evaluation of techniques and characterisation of reference materials
- First improved membrane-electrode-assembly

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
FC power density (W/cm^2)	>1	>1	0.85
FC current density (A/cm^2)	>1.5	>1.5	1.25
Pt loading (mg/cm^2)	<0.15	<0.2	0.4
FC system life time (h)	<5,000	<5,000	2,500

Future steps





- Iterative MEA/cell development – testing – in-situ and ex-situ characterisation – degradation analysis
- Support by computational modeling
- Demonstration of improved stack durability

Conclusions, major findings and perspectives

Reaching the objectives will help to achieve cost-competitiveness of polymer electrolyte fuel cells in the next generation of fuel-cell cars

IMPALA

Improve PEMFC with Advanced Water Management and Gas Diffusion Layers for Automotive Application

Duration

Start and end date: 1 December 2012 - 30 November 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €5.08 million
FCH contribution € 2.64 million

Partnership/consortium list

German Aerospace Center, Germany (coordinator); Commissariat à l'Energie Atomique (France), European Commission (JRC), Consiglio Nazionale di Ricerche (Italy), ITM-Power (UK), Johnson-Matthey Fuel Cells (UK), Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Germany), University of Applied Sciences Esslingen (Germany), Technische Universität Berlin (Germany), Institut National Polytechnique de Toulouse (France), Gwangjiu Institute of Science and Technology (South Korea), Solvay Specialty Polymers (Italy).

Summary/main objectives of the project

- Increase power density (up to the ideal target of 1 W/cm^2) and durability of PEMFC for automotive application with a focus on water management and GDL.
- Technological route: manufacture improved homogeneous (low-risk approach) and innovative non-homogeneous (higher-risk approach) gas diffusion layers (GDL)
- Scientific route: improve knowledge of water management in operating PEMFC and models to better link local properties of GDL to performance of PEMFC

Technical accomplishment/progress/results

- Reference materials have been tested to reach performance level 0: 0.75 W/cm^2 @1.5 A/cm^2 (BOL, 1.5b, 80°C, 50%RH)
- MPL was modified to reach performance close to level 1: 0.90 W/cm^2
- Pore network modeling and characterisation of GDL have started

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
BoL power density (W/cm^2 @1.5 A/cm^2)	> 1	1	0.89
EoL power density (W/cm^2 @1.4 A/cm^2)	> 0.9	0.9	To be checked
Development of novel materials for gas diffusion layers	X	SGL materials will be improved and new structures will be studied	First improvements have been done
Electric conductivities (S/cm)	>2 through-plane >100 in-plane	>2 through-plane >100 in-plane	2.5 To be checked
Intrinsic permeability > 10^{-12} m^2	>10^{-12}	>10^{-12}	10^{-12} – 10^{-11}
In-situ characterization and diagnostic techniques for optimisation of water management	Development of advanced in-situ diagnostic techniques	X-ray visualisation	Under progress
Improvement of PEMFC performance and durability through multiscale modeling and numerical simulation.	Development of multi-scale modeling and numerical simulation tools to be validated through experimental work.	Improvement of pore network modeling and "coupling" with performance models. Extensive validation on ex-situ and in-situ operating cells	Under progress
Contribute to the development of European industry solutions	X	SGL is a European industry	Under progress

Future steps

1. Modify properties of GDL substrate and MPL to increase W/cm^2 up to 1 W/cm^2
2. Start X-Ray and optical liquid visualisation on cells
3. "Multiscale" modeling to link local properties of GDL to performance
4. Validate modeling on ex-situ and operating cells
5. Propose guidelines for improving GDL
6. Perform single cells and stack tests (performance and durability)

Conclusions, major findings and perspectives

- First improvements have been obtained by modifying properties of homogeneous GDL and more innovative GDL will be considered
- To link properties of GDL to performance is still an open question but will be addressed by IMPALA (models, experiments, characterisation)
- Models compared to experiments will help better understanding water management in operating cell
- Refined characterisation of GDL (structure, wettability, effective properties...) will be done

IRAFC

Development of an Internal Reforming Alcohol High-Temperature PEM Fuel Cell Stack

Duration

Start and end date:
1 January 2010 - 30 June 2013

Application area

Early markets

Budget

Total budget €2,529,625
FCH contribution €1,424,147

Partnership/consortium list

Coordinator: Advent Technologies
University of Maria Curie-Sklodowska, NedStack fuel cell technology, Centre National de la Recherche Scientifique (CNRS Strasbourg), Institute of Chemical Engineering Sciences (FORTH/ICE-HT) and Institute fur Mikrotechnik Mainz Gmbh (IMM).

Summary/main objectives of the project

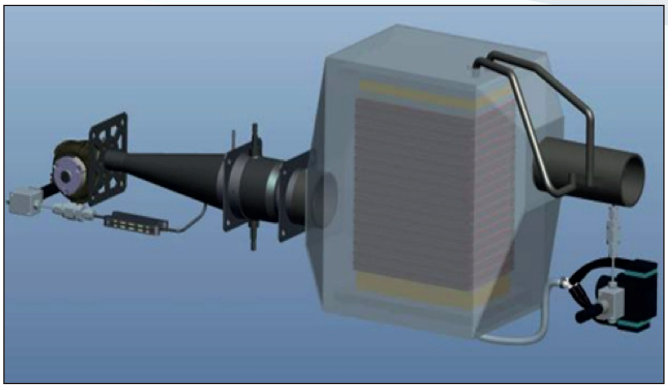
The main objective of the IRAFC project was the development of an internal reforming alcohol high-temperature PEM fuel cell. It consisted of a low-temperature methanol reformer and a high-temperature polymer electrolyte fuel cell in a single compact structure operating at 200°C-220°C. Development of new materials and components were required as well as special systems design. IRAFC system has certain advantages such as use of liquid fuel and compact design and can apply in portable generators, back-up power and UPS-systems.

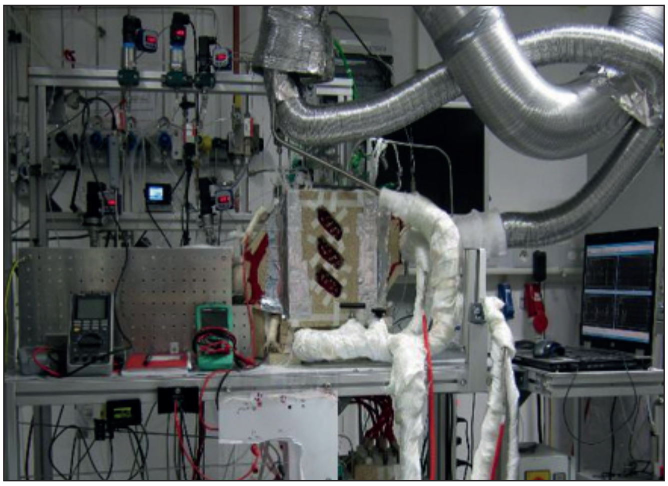
Technical accomplishment/progress/results

- New cross-linked robust membranes have been synthesised with operating temperature of 220°C
- New alcohol reforming catalysts operated at 200°C
- New bipolar plate materials specially designed according to system requirements
- Successful system integration

Contribution to the programme objectives

IRAFC system has the following advantages: easy fuelling, use of liquid fuel, compact design through the combination of reformer/fuel cell.
IRAFC system finds application in the areas of portable fuel cells, stationary back-up and UPS systems, remote and off-grid areas which are in agreement with early markets as described in MAIP and AIP, whose main goal is to show the technology readiness of (i) portable and micro fuel cells for various applications; (ii) portable generators, back-up power and UPS-systems; (iii) specialty material handling vehicles including related hydrogen refuelling infrastructure.





Conclusions, major findings and perspectives

An internal-alcohol-reforming, high-temperature, PEM fuel cell (IRAFC) has been developed using new polymer membranes able to operate at 220°C and new alcohol reforming catalysts with improved activity and stability able to provide stable hydrogen production in the anode environment. The integrated system has been designed, constructed and tested proving the concept of such a compact system which can be potentially used in various applications.

IRMFC

Development of a Portable Internal Reforming Methanol High-Temperature PEM Fuel-Cell System

Duration

Start and end date: 1 January 2013 - 30 April 2016

Application area

Early markets

Budget

Total budget €3,266,389
FCH contribution €1,586,038

Partnership/consortium list

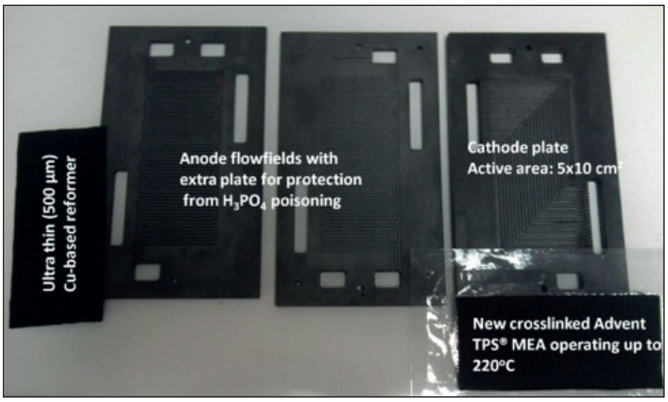
FORTH/ICE-HT (Greece, Coordinator), Advent (Greece), UMCS (Poland), IMM (Germany), UPAT (Greece), ZBT (Germany), JRC-IET (Belgium), ENERFUEL (US), ARPEDON (Greece)

Summary/main objectives of the project

Development/demonstration of 100W internal reforming methanol high-temperature PEM fuel-cell system for portable applications. Main goals to be accomplished: scale-up synthesis and optimisation of the main components (HT-MEAs, methanol reforming catalysts, BoP) developed within the framework of project FCH-JU IRAFC 245202.

Technical accomplishment/progress/results

- Scale-up synthesis of ultra thin Cu-based methanol reformer (5x10cm^2, 500 μm thickness), highly active at 210°C, easy embedding in the cell
- Polymer electrolyte membranes operating at 220°C with high stability (500 hours fuel-cell testing)
- New bipolar plate material operating at 200-230°C.

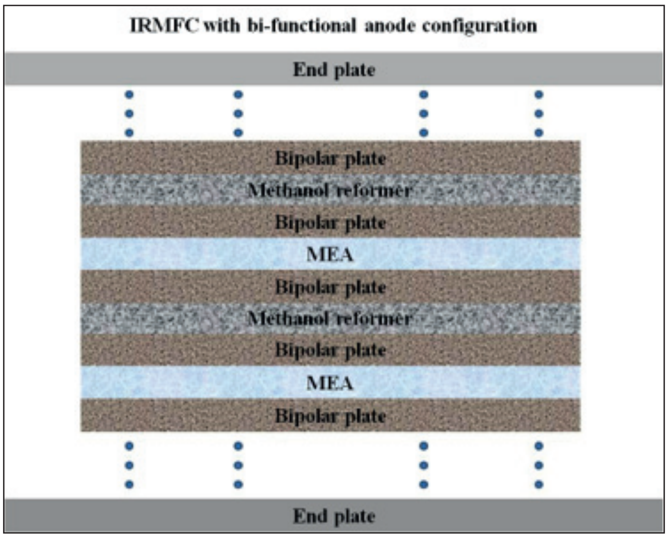


Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
FC system lifetime (h)	>1,000	>1,000	N/A (main components under testing/ optimisation)
FC system efficiency (%)	>30	>30	N/A (single cell evaluation to be obtained)
Specific size (fuel amount excluded) (l/kW)	<50	<50	N/A
Specific weight (fuel amount excluded) (kg/kW)	<35	<35	N/A
Cost prediction for mass production (€/kW)	<€5,000	<€5,000	N/A

Conclusions, major findings and perspectives

The first six months' results clearly demonstrate the IRMFC project progress, feasibility and future success. Novel polymer electrolytes have been prepared while the cross-linking methodology adopted for the first time has demonstrated some excellent results, leading to MEAs operating even above 210°C. New-type methanol reformer and bipolar plates prepared so far also have shown our ability to achieve the objectives of the project.



KeePEMalive

Knowledge to Enhance the Endurance of PEM Fuel Cells by Accelerated Lifetime Verification Experiments

Duration

Start and end date: 1 January 2010 - 30 June 2013

Application area

Stationary power generation and CHP

Budget

Total budget €2,874,206
FCH contribution €1,264,582

Partnership/consortium list

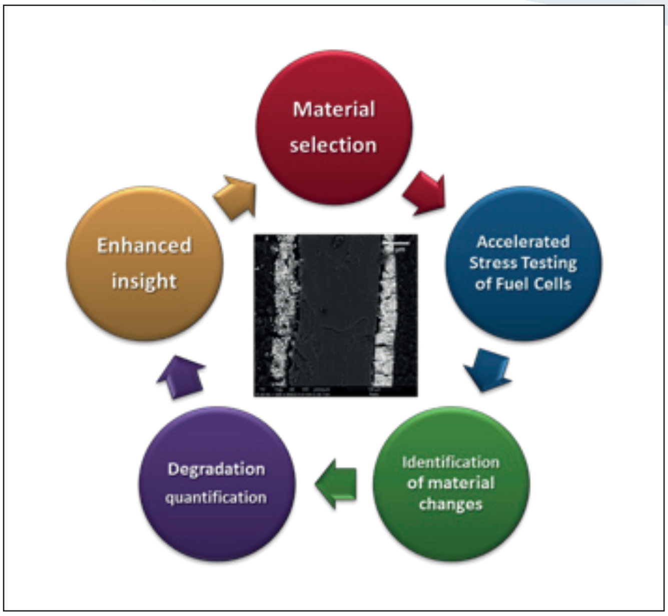
Stiftelsen SINTEF (Norway, coord.), IRD Fuel Cells A/S (Denmark), Stichting EnergieonderzoekCentrum (Netherlands),
CNRS – Centre National de la Recherche Scientifique, Institut Charles Gerhardt (France), FuMA-Tech GmbH (Germany),
EIfER – European Institute for Energy Research (Germany), Technische Universität Graz (Austria), SEAS-NVE (Denmark), European Commission JRC.

Summary/main objectives of the project

- Improve the understanding of degradation & failure modes for stationary PEM fuel cells, with special focus on low-temperature μ-CHP application
- Establish accelerated stress test (AST) protocols, a sensitivity matrix and a lifetime prediction model for stationary μ-CHP applications

Technical accomplishment/progress/results

Five generations of membrane materials have been synthesised and characterised. The initial batch production was successfully scaled up to continuous membrane series production.
By introducing Ce-based radical scavengers the stability of the membrane was further enhanced. Manufacturing of around 200 MEAs and assembly of five fuel cell stacks was done in-house.
Around 25,000 hours single fuel cell testing and more than 3,000 hours of stack testing was carried out to reveal the relationship between operating parameters and degradation rates for typical real life conditions. Statistical design and analysis of the results has shown to be efficient and save time & resources.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
CHP system lifetime (h)	40,000	Not specified	~ 17,000
CHP system electric efficiency (%)	> 45	Not specified	50

Conclusions, major findings and perspectives

Assessment of the field data from real-life operations (at Lolland) has led to improvements in the μCHP systems and taken the technology one step closer to fulfil the stringent 40,000 hour lifetime requirements.
By exchanging some MEA precursors and further optimising the operational conditions the MEA lifetime was increased significantly. The degradation rate was decreased from 20 to 4 μV/h, corresponding to increasing the system lifetime from the previous level of 3,500 hours to an expected 17,000 hours (~ 2 years).
The heat and electricity demand and the related energy & emission savings from utilising CHP-units in Danish households have been mapped for various seasons. During the course of the project the electric system efficiency has been improved to 50%, and the total system efficiency (electricity and heat) to > 80%.

KEEPEMALIVE

LASER-CELL

Innovative Cell & Stack Design for Stationary Industrial Applications Using Novel Laser Processing Techniques

Duration
Start and end date: December 2011- November 2014

Application area
Stationary power generation and CHP

Budget
Total budget €2,877,089
FCH contribution €1,421,757

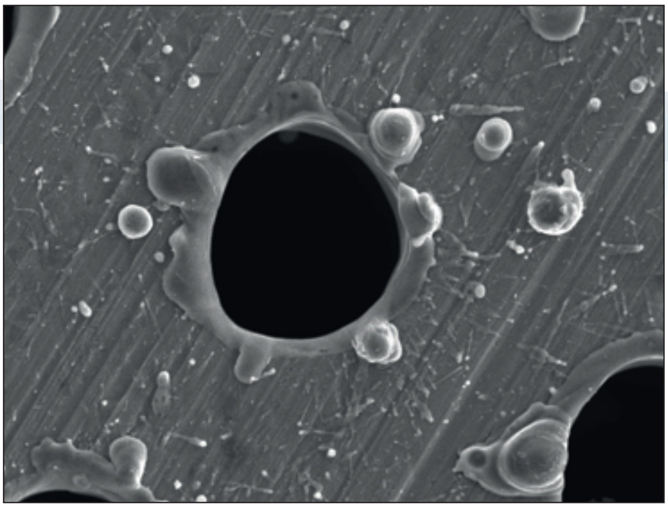
Partnership/consortium list
AFC Energy plc (UK), CENCORP OYJ (Finland), Teknologian Tutkimuskeskus VTT (Finland), Air Products plc (UK), Nanocyl SA (Belgium), Universität Duisburg-Essen (Germany).

Summary/main objectives of the project
1. Refined alkaline fuel-cell design that exploits benefits of laser-processing and novel materials
2. Refined stack design that delivers safety, mass manufacture, ease of assembly, recyclability, & optimal performance

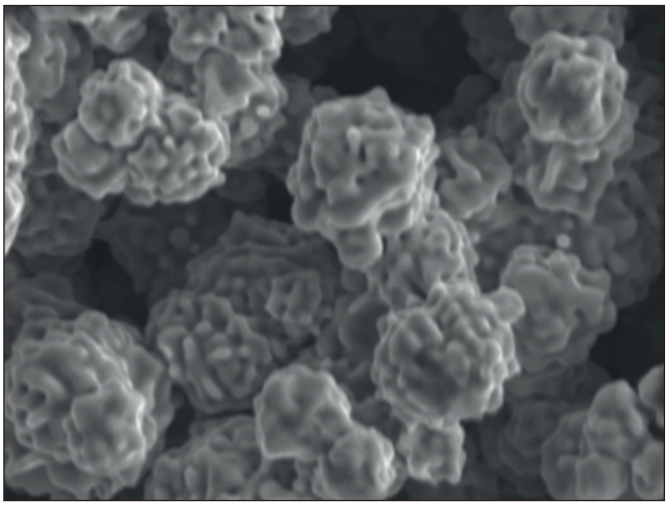
Technical accomplishment/progress/results
- Laser drilling: target speeds achieved
- Laser sintering: performance targets achieved in small-scale trials
- CNT conductive polymers: improved electronic conductivity of CNT-loaded thermoplastic plate
- Substrate design model that distinguishes effective conductivities in in-plane and through-plane directions

Contribution to the programme objectives
2015 targets for stationary:
- 100MW installed electric capacity
- Substrates developed in LASER-CELL will be deployed in the 0.5MW system of project POWER-UP (currently in negotiations). These systems will be commissioned by 2015.
- Cost of €1,500-€2,500/kW for industrial/commercial units
- Lab trials and cost-modeling indicate that stacks developed in LASER-CELL will achieve a cost per kW below these targets – to be confirmed in year three.

Future steps
Construction of prototype stack to test the advances achieved during the first phase.



Laser-drilled sample



Laser-sintered sample

Conclusions, major findings and perspectives
Modeling results and small-scale test results achieved in phase I of the project confirm the appropriateness of tests planned for phase II. Project objectives expected to be achieved on schedule.

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Laser-cell

LiquidPower

Advanced Multi-Fuel Reformer for Fuel-Cell CHP Systems

Duration

Start and end date: 1 October 2012 - 31 May 2015

Application area

Early markets

Budget

Total budget €3.68 million
FCH contribution €1.99 million

Partnership/consortium list

H2 Logic A/S (coordinator)
Catator AB,
Dantherm Power A/S
Zentrum für Brennstoffzellen-Technik Gmbh

Summary/main objectives of the project

The LiquidPower project objectives are:

- R&D of a fuel-cell system for back-up power and telecom applications (BT)
- R&D of a fuel-cell system for materials handling vehicles (MHV)
- R&D of a methanol reformer for onsite hydrogen supply, enabling low-cost hydrogen for the early markets of BT and MHV

Technical accomplishment/progress/results

Technical specifications of R&D tasks: conducted
R&D of fuel-cell systems and reformer: ongoing
First laboratory tests conducted on components and catalyst materials.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
H2 cost €/kg at user site	€7-€30/kg	<€7/kg	>€15/kg
FC system life time (h)	>5,000h	<10,000h	<5,000h
FC system efficiency (%)	40-50%	45-55%	>40%
FC system €/kW volume prod.	€1,500-€2,500	€1,300-€1,800	>€3,000

Future steps

During 2014 complete fuel-cell and reformer prototypes will be finalised and extensive laboratory tests conducted to evaluate ability of reaching technical targets.

Conclusions, major findings and perspectives

The incorporation of catalytic membranes reactors in the PEM fuel-cell micro-CHP systems could improve the efficiency while reducing the cost due to the integration of the reforming and purification in one single unit (working at lower temperature) and the optimised design of the sub-component for the BoP.

LoLiPEM

Long-Life PEM-FCH & CHP Systems at Temperatures above 100°C

Duration

Start and end date: 1 January 2010 - 31 December 2012

Application area

Stationary power generation and CHP

Budget

Total budget €2,677,298
FCH contribution €1,360,227

Partnership/consortium list

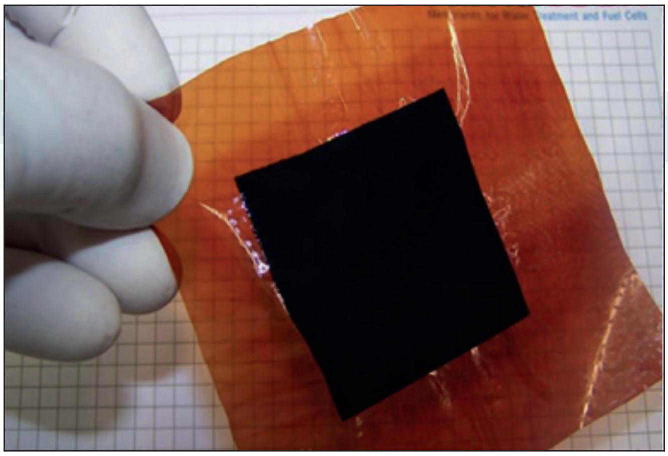
National Research Council – Institute on Membrane Technology (Italy), The University of Rome Tor Vergata (Italy), Aix-Marseille University (France), The University of Saarbrücken (Germany), Edison SpA (Italy), FumaTech GmbH (Germany), MATGAS 2000, A.I.E. and its third part S.E. de Carburos Metalicos sa (Spain), Cracow University of Technology (Poland).

Summary/main objectives of the project

- Development of long-life PEMs operating at temperatures above 100°C
- Preparation and testing of MEAs based on the developed innovative low-cost materials (membrane and catalyst)
- Establishment of accelerated test techniques and methods for MEA testing

Technical accomplishment/progress/results

- Novel PFSA and SAP membranes, catalysts and MEAs.
- Excellent hydrothermal membrane stability, lower cross over and mechanical resistance also at high temperatures leading to a high durability.
- A lifetime of 8,850 h was evaluated based on the reference curve at 75°C, whereas a lifetime of 44,250 h is estimated considering the own temperature of 110°c, 35°C higher.
- Membranes were also produced by a full-scale apparatus.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
PFSA hydrothermal stability	High	up to 120°C	up to 120-140°C
SAPs hydrothermal stability	High	up to 140°C	up to 140°C
Mechanical integrity @ RH cycling and condensing conditions	High	yes	yes
Predicted lifetime	40,000 h	40,000 h	8,500-44,250 h
SAP proton conductivity @ 120°C - 95% relative humidity	High	>0.07 S/cm	>0.07 S/cm

Future steps

Up-scaling of polymer and membrane production based on low-cost materials

Conclusions, major findings and perspectives

The membranes and treatments developed significantly increase the operating temperature in fuel-cell applications up to 120-140°C and give an excellent hydrothermal stability and mechanical properties.
The prepared MEAs revealed performances competitive to those in the literature. Most results were published in 23 papers.

LOTUS

Low-Temperature Solid Oxide Fuel Cells for Micro-CHP Applications

Duration

Start and end date: 1 January 2011- 31 December 2013

Application area

Stationary power generation and CHP

Budget

Total budget €2,954,984
FCH contribution €1,632,601

Partnership/consortium list

Coordinator: Hygear Fuel Cell Systems (Netherlands)
Consortium: SOFCpower (Italy), Fraunhofer-Institut für Keramische Technologien und Systeme (Germany), Domel d.d. (Slovenia), University of Perugia (Italy), European Commission (JRC)

Summary/main objectives of the project

Main objective is a 1kWe micro CHP system based on SOFC technology running at 650°C. The electrical efficiency target is 45% and the overall CHP target is 80%.

Technical accomplishment/progress/results

- Good SOFC stack performance at 650°C
- Process model of the entire system
- Steam reformer, steam generator and BoP hardware meeting the specifications of performance and pressure drop
- Single blower system design

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Electrical efficiency (%)	45	45	42 (based on model)
Overall efficiency (%)	80	80	76 (based on model)
Mass produced system cost in 2020 (€)	<€5,000	< €5,000	€4,750

Future steps

Integrate hardware modules, test system and validate dynamic system model with measured data.

Conclusions, major findings and perspectives

In the LOTUS project, improved solid oxide fuel cells performance at 650°C is shown. The fuel cell is integrated in a complete micro-CHP system, based on a steam reformer and a single blower process design. This leads to a system containing fewer parts, which improves economics and reliability.

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LOTUS

MAESTRO

Membranes for Stationary Application with Robust Mechanical Properties

Duration

Start and end date: 1 January 2011 - 31 March 2014

Application area

Stationary power generation and CHP

Budget

Total budget €2.2 million
FCH contribution €1.04 million

Partnership/consortium list

Centre National de la Recherche Scientifique – CNRS (France), Solvay Specialty Polymers (Italy), Johnson Matthey Fuel Cells (UK), Università di Perugia (Italy), Pretexo (France).

Summary/main objectives of the project

Improve the mechanical properties of the short side chain (SSC) AquivionTM perfluorosulfonic acid (PFSA) ionomer to enable use of highly functionalised PFSA membranes at reduced thickness, for high conductivity and low area resistance, and with long lifetimes.

Technical accomplishment/progress/results

- Membrane tensile properties improved by >50%
- MEAs integrating MAESTRO membranes show improved performance and durability
- Membranes and MEAs show high promise, justifying the investment of laboratory-level membrane scale-up and in durability testing in a stack

Contribution to the programme objectives

AIP09 Section 3.2 Specific topic for the 2009 call for proposals «SP1-JTI-FCH.2009.3.2: Materials development for cells, stacks and balance of plant» Projects are expected to cover:

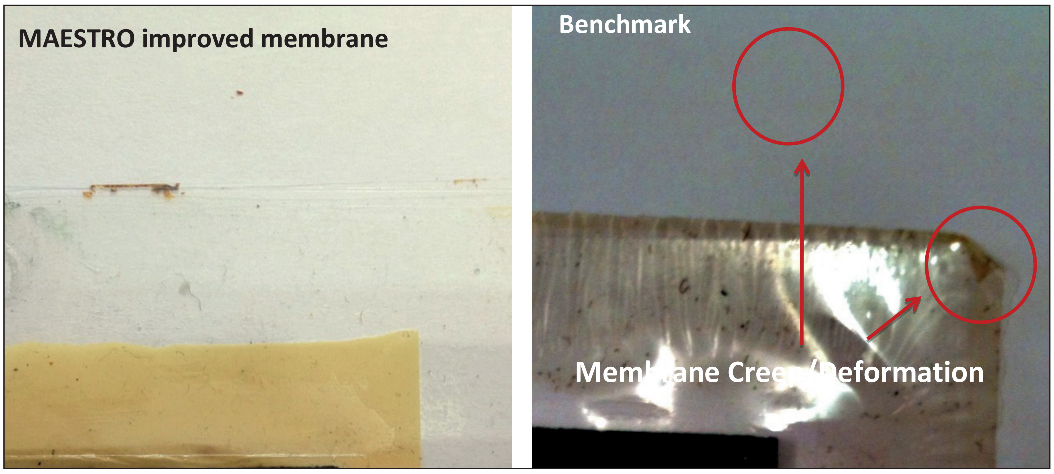
- Development and design of materials to improve performance of both cells and stack and BoP components. Mechanical, thermal and electro-chemical stability should be considered along with lifetime and degradation issues relevant to production cost for single cells and stacks
- Investigation of failure mechanisms… robust low resistance membranes in PEMFCs…
- New and improved material production techniques to reduce cost, emissions and improve yields, quality and performance in industry relevant cells…
- The consortium should include academia, research institutes, material producers and cell/stack manufacturers

Future steps

1. RTD for focused development of best membrane candidates, their applications-specific optimisation, and scale-up
2. RTD for the catalyst layer and electrode design and development in MEAs using the new membranes, for further performance and durability optimisation

Conclusions, major findings and perspectives

- The approaches developed for mechanical stabilisation do not compromise conductivity.
- Excellent perspectives for future exploitation, including by the two industrial partners



MATHRYCE

Material Testing and Design Recommendations for Components Exposed to Hydrogen-Enhanced Fatigue

Duration

Start and end date: 1 October 2012 - 30 September 2015

Application area

Cross-cutting activities

Budget

Total budget €2.5 million
FCH contribution €1.3 million

Partnership/consortium list

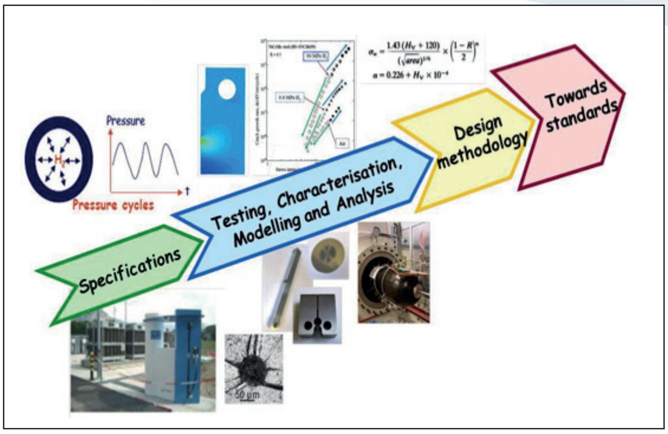
- Commissariat à l'énergie atomique et aux énergies alternatives (CEA)
- Air Liquide
- Teknologian Tutkimuskeskus
- Joint Research Centre (JRC)
- The CCS Global Group LTD
- Centro Sviluppo Materiali SPA
- Dalmine SPA (Tenaris)

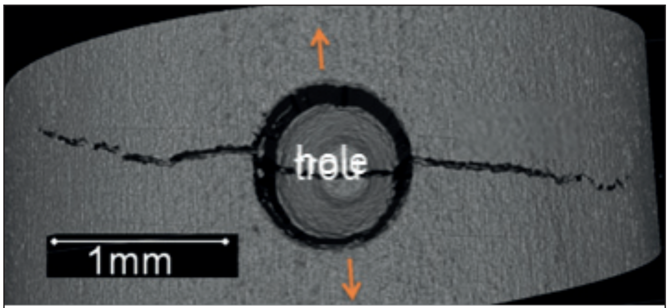
Summary/main objectives of the project

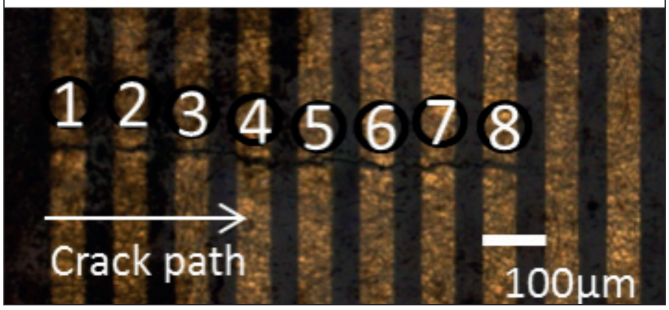
The project aims to develop and provide an easy to implement vessel design and service life assessment methodology based on lab-scale tests under hydrogen gas. The methodology will be based on selection and further development of the most appropriate, reliable and easy-to-handle lab-scale test under hydrogen pressure to quantify the hydrogen induced fatigue of a material. Results and conclusions will allow prioritised recommendations to support ongoing or new RCS initiatives at the international level. Indeed, Mathryce will provide data and methodology to improve European and International standards on high-pressure components exposed to hydrogen-enhanced fatigue.

Technical accomplishment/progress/results

- Several reference pressure cycling patterns, defined from the analysis of the refuelling station operations, have been used to optimise the experimental fatigue protocol.
- A critical review of existing standards addressing design of pressure vessels subject to hydrogen-enhanced fatigue has been done. It was highlighted that different methodologies are used to take hydrogen-enhanced fatigue into account and a single internationally recognised approach is not available yet
- The material characterisation of the provided pressure vessel has begun including a thorough microstructural analysis and a first set of tensile tests under air and hydrogen pressure. The cyclic mechanical behaviour has also been identified.







Contribution to the programme objectives

- A mechanical analysis of the defect at lab-scale or in a pressure vessel allows discussion of the future fatigue test and to estimate the possible scaling effects.
- The experimental developments are under way. They concern the use of crack gauges to detect crack initiation under 340 bar H2 and the design of a "portable" device to test samples under hydrogen pressure

Future steps

1. Experimental campaign to address hydrogen-enhanced fatigue
2. Development of the methodology taking into account these results
3. Defining and launching the full-scale testing campaign under cyclic pressure
4. Preparing a workshop dedicated to the design of pressure vessels subjected to hydrogen-enhanced fatigue

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MATHRYCE

MCFC-CONTEX

MCFC Catalyst and Stack Component Degradation and Lifetime: Fuel Gas Contaminant Effects and Extraction

Duration

Start date and end date: 1 January 2010 - 30 June 2014

Application area

Stationary power generation and CHP

Budget

Total budget €4,233,102
FCH contribution €1,841,834

Partnership/consortium list

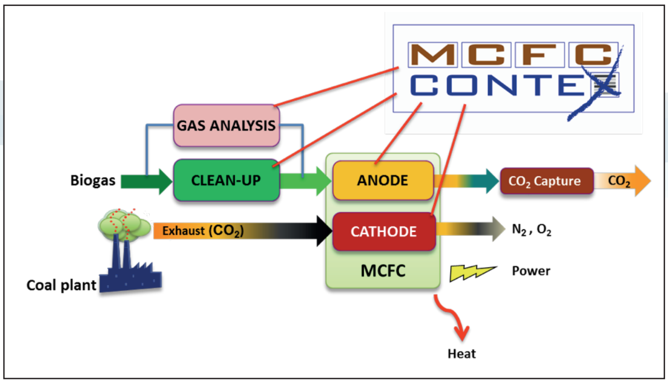
ENEA (coord., Italy), MTU Onsite Energy (Germany), Ansaldo FC (Italy), TU Munich (Germany), Tubitak Marmara (Turkey), KTH (Sweden), University Genoa (Italy), OVM Institute (Romania), University Perugia (Italy), CETaqua (Spain)
External advisors: FuelCell Energy (US), Aqualogy (Spain)

Summary/main objectives of the project

1) A systematic, application-oriented investigation of the tolerance levels of MCFC and reformer catalysts to specified sulphur-based pollutants downstream of clean-up or CO2 separation from power plant flue gas.
2) Evaluation of different cleaning technologies for implementation in a MCFC-driven, organic fuel-fed CHP system. Development of a pilot clean-up system specifically targeted to the requirements of a waste-water treatment plant (WWTP).
3) Development of an accurate, real-time detection system for trace contaminant measurement and monitoring, combining advanced techniques (Raman and laser-induced breakdown spectroscopy).
4) Set-up of a predictive, numerical simulation model that replicates MCFC performance and supports the development of accelerated testing protocols.

Technical accomplishment/progress/results

1) Tolerance levels to H2S at anode side mapped. Discovery of poisoning mechanism of SO2 in the cathode, that is transported to the anode side and is converted to H2S and concentrated.
2) In-depth characterisation of several adsorbents for H2S and Siloxane removal: materials have been selected for the pilot system campaign.
3) Detection for siloxanes proven to targeted requirements. Sulphur compound emission lines are masked in a biogas matrix: enriching techniques are bring investigated.
4) Kinetic validation of numerical model successful. Currently support provided towards definition of accelerated testing protocols.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Lifetime	Towards 40,000 h	Optimise operating conditions	System pilot design
Accelerated testing	Investigation	Numerical-aided accelerating testing methods	First cell tests
FC system efficiency	>40%	>45%	47% reported

Conclusions, major findings and perspectives:

For biogas-fueled systems, it is most feasible to focus on a fully effective clean-up system, ensuring totally clean fuel is fed to the MCFC stack. This can be achieved cost-effectively with accurate selection of adsorbent materials. Real-time detection of contaminants in the system will further enhance reliability.

Future steps

1 – Further investigation of SO2 transport mechanism
2 – Pilot-scale characterisation and study of humidity effects
3 – Enrichment techniques for S-compounds
4 – Validation of accelerated testing protocols.

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MCFC CONTEX

METPROCELL

Innovative Fabrication Routes and Materials for Metal and Anode Supported Proton-Conducting Fuel Cell

Duration

Start and end date: 1 December 2011 - 30 November 2014

Application area

Stationary power generation and CHP

Budget

Total budget €3,436,092
FCH contribution €1,822,255

Partnership/consortium list

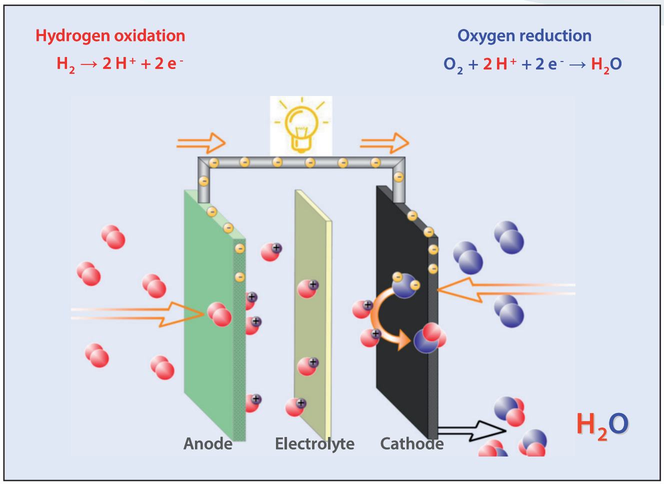
Coordinator: Fundacion Tecnalia Research & Innovation (Spain)
Partners: EIFER (Germany), CNRS/Marion technologies SA (France), DTU/Topsoe Fuel Cell A/S (Denmark), Ceramic Powder Technology AS (Norway), Höganäs AB (Sweden)

Summary/main objectives of the project

- Development of new electrolyte and electrode materials with enhanced properties for improved PCFCs dedicated to 500-600°C.
- Suppress the post-sintering steps using alternative manufacturing routes based on thermal spray technologies and plasma EVD.
- Assess the potential of both metal and anode supported cell architectures to obtain the next generation of PCFCs.
- Bring the proof-of-concept of PCFCs by the set-up and validation of short stacks for APU and gas/micro-CHP (first complete PCFC stack units).
- Assess the PCFC technology as electrolyser.

Technical accomplishment/progress/results

- New materials for PCFCs: (1) BCY and BCZY electrolytes fully sintered at 1200°C with high protonic
- conductivity (H+: 7 mS.cm-1/ dense >95%). (2) Ni-BCZY anode layers and supports sintered at 1200°C with conductivity > 1000 S.cm-1 at 600°C and porosities around 40% (ASR: 0.07Ω.cm2 @ 600°C in a H2 / 3% H2O). (3) Architectured BSCF/BSCF-BCY10 and Pr2NiO4/Pr2NiO4-B-CY10 cathodes with ASR < 0.5 W. cm2 at 600°C and ▯e > 100 S·cm-1. Porous ferritic stainless steel supports with TEC values of around 10.5·10-6 K-1and improved oxidation resistance at 600°C in air through surface stabilisation with RE elements.
- Atmospheric plasma sprayed BCY/BCZY-NiO anodes with ASR values down to 0.45 Ω.cm2.
- Anode supported single cells with an active surface of 3.14 cm2 and power density of 140 mW.cm-2 (Ni-BCYZ/BCYZ-ZnO/BCYZ-BSCF) and 196 mW.cm-2 (Bi-layered Ni-BCY/BCY/BCY-BSCF) @ 0.65V/600°C.



Contribution to the programme objectives

The PCFC technology could significantly contribute to industrialise the FC technology by improving the cell characteristics and lowering drastically the system costs. The following impacts are expected:

- Reduction of the manufacturing steps, through the implementation of innovative fabrication routes with no post-sintering needs.
- The possibility to reduce the service temperature under 600°C will be notably useful to prolong the service life of the metal supports potentially beyond current benchmarks of 40,000 hours.
- The new PCFCs may offer some further advantages for the environment such as higher fuel utilisation in comparison to the SOFC technology.
- Increase of system efficiency, through a better utilisation of the heat produced and a smaller BoP, a lower operating temperatures down to 600°C, a reduction of the energy consumption of at least 7-10% and the elimination of the fuel dilution (since water is formed at the cathode).

Future steps

1. Cell improvement to obtain at least 200 mW.cm^{-2} @ 0.65V, 600°C under wet hydrogen.
2. Elaboration of at least 22 stack cells (footprint of 120x120 mm2).
3. Performance validation of single stack cells in terms of degradation rate (2% or less over 500 h).
4. Manufacture of short stacks (5 cells/stack).
5. Validation of cell performance at stack level under relevant industrial conditions.

Conclusions, major findings and perspectives

- Well-functioning electrode and electrolyte layers have been obtained by conventional processing routes with electrochemical properties beyond the initial targets.
- Optimised anode and metal supports available for the manufacture of single cells at lab-scale.
- Based on single cell tests at lab-scale, a first generation of anode supported stack cells will be manufactured in the next for the construction of first complete PCFC stack units.
- Alternative manufacturing routes based on thermal spray and plasma EVD methods may play a decisive role in the journey to achieve well-functioning metal supported cells. Their lower maturity level will, however, retard the demonstration of this technology at stack level.

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METPROCELL

Nano-CAT

Development of Advanced Catalysts for PEMFC Automotive

Duration

Start and end date: 1 May 2013 - 30 April 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €4,394,330
FCH contribution €2,418,439

Partnership/consortium list

CEA & Armines (France), Tecnalia (Spain), Nanocyl (Belgium), JRC, C-Tech Innovation Ltd (UK), DLR (Germany), Volvo Technology (Sweden)

Summary/main objectives of the project

The main objective of Nano-CAT is to decrease the Platinum (Pt) catalyst loading in MEA and thus price of PEMFC system. The followed routes to succeed in are:

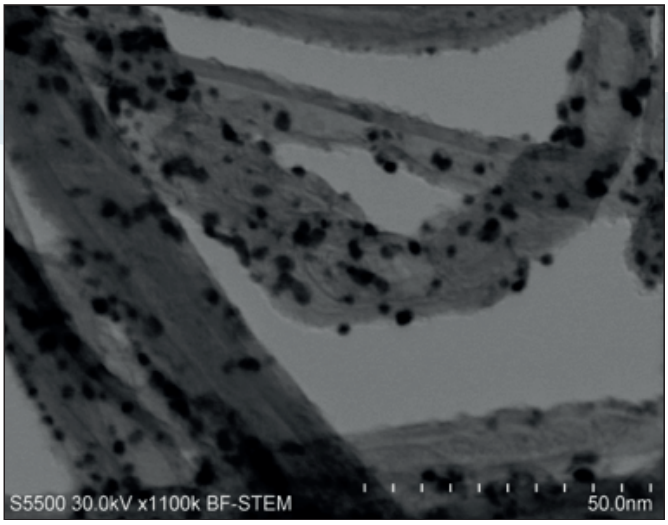
- development of nanostructured innovative catalysts (Pt free and Pt alloy) which give higher mass activity than Pt.
- development of resistant supports which decrease degradation of the active layer and increase the life time of MEA.

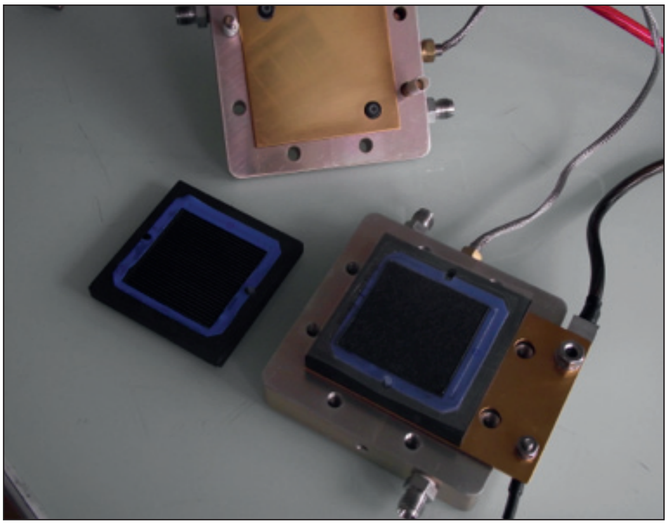
Technical accomplishment/progress/results

- Synthesis of Pt based catalysts on CNT
- Synthesis of Pt free catalysts for HOR and ORR

Contribution to the programme objectives

Call: sp1-jti-fch.2012.1.5	Objectives Of the call	Objectives of the project	Current status
Pt loading	0.1 g/kW	0.1 g/kW @ max 0.3 g/kW @ 55% yield	0.25 g/kW @max 0.8 g/kW @ 55% yield
Power density	1 W/cm^2 @ 1.5 A/cm^2	1 W/cm^2 @ 1.5 A/cm^2	0.750 W/cm^2 @ 1.5 A/cm^2
Lifetime	>5,000 h	10% degradation at 5,000 h	N/A
Cost of PEMFC system	€100/kW	Not defined	N/A





Future steps

1. integration of the as prepared catalyst in MEA
2. set up AST test to quantify the improvement in
3. performance/durability thanks to our catalysts/supports
4. integration of the best ones in stack

Conclusions, major findings and perspectives

At this early stage of the project we succeeded in synthesis of Pt free catalyst and Pt containing catalyst on resistant support with an acceptable mass activity and electrochemical surface area. The next step is the integration in MEA and test in single cell.

NEMESIS2+

New Method for Superior Integrated Hydrogen Generation System 2+

Duration

Start and end date: January 2012 - December 2014

Application area

Hydrogen production and distribution

Budget

Total budget €3,393,062
FCH contribution €1,614,944

Partnership/consortium list

German Aerospace Center (Coordinator); HyGear B.V. (Netherlands), Johnson Matthey PLC (UK), Abengoa Hidrógeno, S.A. (Spain), Abengoa Bioenergía San Roque, S.A. (Spain), Centre for Research and Technology Hellas (Greece), Instituto Superior Técnico (Portugal).

Summary/main objectives of the project

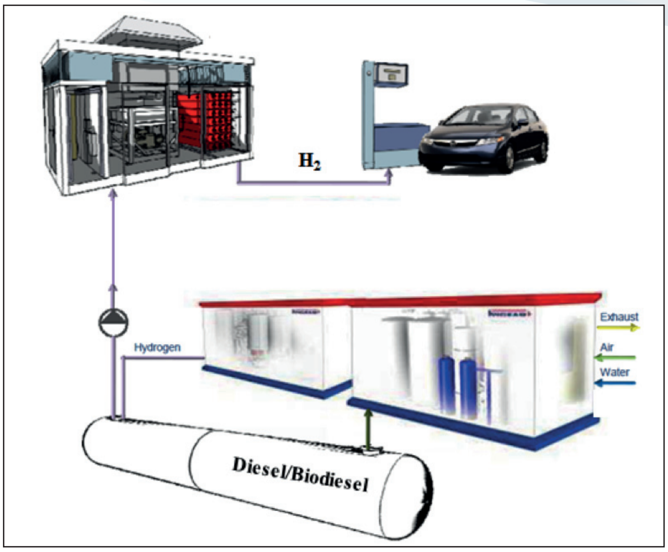
Within the three-year project NEMESIS2+ a small-scale hydrogen generator capable of producing 50 Nm3/h of hydrogen from biodiesel and diesel will be developed.
Decentralised hydrogen production from liquid fuels offers a number of advantages like high energy density and infrastructure already being available. Besides, it is economically advantageous in areas where hydrogen cannot be cost-effectively supplied by a central production plant.

Technical accomplishment/progress/results

- Promising sorbent material for liquid phase desulphurisation of diesel identified
- Development of duel fuel burner which is able to run on liquid fuels and on PSA off-gas
- New reformer and WGS catalyst formulations developed
- Successful SR and WGS long-term test (incl. 1 ppm H2S)

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
System efficiency (HHV H_2 /HHV fuel)	80	70	60
Catalyst durability	Stable long-term operation	> 1,000 hours	N/A (test not finalized)
Scalability (Nm^3/h)	2-750	2-750	5-1,000
H_2 production costs (€/kg)	< 5	< 4	N/A



Future steps

A decision on the final prototype setup has been taken at mid-term. Currently the hardware is being adapted to liquid feedstock (diesel and biodiesel). In the last six months of the project, the NEMESIS2+ hydrogen generator will undergo extensive testing (> 1,000 hours).

Conclusions, major findings and perspectives

The NEMESIS2+ consortium was able to show the feasibility of hydrogen production from biodiesel and diesel by means of steam reforming at elevated pressures. Special emphasis is placed on developing an innovative desulphurisation concept based on liquid-phase adsorption.
Long-term stability of the reforming catalyst is the most critical part of the project. Therefore the effort in the second project period will be increased in order to improve catalyst lifetime.

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NEMESIS 2+
Hydrogen production at refuelling stations from biodiesel and diesel

NEXPEL

Next-Generation PEM Electrolyser for Sustainable Hydrogen Production

Duration

Start and end date: January 2010 - December 2012

Application area

Hydrogen production and distribution

Budget

Total budget €3,353,549
FCH contribution €1,256,286

Partnership/consortium list

SINTEF (Norway - coordinator)
CEA LITEN (France)
Fraunhofer ISE (Germany)
FuMA-Tech GmbH (Germany)
Helion/AREVA Stockage d'Energie (France)
Statoil ASA (Norway)
University of Reading (UK)

Summary/main objectives of the project

The main objective of the NEXPEL project is to develop and demonstrate a PEM water electrolyser integrated with renewable energy sources such as wind and solar. The electrolyser will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (LHV) at a system cost below €5,000/Nm3h^{-1} plant capacity and a target lifetime in excess of 40,000 hours.

Technical accomplishment/progress/results

New materials with higher performance and/or lower costs than state-of-the-art has been developed, such as polyaromatic membranes with high proton conductivity (> 40 mS cm^{-2}), highly active oxygen evolution catalyst based supported Ir (3x mass activity vs. IrO_2) and low-cost current collectors. The membrane and catalyst materials have been incorporated into novel CCMs by Fuma-tech. A new stack design for high pressure operation with new sealing concepts and low manufacturing costs has been developed and two 10 cell stacks have been constructed and function-tested. Cost and market analyses have been performed and a detailed stack cost break down study showed that the NEXPEL stack can reach the programme cost target with annual production volumes of 100 units.

Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current status
Development of new catalyst and materials for lowering costs and improved performance	Reduction of anode noble metal loading to 1 mgcm^{-2}	Improved anode catalyst with 3x mass activity vs. IrO_2 demonstrated
Research and development on advanced power electronics	DC/DC converter with efficiency higher than 97%.	DC/DC converter with 98% efficiency constructed and demonstrated.
Research to improve materials/ components/ systems durability/ reliability	A reduction in system costs to €5,000/Nm^3 production capacity	Stack design for reduced cost and 50 bar operation. €5,000/Nm^3 is achieved at 100 units.
Low-cost, high efficient electrolyser system operating at high pressure	Electrolyser efficiency greater than 75% (LHV)	67% stack efficiency (LHV) at 1Acm^{-2}
Setting up of field demonstration projects and trials on integration of electrolyser with RES.	Field demonstration of one 1Nm^3 PEM electrolyser.	1Nm^3 PEM electrolyser field tested with wind/ solar power.

Future steps

1. Continuation of stack and materials development in FCH-JU project NOVEL
2. Publication of results and findings in six scientific publications

Conclusions, major findings and perspectives

There is significant potential for cost reduction for PEM electrolysers through an integrated approach where industry and research institutions collaborate to reach common goals.
Further research and development of non-active components, such as bipolar plates, current collector and seals, should receive attention as well as efforts to increase the size of PEM electrolyser to the MW scale.
In the drive for lower cost PEM electrolysers suitable for intermittent and highly dynamic operation, high understanding of degradation and lifetime issues are necessary and significant efforts should be applied in order to increase the knowledge of such processes.

NextHyLights

Supporting Action to Prepare Large-Scale Hydrogen Vehicle Demonstration in Europe

Duration

Start and end date: January 2010 - December 2010

Application area

Transport and refuelling infrastructure

Budget

Total budget €1,138,522
FCH contribution €499,303

Partnership/consortium list

Ludwig-Bölkow-Systemtechnik GmbH (Coordinator), AVL LIST GmbH, Bucher-Guyer AG, Centro Ricerche Fiat SCPA, Daimler AG, Element Energy Limited, Stichting Energieonderzoek Centrum, Proton Motor Fuel Cell GmbH, Skoda Electric a.s, Statoil ASA, Total Raffinage Marketing, Vattenfall Europe Business Services GmbH.

Summary/main objectives of the project

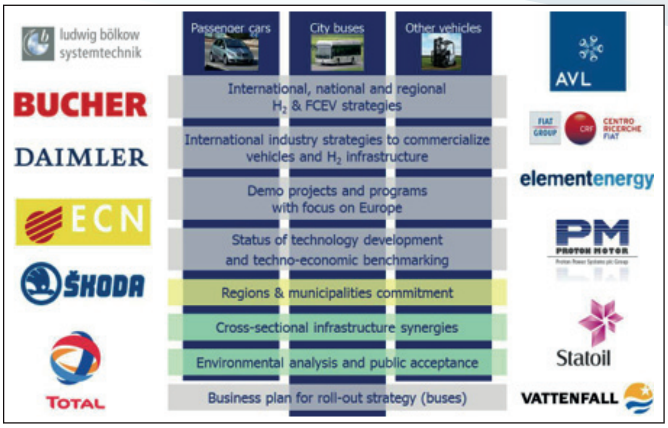
NextHyLights was called for by FCH JU to assist the preparation of next large-scale H2& FCEV demonstration projects in Europe, i.e. to understand the needs of industry and regions to actively participate in the demo projects on H2 & FCs for transport. AIP 2011–AIP 2013, provide insights, recommendations and instruments for adapting AIP 2011 and MAIP and developing AIP 2012 and AIP 2013 to learn about the potential impact on global emissions and public acceptance.

Technical accomplishment/progress/results

- OEMs believe to reach technical goals by 2015 and cost goals by 2020
- Industry has interest in larger-scale projects
- OEMs will focus on world regions with most stringent requirements
- OEMs go where best conditions are provided and least bureaucracy can be expected. No technology breakthroughs but continuous improvements are expected.
- Agreement of car & energy/retail industry on aligned roll-out of vehicles and HRS is needed

Contribution to the programme objectives

- Feasibility study on large-scale demonstration of second-generation fuel cell vehicle fleets and related infrastructure
- Assessment of environmental and social impacts and potential to establish a framework for additional demo sites in Europe
- NextHyLights:
  - For segments 'passenger cars' and 'other vehicles' work plans for the demonstration of second-generation vehicle fleets; for buses a business plan for a roll-out strategy has been developed
  - Environmental analyses and a public acceptance study have been performed
- Study on regional commitment has been prepared



Future steps

Project finished in December 2010

Conclusions, major findings and perspectives

The NextHyLights consortium would highly appreciate if its results are further used e.g. for drafting the next AIPs.

Furthermore, it is recommended to call for a comparable project as soon as the new funding programme has been established. This time the project should receive full funding (100%) as the results are for the benefit of all stakeholders active in the field and the project should be span the full programme period

NOVEL

Novel Materials and System Designs for Low-Cost, Efficient and Durable PEM Electrolysers

Duration

Start and end date: September 2012 - August 2016

Application area

Hydrogen production and distribution

Budget

Total budget €5,743,445
FCH contribution €2,663,357

Partnership/consortium list

SINTEF, Norway (coordinator), AREVA Stockage d'Energie (France), Beneq OY (Finland), CEA LITEN (France), Fraunhofer ISE (Germany), Johnson Matthey Fuel Cells (UK), PSI (Switzerland), Teer Coatings (UK).

Summary/main objectives of the project

The main objective of the NOVEL project is to develop and demonstrate an efficient and durable PEM water electrolyser, utilising the new, beyond the state-of-the-art materials developed within the project. The electrolyser will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (LHV) at rated capacity with a stack cost below €2,500/Nm3h-1 and a target lifetime in excess of 40,000 hours (< 15 μVh-1 voltage increase at constant load).

Technical accomplishment/progress/results

The "First International Workshop Durability and Degradation Issues in PEM Electrolysis Cells and its Components" was organised by Fraunhofer ISE in Freiburg (Germany) on 12 & 13 March 2013 with more than 100 participants from industry and research Institutions.
For the oxygen evolution reaction (OER) Nb doped TiO2 support materials have been synthesised and characterised and Ir nanoparticles have been deposited by a microwave enhanced polyol method. The materials show significantly higher catalytic activity than IrO2 and similar activity to previous catalysts using ATO as support materials. Work on the preparation of radiation grafted membranes using 50 μm thick ETFE base film has begun and preliminary grafting kinetics established. The radiation grafted membranes show much lower hydrogen gas crossover than state-of-the-art perfluorinated membranes.

Contribution to the programme objectives

Objectives of the call	Objectives of the project	Current status
More efficient catalysts for the oxygen evolution reaction presenting lower activation overpotential and new catalyst structures or metal alloys resulting in lower noble metal loadings	Reduction of anode noble metal loading to 0.6 mgcm-2	Improved anode catalyst with 3x mass activity vs. IrO2 demonstrated
Polymer membranes with improved conductivity, low gas crossover and high mechanical stability at operating conditions	Reinforced PFSA and cross-linked radiation grafted membranes. An increased operating temperature to ~100°C and lower gas cross over is targeted	Radiation grafted membranes have been prepared, showing better crossover to conductivity ratios
Alternative materials for bipolar plates and current collectors, replacing the use of titanium as construction material	The electrical and chemical properties of the current collectors will be enhanced by novel, low-cost coatings and alternative materials.	Noble metal coatings and conductive oxide coatings on stainless steels have been prepared.
Low cost, high efficient electrolyser system operating at high pressure	Electrolyser efficiency greater than 75% (LHV)	No stack constructed.
Development and experimental validation of testing procedures and test protocols applicable to PEM electrolyser to determine performance (e.g. power output, efficiency) and endurance. Priority to AST protocols for electrolysers.	NOVEL will develop AST protocols able to isolate and elucidate component degradation mechanisms and suitable for PEM electrolyser lifetime prediction	"First International Workshop Durability and Degradation Issues in PEM Electrolysis Cells and its Components" organised. AST protocols under development.

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Future steps

1. Incorporating catalysts and membranes to functioning MEAs
2. Further development of coating strategies and testing.
3. Testing of NEXPEL stack with new MEAs, development of AST protocols and increased understanding of degradation mechanisms.
4. Design and construction of improved stack and system.

Conclusions, major findings and perspectives

There is significant potential for cost reduction for PEM electrolysers through an integrated approach where industry and research institutions collaborate to reach common goals.
Further research and development of non-active components, such as bipolar plates, current collector and seals, should receive attention as well as efforts to increase the size of PEM electrolyser to the MW scale.
In striving for lower cost PEM electrolysers suitable for intermittent and highly dynamic operation, high understanding of degradation and lifetime issues is necessary and significant efforts should be applied to increase knowledge of such processes.

Figure 2: The audience of the First International Workshop Durability and Degradation Issues in PEM Electrolysis Cells and its Components". More than 100 participants were present.

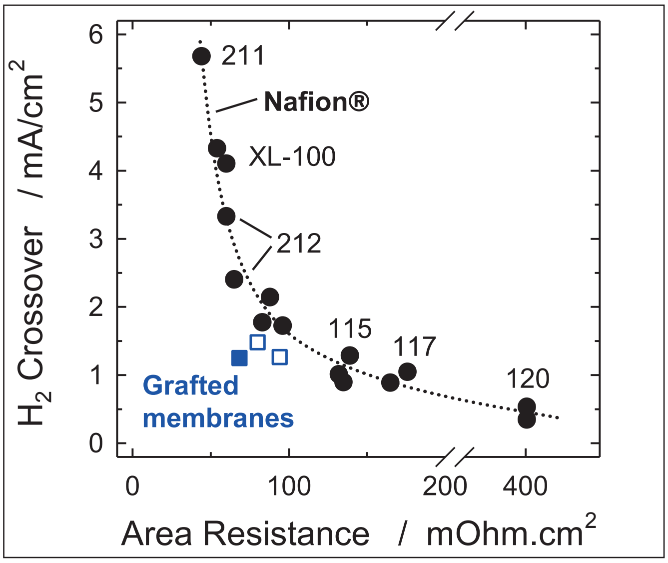
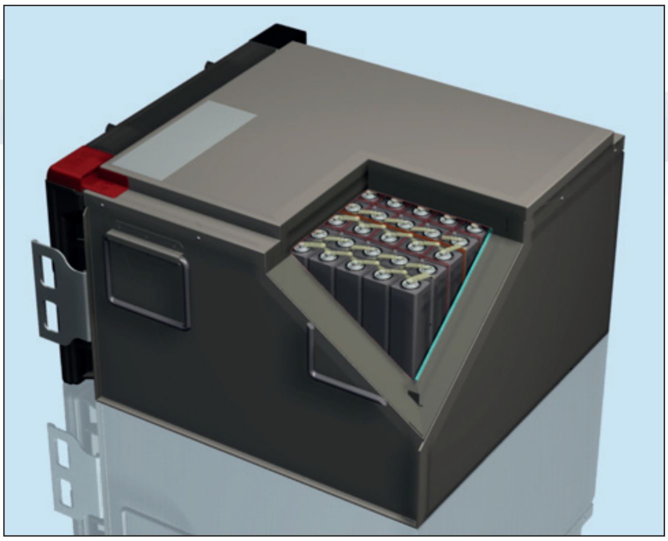


Figure 1: Graph showing the relationship between H2 crossover and resistance for PFSA membranes and the NOVEL radiation grafted membranes.

ONSITE

Operation of a Novel SOFC Battery-Integrated Hybrid for Telecommunication Energy Systems



Duration

Start and end date: 1 July 2013 - 30 June 2016

Application area

Stationary power generation & CHP

Budget

Total budget €5,525,440
FCH contribution €3,012,038

Partnership/consortium list

National Research Council of Italy – Institute of Advanced Energy Technologies, Efceco, Ericsson, FIAMM, HT Ceramix, Bonfiglioli Vectron, Institute Energetyki, Haute Ecole Spécialisée de Suisse occidentale

Summary/main objectives of the project

The overall objective of ONSITE is to develop a proof-of-concept based on SOFC/high-temperature batteries hybrid technology with progress beyond state-of-the-art and towards telecom market requirements. The requirements for the proof-of-concept system will be gathered from existing market intelligence and techno-economic analysis.

Technical accomplishment/progress/results

N/A

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Overall efficiency	85%	90%	N/A
Electric efficiency	55%	55%	N/A

Future steps

1. System requirements definition
2. Overall system design
3. Initial modeling activities
4. SOFC modules development

Conclusions, major findings and perspectives

Synergic partner activities have been giving a common development path to choose an integration scheme to integrate different technologies and devices.
The project, although just begun, already shows promise of interesting market perspectives, thanks to the strong experience and well-balanced competences of the consortium partners.

PEMICAN

PEM with Innovative Low-Cost Core for Automotive Application

Duration

Start and end date: 1 April 2011- 31 March 2014

Application area

Transport and refuelling infrastructure

Budget

Total budget €3.96 million
FCH contribution €1.86 million

Partnership/consortium list

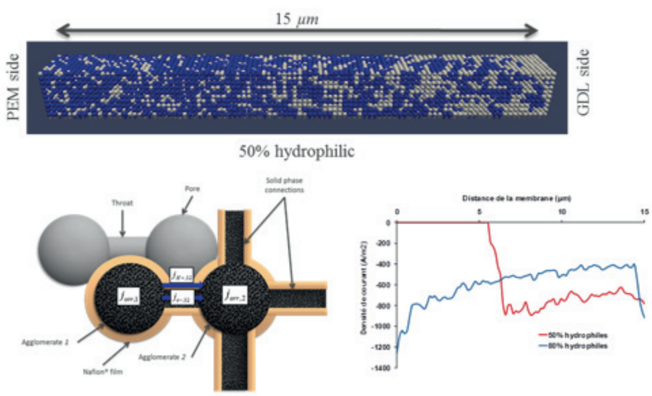
CEA/LITEN - coordinator (France), Adam Opel AG (Germany), Solvay Specialty Polymers (Italy), Tecnalia (Spain), Timcal (Switzerland), Imperial College (UK).

Summary/main objectives of the project

- Reduce Pt cost of PEMFC from roughly 1 gPt/kW down to ideally 0.15 gPt/kW for automotive application
- Technological route: tune raw materials (Aquivion ionomer and Carbon Black), manufacture thin and structured active layers
- Scientific route: characterise active layers (fundamental electrochemistry, H+ conductivity), better link properties to performance (pore network and performance modeling).

Technical accomplishment/progress/results

- Raw materials have been produced and characterised
- Low-loaded MEA have been manufactured (50+150µg/cm^2)
- Target of 0.58 gPt/kW has been reached (80°C, 50%RH, 1.5b, H2/air)
- Performance with AquivionR can be higher than with NafionR
- Models are being developed and improved
- Innovative test stands are under validation for characterisation



Full charge/mass two-phase Pore Network Model of CCL

Contribution to the programme objectives

	Objectives of the call	Objectives of project	Current status
Reduce Pt cost from 1 (gPt/kW) down to ideally	0.15	0.15	0.58 (key issues are power density and durability)
Ensure durability under dynamic operation	5,000 h	5,000h	Under investigation
Contribute to the development of European Industry solutions	X	X	AquivionR (Solvay) and Carbon Black (Timcal) are promising alternative solutions
Reduce total Pt loading from 0.5 (mg/cm^2) to ideally		0.1	0.15
Study proton conduction in the active layer	X	X	Innovative test stands allowed ob-taining first results on H+ conduction and fundamental electrochemistry
Develop modeling	X	X	Innovative models (Pore Network) allowed proposing improvements of classical performance models

Future steps

1. Increase durability
2. Then reduce even more Pt cost if durability and power density are sufficient
3. Finalise characterisation of active layers

Conclusions, major findings and perspectives

- Different manufacturing techniques (ink jet, PVD, DED, gradients) have allowed reducing Pt loading (mgPt/cm^2)
- The thinner the active layer is the better Pt is used (A/mgPt)
- Power density (see AUTOSTACK outputs) and durability (see IMPACT ongoing project) are key issues for low-loaded MEA > first results have been obtained but further developments are needed to reach all targets for automotive application
- Gas diffusion, proton conduction and local electrochemical behaviour are crucial; specific characterisation and modeling have helped improve current knowledge
- Same approach could be used in future projects with other catalysts to reduce even more Pt cost and increase performance

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PHAEDRUS

High-Pressure Hydrogen All-Electrochemical Decentralised Refuelling Station

Duration

Start and end date: 1 November 2012 - 31 October 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €6,309,832
FCH contribution €3,566,343

Partnership/consortium list

Hydrogen Efficiency Technologies (Netherlands) Coordinator; ITM power Limited (UK), H2 Logic (Denmark), Raufoss Fuel Systems (Norway), Daimler (Germany), Shell Global Solution (Netherlands), Bundesanstalt fuer Materialforschung und Pruefung (Germany), Association pour la recherche et le développement des méthodes et processus industriels – ARMINES (France), Hochschule Esslingen (Germany), Uniresearch (Netherlands).

Summary/main objectives of the project

The project aims at developing and validating a new concept for 70 MPa HRS infrastructure with a modular dispensing capacity in the range of 50-200 kg per day.

Technical accomplishment/progress/results

Some of the project expected results are:

- An electrochemical hydrogen compression system consisting of parallel units for compression up to 100 MPa at a peak production of 10 to 50 kg/hr;
- Storage tanks at low (10-20 MPa), or medium (50 MPa) and high pressure (100 MPa);
- A dispensing system equipped with a pre-cooling unit, with a capacity of 5 kg/3 min.

Contribution to the programme objectives

The project addresses the complete scope and objectives of Topic SP1-JTI-FCH.2011.1.8: Research and development of 700 bar refuelling concepts & technologies

	HRS size	2010 state-of-the-art	2015 target	2020 target
HRS CAPEX	50-80kg/day	<€1m	<€0.6m	-
	200 kg/day	<€1.5m	<€1m	<€0.6m
H2P CAPEX	Price per Nm^3/hour	€4,100	€3,500	€2,000
EU market volume (no. of stations)		<75	<300	>2,000
Hydrogen price		€15-20/kg	€10-15/kg	€5-10/kg

Future steps

The project is scheduled for three years and can be regarded as phase one of a two-step development.
Phase 1 (PHAEDRUS project): technology development and validation on a 5kg/day scale (+ design 200kg/day)
Phase 2: demonstration of a scalable 200kg/day hydrogen refuelling system

Conclusions, major findings and perspectives

The project has been running for nearly one year. The main results achieved so far are:

- Quantified economical and technical analysis
- High-pressure electrolyser on test
- High-pressure electrochemical compressor on test

Targets suggested by the FCH-JU MAIP (update draft version July 2011)

	2011 State-of-the-art	2015 Targets within project
Daily capacity	50-200 kg	50-200 kg
One hour instant capacity	15 kg	33 kg
Back-to-backs within one hour	1	2
Repeatability of hourly profile	1 hour	3 consecutive hours
SAE J2601 verification	Partly	Fully
Metering accuracy verification	Partly	Fully
HRS module footprint	>50 m2	15-30 m2
Scalability & modularisation	Limited	Implemented
HRS CAPEX/kg daily capacity	€7,500-€20,000	€5,000-€12,000
OPEX @ 80% utilisation	Negative	Balanced

Premium Act

Predictive Modeling for Innovative Unit Management and Accelerated Testing Procedures of PEFC

Duration

Start and end date: 1 March 2011 - 28 February 2014

Application area

Stationary power generation and CHP

Budget

Total budget €5,370,190
FCH contribution €2, 513,251

Partnership/consortium list

Coordinator: CEA

Partner Name	Ind or Res	Country
1 – CEA / LITEN	RES	France
2 – IRD FUEL CELLS A/S	IND	Denmark
3 – POLITEC. DI MILANO	RES	Italy
4 – DLR	RES	Germany
5 – ICI CALDAIE	IND	Italy
6 – JRC IE	RES	EU
7 – SOPRANO	IND	France

Summary/main objectives of the project

A general objective is to contribute to the improvement of stationary fuel-cell systems' durability, keeping in mind that the target required is 40,000h.
The project considers the micro-CHP application for systems with different requirements: two fuel-cell types based on two fuels different from pure hydrogen, direct methanol fuel cells (DMFC) and proton exchange membrane fuel cells (PEMFC) using reformate.
Specific objectives are to propose operating strategies, enhancing lifetime of given membrane electrodes assemblies (MEAs) in given stack and system and to design a lifetime prediction methodology based on coupled modeling and composite accelerated tests experiments (ranking of selected MEAs in real conditions and then following accelerated tests).
Technical approach is based on the following actions:

- Fuel-cell tests (at system, stack and single cell levels) in nominal and critical conditions
- Studies of the components microstructure and properties before and after ageing
- Modeling of the degradation mechanisms and of performance
  > Identification of main parameters affecting degradation
  > Development of specific accelerated stress tests
  > Proposal of operating strategies and of a lifetime prediction methodology

Contribution to the programme objectives

Related project achievements

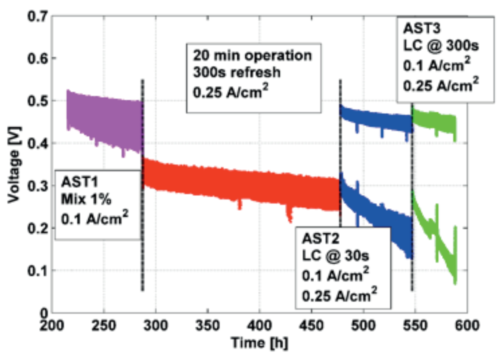
- Analyses of degradation for DMFC and PEMFC operating with reformate fuel, for μCHP systems
- Use of systems feed-back information, application of ageing tests in single cells and stacks (Cf. fig 2)
- Sensitivity studies (e.g. fuel compositions, CO or MeOH concentrations, humidity, temperature)
- In-situ (e.g. electrochemical and mass transport measurements) and ex-situ investigations (identification and use of most relevant advanced techniques = FTIR or XPS as spectroscopic method for chemical mapping and transmission electron microscopy coupled with chemical structure analysis at atomic scale)
- Degradation mechanisms identified/common issues for the two technologies:
- Reversible and non reversible degradation
- Main causes for permanent losses (with reinforced membranes) = catalyst particles degradation related to local conditions
- Ruthenium dissolution anode side detected at very early stage of ageing (identification of detailed mechanism leading to Pt-Ru particles in the membrane)

Dissemination

– A workshop on MEA degradation processes, 26-27 September 2012 in Grenoble, France
- 10 publications (done or planned) in scientific journals
- 15 communications (done or planned) in international conferences

Conclusions, major findings and perspectives

Last period will be dedicated to improved understanding thanks to additional aged samples characterisations, to deeper analyses of impacting parameters (e.g. temperature, air bleeding, reactants properties) and focused on the validation of complex specific accelerated stress tests, combining load cycles and other critical parameters (e.g. cathode stoichiometry, temperature, depending on the FC technology and always fuel impurities). Validation will be done with different MEAs, varying mainly GDL configuration for DMFCs, and anode catalyst layers for PEMFC.



Accelerated Stress Tests performed in DMFC single cell

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Premium Act

PrimoLyzer

Pressurised PEM Electrolyser Stack

Duration

Start and end date: January 2010 - July 2012

Application area

Hydrogen production and storage

Budget

Total budget €2,629,463
FCH contribution €1,154,023

Partnership/consortium list

IRD A/S (coordinator), Stichting Energieonderzoek Centrum Nederland, Valtion Teknillinen Tutkimuskeskus, Fuma-Tech Gesellschaft fuer funktionelle Membranen und Anlagentechnologie MBH, Abengoa Hidrógeno & Åbo Akademi

Summary/main objectives of the project

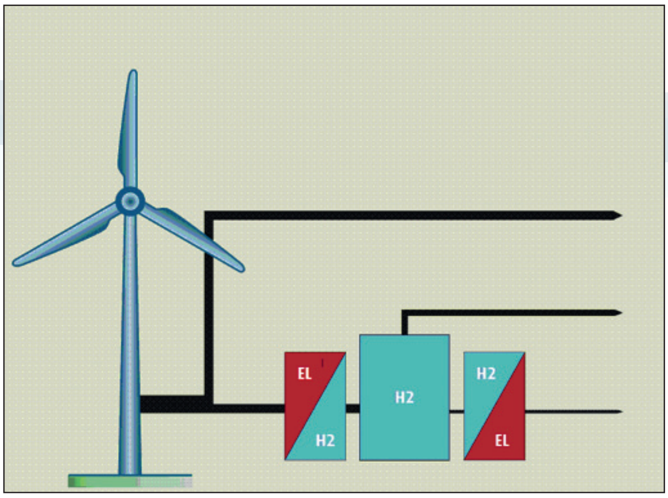
The primary objective of the PrimoLyzer project was to develop, construct, and test a cost-minimised highly efficient and durable PEM-electrolyser stack aimed for integration with domestic μCHPs. This was achieved through a combination of the following activities:

- Basic material R&D on catalyst and membrane
- Process development to fabricate high performance MEAs
- Stack engineering
- Continuous test

Technical accomplishment/progress/results

The work was initiated by an analysis of a PEM electrolyser aimed for integration with surplus wind and solar power. The results made the base for the stack specification.

The basic MEA precursor R&D includes: HER & OER catalyst and PFSA membrane development. Several MEAs have been manufactured and tested for longer periods [in total ≈17,000 test hours]. The best performing MEAs are equipped with the PrimoLyzer OER catalyst and the PrimoLyzer membrane. A PEMEC stack for direct high pressure H2-production was designed and tested.



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
H_2 pressure	10 MPa	10 MPa	10 MPa
MEA efficiency	1.64 V @ 1.2 A/cm^2	1.64 V @ 1.2 A/cm^2	IR corrected: <1.55 V @ 1.2 A/cm^2
Lifetime	>40,000 h	MEA degradation rate: ≤30 μV/h	MEA degradation rate: ≤1 μV/h
Cost	<€5,000/Nm^3 H_2 capacity	Stack cost: <€5,000/Nm^3 H_2 capacity	Stack cost: <€5,000/Nm^3 H_2 capacity

Future steps

The partners aim to continue the work in a PrimoLyzer II project that will include system integration and field test together with RES.

Conclusions, major findings and perspectives

The developed PEM electrolyser stack cost is well below €5,000 in small scale production [100 units]. The concluding stack test showed the following efficiencies:

- PEMEC stack: P_{AC}->H_2: 60%
- PEMEC system: P_{AC}->H_2+P_{TH}: 96%

PROSOFC

Production and Reliability Oriented SOFC Cell and Stack Design

Duration

Start and end date: 1 May 2013 - 30 April 2016

Application area

Hydrogen production and distribution

Budget

Total budget €7,359,054
FCH contribution €3,011,000

Partnership/consortium list

AVL List GmbH, Topsoe Fuel Cell A/S, Dynardo GmbH, Technical University of Denmark, Forschungszentrum Jülich GmbH, Karlsruhe Institute of Technology, Imperial College, Joint Research Centre (JRC).

Summary/main objectives of the project

The PROSOFC project aims at improving the robustness, manufacturability, efficiency and cost of Topsoe Fuel Cell's state-of-the-art SOFC stacks so as to reach market-entry requirements. The key issues are the mechanical robustness of solid oxide fuel cells, and the delicate interplay between cell properties, stack design, and operating conditions of the SOFC stack. The novelty of the project lies in combining state-of-the-art methodologies for cost-optimal reliability-based design (COPRD) with actual production optimisation.

Contribution to the programme objectives

Objectives of the call	State of the art	Objectives of the project
Improved electrical efficiency	ASR=670mOhm*cm^2	ASR=600mOhm*cm^2
Better robustness, better lifetime, improved manufacturing methods	No overall understanding of interplay between cell failures and design and production parameters	Identify major failure modes and link them to stack design and production using an statistical simulation approach operation in real life environment >4,000 h
Cost reduction	Index 100 (M0) Yield rate: <70%	Index 75 (M36) Yield rate: 95%

Conclusions, major findings and perspectives

Considering the current project duration of five months, progress towards stated objectives is limited. One focus is to coordinate the simulation tasks in WP2, WP3 and WP4. For a productive and goal-targeted procedure a simulation workshop took place where the significant failure modes in regard of the treated stack design were discussed. Based on this the simulation models will be defined and the needed input and outcome at the model interfaces will be determined. The types of failure modes have been specifically investigated before the workshop for the failure probability (FP) analysis. The FP sheet will be taken as an input for the reliability program in WP5.
Besides that the boundary conditions for the 4,000 h stack tests in WP7 have been defined. AVL and JRC will align their stack test rigs in a way that the results are comparable in the best way possible. Based on the outcome of the FP sheet the parameters which have to be measured during the stack test will be determined. Furthermore, a reliability-oriented stack test programme will be developed.

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PROSOFC

Puma Mind

Physical Bottom-Up Multiscale Modeling for Automotive PEMFC Innovative Performance and Durability Optimisation

Duration

Start and end date: 17 December 2012 - 17 December 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €4,100,000
FCH contribution €2,300,000

Partnership/consortium list

Coordinator: CEA
CEA/LITEN (France), DLR (Germany),UNISA (Italy),CSIC (Spain),HSO (Germany), ENSL (France), JRC (Belgium), SFU (Canada),VODERA (UK), IDIADA Spain), LRCS (France).

Summary/main objectives of the project

The main goal of PUMA MIND is to establish a predictive multi-scale modeling tool of PEMFC durability as function of its components composition and operating conditions that should be representative of automotive applications. More precisely, this modeling tool will adhere to an integrative approach combining:

- a detailed model of the electrochemical phenomena
- a detailed model of the transport processes
- a 1D cell-level multi-scale model describing the competitive mechanisms at multiple scales (from the material to the cell level) and allowing calculating their relative influence on the macroscopic performance and durability under current cycled conditions.
- a 2D cell-level multi-physics CFD model to predict instantaneous efficiency
- an innovative diagnostic and control-oriented physical model for online PEMFC diagnosis and real-time optimisation of the operating conditions.

Contribution to the programme objectives

Objectives of the call	Related project achievements
"Development of multi-scale modeling and numerical simulation tools for increasing the performance and durability of PEM fuel cells. These computer-based tools are to be validated through experimental work"	• DFT calculation of adsorption energies on a Pt201 nanoparticule (Nano scale). • Kinetic Monte Carlo for kinetic constants calculation based on DFT results (mesoscale). Ongoing development. • Models coupling the nano/meso/micro scales (under Matlab/Simulink). • Lumped-control oriented models based on micro scales inputs. • In-situ investigations: SAXS (ESRF, Grenoble) for PEM water content. • Ex-situ post-mortem GDL computed tomography for reconstruction. Effective properties calculation.
"Lifetime predictions,... research to establish methodologies as well as tools for modeling, operational controls and diagnostics"	• Ongoing development of an online diagnostic model to optimise the operating conditions. • Ongoing modeling of degradation mechanisms at various scales: carbon corrosion, platinum coarsening, PTFE ageing. Development of a local degradation model. • In-situ investigation of the water content in PEM with ageing (SAXS).

Dissemination

- Workshop "Multi-scale modeling of PEMFC", 12-13 June 2014 in Grenoble, France
- Tutorial and organised symposium on multi-scale modeling within the 64th Annual Meeting of the ISE, 8-13 September 2013, Queretaro, Mexico
- A tutorial on multi-scale modeling at the CECAM workshop (Jülich Research Centre, Germany)
- 10 Publications (done or planned) in scientific journals
- 10 Communications (done or planned) in international conferences
- 1 book (Polymer Electrolyte Fuel Cells: Science, Applications and Challenges, A.A. Franco, Ed., CRC Press, Taylor and Francis group, FL, USA (2013).

Conclusions, major findings and perspectives

The next year will be dedicated to

- the ongoing development of the performance and degradation models at various scales and coupling these scales (DFT calculations including solvent contribution, KMC simulation and local degradation model, electrodes, GDL and membrane transport properties, diagnostic tools)
- Experimental validation (RRDE, half-cell, single cell, SAS)
- Fuel-cell roadmap, workshop organisation.

PURE

Development of Auxiliary Power Unit for Recreational Yachts

Duration

Start and end date: 1 January 2013 - 31 December 2015

Application area

Early markets

Budget

Total budget €2,884,875
FCH contribution €1,641,194

Partnership/consortium list

Coordinator: HyGear Fuel Cell Systems (Netherlands)
Consortium: Technical University of Denmark (Denmark), Aerosol and Particle Technology Laboratory/Centre for Research and Technology Hellas (Greece), European Commission, JRC, Damen Shipyards Gorinchem (Netherlands).

Summary/main objectives of the project

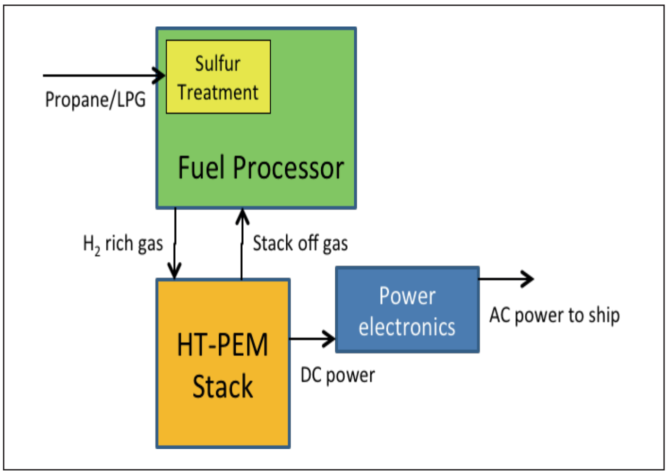
In the project a portable fuel-cell system is developed, built and tested. The system is LPG/propane-fuelled and based on a HT-PEM fuel cell. The 500We system has strict requirements for size, weight and cost.

Technical accomplishment/progress/results

- The system requirement document is finalised.
- Additional technical input from MEA/stack requirements have resulted in a process-flow diagram which is used for modeling.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
System weight (kg)	35 /kWe	17.5	Too early to state
System volume (l)	50 /kWe	25	Too early to state
FC system efficiency (%)	>30	>30	± 30 (based on modeling)
System cost	< €5,000/kWe	< €2,500	€2,400



Future steps

1. Improve MEA cost and reliability
2. Define desulfurisation options
3. System development and construction
4. Environmental system testing in laboratory and on a ship

Conclusions, major findings and perspectives

Major findings at this early stage of the project are the definition of the requirements based on the customer input of the maritime industry and the technical input from the HT PEM MEA industry. These requirements lead to decisions on items like the process design and catalyst selection, bearing in mind the strict volume and weight criteria.

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pure
auxiliary power unit for recreational yachts

RAMSES

Robust Advanced Materials for Metal-Supported SOFC

Duration

Start and end date: 1 January 2011 - 31 December 2013

Application area

Stationary power generation and CHP

Budget

Total budget €4.7 million
FCH contribution €2.1 million

Partnership/consortium list

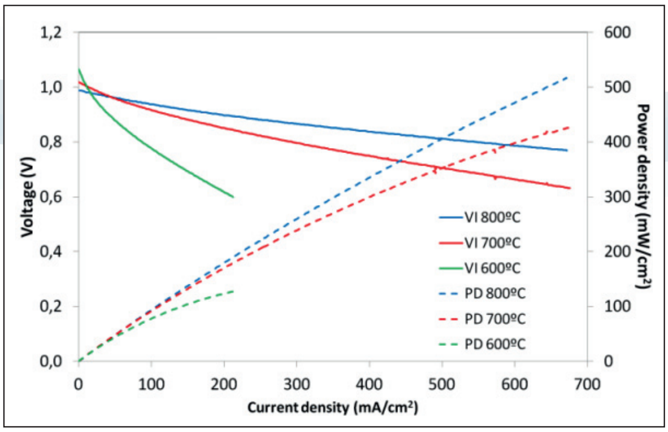
1. Commissariat à l'Energie Atomique (Research), France - coordinator
2. SOFCpower S.p.a. (SME), Italy
3. Centre National de la Recherche Scientifique (Research), France
4. Höganäs AB (Industry), Sweden
5. Baikowski (Industry), France
6. AEA S.r.l (Industry), Italy
7. Stiftelsen SINTEF (Research), Norway
8. Ikerlan S. Coop. (Research), Spain
9. Copreci S. Coop. (Industry), Spain
10. National Research Council Canada (Research), Canada

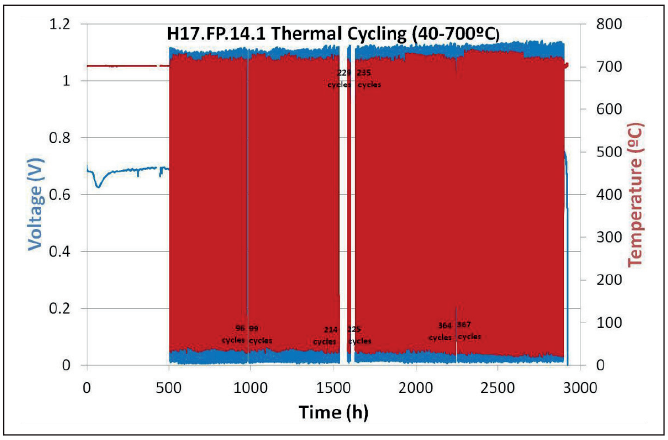
Summary/main objectives of the project

The RAMSES project aims at developing an innovative high-performance, robust, durable and cost-effective solid oxide fuel cell based on the metal-supported cell concept i.e. the deposition of thin ceramic electrodes and electrolyte on a porous metallic substrate.
Both planar and tubular cells have been developed. By considering advanced materials tailored for this application, such cells aim to operate at 600°C not only in hydrogen but also in methane steam reforming. Degradation upon thermal and redox cycling has been also considered.

Technical accomplishment/progress/results

Within the FCH-JU RAMSES project, materials, components and processes have been tailored for MSCs.
A metal substrate suitable for metal-supported cell has been developed by HÖGANÄS, able to achieve the targets set in terms of porosity, sinterability and oxidation resistance.
Materials and procedures for coating of the porous metal supports were developed by SINTEF. Among the different compositions investigated, the two selected coatings for the porous supports were La(Mn0.5Co0.5)0.8 and LaMn0.8. The oxidation resistance tests at 600°C showed that the coating was very efficient to improve the oxidation resistance in wet hydrogen (AMSC option, anode deposited on the metal) for the pre-sintered metal support, from the comparison of weight increase for coated and uncoated metal supports after 500 h in wet hydrogen (Ar-2%H2-8%H2O). The oxidation resistance in air (CMSC option, cathode deposited on the metal) was also improved by the coating but is still satisfactory without coating. The project





criterion for the stability of the metal support (i.e. oxide thickness <3 µm after 500 h at 600°C) is fulfilled for uncoated and of course coated substrate in CMSC operating conditions and for coated substrate in AMSC operating conditions.
A strategy of piece by piece validation has been used to optimise all other metal-supported cell components. Thus, a customised electrolyte powder has been developed by BAIKOWSKI, allowing a decrease of the sintering temperature of 100°C compared to the reference Tosoh 8YSZ powder, while keeping the same ionic conductivity.
Works carried out at CEA, SP and CNRS-BX allowed developing modified Ni-YSZ anode as well as a nickelate-based cathode that were found to reach the performance targets set in the project, with polarisation resistances of 0.37cm^2 and 0.20 cm^2 at 600°C in H2 and air respectively.
Tubular metal-supported cells including RAMSES metallic substrate and electrolyte materials have been successfully produced and tested by IKERLAN, leading to an ASR of 1.56 cm^2 at 600°C and 0.42 cm^2 at 700°C, in line with the project objectives. Durability over 500 h has been demonstrated, and 500 thermal cycles have been successfully applied for a total operation time of almost 3000 h.
More difficulties were faced to manufacture planar cells, and several tasks have been added in the project to overcome these difficulties.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Stationary FC competiti-veness / other technologies	Achievement of principal technical and economic specifications	Increase SOFC durability & cost reduction	N/A (test not finalised)
Fuel	Use of multiple fuels	H_2 and internal steam reforming	H2 in tubular MSC N/A in planar MSC (test not finalised)
Lifetime	>40,000h	Correspon-ding cell degradation rates	Durability de-monstrated in tubular MSC

Future steps

At this stage, most of the project's targets at the components level were achieved. At the scale of complete cells, the milestone has been achieved on tubular cells, and up-scaling activities are ongoing as expected.

More difficulties were faced to manufacture planar cells, and several tasks have been added in the project to overcome these difficulties. The contingency plan established at the beginning of the project has been activated, and solutions of each issue encountered have been proposed and are currently tested and/or validated.

According to the contingency plan, no up-scaling activity on planar cells will be done within the project.

Conclusions, major findings and perspectives

The competitive advantage expected from this project consists in the development of metal-supported SOFCs sustaining long-term durability and demonstrating cost reduction of a promising technology. All partners of the consortium are willing to take part in the exploitation of the promising project results.

R&D and industry partners will patent relevant results on the cell technology. On the basis of the project results, they will proceed to the demonstration of the technology at a representative scale and in a representative environment/application (proof-of-concept).

Industry partners will then ensure the industrial and commercial exploitation of the project results. The Consortium Agreement takes care of this.

Since some issues still remain and because MSC geometry is very attractive, follow-up projects would be necessary on this topic.

ReforCELL

Advanced Multi-Fuel Reformer for Fuel-Cell CHP Systems

Duration

Start and end date: 1 February 2012 - 31 January 2015

Application area

Stationary power generation and CHP

Budget

Total budget €5,546,194
FCH contribution €2,857,211

Partnership/consortium list

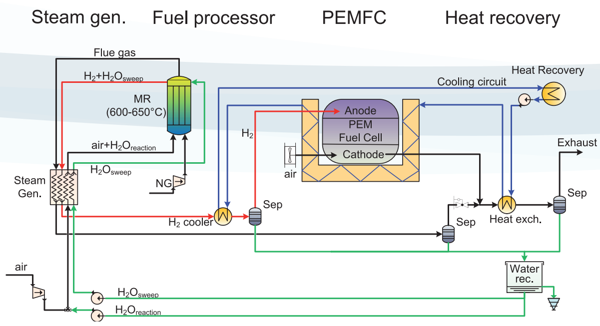
Coordinator: Fundación Tecnalia Research & Innovation.
Technische Universiteit Eindhoven, Commissariat à l'energie atomique et aux energies alternatives (France), Politecnico di Milano, Stiftelsen Sintef, ICI Caldaie spa, Hygear bv, Soprano Industry, Hybrid Catalysis bv, Quantis sàrl, European Commission (JRC).

Summary/main objectives of the project

Developing a high-efficiency PEM fuel cell m-CHP system by using catalytic membrane reactor for the hydrogen production together with an optimised design of the sub-component for the BoP.

Technical accomplishment/progress/results

- Industrial requirements of the m-CHP system
- Advanced catalyst for ATR (< 700°C)
- Pd-based membranes by PVD direct deposition and non-direct deposition
- Micro-channels membrane reactors and a lab-scale membrane-assisted fluidised bed reactor for ATR
- Layout of CHP in case of natural gas fuelled MR



Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Viable mass production		Mass production technologies	N/A
CHP life time (years)	> 10	> 10	N/A
Electrical efficiency (%)	> 42	> 42	N/A
Overall efficiency CHP (%)	> 80	> 90	N/A
Cost target by 2020 (kW)	5,000	5,000	N/A
Recyclability	yes	LCA and safety study	N/A

Future steps

1. Addressing sealing issues on the membranes
2. Lab-scale testing of the CMR
3. Pilot-scale CMR reformer development & testing
4. Selection of BoP components and FC stacks
5. Integration and testing of the new m-CHP system
6. Life-cycle analysis

Conclusions, major findings and perspectives

The incorporation of catalytic membranes reactors in PEM fuel-cell micro-CHP systems could improve the efficiency while reducing the cost due to the integration of the reforming and purification in one single unit (working at lower temperature) and the optimised design of the sub-component for the BoP.

RESelyser

Hydrogen from RES: Pressurised Alkaline Electrolyser with High Efficiency and Wide Operating Range

Duration

Start and end date: November 2011- October 2014

Application area

Hydrogen production and distribution

Budget

Total budget €2.89 million
FCH contribution €1.48 million

Partnership/consortium list

Coordinator: Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Partners: Vlaamse Instelling voor Technologisch Onderzoek n.v. (VITO), Hydrogenics Europe nv. Danmarks Tekniske Universitet(DTU)

Summary/main objectives of the project

The project RESelyser develops high-pressure, highly efficient, low-cost alkaline water electrolysers that can be integrated with renewable energy power sources using an advanced membrane concept, highly efficient electrodes and a new cell concept. Quantitative objectives: efficiency >80%; 1,000 on/off switching cycles; €3,000/(Nm_3/h) plant capacity.

Technical accomplishment/progress/results

Novel diaphragms with internal electrolyte bypass and properties for maximum benefit of the cell were developed and produced in technical size. The cell concept was realised. Electrode coatings were developed that reduce the overpotential of a nickel electrode by 210 mV for the cathode and 161 mV for the anode thus increasing the efficiency. A 10kW stack is constructed and ready for long-term real condition testing.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Power level single stack	exceeding 5kW	30kW	10kW stack is assembled and ready for tests
Efficiency @ Current density 0.75 A/cm^2	>80% on HHV basis	>80% on HHV basis 300 cm^2 electrodes, low-cost materials	Efficiency h=70% on HHV basis at 0.75 A/cm^2
Electrolyser system operating at high pressure	15MPa = 150 bar with compression or 3MPa = 30 bar without compr.	100-150 bar concept, 25 bar realisation	Tests now up to 5 bar
Retention of % of initial efficiency over at least 1,000 on/off switching cycles	>90%	> 90% demonstrated with 10kW electrolyser	Tests at a too early stage
Modular system cost	€1,000 per Nm^3/h plant capacity for the stack and €3,000/Nm^3 for a complete system	System costs €3,000/(Nm^3/h) plant capacity for the complete system	N/A (technique not finalised)

Future steps

1. Long-term test of 10kW stack
2. Design, construction and tests of 30kW, 25-bar stack
3. System concept

Conclusions, major findings and perspectives

The key steps towards a next generation alkaline water electrolyser better adapted to highly fluctuating current supply as when connected to RES were achieved: Membranes for a new concept were developed, electrodes for higher efficiency were demonstrated and a new cell design is available as single cell and stack.

ROBANODE

Understanding and Minimising Anode Degradation in Hydrogen and Natural Gas-Fuelled SOFCs

Duration

Start and end date: 1 January 2010 - 31 December 2012

Application area

Stationary power generation and CHP

Budget

Total budget €3,394,888
FCH contribution €1,568,530

Partnership/consortium list

Foundation for Research and Technology Hellas-Institute of Chemical Engineering Sciences (Greece), Technische Universität Clausthal (Germany), National Technical University of Athens (Greece), Ecole Polytechnique Federale de Lausanne (Switzerland), Agencia Estatal Consejo Superior de Investigaciones Cientificas (Spain), Centre National de la Recherche Scientifique - CNRS (France), Materials Industrial Research & Technology Center (Greece), Saint-Gobain Centre de Recherches et d`Etudes Européen (France).

Summary/main objectives of the project

The main objective of ROBANODE was the study, understanding and modeling of the degradation mechanisms of state-of-the-art (SoA) Ni-based anodes. This study focused on:

- Agglomeration of Ni particles due either to thermal or electrochemical sintering
- Degradation due to carbon deposition and tolerance improvement under CH_4 Internal Steam Reforming (ISR) conditions.
- Degradation due to sulfur contamination and tolerance improvement under CH_4 ISR & H_2S

Contribution to the programme objectives

ROBANODE contributed to the objectives of the Programme "Degradation and lifetime fundamentals of SOFCs" as it concerns:

- Improvement and optimisation of the properties and design of (SoA) Ni-based anodes
- Minimisation of degradation due to carbon deposition and sulfur poisoning in CH_4 fueled SOFCs operating at 700-900°C under $H_2O/CH_4 < 1$ and in the presence of H_2S (up to 30 ppm)
- Long-term stability and reliability of natural gas fueled SOFCs operating at 700-900°C (exhibiting degradation rate less than 0.5%/1,000 hours and reaching operational lifetime of 40,000 hours).

Conclusions, major findings and perspectives

- Development of a mathematical model for prediction of the (SoA) Ni-based anode performance and degradation
- Development and improvement/optimisation of (SoA) Ni-based anodes, easily commercialised, for CH_4 fuelled SOFCs, under internal reforming or direct oxidation conditions
- Study of the degradation mechanism due to thermal and electrochemical sintering
- Study of the degradation mechanism due to carbon deposition and sulfur poisoning

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ROBANODE

SAPIENS

SOFC Auxiliary Power In Emissions/Noise Solutions

Duration

Start and end date: November 2012 - October 2015

Application area

Early markets

Budget

Total budget €2.4 million
FCH contribution €1.6 million

Partnership/consortium list

ADELAN Ltd (coordinator), Autosleepers, CARRD, CUTEC, JRC, IREC and ZUT

Summary/main objectives of the project

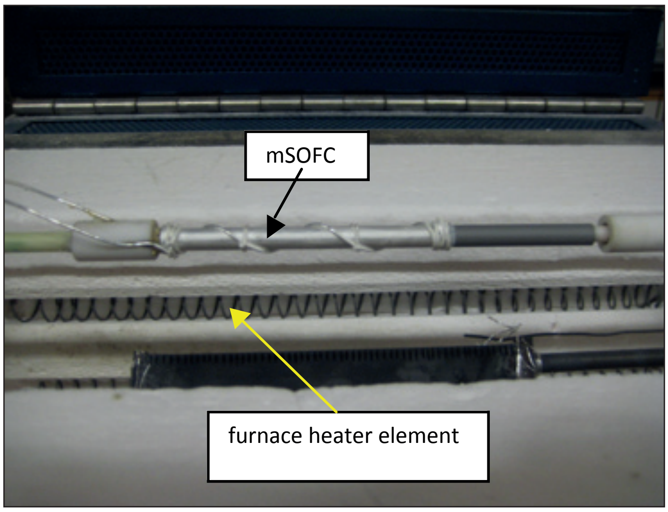
Aims to design, build and demonstrate several SOFC systems in recreational vehicles (RVs). The system is a hybrid power supply to provide lighting, communications and entertainment, with additional heat available for hot water. Autogas propane is the fuel available throughout the EU. A sulfur absorber and CPOX processor will be built into the system with additional electrical and mechanical balance of plant.

Technical accomplishment/progress/results

Microtubular cells have been tested and put together in sub-stacks ready to assemble full stacks.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
e.g. Number of RVs	>1	5	Not yet installed
e.g. FC system life time (h)	>1,000	>1,000	Tests to be agreed
e.g. FC system efficiency (%)	>40	>40	Not yet measured



Future steps

1. Build full stacks
2. Test autogas propane reformer
3. Build BOP and integrate stack
4. Demonstrate in RVs to give impact

Conclusions, major findings and perspectives

The early market need for RV fuel-cell auxiliary power supplies has been shown over the past several years with DMFCs. Moving to autogas propane with rapid starting microtubular SOFCs gives added benefit to consumers because of readily available fuel across the EU plus available hot water.

SAPPHIRE

System Automation of PEMFCs with Prognostics and Health Management for Improved Reliability and Economy

Duration

Start and end date: May 2013 - April 2016

Application area

Stationary power generation and CHP

Budget

Total budget € 3,226,400
FCH contribution €1,745,700

Partnership/consortium list

SINTEF Foundation (Coordinator, Norway), European Institute for Energy Research (Germany), FCLAB Research Federation (France), University of Split (Croatia), Centre for Solar and Hydrogen Energy Research (Germany). Dantherm Power A/S (Denmark).

Summary/main objectives of the project

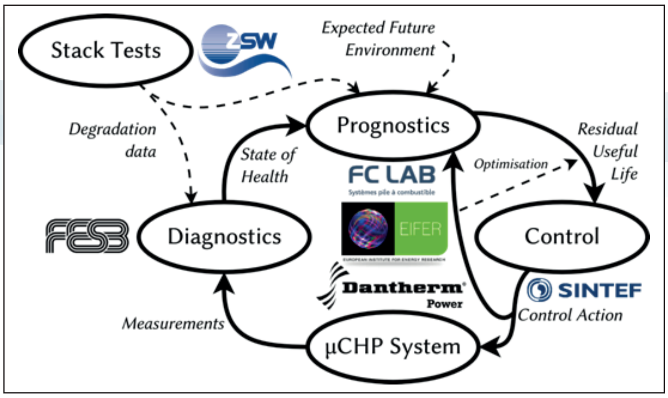
Sapphire aims to develop a control system able to maximise the lifetime of LTPEM fuel-cell systems by integrating knowledge about cell degradation with a prognostic algorithm.

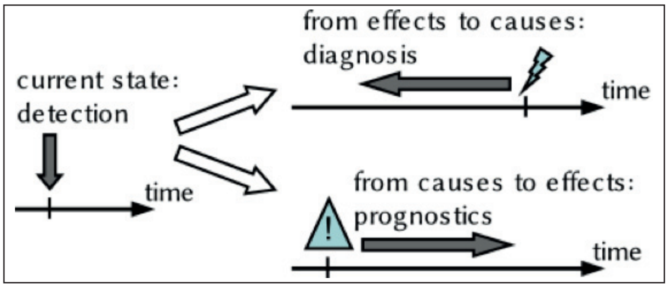
Technical accomplishment/progress/results

The project has just started and there are no significant results yet. All partners report being on schedule with their activities.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Stack lifetime with current technology	20,000 h	20,000 h	5,000 h
Controller unit price	€100/kW	€100/kW	N/A





Future steps

1. Experiments on single cells, short stacks, complete µCHP systems
2. Diagnostics: classification of degradation phenomena
3. Prognostics: synthesis of prognostic algorithm
4. Control: synthesis of prognostic-aware control system
5. Hardware implementation of the control system
6. Validation on complete Dantherm system

Conclusions, major findings and perspectives

Sapphire is the first major project applying the methods of prognostics and health management (PHM) to fuel cells. The project consortium is small but comprehensive, covering the field from FC degradation fundamentals to prognostics and control, from assembly of short test stacks to commercial µCHP systems.

SCORED 2:0

Steel Coatings For Reducing Degradation

Duration

Start and end date: 1 July 2013 - 30 June 2016

Application area

Stationary power generation and CHP

Budget

Total budget €3,656,757
FCH contribution €2,183,023

Partnership/consortium list

University of Birmingham (coordinator), Teknologian Tutkimuskeskus VTT, EPFL, ENEA, Teer Coatings Ltd, Turbocoating, SOFCpower.

Summary/main objectives of the project

The project looks into coated steel components for SOFC with markedly improved properties with regard to chromium release, contact resistance and scale growth. Optimised combinations of protective layer materials with different steel qualities (including low-cost options) will be chosen for testing and influence, practicality and cost of different methods of coating analysed.

Technical accomplishment/progress/results

The project has just started and is in the process of finalising the test matrices and testing procedures

Contribution to the programme objectives

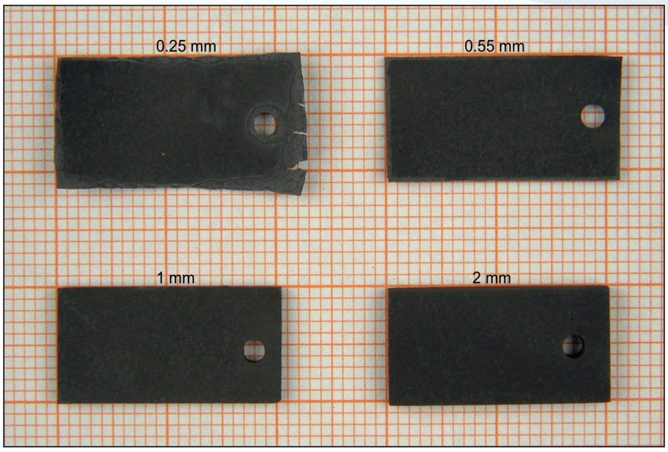
	Objectives of the call	Objectives of the project	Current status
Lifetime of stationary fuel-cell systems	>10 yrs small systems >15 yrs large systems	120,000 hours service life	project just started

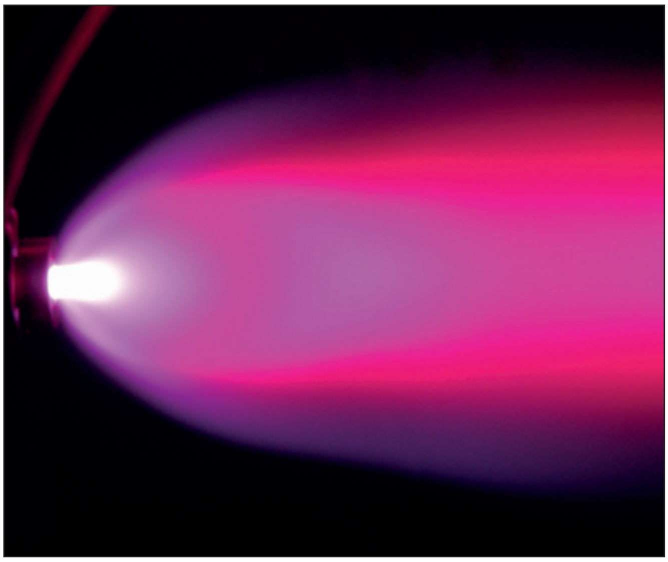
Future steps

1. preparation of samples for testing
2. long-term (3,000 hour) tests
3. contact resistance and weight-gain characterisation
4. microscopic examination

Conclusions, major findings and perspectives

Longevity of steel components is of ultimate importance for long durability and service lifetime of SOFC systems. This refers not only to the stack materials but also all BoP components upstream of the stack. Therefore the high-quality coating of all steel components with a robust and long-term stable protective layer is of great importance for the market success of fuel cells for stationary applications.





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SCOTAS-SOFC

Sulphur, Carbon, and Re-Oxidation-Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells

Duration

Start and end date:
1 October 2010 - 30 September 2013 (31 December 2013)

Application area

Stationary power generation and CHP

Budget

Total budget €4,368,579
FCH contribution €1,701,770

Partnership/consortium list

Technical University of Denmark, and Forschungszentrum Jülich (Germany), Hexis AG (Switzerland), Topsøe Fuel Cell A/S (Denmark), University of St Andrews (UK).

Summary/main objectives of the project

Demonstration of an all ceramic fuel cell based on a strontium titanate ceramic to mitigate known failures in the operation of micro-CHP SOFCs, e.g. grid outage and desulfuriser breakdown, known to be harmful to SoA Ni-YSZ based SOFCs.

Technical accomplishment/progress/results

Upscaling of cell production using three candidate materials and full cell tests under application-relevant conditions. 100 cells have finally been produced, stacked and operated in a 0.8kW system test using pipeline natural gas.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Durability	Solutions to specific identified failure mechanisms	Materials based solution to three main failure mechanism for micro CHP redox tolerance, sulphur poisoning and carbon content in the fuel	Redox tolerance proven overload tolerance S-tolerance indicated
Costs/ durability	Recommendations for use of materials in specific stack or BoP components	Evaluate strontium titanate materials to replace Ni in Ni-cermets	Three materials have been assessed
FC system efficiency (%)	Proof of improved performance for existing design of cells, stacks and BoP	Simplified system design through more robust cells	Part of the final assessment
Costs manufacturing	New material production techniques and new inspection techniques	Infiltration of electrocatalysts into porous ceramic structures	Need for optimisation and upscaling identified

Future steps

1. Analysis of the system test results
2. Extension of the concept to other electro catalytic active infiltrates
3. Development of infiltration process for volume manufacturing
4. Identification of large-scale materials supplier for strontium titanates

Conclusions, major findings and perspectives

The concept of a ceramic anode shows promising redox stability and performance exceeding 0.5 W/cm2 in single cell tests. Stability and S-tolerance varies with the choice of electro catalysts and their infiltration process. Performance of a larger batch of electrolyte-supported cells prepared by screen printing is reproducible and showed stability in an initial test period of <100 hs, (21% electrical efficiency and 60% fuel utilisation).

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scotas
ROBUST FUEL CELLS

SMARTCat

Systematic, Material-Oriented Approach Using Rational Design to Develop Break-Through Catalysts for Automotive PEMFC

Duration

Start and end date: 1 June 2013 - 31 May 2017

Application area

Transport and refuelling infrastructure

Budget

Total budget €4,963,497
FCH contribution €2,634,701

Partnership/consortium list

CNRS (France), SINTEF (Norway), DTU (Denmark), CEA (France), BM (Netherlands).

Summary/main objectives of the project

New and innovative electrodes using tri-metallic low Pt-content (0.01 mg-2, 0.05g/kW) based catalyst nanoparticles and nanostructured layers combined with new and corrosion resistant metal-doped oxide-based materials Σ1-10 Scm-1). Upscaling HT membranes proton conductivity > 60 mS/cm @ 40°C; > 200 mS/cm @ 180°C. Enable to optimise and to automate the production of MEAs (60/day). Prove the viability of the new concept for automotive applications (220 cm^{-2}, 5,000h durability).

Technical accomplishment/progress/results

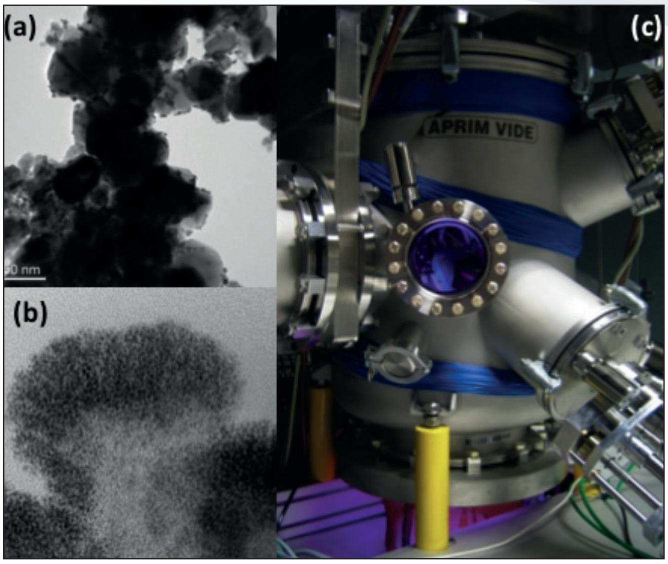
Roadmap of the project as the 1st deliverable. First DFT calculations of Pt on Sb doped SnO_2 oxide supports. Plasma sputtering experiment testings for trimetallic catalyst deposition. Delivery of the MEA automated manufacturing process.

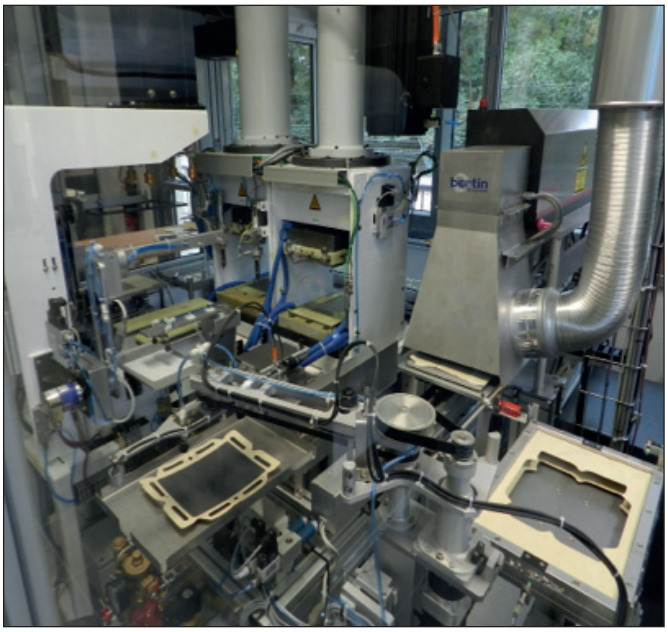
Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Project roadmap	1	1	1
WP1 specifications	1	1	1

Future steps

1. Metal oxide support synthesis
2. Tri-metallic catalyst deposition and characterisation
3. PYPO HT membrane synthesis





Conclusions, major findings and perspectives

The SMARTCat project started last June 1st. In five months, the project roadmap, the specifications of the project have been established. The first simulations on Pt interactions with doped metal supports as well testing experiments for tri-metallic catalyst are now ongoing.

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SMARTCat

SOFC-Life

Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models

Duration

Start and end date: 1 January 2011 - 31 December 2013

Application area

Stationary power production and CHP

Budget

Total budget €5,700,000
FCH contribution €2,400,000

Partnership/consortium list

Forschungszentrum Jülich GmbH (coordinator), Hexis AG, HTceramix, Topsøe Fuel Cell A/S, Commissariat à l´energie atomique, DTU-EC, Eidgenössische Materialprüfungs- und Forschungsanstalt, Institute of High Temperature Electrochemistry, Valtion Teknologian Tutkimuskeskus VTT, Ecole Polytechnique Fédérale Lausanne, Imperial College, Electricité de France, Zürcher Hochschule für Angewandte Wissenschaften.

Summary/main objectives of the project

- Understand the details of the major SOFC continuous degradation effects (stability of anode cermet and SotA cathode materials, nickel-steel corrosion, cathode- and anode-interconnect interfaces)
- Develop models that predict single degradation phenomena
- Transfer the physical-chemical models to electrochemical models
- Re-assemble the single effect models to a full SRU lifetime prediction model

Technical accomplishment/progress/results

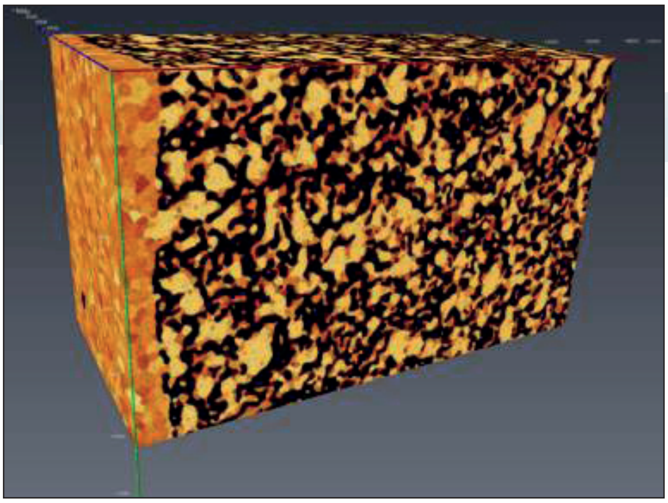
Resistance and conductivity of selected components and interfaces determined over time. Only the interconnect steel with and without coating in air shows an increase of resistivity with time, which can be considered to be a major contribution to the overall degradation observed in SRUs and stacks.
Microstructural parameters as function of operating conditions and time for cathodes and anodes have been extracted for use in the respective sub-models.
Cellular automaton model developed to predict 3D microstructure evolution, and corresponding degradation of polarisation resistance, of Ni/YSZ anodes and LSM/YSZ cathodes.

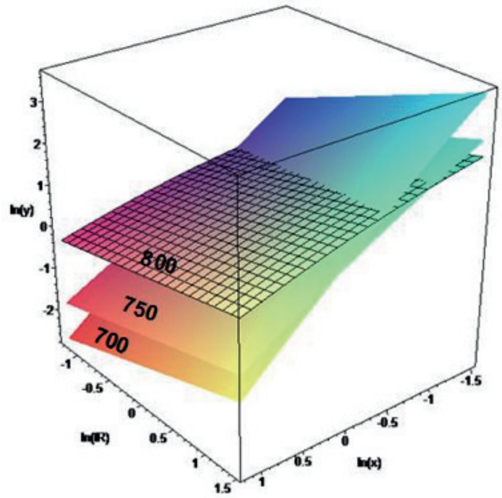
Contribution to the programme objectives

SOFC-Life addresses basic research activities directed to degradation and lifetime fundamentals of SOFC technology, particularly focusing on SOFC materials available and in industrial application today

Future steps

Re-assemble the sub-models to a full SRU model.





Conclusions, major findings and perspectives

From the four themes investigated only processes at the cathode-interconnect interface can be considered to be a major contribution to the overall degradation observed in SRUs and stacks.
Further RTD activities:
Degradation models will require further refinement to make them applicable to a wider range of cell types and operating conditions.
Basic understanding should be applied to develop soundly-based accelerated tests.

SOFCOM

SOFC CCHP with Poly-Fuel: Operation and Management

Duration

Start and end date: 1 November 2011 - 31 October 2014

Application area

Stationary power generation & CHP

Budget

Total budget €6,261,369
FCH contribution €2,937,758

Partnership/consortium list

Coordinator: Politecnico di Torino (IT)
Companies: Topsoe Fuel Cells A/S (DK), Società Metro-politana Acque Torino spa (IT), Matgas 2000 A.I.E. (SP)
Research Centres: Teknologian Tutkimuskeskus VTT (FL), Consiglio Nazionale delle Ricerche (IT), Instytut Energetyki (PL)
Universities: Ecole Polytechnique Fédérale de Lausanne (CH), Technische Universitaet Muenchen (DE), Università di Torino (IT)

Summary/main objectives of the project

The general aim is the technological demonstration of the use of biogenous fuels (biogas, bio-syngas) as renewable fuels in high-efficiency electrochemical CHP generators (solid oxide fuel cells), able also to separate and reuse the CO_2 in its exhaust streams.

Technical accomplishment/progress/results

1. Define and operate new proof-of-concept fuel-cell systems fully integrated with biomass processing units and carbon sequestration and handling technologies: design done, construction on the way.
2. Fuel issues considering detailed poisoning mechanisms, advancing in cleaning and processing technologies: quite complete.

Contribution to the programme objectives

AIP target	How SOFCOM addresses the AIP target
Development of proof of concept prototypes that combine fuel cell units into complete systems, interface with devices featuring delivery of customer requirements (e.g. power, heat, cooling and CO2 capture), also integrating renewable energy	The present project develops two proof-of-concept demonstration plants, which integrate SOFCs into complete systems. The demonstration site in Turin (Italy) consists of a SOFC generator fully integrated in a large waste-water treatment plant producing biogas; the generator produces electrical power plus heat, and also integrates a CO2 separation and reutilisation module. The demonstration site in Helsinki (Finland) is based on the integration of the SOFC with another fuel typology: a bio-syngas (from gasification).
Maintenance and repair issues to reduce downtimes from known failure mechanisms	The formulation of repair strategies, the monitoring analysis on the long run, and the development of pre-normative results leading to recommended practices for those plants will be part of the final results of the project.
Identification of technical and economic requirements in order to be competitive in the marketplace	This part is analysed in the last period, following the real experience performed in the demonstration activity, with a scale-up analysis of the integrated SOFC systems studied.
Validation activities, performed in a real system environment or with real equipment in a simulated system environment	The proof-of-concept validation of the tested systems on the demonstration sites will be one of the main results of the project.
Fulfilment of the diverse application needs	The demonstration fulfils all the application needs listed in the topic: combine fuel cell units into complete systems, integration and testing with fuel delivery and processing subsystems; interface with devices featuring delivery of customer requirements (power, heat, cooling and CO2 capture).
Validation of the whole system built, integration into power plants and networks	This validation will be achieved through the scale-up analysis of the integrated SOFC systems, following the real experience performed in the demonstration activity.

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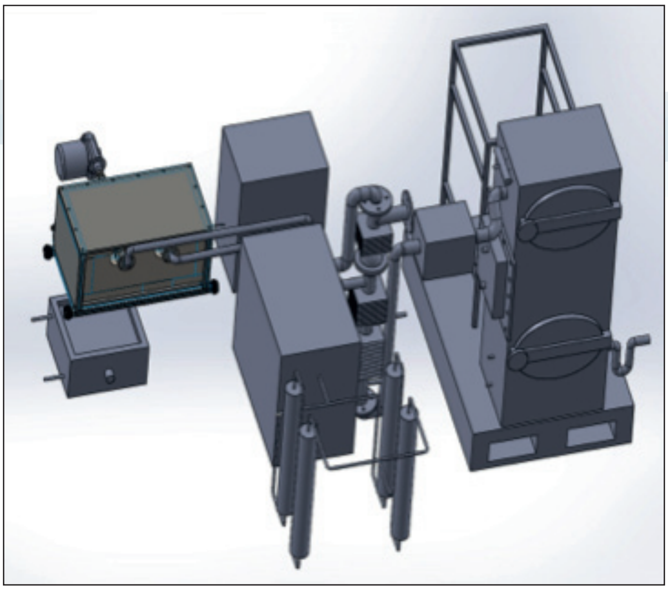
sofcom
FCH-JU project

Establishment of quality control procedures and techniques to ensure quality of systems	A detailed blueprint of the proof-of-concept installation has been developed, in order to avoid any problem in the implementation of the proof-of-concept parts (provided by the partners involved in WP6) and its integration with the existent industrial plant.
Addressing relevant manufacturing solutions linked to the validation of fuel cell systems	The most relevant manufacturing solutions defined in the concept design of the systems (WP4 and WP5), are applied in the two demonstrations (WP6 and WP7) and will be analysed and validated in the final analysis of the lessons learned (WP8).



Future steps:

1. Installation and test demo Turin: January 2014
2. Installation and test demo Helsinki: Nov 2013
3. Completion of lab analysis test: April 2014
4. Completion of system analysis: after the demo

Conclusions, major findings and perspectives:

From the two demonstration activities, feedback to other RD&D activities to remove technical barriers to successful larger scale demonstration could be available. WP2 and WP3 will provide specifications to design proper clea-ning, processing and CO2 removal components. WP4 and WP5 will provide layout of integrated plants to be demonstrated. The two real demonstrations and the final WP8 (operation and maintenance, repair strategies, guidelines for scale-up) will provide feedback to other RD&D activities at a larger scale.

SOFT-PACT

Solid Oxide Fuel-Cell Micro-CHP Field Trials

Duration

Start and end date: 8 July 2011 - 8 October 2015

Application area

Stationary power generation and CHP

Budget

Total budget €10,313,000
FCH contribution €3.950,000

Partnership/consortium list

Coordinator: E.ON
Ceramic Fuel Cells, Ideal Boilers and HOMA Solutions

Summary/main objectives of the project

Deploy pathfinder BlueGen fuel-cell systems. Develop and deploy integrated fuel-cell mCHP system. Remote control and diagnostics of all the systems from a central point in real time. Long-term reliability and life data from the systems. Identify and quantify benefits to the homeowner. Training and reskilling of installation and maintenance engineers.

Technical accomplishment/progress/results

EU market study: Opportunities for fuel cells microCHP. Specification for Integrated fuel-cell (IFC) microCHP system. Market barriers and learning from BlueGen pathfinder field trail. Unique IP for fuel-cell thermal recovery. Testing & production started on IFC units for field trial.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Deployment of fuel cells within trial	10	Up to 100	40 BlueGen systems
FC system lifetime (h)	> 5,000	> 10,000	Ongoing assessment
FC system electrical efficiency (%) (HHV)	> 40	> 40	56->42 (over lifetime)
Cost reduction	€5,000/kW	25% Reduction on BlueGen	Achieved

Future steps

1. LCA assessment of BlueGen
2. Build & test integrated fuel-cell (IFC) systems
3. Field trial deployment of IFC systems
4. Monitoring data analysis

Conclusions, major findings and perspectives

Large opportunities for fuel cell deployment within EU if price target can be achieved with policy and incentive support for local governments.
To meet all EU markets (gas types and local regulations) requires a range of systems.
Deployment of systems via local installation companies requires time and investment.

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SOFT-PACT

SOL2HY2

Solar to Hydrogen Hybrid Cycles

Duration

Start and end date: 1 June 2013 - 31 May 2016

Application area

Hydrogen production and distribution

Budget

Total budget €3,701,300
FCH contribution €1,991,115

Partnership/consortium list

EnginSoft SpA, Aalto-korkeakoulusäätiö, Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), Agenzia per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA), Outotec Oyj, Erbicol SA, Oy Woikoski AB.

Summary/main objectives of the project

The aim of the SOL2HY2 project is ultimately to demonstrate that 'green' hydrogen production is possible through the realisation of Outotec® open cycle and hybrid-sulphur (HyS) cycle using only solar energy.

Technical accomplishment/progress/results

- Project kick-off meeting held 17-18 June 2013
- Partners have started experiments and preparation of first deliverables

Contribution to the programme objectives

Objectives of the call	Objectives of the project
To develop a portfolio of sustainable H_2 production processes ... from carbon-free or lean energy sources.	Combined strategy of introduction of stepwise, carbon-free cycles for large-scale flexible H_2 production plants, tailored for a specific site and investments required.
Special attention is given to the production of H_2 from fluctuating sources. Various sustainable H_2 production and supply chains must be demonstrated.	Solar power as input balanced by a thermal storage integrated with new Outotec® open cycle and HyS. Some key solutions and the whole production cycles will be integrated and tailored.
R&D in innovative H_2 production and supply chains from renewable energy sources have aim of having launched R&D proof-of-concept projects for all production pathways identified as promising.	Sulphur-based cycles have been identified as the most promising. The SOL2HY2 will, for the first time, link new concepts with solar-driven power leading to the proof-of-concept and key systems demonstration.

Future steps

1. Development of the key process components and units (SD-electrolyser, thermal storage, solar interface, reactors)
2. Design of the flowsheets and future plant concepts
3. Fabrication of key materials solutions
4. Multi-objective design and optimisation

Conclusions, major findings and perspectives

The project is at its earlier starting stage; the major findings and conclusions are expected later according to the project research plan.

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SOL 2HY2

SSH2S

Fuel Cell Coupled Solid-State Hydrogen Storage Tank

Duration

Start and end date: 1 February 2011 - 31 July 2014

Application area

Hydrogen production and distribution

Budget

Total budget €3.5 million
FCH contribution €1.6 million

Partnership/consortium list

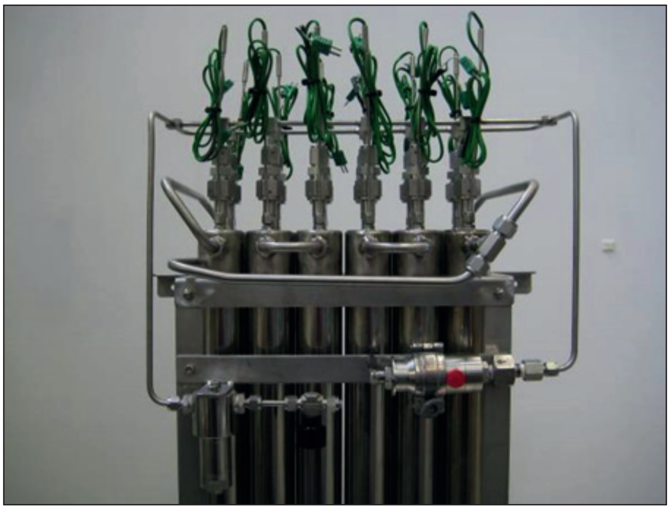
Coordinator: Università di Torino (Italy). Partners: Institute for Energy Technology (Norway), Karlsruhe Institute of Technology (Germany), Deutsches Zentrum für Luft- und Raumfahrt (Germany), Tecnodelta (Italy), Serenergy (Denmark), Centro Ricerche Fiat (Italy), European Commission JRC (Belgium).

Summary/main objectives of the project

- Development of a solid-state hydrogen storage tank fully integrated with a fuel cell.
- Well assessed hydrogen storage material (i.e. a mixed lithium amide/magnesium hydride) considered as the active material for the tank.
- New materials (i.e. mixed borohydrides) also investigated.
- Application of the hydrogen tank on a real system investigated with a 1 kW prototype on a high-temperature polymer electrolyte membrane (HTPEM) fuel cell.
- If suitable performances will be obtained, a scale-up of the tank to a 5 kW APU.

Technical accomplishment/progress/results

- Physico-chemical characterisation of existing and novel materials for solid-state hydrogen storage.
- Ab-initio and thermodynamic/kinetic calculations to determine the selection of materials.



Prototype tank

- Synthesis of materials by ball milling, firstly in a laboratory scale and then scaled-up.
- A new two-materials concept for the tank, combining hydrogen sorption properties of complex hydrides and metal hydrides.
- Synergic effects promoting fast hydrogen sorption reactions, via careful control of thermal exchanges
- Fluido-dynamic modeling of different tank concepts, with experimental validation in a lab-scale tank.
- Development of a prototype tank optimised for use with the selected materials.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Storage materials	ΔH < 40 kJ/mol H_2 T_{dec}<200°C	Approx. 5 wt% H_2 Double materials concept	Up to 4.5 wt% H_2 Reversibility at 180°C Single reaction step
System for H_2 storage	5 wt% 4.5 kg H_2/100l H_2 flow of 2 g/sec	H_2 flow: 20 Nl/min for 2h	H_2 flow: 5 Nl/min for 4h Stability on cycling
Cost-effective H_2 storage	€500/kg of stored H_2 in serious production	< €1,250/kg H_2	Not yet available, but higher than goal

Future steps

- Integrate materials/tank system with a low-power HT-PEM fuel cell (1 kWel).
- If suitable performances, scale-up of the tank to a 5 kW APU.
- Critical techno-economic evaluation.

Conclusions, major findings and perspectives

- Material for a solid-state hydrogen tank with capacities of up to 4.5 H2 wt%, fully reversible at 180°C and with high stability on cycling developed.
- New concepts on the design and the coupling of solid state hydrogen tank with HT-PEM fuel cells
- Development of a prototype 1 kW integrated system and the possible application to a 5 kW APU.
- On the basis of a techno-economic evaluation at the end of the project, the possible commercial impact of the developed APU system will be evaluated.

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Stack-Test

Development of PEM Fuel-Cell Stack Reference Test Procedures for Industry

Duration

Start and end date: 1 September 2012 - 31 August 2015

Application area

Cross-cutting activities

Budget

Total budget €4,932,933
FCH contribution €2,909,898

Partnership/consortium list

ZSW (Coordinator), CEA, DTU, DLR ICRI, AAU, NEXT-E, CIDETEC, Fraunhofer ISE, JRC-IET, Symbio FC.

Summary/main objectives of the project

- Definition and validation of generic test modules for PEM-fuel cell stacks addressing:
  - performance
  - endurance
  - safety
- Definition and validation of application specific test programmes for:
  - automotive applications
  - stationary applications
  - portable applications
- Liaison to international standardisation activities.
- Establish an international advisory group.
- Carry out workshops on PEM fuel-cell stack testing.

Technical accomplishment/progress/results

- Review of international standardisation activities completed, first annual update in preparation.
- Test matrix agreed.
- Draft test modules and test programmes available.
- Started shipment of stacks to partners carrying out validation experiments.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Performance test procedures	Test procedures	Validated test procedures	Draft available
Endurance test procedures	Test procedures	Validated test procedures	Draft available
Safety and environment tests	Test procedures	Validated test procedures	Draft available
Regular and harsh conditions	Test procedures	Validated test procedures	To be defined

Future steps

1. Validation of test modules and test programmes using stacks provided by CEA and ZSW.
2. Review and adapt/improve test modules and test programmes.
3. Carry out first progress workshop 28-29 January 2014.
4. Carry out international workshop on PEM stack testing 3-4 June 2014

Conclusions, major findings and perspectives

Methodology as defined in the previous projects FCTESTNET and FCTESQA confirmed and adapted to stack testing.
Common set of test modules defined.
Differentiation to performance, endurance and safety testing can be done via rest programmes.
Application-specific differentiation can be done via the composition of test programmes and the definition of operating conditions.
Format of test modules, test programmes and test reporting from FCTEST-NET/FCTESQA required simplification after review.

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STACK-TEST

STAMPEM

Stable and Low-Cost Manufactured Bipolar Plates for PEM Fuel Cells

Duration

Start and end date: 1 July 2012 - 30 June 2015

Application area

Transport and refuelling infrastructure

Budget

Total budget €5,223,807
FCH contribution €2,576,505

Partnership/consortium list

Stiftelsen SINTEF (Norway) Coordinator, Teer Coatings Ltd (UK), Miba Coatings Group (UK), ElringKlinger AG (Germany), Fraunhofer Gesellschaft zur Förderung der angewandten Forschung (Germany), University of Birmingham (UK), Fronius International GmbH (Austria)

Summary/main objectives of the project

The main objective of STAMPEM is to develop durable coatings materials for metal-based bipolar plates, that can be mass produced for less than €2.5/kW of rated stack power at mass production volumes of 500,000 pieces annually. Properties after extrapolated 10,000 hours from AST single cell testing shall still be within the AIP specifications. The main parameters are contact resistance (< 25 mohm cm2) and corrosion resistance (< 10 µA/cm2).

Technical accomplishment/progress/results

Some BPPs/coatings already show performance (ICR and corrosion resistance) better than targets for BoL as well as after ex-situ and in-situ testing. Accelerated stress tests of BPPs in fuel cells indicate that there are coatings/concepts with comparable performance to gold-coated stainless steel. Work on manufacturing and processing issues are also progressing along with the project, where pre-treatment of substrate, coating techniques and the stamping process, including plate joining, are the most important steps.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Contact resistance	< 25 mohm cm^2 at relevant clamping pressures	< 25 mohm cm^2 after 10,000 hours extrapolated from AST	< 10 mohm cm^2 at BoL and after 100 hours in-situ AST
Corrosion resistance	< 10 µA/cm^2	< 10 µA/cm^2 after 10,000 hours extrapolated from AST	< 1 µA/cm^2 in 1 mM H_2SO_4 at 0.8 V_{SHE} and 80 °C at BoL
Corrosion stability	> 5,000 h	10,000 hours extrapolated from AST	N/A (test not finalised)
Handling properties	Sufficient for stack assembly/manufacture process, including coating scratch resistance and coating/surface adhesion	Sufficient for stack assembly/manufacture process, including coating scratch resistance and coating/surface adhesion	N/A (test not finalised)
Costs (excluding taxes and levies)	€2.5/kW at 500,000 pieces annually	€2.5/kW at 500,000 pieces annually	N/A (test not finalised)

Future steps

1. In-situ full size operation of most promising coatings in single cells (incl. segmented cell to investigate local degradation), stacks and finally verification in systems
2. Analyse ion release rates to MEA/GDL and product water
3. Investigate effect of manufacturing steps on coating/substrate properties
4. Improve coatings based on feedback from tests
5. Techno-economic assessment

Conclusions, major findings and perspectives

The STAMPEM project approaches BPP topic with a consistent value chain from BPP and coating research to stack manufacturing. Results from the project so far indicate that the technical requirements of BPPs/coatings most likely will be fulfilled. The cost target is however more difficult to reach. One key point here is linked to processing of plates and coatings, as manufacturing by stamping post-coating requires a BPP-coating system which maintains the protective and conductive properties, especially as the materials may stretch up to 30-40% during stamping.
More generally related to PEM fuel cell durability testing is the use and validation of AST protocols. It is difficult to design tests which target and accelerate only specific components and still represent relevant operation.

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STAMPEM

STAYERS

Stationary PEM fuel cells with lifetimes beyond Five Years

Duration

Start and end date: 01 Jan 2011 - 30 June 2014

Application area

Stationary power production and CHP

Budget

Budget €4.1 million
FCH contribution €1.9 million

Partnership/consortium list

Nedstack Fuel Cell Technology bv (coordinator), Solvicore GMBH, Solvay Specialty Polymers S.P.A, SINTEF, Joint Research Centre (JRC).

Summary/main objectives of the project

Goal: > 40.000 hours stationary operation lifetime of PEM fuel cell
Motivation: a lower replacement frequency of PEMFC stacks substantially reduces cost of ownership of a PEM Power Plant.

Technical accomplishment/progress/results

- Several improved membranes have been developed as well as a novel process route, resulting in AST lifetime indications well over 40.000 hours for the latest scavenger-containing membrane variation
- Four iterations of MEA's (50 types in total) have been produced and evaluated by AST's, lab testing and industrial field tests
- 20.000 operational hours in an industrial test facility have already been achieved within the project; dedicated software has contributed in revealing the predominant degradation mechanisms
- Improved stack hardware components have been developed and are currently being evaluated in field tests and ASTs
- AST tests have been developed that successfully mimic the observed irreversible and reversible decay
- Using CFD a 3D two-phase model has been developed and validated with experimental BOL and EOL results.

Future steps

- Evaluation and lifetime prediction of the final SC-4 MEA and stack hardware iteration by field tests and ASTs
- Post mortem analyses of the latest MEA generations
- Evaluation of mitigation strategies to counteract reversible decay

Contribution to the programme objectives:

	Objectives of the call	Objectives of the project	Current status
FC system lifetime (h)	>40,000	>40,000	>40,000 (prelim. estimate)

Conclusions, major findings and perspectives

- The predominant degradation mechanisms in stationary operation have been determined to be:
  - Cathode ECSA loss, partially reversible by poisoning through contaminant traces
  - Cathode increase of proton resistance
  - Reversible anode ECSA loss by CO contamination
- Evaluation of stack hardware components of up to 20,000 hours lifetime indicates that seals are the only limiting factor; improved seals have been developed
- The excellent AST results for the membrane and the low decay rates (<2μV/h) obtained in the first 5,000 hours give a very good perspective on obtaining the 40,000 hours lifetime target with the final SC-4 MEA iteration

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STAYERS

SUAV

Microtubular Solid Oxide Fuel-Cell Power System Development and Integration into a Mini-UAV

Duration

Start and end date:
1 December 2011- 30 November 2014

Application area

Early markets

Budget

Total budget €3.8 million
FCH contribution €2.1 million

Partnership/consortium list

HyGear Fuel Cell System (coordinator), Adelan, Catator, CNR-ITAE, EADS UK, EADS Deutschland, efceco, West Pomeranian University of Szczecin, University of Birmingham, SURVEYCopter

Summary/main objectives of the project

SUAV aims to design, optimise and build a 280W mSOFC stack, and to integrate it into a hybrid power system comprising the mSOFC stack and a battery. Additional components of the system are a CPOx processor to generate reformate gas from propane and other equipment for the electrical, mechanical and control balance of plant (BoP). These parts will be constituents of an entire fuel cell power generator to be tested in the lab and, after further optimisation and miniaturisation, in a mini-UAV (unmanned aerial vehicle) platform. The aim is to double the flight time of present UAV.

Technical accomplishment/progress/results

- Top-level requirements for fuel-cell system accomplished (targets for system to get into flight mission)
- Stack achieves presently 300W with 60 cells
- System models including SOFC and CFD modeling

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Stack power	200W net.	280W	300W (60 cells)
Fuel processing	N/A	Pre-reforming of fuel on board	CPOX-mesh integrated into system
Development of balance of plant (BoP)	Mminiaturised BoP (mech. + electr.)	Miniaturised BoP (mech. + electr.)	Under development
Approval of technology	Approval through testing	Lab-test flight test	Planned in 2nd period

Future steps

1. Improve the cells to reach higher power
2. Build SOFC stack and integrate it into the system
3. Test system in lab and validate system model with test results
4. Integrate fuel-cell generator into mini-UAV and perform flight mission

Conclusions, major findings and perspectives

The development of a microtubular SOFC stack to meet UAV requirements brings challenging mass and weight constraints. UAV's are a highly interesting market for micro-SOFC, especially for the time extension of UAV missions.

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V ehicle

SWARM

Demonstration of Small Four-Wheel Fuel-Cell Passenger Vehicle Applications in Regional and Municipal Transport

Duration

Start and end date:
1 October 2012 - 30 September 2016

Application area

Transport and refuelling infrastructure

Budget

Total budget €17,417,942
FCH contribution €6,978,277

Partnership/consortium list

PLANET Planungsgruppe Energie und Technik GbR (coordinator), Riversimple, H_2O e mobile GmbH, GESPA GmbH, Air Liquide Advanced Technologies, University of Birmigham, Coventry University Enterprises Ltd, Birmingham City Council, Université Libre de Bruxelles, Université de Liège, Jade-Hochschule Wilhelmshaven/Oldenburg/Elsfleth, EWE-Forschungszentrum für Energietechnologie eV, Universität Bremen, TÜV Süd, Service Public de Wallonie, Element Energy Limited, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH.

Summary/main objectives of the project

Delivery and operation of a critical mass of passenger and delivery vehicles (close to 100 vehicles) and infrastructure (3 new H_2 refuelling stations), development of commercialisation and market-entry strategies, enlargement and extension of existing hydrogen infrastructure, extensive performance monitoring.

Technical accomplishment/progress/results

High efficiencies of vehicle drive-trains, use of industrial by-product hydrogen and electrolytically-derived hydrogen based on renewable energy input, low-cost vehicles.

Contribution to the programme objectives

	Objectives of the call	Objectives of the project	Current status
Number of hydrogen cars	n/a	92	In preparation
Number of new HRS	n/a	3	3 from 2014
Energy efficiency tank to wheel	40%	>40%	t.b.c.
H2 price at pump (€/kg)	<€13	€10	t.b.c.

Future steps

1. Roll-out of vehicles
2. Commissioning of HRS
3. Integration of additional users of HRS
4. Extensive evaluation of HRS and vehicles in everyday conditions.

Conclusions, major findings and perspectives

In the demonstration phase of the project, the vehicles will be delivered to the corresponding sites and the infrastructure will be built up. Market entry strategies will be developed and the vehicles will be improved towards the end of the project.

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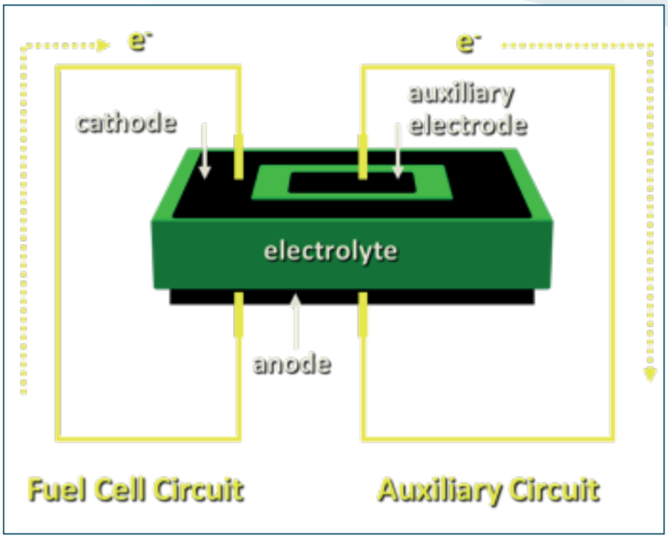
SWARM
Demonstration of Small 4-Wheel fuel cell passenger vehicle Applications in Regional and Municipal transport

T-CELL

Innovative SOFC Architecture Based on Triode Operation



Duration

Start and end date: 1 September 2012 - 31 August 2015

Application area

Stationary power production and CHP

Budget

Total budget €3,424,167
FCH contribution €1,796,267

Partnership/consortium list

Centre for Research and Technology Hellas (coordinator), Foundation for Research and Technology Hellas, Centre National de la Recherche Scientifique (CNRS), Ecole Polytechnique Federale de Lausanne, Instituto de Ciencia de Materiales de Sevilla, MANTIS Deposition Ltd, Prototech AS, SOFCpower.

Summary/main objectives of the project

- Investigation of the synergetic effect of advanced Ni-based cermet anodes modified via doping with a second or a third metal in conjunction with triode operation, in order to control the rate of carbon deposition and sulphur poisoning
- The development of a detailed mathematical model in order to describe the triode mechanism at the molecular level
- Proof of the triode concept through the development and performance evaluation of a prototype triode stack

Technical accomplishment/progress/results

- Preparation of complete single triode cells using standard and modified anodes
- Establishment of the triode SOFC testing protocol
- Identification of triode stack design options

Contribution to the programme objectives

The demonstration of triode architectures is expected to enhance SOFC power output to a factor of 10 and overall thermodynamic efficiency (>55%) as well as to offer a unique tool for controlling the rate of carbon deposition and poisoning by fuel impurities. The T-CELL project proposes the development and evaluation of a prototype triode stack, in order to increase understanding in stack and system level and identify the requirements for fully-integrated systems.

Future steps

1. Study of the effect of triode operation on fuel cell performance and on degradation phenomena
2. Definition of necessary requirements for successful design and operation of triode fuel cells

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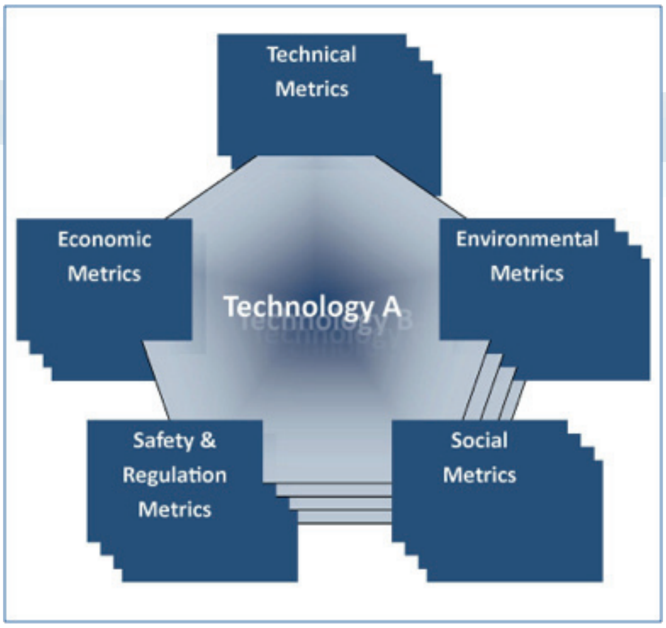
Tcell

TEMONAS

Technology Monitoring and Assessment



Duration

Start and end date: 1 September 2011 - 31 May 2013

Application area

Cross-cutting activities

Budget

Total budget €1,800,602;
FCH contribution €1,132,046

Partnership/consortium list

Claassen Industrie Management Trading GmbH, Planet Planungsgruppe Energie und Technik GBR, European Fuel Cells Forum AG, Comissariat à l'energie atomique et aux energies alternatives (CEA), Janina Agnieszka Swiech-Skiba, Bana Consulting Lda, Herbert Wancura – Synergesis Consulting.

Summary/main objectives of the project

Provide a functional and integrated TMA tool specifically tailored for the needs of research programme progress evaluation
1. Data entry addressing inconsistent data descriptions and parameter names as well as inaccurate results, different levels of information reliability and confidentiality.
2. Design and implement a data QM process including validation.
3. Develop a methodology to assess, benchmark and monitor the progress of individual projects and technologies
4. Implement a methodology for multi-criteria comparison
5. Expert opinion integration in a structured format
6. Develop the necessary query, result integration and reporting tools

Technical accomplishment/progress/results

Delivered the integrated TEMONAS software solution.

Contribution to the programme objectives

TMA tool delivered and installed, user training completed.

Future steps

TEMONAS tool development completed, update & maintenance.

Conclusions, major findings and perspectives

Solutions for submission of usable performance data by projects require changes in the contractual arrangements.
Project and programme reviews are then possible in a fact-based transparent format.

TrainHy

Building Training Programmes for Young Professionals in the Hydrogen and Fuel-Cell Field

Duration

Start and end date: 1 October 2010 - 30 September 2012

Application area

Cross-cutting activities

Budget

Total budget €381,370
FCH contribution €269,105

Partnership/consortium list

University of Birmingham (coordinator)
Forschungszentrum Jülich GmbH
Risø DTU
University of Ulster
Heliocentris

Summary/main objectives of the project

The project devised a system of vocational education and training (VET) for post-graduate engineers and scientists.

Technical accomplishment/progress/results

A curriculum concept was developed that offers an interconnected multi-disciplinary system of face-to-face and distance learning programmes that can be attended in parallel to other studies or professional work.

Contribution to the programme objectives

Establishment of training activities for graduate students.

Future steps

In the absence of FCH JU funding attempts are being made at organising and further developing the summer school and curriculum concepts on a private basis.

Conclusions, major findings and perspectives

Training activities are very necessary in creating the human resources base for the future development of FCH technologies. A joint curriculum helps in developing a mutual understanding of teaching content and quality standards. Continuous support is necessary in sustaining the preparation, development and administration of teaching content supplied to universities.

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TrainHy

TriSOFC

Durable Solid Oxide Fuel-Cell Tri-Generation System for Low-Carbon Buildings FUL

Duration

Start and end date: 1 August 2012 - 31 July 2015

Application area

Stationary power generation and CHP

Budget

Total budget €2,735,560

Partnership/consortium list

University of Nottingham (UK), Royal Institute of Technology (Sweden), The University of Birmingham (UK), IDMEC (Portugal), GETT fuel cells International AV (Sweden), Vestel Savunma Sanayi, A.S. (Turkey), Complex (Poland), Swerea IVF (Sweden).

Summary/main objectives of the project

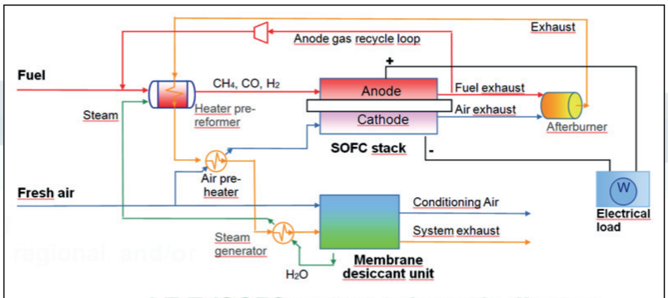
Parameter	Goal
LT-SOFC power	200-1,500W
System efficiency	> 90%
Electrical efficiency	> 45%
Lifetime	> 40,000 hours
Cost targets	L<€400/kWe

Technical accomplishment/progress/results

Development of single component materials (LiNiCuZn).
Maximum performance achieved:
OCV = 0.95 V, I = 1016 mA/cm2 at 230 mV @ 550°C
Compared to a three component pellet with performance of
OCV= 0.95 V, I = 875 mA/cm2 at 180 mV @ 550°C
Development of micro-tubular fuel cells.
Maximum performance achieved:
OCV =f 0.9V, I = 0.8A, P = 0.22W.
1-D & 2-D modeling of the desiccant dehumidification and cooling system.
Potassium formate offered the best solution.

Contribution to the programme objectives

Results proved the concept of the single component low-temperature material in the laboratory.
Modeling enabled the dehumid/cooling/storage system to be optimised for the fuel cell and its location



LT-TriSOFC system schematic diagram

Future steps

1. Scale-up of manufacture and production
2. Prove long-term performance in real conditions
3. Develop fuel-cell stack and BoP
4. Integrate fuel cell and tri-generation system
5. Test in lab conditions
6. Test system in field trials.

Conclusions, major findings and perspectives

Project has produced good results for:

- single component material
- low temperature operation
- tri-generation optimisation.

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TriSOFC

UNIfHY

UNIQUE Gasifier for Hydrogen Production

Duration

Start and end date: 9 January 2012 - 31 August 2015

Application area

Hydrogen production and distribution

Budget

Total budget €3,555,652
FCH contribution €2,203,599

Partnership/consortium list

CIRPS: Interuniversity Research Centre for Sustainable Development (Italy)
PALL: Pall Filtersystems Gmbh Werk Schumacher (Germany)
ENEA: National Agency for New Technologies, Energy and Sustainable Economic Development (Italy)
HYGEAR: "Engineering for sustainable growth" (Netherlands)
UNISTRA: Université de Strasbourg (France)
EPC: Engineering, Procurement & Construction (Germany)
ALH2E: Air Liquide (France)

Summary/main objectives of the project

The project aims to develop a biomass steam gasification process coupled to syngas purification to produce pure hydrogen from biomass, increase well-to-tank efficiency and contribute to a sustainable energy portfolio, exploiting results obtained in past R&D EU projects on hot gas catalytic conditioning.

Technical accomplishment/progress/results

Continuous gasification tests integrated by tar catalytic reforming and particulate abatement have been performed. The results show the effectiveness of the system to achieve a syngas rich in hydrogen, free of particulates and poor in TAR.

Future steps

1. CO conversion by the water-gas shift (WGS) units and
2. Pressure swing absorption process for H_2 separation.

Conclusions, major findings and perspectives

Through development and scale-up activities on materials and reactors for the integration of advanced biomass steam gasification and syngas purification processes, UNIfHY aims to obtain continuous pure hydrogen production from biomass. The project is based on the utilisation of plant components of proven performance and reliability and well-established processes (UNIQUE coupled gasification and gas conditioning technology with catalytic filter candles inserted in the gasifier freeboard for particulate and tar abatement, water-gas shift and pressure swing adsorption (PSA). New foam catalysts for atmospheric pressure WGS are realised and utilised to develop fixed-bed reactors, integrated with a tailored PSA in a portable purification unit.

Contribution to the programme objectives:

H2 content in the fuel gas	34% (gasifier exit)	55% (WGS exit)
H2 conversion efficiency	>66%	
H2 purity in the final product	>99% (PSA exit)	
H2 price at pump (€/kg)	~5	

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Unifhy

Fuel Cells and Hydrogen Joint Undertaking

Programme Review 2013 – Final Report