



Fuel Cells and Hydrogen Joint Undertaking



Programme Review 2012 Final Report



Fuel Cells and Hydrogen Joint Undertaking
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Fuel Cells and Hydrogen Joint Undertaking

Programme Review 2012

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List of acronyms

AA	Application Area
AIP	Annual Implementation Plan
APU	Auxiliary Power Unit
CHP	Combined Heat and Power (generation)
CCS	Carbon Capture and Storage
DoE US	Department of Energy, US
EIB	European Investment Bank
FP7	7th Research and Development Framework Programme of the EU (2007-2013)
GHG	Greenhouse Gases
IG	Industry Grouping
IPHE	International Partnership for Hydrogen in the Economy
ISO	International Organization for Standardization
JU	Joint Undertaking
LCA	Life Cycle Assessment
MAIP	Multi-Annual Implementation Plan
MCFC	Molten Carbonate Fuel Cells
OEM	Original Equipment Manufacturer
PEMFC	Proton Exchange Membrane Fuel Cells
PNR	Pre-Normative Research
RCS	Regulations, Codes and Standards
RG	Research Grouping
SET-Plan	Strategic Energy Technology Plan
SME	Small and Medium Enterprises
SOFC	Solid Oxide Fuel Cells
SRA	Strategic Research Agenda
TRL	Technology Readiness Levels
UPS	Uninterruptible Power Supply

Executive summary

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a unique industry-led Public-Private Partnership, established in 2008 between the European Commission, Industry and the Research Community. It brings public and private interests from across Europe together, with the objective of accelerating the development of fuel cells and hydrogen technologies in Europe to enable their commercial deployment between 2010 and 2020.

The FCH JU defines and implements, together with its members, a targeted multi-annual research and development programme for these innovative energy technologies. This is supported with a ring-fenced budget of nearly € one billion between 2008 and 2013 contributed jointly and on a 50/50 basis by private and public actors.

Annual research agendas are designed to deliver the strategic direction and the multi-annual plan across five application areas (AA): Transportation and Refuelling infrastructure, Hydrogen Production, Storage and Distribution, Stationary Power Generation & CHP (combined heat and power), Early Markets and Cross Cutting activities.

A periodic independent assessment of the portfolio of projects is a valuable instrument to steer the management of the programme and identify relevant adjustments where needed, while preparing for the next phase of the programme under Horizon 2020.

Initiated in 2011, the 2012 programme review edition covered 71 'live' projects from the 2008, 2009 and 2010 calls for proposals, together with some projects from the 2011 call. Total funding for these projects stands at close to € 450 million, 50% of which comes from FCH JU financial contributions and 50% of which comes from industry and research in-kind contributions.

23 independent reviewers from Europe, Japan and the USA with expertise and experience in the Fuel Cell and Hydrogen technology field reviewed these projects based on both written and presentation material provided by the projects themselves and the FCH JU. The portfolio of projects was assessed against a range of criteria, with rapporteurs providing an overview of the five Application Areas, as detailed further.

The 2012 Programme review confirms the FCH JU has continued to make progress against its principle objectives as set out in the Multi-Annual Implementation Plan (MAIP), notably vehicles and materials performance, durability, and costs reduction for both components and systems. A significant extension of the demonstration projects in all application areas is welcome and matched by a sustained industry involvement in the portfolio, 50% of which are SMEs.

The Transportation and Refuelling infrastructure application area has grown to include both an extension of demonstration activities with a large bus project, HighV.LO City, following up the CHIC project and projects strengthening technology development, such as DESTA, HyTEC and FCGEN. Improved vehicle performance, durability, and the development of a cost-efficient initial Hydrogen Refuelling Infrastructure are clear indicators of progress. There is an opportunity to extend demonstrations across the Member States and the regions, with the benefit of enhancing the Europe wide hydrogen refuelling stations infrastructure. Work also needs to continue on standardisation to ensure that the challenges of fuel metering and fuel quality are addressed appropriately. Volume-building towards mass commercialisation remains, however, a challenging target, although it is clear that the multi-annual strategic ambition goes well beyond the remit of this program's scope and budget.

Hydrogen Production, Storage and Distribution activities continue to address the production challenge, especially the production of green hydrogen, with a mix of mature and developing technologies, such as water electrolysis (Elygrid and RESelyser projects), biomass gasification, fermentation (Hytime project) and solar technology (ArtipHyction project). Strengthened efforts on storage to complement renewable production pathways (HYunder project), improve solid stage hydrogen storage (SSH2S, Bor4store projects) and on distribution of hydrogen (IDEALHY, DeliverHy projects), are valued. The potential to use hydrogen for large scale storage of energy from intermittent renewable energy sources still generates a lot of interest.

The Stationary Power Generation and Combined Heat and Power application area has significantly developed with an increase of demonstration projects able to provide valuable experience and learning for Europe. Targets on volume and costs for 2015, are being achieved: demonstration of more than 1000 1-2 kW systems (project ene.field) from 9 manufacturers supported by 24 utilities in 12 Member States, is complemented by a 1MW commercial system H₂-based in Hungary targetting more than 20,000 hours operation, electrical efficiency of 48% and a cost of system 2.5 mill Euro/MW (equivalent of 2500 Euro/kW) (project ClearGen Demo). In terms of technical targets, electrical efficiencies of more than 60% will also be demonstrated (project SOFT-PACT) through demonstration of an additional 100 micro-CHP units in Germany, UK, Italy and Benelux. In terms of research needs, the opportunity to develop road-mapping, in close collaboration with industry, has been emphasized.

Regarding *Early Markets*, the portfolio continues to be well aligned with strategic objectives: three flagship projects HyLIFT-DEMO, Shel and Mobypost focus on forklifts, postal delivery vehicles as well as trucks for airport usage. Back-up power systems are addressed with two large projects, FCPoweredRBS and FITUP, focused on back-up systems for telecommunication applications. These latter projects are paving the way for deployment with some of the manufacturers optimizing their production lines for larger commercialisation. Innovative personal power solutions, and unmanned flying vehicles, are also explored as part of the portable and micro-fuel cells for personal power solutions.

Finally the strategic role of *the cross-cutting activities* for the whole programme is acknowledged, with notably the new socio-economic tool on technology assessment and progress (Temonas project). Further work to address market obstacles arising from variability of regulations, standards and permit procedures, now timely, would be welcome. Achievements in education and training, reaffirmed as a priority, is to be maintained with appropriate consideration on follow-up and updating beyond the life of the projects, because challenges in this area will only increase as fuel cells and hydrogen technologies move closer to deployment.

The 2012 Review concluded that some quantitative targets would be worth revisiting or complementing with application-specific or commercially relevant targets, to better account for technology improvements and priorities.

Shared learning between projects and across the portfolio, could be further explored, through exchanges of information, data banks or workshops. In particular, where synergies are free from IPR issues and commercial interest, the FCH JU portfolio would also benefit from collaborations on safety issues.

To enable more flexibility and interaction between the application areas, consideration might be given to simplifying the current programme structure for a second phase of the FCH JU programme under Horizon 2020.

Enhanced cooperation with national and regional programmes could be considered for demonstration activities, by nature budget intensive, while international cooperation remains key to understand and align with the state-of-the-art.

The European fuel cells and hydrogen sector¹ acknowledged in a survey conducted in 2012, the key role the FCH JU partnership has had in providing medium to long-term stability for R&D public funding for the sector as well as long-term commitment to the industry. In challenging economic times, the Joint Undertaking's contribution to European competitiveness, in uniting the various stakeholders in the European FCH community behind deployment whilst supporting nascent technologies is highly valued.

The Fuel cells and hydrogen sector reported that on average, its annual turnover has increased by 10% (on a 2012 total of € 0.5 billion), R&D expenditures were up by 8% (on a 2012 total of € 1.8 billion) and market deployment expenditures rose 6% (on a 2012 total of € 0.6 billion), confirming the leverage effect FCH JU investments had across the whole sector. Further with a 16% per annum rise in patents granted in the EU to European businesses, the sector has also outpaced the rest of the industry (1,5 % average annual growth for all EU industries).

¹ Study on the trends in investments, jobs and turnover in the Fuel cells and Hydrogen sector. Way forward for European support, published February 2013 by the FCH JU.

Introduction

Europe is committed to change of the energy paradigm toward a more self-sufficient, cost-effective and decarbonized energy system. Only by supporting innovative energy production, infrastructure build-up, including storage, while promoting efficiency - friendly measures, can Europe respond to its environmental and energy challenges whilst also delivering economic growth. The energy transition agenda will require more integration between transport and energy systems and an increased ability to manage intermittent renewable energy systems.

Fuel cell and hydrogen technologies will be part of the solutions currently being developed to facilitate this transition and have a clear potential to achieve Europe's climate change, energy and environmental objectives, whilst also bringing about economic growth. Hydrogen is recognized as one of the very few near-zero-emissions energy carriers that could be a significant part of the EU's future low-carbon energy and transport sectors.

International developments show that fuel cell and hydrogen technologies are also being considered as promising future tools, and in countries such as Japan, Korea, US, Canada and China preparations are being made for the broader deployment of these technologies.

Recognising the potential for European growth and competitiveness, the Fuel Cell and Hydrogen Joint Undertaking (FCH JU), a unique Public Private Partnership between the European Commission and the industry and research communities, was established in 2008 through the Council Regulation (EC) 521/2008.

As the first public-private instrument established under the European Strategic Energy Technology Plan (SET-Plan), with a budget of nearly one € billion between 2008 and 2013, the FCH JU brings public and private interests from across Europe together, with the aim of speeding up the development of fuel cells and hydrogen technologies in Europe to enable their commercial deployment in the years to 2020.

The partnership aims to define and implement an industry-driven integrated RTD programme carried out by and in cooperation with its stakeholders: industry including SMEs, research centres and universities, together with the Member States and Europe's regions and municipalities.

The FCH JU supports RTD developments and demonstrations through a series of projects that cover the entire RTD range of activities from basic and breakthrough research through applied research (RTD) to demonstrations of fuel cell and hydrogen technologies. These are complemented and supported by cross-cutting activities e.g. Regulations, Codes and Standards, Pre-Normative Research, socio-economic analysis, life cycle analysis, market support, public awareness, education and training.

The projects are funded on a 50/50 basis by both private (in-kind contributions) and public sectors (in-cash contributions), the FCH JU contribution being awarded as grants through annual open and competitive calls for proposals.

Such a multi-annual commitment provides a safe sanctuary for technological innovation and a stable environment to enable stakeholders to make long-term investment plans.

The activities are guided by a long-term strategy document, the Multi-Annual Implementation Plan (see figure 1), which outlines the scope and details the planning for research and demonstration in the long term as well as defining a tentative budget breakdown for the full period 2008-2013 by application area (see Figure 2) and by action category (see Figure 3).

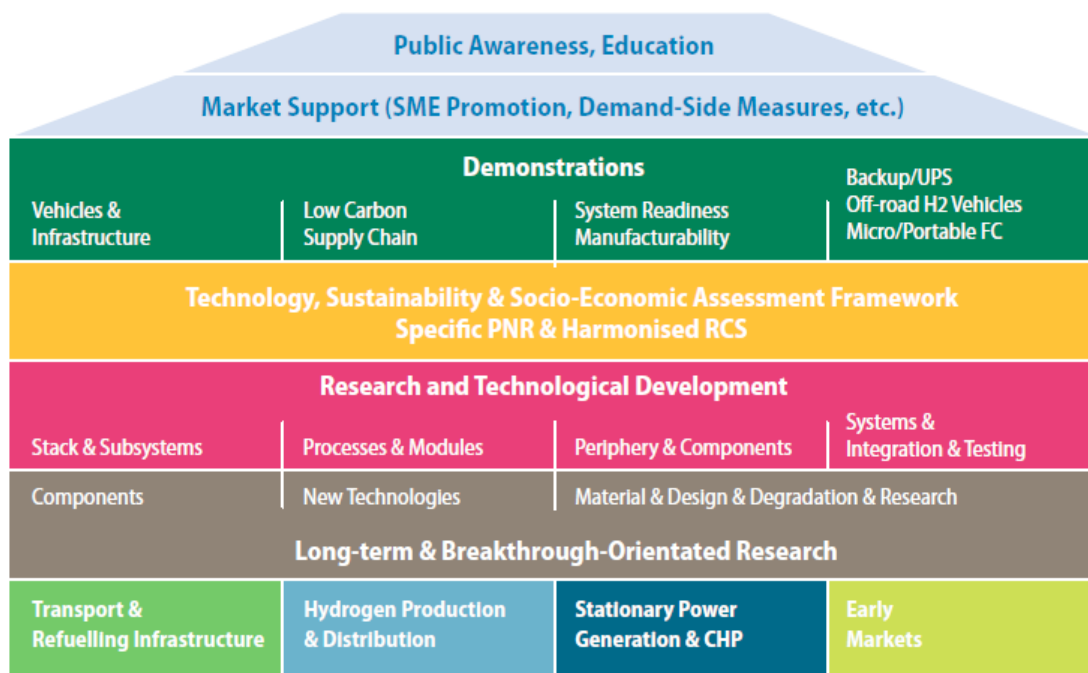


Fig. 1 Multi-annual implementation plan (MAIP) 2008-2013

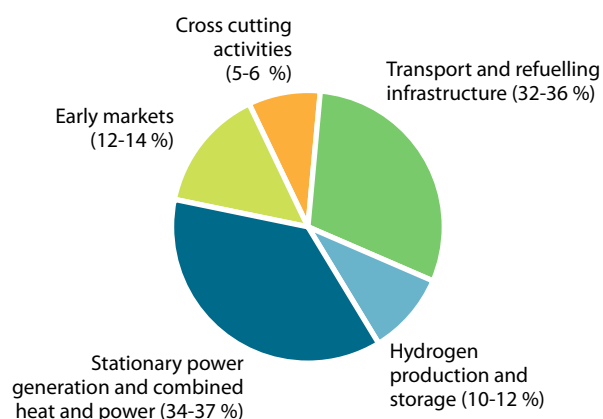


Fig.2 Budget breakdown by application area

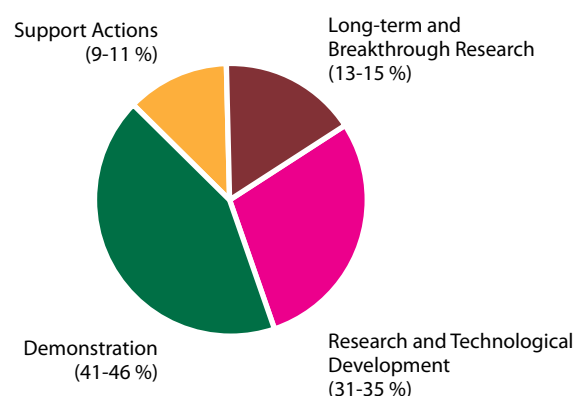


Fig.3 Budget breakdown by activity type

The Multi-Annual Implementation Plan (MAIP) is divided into five main application areas:

- Transport and refuelling infrastructure
- Hydrogen production and distribution
- Stationary power generation and combined heat and power
- Early markets
- Cross-cutting activities such as regulations, codes and standards, pre-normative research, socio-economic research, technology and life-cycle assessments, market support, public awareness, and education.

The strategy and objectives set out in the MAIP are translated into Annual Implementation Plans (AIP). These AIPs issue Calls for Proposals which set out the research and demonstration topics for which each AA is seeking proposals.

Six calls for proposals have been published: 2008, 2009, 2010, 2011 2012 and 2013. The calls from 2008 to 2011 have resulted in over 100 projects, which are currently being managed by the Programme office. In total, over 700 research organisations and/or industry, a quarter of the latter being SMEs, have benefited from the FCH JU's support between 2008 and 2011. Figure 4 provides a breakdown of these funds by country.

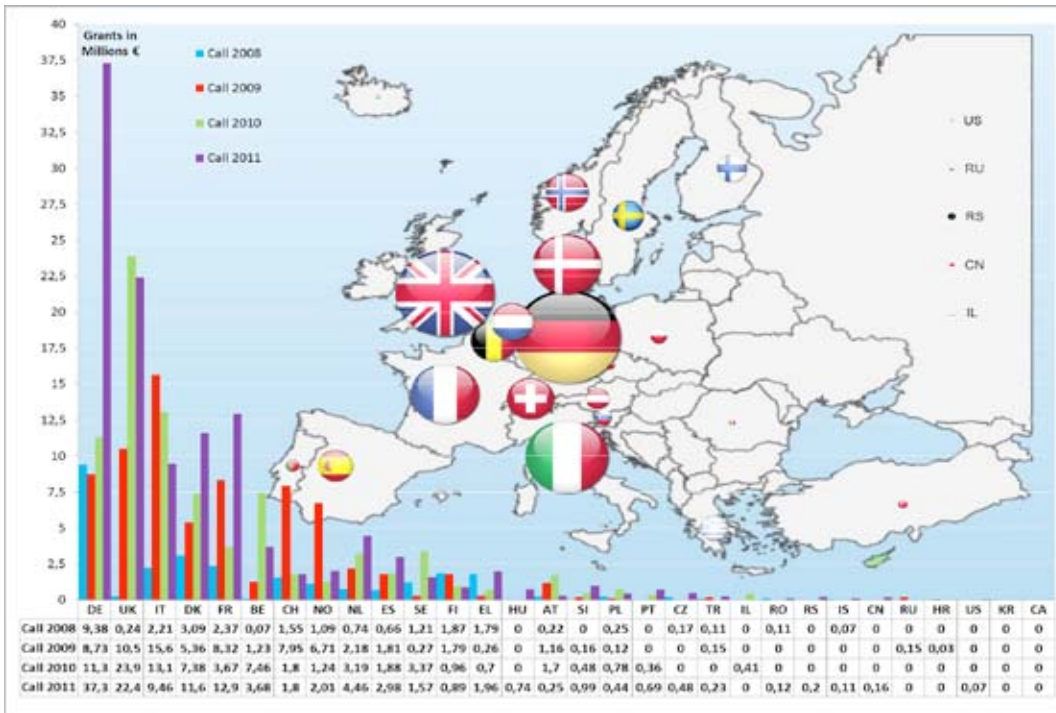


Fig 4. Programme participation per country (2008-2011)

As part of its strategic programme management, as recommended in its first interim evaluation, the FCH JU began an annual review of its projects' portfolio in 2011. This aims to assess the progress of the FCH JU program in relation to the achievement of the targets of its Multi-Annual Implementation Plan (MAIP), the Annual Implementation Plans, as well as the evolution versus international developments.

Following the 2011 exercise the second edition of the annual Program Review Days took place on 28 and 29 November 2012. These covered the entire portfolio of on-going FCH JU funded-projects from the 2008, 2009, 2010 calls and some projects from the 2011 call, in total 71 projects.

A team of 23 independent reviewers from Europe, Japan and USA², assessed the portfolio of projects, remotely and during the review days. One rapporteur per session aligned the views of all corresponding reviewers for that session, while rapporteurs further consolidated sessions' assessments per application area, which provided the basis for this final report.

At a time when the current programme, which is due to complete its first funding phase in 2013, is reflecting on its achievements and preparing for Horizon 2020 ambitions, the impact assessment of the FCH JU programme is gaining momentum. The Fuel Cells and Hydrogen sector has invested considerably in research and demonstration and is planning larger and broader deployment plans for the seven years to 2020.

Infrastructure investments, new research needs, regulatory support are considered key for the next seven years. Industry and research players are fully committed to supporting the sector's development, and are calling for enhanced support from the public authorities.

² C. List of reviewers p. 37.

FCH JU

Project portfolio analysis

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Transportation and refuelling infrastructure

Strategic priorities

The main objective of the Transportation Application Area strategy is the testing and development of competitive hydrogen-fuelled road vehicles and corresponding refuelling infrastructure, together with full supporting elements for market deployment and increased industrial capacity. The emphasis is on large scale fleet demonstrations, including cars and buses, plus a number of refuelling stations Europe wide. Such demonstrations are to test for durability, robustness, reliability, efficiency and sustainability of vehicles and infrastructures for everyday use. The original global market objectives were for thousands of vehicles by 2015 and mass production from 2020.

The application area has also sought to support activities focused on developing a credible European leadership in stack research and development, working with OEMs, the supply industry and research institutes; undertake research and technology development to improve PEMFC for transport use, for example stable and long life membranes, stable and low cost catalysts, corrosion resistance and low weight, cost and volume bipolar plates; and finally to support heavy duty transport applications with the common goal of reducing CO₂ emissions and local pollution and increasing the efficiency of on-board power generation. It sees opportunities to co-ordinate activities with the other AAs.

109 M€ have been allocated from the budget 2008-2011 to support 21 projects so far, covering mainly demonstrations (66% of the budget being in line with MAIP targets of 65,4%). Overall, this AA accounts for about 36% of the FCH JU operational budget, which is at the upper boundary of the 32-36% range foreseen in the MAIP.

The portfolio of projects is composed of 3 bus projects (total of 49 units) and 3 car projects (total of 37 passenger cars + 95 minicars with range extenders) for the demonstration projects, while 2 projects are developing APU for trucks, one with SOFC and one with PEM technology. Several projects deal with components-level R&D activities. One project (HYQ) covers fuel quality and one project deals with hydrogen storage (HyCOMP, addressed here under cross cutting activities). Two support projects which have been concluded are not part of this programme review.

The portfolio of Transport and Refuelling infrastructure projects has grown to include both an expansion of demonstration activities, with the HighV.LO City bus demonstration project complementing the CHIC activity, and projects focused on technology development, DESTA, HyTEC and FCGEN. The addition of work on APUs for trucks strengthens the AA's coverage of transport applications. The reviewers noted that the projects aligned with the MAIP and there were opportunities for demonstration projects to work together and share learning.

Demonstrations

Good progress has been made by demonstration projects both in terms of extending vehicle performance, including durability, and in the development of an initial Hydrogen Refuelling Station (HRS) infrastructure. Looking towards the future the opportunity exists for extending these demonstration activities to further cities and regions in the Member States, with the benefit of extending the HRS infrastructure and in enhancing hydrogen mobility between regions and Member States.

The reviewers held the view that demonstrations should target more 'early customers' both for fuel cell cars and buses to improve understanding of user acceptance issues. Early customers for fuel cell cars could be incentivised with daily use and rental schemes, whilst bus drivers and depot operators could also be involved in acceptance assessments. Part of the latter challenge was to increase bus availability from 85% levels to match real service demands, and enable assessment of performance in daily service.

Further comments on bus demonstrations focused on the need to look towards a second phase from 2015-16 which would involve more cities testing fuel cell buses. Reviewers noted that rules and funding rates for this phase were as yet unknown, but also that bus OEMs had yet to confirm the readiness or availability of second generation fuel cell buses.

Regarding hydrogen refuelling stations, cost targets have been achieved as most are in the price range of 1-2 M€ for 50-200 kg/day capacity; volumes however still need progress. Furthermore, the HRS activities still require development to ensure that standards are harmonized so that the challenges of fuel metering and fuel quality can be addressed. Safety and permitting issues would benefit from a holistic, industry rather than a customized approach.

Progress was thus evident in the demonstration projects, but reviewers noted that further basic research was required, even if it were not on the critical path for products moving towards deployment in the markets.

Technology R&D

The reviewers emphasized the need for the FCH JU programme to support basic and applied R&D for the AA, to improve performance of components and systems, and also to reduce cost, for example for bus drive trains. Further basic R&D was required for longer term developments, whilst frequent reassessment of R&D needs were necessary to maximise relevance of R&D for transport applications in addition.

More specific comments related to APUs for trucks, with reviewers noting that the market opportunity in Europe was unclear being influenced by the level of future truck hybridisation, and as such recommended that developments should await the recently initiated technology assessment. Finally, efforts in the area of low cost platinum catalysts need to be part of more comprehensive European action for development of new low cost, high performance stack components. Future AIPs issued by FCH JU should address this issue.

In general, reviewers identified some grounds for adjustments, especially on the 2015 targets for vehicles and Hydrogen Refuelling Stations which will be difficult to achieve, even though good progress has been made in vehicle performance and durability, and with HRS infrastructure. Volumes and interest have increased, though not to the levels required for mass commercialisation. For buses, the objective of realising 500 fuel-cell powered units in operation by 2015 is still out of range, despite purchasing prices coming closer to the 1M€ range target. MAIP targets could also be expanded to include reference to system lifecycle and well-to-wheel emissions for example.

Reviewers also emphasized the linkages between the Transport and Hydrogen Production and Distribution AA, noting that work in the latter area must address the issues of production of lean or no carbon hydrogen, preferably utilising renewable energy sources, whilst also considering synergies from competing energy carriers and competing technologies.

Project name	Type	Description	Coordinator	EC Funding (M€)
H ₂ Moves Scandinavia	Demonstration car fleet and station	European project H ₂ moves Scandinavia sets out to gain customer acceptance for electric vehicles with fuel cells in Scandinavia.	Ludwig-Bölkow-Systemtechnik GmbH,	7.8
CHIC	Demonstration bus fleet	Partnerships between cities which have previously gained experience with hydrogen powered buses and 14 new cities and regions in Europe which are considering moving into the field. These partnerships will facilitate the effective and smooth introduction and expansion of the new systems now and into the future.	Daimler	25.8
High V.LO City	Demonstration bus fleet	Implement a fleet of 14 H ₂ hybrid FC commercial public buses in 3 regions across Europe as well as establish and enhance three hydrogen production and refuelling facilities, linked to economical and sustainable hydrogen production plants.	Van Hool	13.49
HyTEC	Demonstration	Demonstration of up to 30 new hydrogen vehicles in the hands of real customers in Denmark and UK, in three vehicles classes: taxis, passenger cars and scooters. These will be supported by new hydrogen refuelling facilities, which combine with existing deployments to create two new city based networks for hydrogen fuelling.	Air Products	12
PEMICAN	New material of automotive PEMFC	The objective of PEMICAN is to develop and manufacture MEA (membrane Electrode Assembly) with reduced Platinum cost.	Commissariat à l'énergie atomique (CEA), France	1.8
FCGEN	Demonstration on-board power generation	To develop and demonstrate a proof-of-concept complete fuel cell auxiliary unit in a real application, on-board a truck.	Volvo	4.34
DESTA	Demonstration of Auxiliary power unit	demonstration of the first European Solid Oxide Fuel Cell (SOFC) Auxiliary Power Unit (APU) for trucks.	AVL	3.87

Hydrogen Production, Storage and Distribution

Strategic priorities

This Application Area aims to develop and where possible, fully implement a portfolio of sustainable hydrogen production, storage and distribution processes which can meet 10% - 20% of the hydrogen demand for energy applications from carbon-free or carbon-lean energy sources by 2015, complemented with preparatory work to enable the wide spread introduction of hydrogen infrastructure beyond 2020.

Given the range of processes with differing degrees of maturity, production capacity and sustainability, the emphasis is on R&D for mature production and storage technologies, whilst also supporting longer term, fully sustainable production and supply pathways. Mature technologies include: i) reforming bio-fuels plus conventional fuels; ii) cost-efficient low-temperature electrolyzers adapted for large scale use of carbon free electricity; iii) biomass gasification.

Longer term technologies include water splitting together with thermo-chemical processes based on solar, nuclear or waste heat plus development of low temperature, low cost biological hydrogen and photo-electrochemical processes for direct hydrogen production.

Production methods are allied to storage options to include high volumes e.g. underground and liquefaction, plus long term breakthrough solid and liquid materials storage.

The programme recognises the variety of technologies under development and their varying maturities by identifying a mid-term need for carbon lean hydrogen (supply up to 50% of the anticipated hydrogen energy demand from renewable energy sources by 2020), and longer term requirement for sustainably produced hydrogen, with a zero carbon foot print. It has sought to support a range of mature and developing hydrogen production technologies, with further developments in the area of storage and distribution.

As of now, over 35 M€ have been allocated from the budget 2008-2011 to support 21 projects in this area, which is in line with the MAIP target of 10-12%.

Hydrogen Production

Natural gas reforming (SMR), coal gasification and water electrolysis are proven technologies that can be applied at an industrial scale. For the next 15-20 years, SMR and water electrolysis are likely to be the main sources of hydrogen, whereas only the latter will be able to provide CO₂ free or lean hydrogen without additional Carbon Capture and Storage (CCS).

Water electrolysis may be coupled to renewable energy sources (RES) and has potential to support grid stabilization. Energy storage issues arising from the increasing Hydrogen production via biomass gasification, fermentation and solar (-thermal/ electrochemical) technology are other methods with high potential in the long term. SMR of biogas is another possible source of green hydrogen.

The various projects are focused on sustainable hydrogen production via water electrolysis or developing innovative technologies such as water splitting via solar energy (ArtipHyction) or biological hydrogen production through fermentation (Hytime).

The PrimoLyzer project developed and tested a cost-minimised, highly efficient and durable PEM-Electrolyser stack for integration with domestic μ CHPs, with a hydrogen outlet pressure of 5-10 MPa. Results show that the best performing MEAs managed to exceed the project objective with even less than the targeted catalyst loading. Costs could be brought down to less than 5,000 €/Nm³/h if the stack production is up-scaled to 100 units.

The FCH JU's Hydrogen Production and Distribution projects have expanded significantly within the past year: more mature electrolysis production technologies have seen the addition of projects developing alkaline based technologies, Elygrid and REselyser, as well as a further PEM focused activity Electro-HyPEM; more innovative technologies are supported through CoMETHy, ArtipHyction and HYTIME, together with HYSEPS-2 and NEMESIS2+, the latter continuing the work of previous projects; whilst storage and distribution is being addressed in HyUnder, IDEALHY, DeliverHy, Bor4Store. These and the existing projects contribute to the MAIP's major aims and topics, and there is little evidence of overlaps.

Reviewers found that the balance between mature and innovative hydrogen production technologies was good, but there was a need to ensure that the latter continue to be supported by the FCH JU. Electrolysis based projects were well represented, with a mixture of PEM, alkaline and SOFC technologies. Innovative, longer term projects were represented, but further support is required for technologies incorporating biomass integration. Overall there is a need to maintain effort on alternative lower-cost sustainable hydrogen production technologies, and the FCH JU should support a plurality of technologies with future promise.

Technology progress appeared clearly in some projects, for example in projects which were continuing the work of previous European FP6 and 7 activities. However reviewers would have favoured, for a better identification of real innovation, more reference to state-of-the-art and competing technologies and more attention to the need to understand other energy and storage technologies both from the perspective of competition, but also possible synergies.

Areas for concern relate to the emphasis of projects on basic and applied R&D rather than demonstrations, although this had been partly addressed already with the project Don Quichote (*not part of the 2012 review*) which is the extensive demonstration of hydrogen production by renewable electricity, compression, storage and end use of hydrogen in transport applications or for grid balancing. By storing excess renewable electricity in large quantities in hydrogen, otherwise unused renewable energy can be used to power transport and other applications.

Additionally whilst work on materials and component development is seen as necessary, there is lack of systems development work. The FCH JU needs to show that its activities are leading to possible solutions to hydrogen production, especially sustainable hydrogen production. As noted above linkages of projects with renewable energy sources was deemed to have been strengthened.

Hydrogen Distribution and Storage

For hydrogen to be a useful future fuel, it has to be conveyed to the point of use and stored.

Distribution of hydrogen includes transmission and distribution pipelines, compressors, pressure-regulating equipment, and above- and below ground storage facilities near fuel markets.

Hydrogen storage is a critical issue that still needs to be addressed in order to establish a hydrogen economy. The constraints for the storage of H₂ are highest for road transport, with compressed gas cylinders being the most likely option.

Storage of hydrogen for stationary applications will likely be linked to coupling with RES. The potential of hydrogen for large scale storage of energy from intermittent renewable energy sources is currently generating a lot of interest, but outside the current scope of the Application Area's objectives.

Storage technologies are being developed in order to complement renewable production pathways and help establish the supply chain for hydrogen (SSH2S, Bor4store) on improving solid state hydrogen storage. Options for distributing hydrogen are also studied. IDEALHY is an enabling project to develop an economically viable hydrogen liquefaction capacity for Europe. This will help in accelerating rational infrastructure investment and enabling the rapid spread of hydrogen refuelling stations across the continent. IDEALHY will investigate the different steps in the liquefaction process in detail, using innovations and greater integration in an effort to reduce specific energy consumption by 50% compared to the state of the art, and simultaneously to reduce investment cost.

The growing portfolio of storage and distribution projects is welcomed by the reviewers: HyUnder was deemed to be especially significant as part of the solution to the storage of excess power from intermittent renewable sources. However, more work in the area of integration of fuel cell and hydrogen technologies with renewables is required.

The work on solid state storage continues activity funded under FP6 and FP7 frameworks, but reviewers recognised an opportunity to support further low temperature or hybrid system developments, eg cryo-compressed or low temperature high pressure solid state storage. Reviewers felt that in addition regenerative liquid materials for hydrogen storage had not received the attention it deserves.

Generally the programme and the projects need to integrate the state-of-the-art globally to ensure that lessons learned from other regions are incorporated into the MAIP and the projects themselves. According to the reviewers, this applied especially to solid state storage technologies, where work in the USA for example, has been more advanced than within Europe.

Reviewers welcome the expansion of the portfolio, but highlight weaknesses: the scale of the projects tends to be limited in terms of size and funding, there is for example only one storage project with ambitions of more than a MW, and therefore suitable for grid balancing duties. Targets regarding the total production capacity from renewables are not likely to be met with the current portfolio, partly because there is no project focused on centralised large scale production of hydrogen via water electrolysis.

In general, reviewers noted that the current MAIP uses a number of limited technical targets, with a preference for techno-economic ones; these are not seen as sufficient to steer breakthroughs of quick growth non-mature technologies and more detailed application specific targets are deemed necessary. In addition defining application specific requirements will assist in understanding commercial opportunities and targets, for example achieving a balance between capital costs and process efficiencies.

Since integration of hydrogen with renewable power is an essential objective of the FCH JU's activities, more emphasis on the genuine integration of renewables into projects is critical if fuel cell and hydrogen technologies are to contribute to meeting Europe's energy challenges. The well to tank CO₂ intensity of all the production technologies is not adequately considered and should be part of the techno-economic assessment of all projects.

As part of this any future FCH JU programme might consider simplifying the AA structure to enable more flexibility and interaction between Hydrogen Production and Distribution, and Transport, Stationary and Early Market applications.

Opportunities for shared learning between projects and across the FCH JU portfolio have been identified. For hydrogen production and distribution this includes joint learning on HAZOP issues, where projects would benefit from an exchange of information and hard data. Additionally where learning is free from IPR issues and commercial interest projects should collaborate in the safety field. The proposed workshop on solid state storage solutions is a good starting point. A dedicated Cross-cutting project to make publicly available a range of safety analyses, data, risk assessment methods and guidelines would allow benefits to be spread to other FCH JU projects.

In terms of cooperation at national level, reviewers recommend enhanced co-ordination between National and regional programmes activities and FCH JU, notably for demonstrations projects which tend to be expensive and consume significant parts of FCH JU budget. International co-operation beyond Europe FCH JU is also recommended, with benefits to be gained from actively engaging with programmes in the USA, Canada, Japan, Australia, China, South Korea.

Project name	Type	Description	Coordinator	EC Funding (M€)
HYDROSOL-3D	Sustainable H ₂ production	Demonstration of a CO ₂ -free hydrogen production and provision process and related technology, using two-step thermochemical water splitting cycles harnessing concentrated solar radiation.	Center for Research and Technology, Greece	1
ArtipHyction	Sustainable H ₂ production and solid state storage	Development of improved and novel nano structured materials for photo-activated processes as well as chemical systems for highly efficient low temperature water splitting using solar radiation.	Hysystech	2
Hytime	Sustainable H ₂ production and solid state storage	Construction of a prototype process based on fermentation of biomass for delivering 1-10 kg hydrogen per day and to develop a biohydrogen production system as a stepping stone to pre-commercial application.	SDLO	1.6
Bor4Store	Sustainable H ₂ production and solid state storage	Development of novel cost-efficient boron hydride based hydrogen high capacity storage materials.	Helmholtz-Zentrum GmbH	2.27
DeliverHy	Sustainable H ₂ production and distribution	The project will assess the effects that can be achieved by the introduction of high capacity trailers composed of composite tanks with respect to weight, safety, energy efficiency and greenhouse gas emissions.	LBST	0.71
IDEALHY	Sustainable H ₂ production and liquefaction	Development of a generic process design and plan for a prospective large scale demonstration of efficient hydrogen liquefaction in the range of up to 200 tonnes per day.	Shell	1.29
ELECTROHYPEM	Sustainable H ₂ production	Development of cost-effective components for PEM electrolysers with enhanced activity and stability in order to reduce stack and system costs and to improve efficiency, performance and durability.	CNR	1.35
ELYGRID	Sustainable H ₂ production	Contribution to the reduction of the total cost of hydrogen produced via electrolysis coupled to renewable energy sources, mainly wind turbines, and focusing on megawatt size electrolyzers (from 0,5 MW and up).	Foundation for Hydrogen in Aragon	2.1

Project name	Type	Description	Coordinator	EC Funding (M€)
Reselyser	Sustainable H ₂ production	Development of high pressure, highly efficient, low cost alkaline water electrolyzers that can be integrated with renewable energy power sources (RES) using an advanced membrane concept, highly efficient electrodes and a new cell design.	DLR	1.48
SSH2S	H ₂ storage	Development of a full tank-FC integrated system and to demonstrate its application on a real system.	University of Turin, Italy	1.6
NEXPEL	New electrolyzers	Demonstration of an efficient PEM electrolyser integrated with Renewable Energy Sources.	Sintef, Norway	1.3
ADEL	New electrolyzers	Development of a new steam electrolyser concept aimed at optimizing the electrolyser life time by decreasing its operating temperature whilst maintaining satisfactory performance level and high energy efficiency.	Htceramix, Switzerland	2
Primolyzer	New electrolyzers	Development, construction and test of cost-minimised highly efficient and durable PEM-Electrolyzer stack aimed for integration with domestic μ CHPs.	IRD, Denmark	1.2
CoMETHY	Hydrogen production and purification activities	Intensification of hydrogen production processes, developing an innovative compact and modular steam reformer to convert reformable fuels (natural gas, biogas, bioethanol, etc.) to pure hydrogen, adaptable to several heat sources (solar, biomass, fossil, etc.) depending on the locally available energy mix.	ENEA	2.48
NEMESIS2+	Hydrogen production and purification activities	Development of a small-scale hydrogen generation prototype capable of producing 50 Nm ³ per hour from diesel and biodiesel at refuelling stations.	DLR	1.61
Hy2Sep_2	Hydrogen production and purification activities	Design and testing of hybrid separation schemes that combine Membrane and Pressure Swing Adsorption (PSA) technology for the purification of H ₂ from a reformat stream that also contains CO ₂ , CO, CH ₄ , and N ₂ .	ICEHT	0.82

Stationary power generation and CHP

Strategic priorities

The strategy for the Stationary Power Generation and CHP area in the MAIP is to improve the technology for fuel cell stacks and balance of plant components to the level required to enable products to bridge the gap between laboratory and pre-commercial systems for power or power and heat. This AA has sought to provide a pathway supporting necessary basic and breakthrough research at one end of the research spectrum, through applied research including proof-of-concept, to technology validation and field demonstrations at the other end.

Further development of the main fuel cell technologies (SOFC, MCFC and PEMFC) in order to improve performance, durability, reliability, robustness and costs is targeted. The FCH JU has focused therefore on the one side on a better understanding of degradation and lifetime fundamentals, development of novel cell and stack architectures, reliable control and diagnostic tools and balance of plant, and on the other side on demonstrating proof-of-concept, validation and demonstration activities, the latter to include full integration into existing fuel and grid infrastructures. It also recognises the opportunity to co-ordinate R&D with other AAs.

The overall objective of this application area is to improve the technology for fuel cell stack and balance of plant components to the level required by the stationary power generation and CHP markets by bridging the gap between laboratory prototypes and pre-commercial systems.

In this respect, 100 € mill have been allocated from the budget 2008-2011 to support 35 projects so far, covering the whole value chain from long-term and breakthrough orientated research (degradation and lifetime fundamentals related to materials and typical operation environments for relevant power ranges) to technology validation (proof-of-concept fuel cell systems and their interactions with supply & demand interfaces i.e. other power generation devices, cooling/heating systems, and with the infrastructure i.e. grid interface, fuel supply and local power output) and market capacity building across all applications (full scale field demonstrations of proven systems in real end user environment).

The portfolio of projects has expanded since the last review exercise, the primary improvement being the development of demonstration projects. With the portfolio of projects supported so far, it can be said that progress is being made towards the most important targets on volume and costs for the medium-term, 2015 set up by the MAIP document: demonstration of more than 1000 units 1-2 kW systems (project ene.field) from 9 manufacturers supported by 24 utilities in 12 Member States, 1MW commercial system H₂-based in Hungary for more than 20000 hours operation, electrical efficiency of 48% and a cost of system 2.5 mill €/MW (equivalent of 2500 €/kW) (project ClearGen Demo). In terms of technical targets, electrical efficiencies of more than 60% will also be demonstrated (target being more than 45%) (project SOFT-PACT) through demonstration of additional 100 micro-CHP units in Germany, UK, Italy and Benelux.

Degradation and New Materials

The Stationary portfolio has a range of projects addressing the needs for a better understanding of degradation and for assessing new materials.

14% of the budget is dedicated to degradation and lifetime fundamentals in all technologies, combined with additional 10% on materials aspects and another 10% on next generation of cell and stacks. Different teams in Europe are currently addressing the development of accelerated stress tests (AST) protocols for cells/stack in H₂/air and reformat/air (average voltage decay rate of 1.5µV/h within the 26,000 hours of a three years project), followed by predictive modeling for system lifetime in case of low temperature PEM technology (project KEEPEMALIVE) or a degradation rate less than 5 µV/h at 200 mA/cm² for high temperature PEM technology (project DEMMEA).

In case of SOFC, emphasis was put on understanding of Ni-based (state-of-the-art) SOFC anode degradation (project ROBANODE) while also looking at new designs for the anode and anode support layer based on strontium titanates (operating 750-920 °C) (project SCOTAS-SOFC) or developing new Metal Supported Cell using a gas-permeable porous metallic substrate for both planar and tubular cells (operating 600°C) (project RAMSES).

Following on from 2011 Review which found that there was an imbalance between PEMFC and other fuel Cell types, further work needs to be done to encourage more SOFC degradation projects for example. In addition further development of accelerated test procedures is sought.

The reviewers also recommend that given the scale of the challenge in the basic research area efforts the FCH JU should support and encourage those projects that demonstrate real progress.

Conversely more work on radical new materials for cell and stacks is not perceived as offering sufficient added value for the FCH JU, given that these projects will take a very long time to come to fruition, if at all. By way of example the reviewers stated that projects with the objective of taking new materials through to system integration in three years are extra-ordinarily ambitious, unrealistic and should be discouraged. This view points to a need to ensure that the selection process used by the FCH JU should be more rigorous in seeking to support projects with realistic and achievable goals.

Diagnostics

Another 10% of the budget is dedicated to BoP components improvement, sustained by additional 5% on operation diagnostics tools. Support was provided to activities on development of anode and cathode side SOFC subsystems and individual components (scalable stack modules, air side fluid, thermal management and mechanical solutions) - for future 10 to 250 kWe atmospheric SOFC systems (projects ASSENT and CATION). A GENERIC tool to diagnose the health of a SOFC system (no more than 1 maintenance/year, detect at least 60% of degradations with a rate > 0.5%/1000hrs, etc) has been developed under project GENIUS, while a solution based on on-line electrochemical impedance spectroscopy (EIS) as an effective diagnostic tool - implemented on-board with a new DC/DC converter is currently explored by project D-CODE.

The 2011 Review highlighted the issue of the appropriateness of some projects focusing on the development of generic tools, given the variability of systems and technologies being developed. The issue was raised again in 2012, with reviewers noting that there was little evidence to suggest that the 'plug in, diagnose and prevention of faults' systems under development will work. Rather they concluded that system specific approaches were probably necessary and that industry should clearly specify what can realistically be implemented to achieve improvements on the subject in the next five years.

Proof of Concept (PoC) and Demonstrations

About 10% of funds are also dedicated in supporting different proof-of-concept projects, especially in the SOFC technology either for a Low Temperature SOFC system prototype which can operate at 650°C with reduce down time by integrating mass produced Gas Air Delivery, electrical system efficiency of minimal 45% and total system efficiency of minimal 80% (project LOTUS) or for a fully automated and integrated SOFC CHP system with an electric power output of 770W gross on the stack, electrical efficiency of more than 35% , total efficiency of the system up to 78% in facilities and performance degradation of the fuel cell unit around 10%/1000h operation (project Asterix3).

The greatest share, 41%, of the budget was spent in demonstration activities, especially in small CHP-residential applications, involving both PEM and SOFC technologies. Project SOFT-PACT, through the leader E.ON intends to deploy 100 micro-CHP units (Gennex SOFC based provided by Ceramic Fuel Cell Limited company) in Germany, UK, Italy and Benelux and to demonstrate an electrical efficiency of at least 60% and address the most important commercial challenges by developing the whole supply chain, mass manufacturing aspects and European housing stock availability, ultimately addressing the certification schemes in the different Member States, Standard Assessment procedures and Grid connection standards.

In addition, the Ene-field project, a major demonstrator which has just started in 2012, aims at testing about 1,000 micro-CHP units from 9 European manufacturers (both PEM and SOFC based), supported by 24 utilities across 12 Member States of the EU. As regards industrial applications, 1 MW CHP system (PEM based) will be demonstrated in Hungary by project ClearGen Demo using by-product hydrogen (industrial waste hydrogen) from a chlor-alkali plant. This big system will try to achieve a cost reduction to 2.5 mill Euro/MW and 48% electrical efficiency for at least 20,000 Hours operation in real conditions.

With the stationary portfolio being expanded and strengthened with more PoC and Demonstration projects, the reviewers were keen to ensure that learning was maximised for the stationary community as a whole and that the learning from demonstration activities was fed back into R&D efforts. The dissemination efforts of some projects were felt to be insufficient, and that there was an opportunity to utilise independent assessment/reviews as a possible way to allow issues to be identified and relayed to the R&D base, perhaps adopting systems used in Government programmes in the USA. An additional point was that there appeared to be little appreciation amongst projects of state-of-the-art in the demonstration field, especially at the international level.

Reviewers were concerned that some Demonstration projects were inappropriate given the relative immaturity of the technology and high costs. There was doubt about the technology readiness of some systems, especially SOFC, where more work on stack reliability and maturity was deemed necessary. Additionally reviewers questioned whether more work was required on component developments to achieve real breakthroughs rather than emphasizing yet more system development. The importance of technology readiness for demonstration is recognised in the MAIP and AIP: projects are required to demonstrate success in Proof of Concept and Validation activities before proceeding to Demonstration. A such if there are examples of inappropriate demonstration projects then there is reason to look at the proposal and selection processes.

Even given some of the issues identified above reviewers are keen to see manufacturing developments supported in the Stationary AA to ensure that costs and quality are effectively addressed. It is notable that the 2013 AIP Call has a specific manufacturing call, although reviewers do question whether the FCH JU is the right framework for this type of activity.

In general, reviewers considered that current targets need to be supplemented, with an emphasis on commercially relevant measures, including cost of ownership. There is also an opportunity to undertake more road mapping to better understand R&D needs to ensure that projects are focused on these critical areas. The FCH JU has indeed recognised the role of such activities, and plans for a combined review and road mapping exercise in the 2013 AIP. Industry is encourage to become a more active driving force especially in the fields of basic and applied research, so that market needs are fully addressed.

Regarding learning opportunities from the whole portfolio of projects, the role of workshops, and advisory boards has been identified.

A valuable addition to the FCH JU's activity in this field would be the development of centralised data banks, where this is possible within the restrictions of Intellectual Property rights. There is also a need for better interaction with the activities of Member States, of which there are some good examples, but not enough. Finally international co-operation should be enhanced if only to enable a better understanding of state-of-the-art.

Reviewers also identified an opportunity for the FCH JU to support Cross-Cutting projects addressing the common issues affecting all stationary demonstrations of the 'obstacles' encountered in the variability of regulations, codes and standards, for example official building codes, siting permits and gas quality, across Europe's Member States and even within the Member States.

Project name	Type	Description	Coordinator	EC Funding (M€)
RAMSES	New materials & stacks	The project aims at developing an innovative high performance, robust, durable and cost-effective Solid Oxide Fuel Cell based on the Metal Supported Cell concept.	CEA, France	4.7
MAESTRO	New materials & stacks	The objective of MAESTRO is to improve the mechanical properties of low equivalent weight state of the art perfluorosulfonic acid membranes using chemical and thermal processing and filler reinforcement methodologies.	CNRS, France	2.26
SCOTAS-SOFC	New materials & stacks	The project will demonstrate a new full ceramic SOFC cell with superior robustness regarding sulphur tolerance, carbon deposition (coking) and re-oxidation (redox resistance). Such a cell mitigates three major failure mechanisms which today have to be addressed at the system level.	Technical university, Denmark	4.4
SOFC-Life	New materials & stacks	This project is concerned with understanding the details of the major SOFC continuous degradation effects and developing models that will predict single degradation phenomena and their combined effect on SOFC cells and single repeating units.	Forschungszentrum Jülich, Germany	2.4
D-CODE	Degradation issues	The D-CODE project aims to develop and implement on-line electrochemical impedance spectroscopy (EIS) to have direct and meaningful information on the system status. The D-CODE project's outcomes are expected to improve management and operational capabilities of both low and high temperature PEM fuel cells, to enhance monitoring capabilities, increase maintenance intervals with higher MTBF and reduce degradation rate, while optimizing system performance.	University of Salerne, Italy	1.1
MCFC-CONTEX	Degradation issues	MCFC-CONTEX aims to tackle the degradation of components by investigating poisoning mechanisms caused by alternative fuels and applications and determining precisely MCFC tolerance limits for long-term endurance and by optimizing fuel and gas cleaning to achieve tailored degrees of purification according to MCFC operating conditions and tolerance.	ENEA, Italy	1.8
ROBANODE	Degradation issues	The ROBANODE project proposes an integrated strategy for understanding the mechanism of processes which cause anode degradation in hydrogen and natural gas fuelled SOFCs by combining robust theoretical modelling with experiments over an extended range of operating conditions, using a large number of modified state-of-the-art Ni-based anodes.	Foundation for Research and Technology, Greece	1.5

Project name	Type	Description	Coordinator	EC Funding (M€)
KEEPEMALIVE	Degradation issues	KEEPEMALIVE aims to establish improved understanding of degradation and failure mechanisms, accelerated stress test protocols, sensitivity matrix and lifetime prediction models for Low Temperature PEMFC to enable a lifetime of 40 000h at realistic operation conditions for stationary systems, in compliance with performance and costs targets.	Stichting Energieonderzoek Centrum, Netherlands	1.2
DEMMEA	Degradation issues	The objective of the present proposal is to understand the functional operation and degradation mechanisms of high temperature H ₃ PO ₄ PEM and its electrochemical interface.	Advanced Energy Technologies Greece	1.6
PREMIUM ACT	Degradation issues	Project on the durability of PEFC (Polymer Electrolyte Fuel Cells), targeting one of the main hurdles still to be overcome before successful market development of stationary fuel cell systems.	CEA-Liten, France	2.5
LoLiPEM	Degradation issues	The main objective is to give a clear demonstration that long-life stationary power generation, CHP systems based on PEMFCHs operating above 100°C can now be developed on the basis of recent knowledge on the degradation mechanisms of ionomeric membranes and on innovative synthetic approaches recently disclosed by some participants of this project.	National council for Research, Italy	1.4
STAYERS	Degradation issues	Project STAYERS is dedicated to the goal of obtaining 40,000 hours of PEM fuel cell lifetime employing the best technological and scientific means.	NEDSTACK, Netherlands	1.9
GENIUS	Operation diagnostics	The GENIUS project aims to develop a "GENERIC" tool that would only use process values (normal measurements and system control input parameters) to evaluate the state of health of any SOFC system.	European Institute for Energy Research, Germany	2.07
DESIGN	Operation diagnostics	The project proposes to study the influence of slow acting damaging conditions on measures performed on the stack sub-components: the Cells and the Single Repeating Units (SRU) and on small stacks.	CEA, France	1.7
LOTUS	Proof-of-concept and system component development	The LOTUS project is to build and test a Low Temperature SOFC system prototype based on new SOFC technology combined with low cost, mass-produced, proven components. The use of a modular concept and design practices from the heating appliances industry will reduce maintenance and repair downtime and costs of the system.	Hygear, Netherlands	1.6

Project name	Type	Description	Coordinator	EC Funding (M€)
ASTERIX3	Proof-of-concept and system component development	The objective of the collaboration was to evaluate HTceramix's SOFC technology in perspective of development of a residential micro-CHP application with a strong and well defined market focus.	Dantherm, Denmark	1.3
ASSENT	Proof-of-concept and system component development	This project is focused on the development of fuel and water management for SOFC systems. The fuel management, and especially recirculation, is a key question in achieving high electric efficiency and rejecting external water supply.	VTT, Finland	2.0
CATION	Proof-of-concept and system component development	This project is focused on the development of SOFC system's air side fluid and thermal management and mechanical solutions, i.e. cathode subsystem and individual components.	Technical Research Centre, Finland	2.6
SOFT-PACT	Demonstration	Large scale field demonstration of Solid Oxide Fuel Cell (SOFC) generators that can be utilised in residential applications.	Eon	3.9
ClearGen Demo	Demonstration	Integration and demonstration of large stationary fuel cell systems for distributed generation.	Logan Energy	4.6
Ene-Field	Demonstration	European-wide field trials for residential fuel cell micro-CHP.	Cogen Europe	26
Reforcell	Proof-of-concept and system component development	Development of a new multi-fuel membrane reformer for pure hydrogen production (5 Nm ³ /h) based on Catalytic Membrane Reactors in order to intensify the process of hydrogen production through the integration of reforming and purification in one single unit.	Tecnia	2.85
Flumaback	Proof-of-concept and system component development	Improvement of the performance, life time and cost of BOP components of back up fuel cell systems specifically developed for emerging countries where long black-outs occur and difficult operative conditions are present.	Electro Power Systems	2.98
SOFCOM	Proof-of-concept and system component development	Demonstration of the technical feasibility, the efficiency and environmental advantages of CCHP (a three product plant based on cogeneration of cooling, heat and power) based on SOFC (solid oxide fuel cell technology).	Politecnico di Torino	2.9

Project name	Type	Description	Coordinator	EC Funding (M€)
EURECA	New materials and stacks	Development of the next generation of micro combined Heat-and-Power (μ -CHP) systems based on advanced PEM stack technology to overcome the disadvantages of complex gas purification, gas humidification and low temperature gradients for heat exchangers with operating temperatures of 90 to 120°C.	Next Energy	3.55
Metsapp	New materials and stacks	Development of novel cells and stacks based on a robust and reliable up-scale-able metal supported technology for stationary as well as mobile applications.	Topsoe	3.39
Metprocell	New materials and stacks	Development of innovative Proton Conducting Fuel Cells (PCFCs) by using new electrolytes and electrode materials and implementing cost effective fabrication routes.	Tecnalia	3.43
MMLCR+SOFC	New materials and stacks	Working towards mass manufactured, Low Cost and robust SOFC stacks.	Juelich	2.06
Laser-cell	New materials and stacks	Innovative cell and stack design for stationary industrial applications using novel laser processing techniques.	AFC Energy	1.42

Early Markets

Strategic priorities

With the objective to build up and sustain an early manufacturing and supply base for fuel cells products and systems Early Markets aim to show technology readiness by focusing on demonstrations and ready-to-market products that are able to provide real world operational experience to feed back into the RTD process.

Short term demonstrations cover mainly i) portable and micro-fuel cells, ii) portable generators, back-up power and UPS systems, iii) speciality vehicles, including hydrogen related infrastructure, together with technology development projects with commonality with the Transportation and Stationary AAs. Main focus are on cost competitiveness, lifetime, reliability and sustainability of devices and systems.

The Early Markets strategy has been to develop and deploy a range of fuel cell based products with near term market potential. As such demonstrations are a substantive part of the project portfolio, supported by specific R&D projects focused on improving performance and achieving cost reductions of the key technologies. Projects fall into one of three categories: Material Handling vehicles, primarily fork lift trucks; portable and micro-fuel cells for personal power solutions; and back-up and UPS power systems, especially for remote applications such as telecoms towers.

The portfolio of projects in this Application Area after three calls is well aligned with the overall strategy set up in the MAIP. With three flagship projects HyLIFT-Demo, SHEL and Mobypost covering material handling vehicles, over fifty vehicles should be in the warehouses by 2013. These are not limited to forklifts, but they include ten postal delivery vehicles and two trucks for airport usage, including their fuel logistics.

On the other identified early market, two important projects, FCPoweredRBS and FITUP have been launched to cover back-up and off-grid power supply. They are mainly focused on telecommunication applications such as radio based stations. Over 35 units will be installed in the field and some more used for assessment in specialized research laboratories. This is a real success story: following the first results, some of the manufacturers of the systems are optimizing their production lines and are close to fully commercial products.

In the portable application sector, new concepts are being explored for innovative solutions for fuel cells and the fuel logistics such as fuel cartridges that include reforming capabilities or reforming processes previous to the fuel cells, but integrated with them (DURAMET). Novel market opportunities such as unmanned flying vehicles and recreational boats are covered with different fuel cell concepts (SUAV).

Taken as a whole, this portfolio covers the objectives of the MAIP, although the reviewers expressed concern that some of these projects were not progressing as well as had been initially planned. Demonstration projects had experienced difficulties attracting clients for demonstration activities, whilst others, without OEMs in the consortium appeared to have no clear route to market. Some projects were affected by issues with the consortium or OEM suppliers, with at least one of the latter going bankrupt, and the difficulty in attracting clients for demonstrations. With regard to the latter reviewers recommended that demonstration projects should only start when end-users had been identified and signed-up.

However, perhaps the greatest concern of the reviewers is whether or not the portfolio of projects were innovative or merely copying ideas and concepts already developed or under development elsewhere in the world. They questioned the value of the latter activities to the FCH JU, stating that it might be better supporting innovative concepts. Further they proposed that fewer demonstrations, and more basic and applied R&D projects were supported.

Portable applications

The projects were deemed to be addressing the issues of the MAIP, but it was not clear how projects were 'positioned' against each other. Reviewers' primary cause for concern was that the portfolio comprised too much basic and applied R&D, and not enough demonstration activity. Many of them seemed to be focused on cell and stack developments, rather than achieving any of the demonstration activities. Furthermore the business cases, as presented, were felt to be weak. Reviewers therefore recommended that the portfolio required strengthening with projects focused on 'real' Early Markets and hence were more advanced in terms of Technology Readiness Levels. The business perspective of projects was further weakened by poor competing technology assessments.

Reviewers recommended undertaking a technology assessment to assist the FCH JU in identifying the real opportunities and needs in the portable space.

Back-up and off-grid applications

The two projects for this category appeared to address the AIP objectives and were broadly achieving progress in demonstrations. Performance targets were compatible with the AIP and MAIP, although there was some ambiguity regarding definition of targets as they relate to back-up systems operating for only short periods of time in any one year, as opposed to continuous operation. Further failure to present convincing competing technology assessments meant that there was uncertainty about whether targets in the MAIP continued to be valid.

Reviewers were concerned that an emphasis on demonstrations was to the detriment of progress on cost reductions and technical problem resolution, and hence the improved systems sought by MAIP. The reviewers argued that consideration should be given to strengthening the portfolio to counter this apparent weakness in technical development. The FCH JU has sought to address this issue with one project now on-going and another being negotiated.

Material Handling

The Material Handling projects have now been underway for more than a year. These are clearly aligned with the MAIP, but reviewers were concerned that maximum value added was unlikely to be achieved. Similarly they were convinced that the MAIP targets for vehicles would not be achieved.

Reviewers were especially critical of the mix of R&D and demonstrations, arguing that timing and resources meant that demonstrations were unlikely to be able to utilise any R&D advances within the timescale of the project. For example it would be preferable for demonstrations to use standardised HRS systems. They recommended that in the future projects should have a clear split between demonstrations and R&D in order that resources could be focused on one or the other objective. R&D was necessary to advance technologies in terms of performance and costs, but these should be separate from demonstrations.

Reviewers also expressed concern that projects were not able to present a good assessment of competing technologies, and as such requested that market and total cost of ownership assessments be undertaken to inform future Materials Handling demonstration projects. In addition there was a concern that for some projects there was no clear route to market for technologies, the consortia including technology developers and research, but not OEMs.

In general, reviewers recommended that targets for Early Market applications be reviewed to define their relevance in what is a fast moving and highly variable sector. As part of this, reviews of the technology requirements and market opportunities were recommended prior to commissioning of further demonstration activities. This was considered to be especially important for microFCs where competing technologies such as batteries and other fuel cell systems existed. Further work was required on performance metrics to ensure consistency of interpretation.

It is believed there are considerable opportunities for interaction between projects in the portfolio, for example safety, regulations and codes, as well as with European Member State programme. Collaboration within the FCH JU portfolio and with Member States projects and programmes is evident in several cases, but currently under-developed by projects, which would be able to significantly benefit industry and allowing it to take advantage of the FCH JU partnership. The FCH JU could assist through running technical thematic workshops to disseminate learning across the FCH JU portfolio and those of the MS, eg linkages between Materials Handling and Refuelling Infrastructure.

Project name	Type	Description	Coordinator	EC Funding (M€)
Mobypost	Demonstration of FC vehicles	Low pressure storage solutions for hydrogen over two fleets of five vehicles on two different sites for postal mail delivery. Development of the vehicles and the associated refueling stations with due consideration of certification and public acceptance.	Institut Pierre Vernier, France	4.2
SHEL	Demonstration of forklifts	Demonstration of 10 units of 1.5-2.5 ton FCH FLT's and associated hydrogen refuelling infrastructure across 3 sites in Europe: UK, Spain and Turkey. The project also develops unified rapid product certification and infrastructure build approval procedures across the EU.	Cidetec, Spain	2.44
HyLIF-DEMO	Demonstration of forklifts	2 year demonstration of 30 units of 2.5-3.5 tons forklifts with a fully integrated 3rd generation fuel cell system, as well as 2 year demonstration of hydrogen refuelling infrastructure at 3 end-user sites throughout Europe.	LBST, Germany	2.88
ISH2SUP	H ₂ supply for micro-fuel cells	Research and development of the cartridge technology and the electrical system.	Aalto University	1.0
IRAFC	Development of PEM fuel cell stack	Development of an internal reforming alcohol high temperature PEM fuel cell.	Advanced Energy Technologies	1.4
FITUP	Demonstration of back-up power systems	Installation of 19 market-ready fuel cell systems from 2 suppliers as UPS/ backup power sources in selected sites across the EU. Real-world customers from the telecommunications and hotel industry will utilize these fuel cell-based systems, with power levels in the 1-10kW range, in their sites.	Electro power systems	2.47
DURAMET	Systems development	Development of direct methanol Fuel cells components for application in auxiliary power units (APU) as well as for portable systems.	CNR	1.49
SUAV	Systems development	Design, optimization and building of a 100-200W mSOFC stack, and its integration into a hybrid power system comprising the mSOFC stack and a battery. All these components will be integrated into a mini Unmanned Aerial Vehicle platform like the CopterCity of SurveyCopter.	Hygear	2.1
FCPowerdRBS	Demonstration	An EU-wide set of field trials that demonstrates the industrial readiness and market appeal of power generation systems for off-grid Radio Base Stations based on fuel cell technology and photovoltaic panels	Ericsson	4.22

Cross-Cutting activities

Strategic priorities

The Cross-cutting AA supports the fuel cell and hydrogen sector activities in the other Application Areas with a range of projects including those focused on socio-economic, environmental and energy impact of the FCH technologies, the development of processes to monitor the RTD programme, and support the European fuel cell and hydrogen sector to commercialise its products.

In particular Regulation Codes and Standards (RCS) are identified as a critical activity requiring support of the FCH JU to address barriers associated with varying standards across Europe and the developments to ensure harmonisation; socio-economic research is seen as playing a role in providing data and information to educate and inform policy and decision makers, investors and end users; Life Cycle Assessments enhance the understanding of the environmental and sustainability benefits and challenges of FCH products; and training and general public education and awareness are necessary to advance the general understanding of FCH technologies.

Cross-Cutting projects are both necessary and critical to realisation of the FCH JU's overarching commercialisation objective.

In this respect, over 8 €m have been allocated from the budget 2008-2011 to support 9 projects so far, covering three distinct topics: training and education with three projects, TrainHy, HyProfessionals and HyFacts, all of which have either finished or are about to finish; Socio-economic studies with FC-EuroGrid and the relatively newer Temonas; plus Pre-normative Research and Life Cycle Analysis (PNR & LCA) projects, HyQ, HyComp, HyIndoor and FC-HyGuide. It is notable that only two projects, Temonas and HyIndoor, had been added to the portfolio in the past year, which is a concern given the importance of the Cross Crossing AA.

Reviewers state that the **Education and Training** projects are adequately funded to meet their objectives, but also note that the efforts in this area should be continued and consideration given to a budget increase given that the challenge will only increase as fuel cell and hydrogen technologies move closer to early market deployment.

HyFacts is developing high quality and up-to-date training materials for regulators and public safety officials. A comprehensive map of existing educational and training activities in Europe has been produced, the target audience identified and a database with hundreds of contacts of public safety officials and other interested persons created.

The TrainHy project has developed an International Curriculum on fuel cell and hydrogen technologies for post-graduate students and young professionals. Two summer schools have been organised to verify and evaluate the applicability of the curriculum concepts and develop a course and e-learning structure within which the educational programme can be organised.

The HyProfessionals project has developed an online course in order to train technicians and vocational training centres (teachers and students) in electric vehicles, hydrogen and FCEVs. They carried out a mapping of existing training initiatives, materials and funding programs, made proposals for new initiatives by means of a gap analysis (current training offer vs. industry expectations) and have been implementing initiatives through two pilot actions (200 person-week trained), and an E-library.

More information about the 'actual outcomes'; indicators such as organisations contacted, training and assessment criteria by which progress could be tracked for training projects.

The two **Socio-economic studies** cover two aspects of the MAIP and meet the specific requirements of the MAIP. The reviewers noted that the value of both would be determined by the quality of targets and benchmarks in the case of FC-EuroGrid, and whether and how the FCH JU could access data and other information to make use of the Temonas assessment tool. Both projects could potentially be used to inform the future development of the FCH JU, MAIP 2.0. Their primary concern was the extent to which the outputs of the projects would be used by industry and the FCH JU. Interaction is critical for the former, and although there is evidence that advisory boards are used, these appear to have had limited involvement to date. Additionally international involvement could be strengthened.

Nonetheless, reviewers feel that an overall project assessing the requirements of the commercialisation in terms of objectives, benchmarks and assessment activities is required to ensure that future FCH JU activities are focused on the right areas.

PNR and LCA are sufficiently addressed by the four projects currently underway. Furthermore the FCH JU is encouraging use of LCA as part of projects in the other AAs. With regard to PNR and LCA projects reviewers stated a clear need for progress and achievements to be documented centrally to identify the advances made and the gaps to be filled.

More specifically the FCH JU and projects should devote more time for planning for how the results of their work would be utilised in the future, and to identify what future work was required. Reviewers were critical of the apparent lack of industry and end user involvement in the projects. Failure to involve these groups meant that there was a failure to capture the views of the entire value chain, with the result that the projects were biased by the nature of the consortia participants. Reviewers concluded that more involvement from across the value chain was required to avoid niche viewpoints. As such AIPs should state that, for approval in the future, PNR and LCA projects needed to include the entire value chain from developers through suppliers to end users as participants. This would enable a better understanding of the challenges and maximise the extent to which results are utilised by industry.

In general, reviewers believe that the current portfolio of nine projects provide adequate coverage of the key elements of the MAIP, but more effort on budget should be expended in the coming few years to ensure that the progress that has been made is maintained and enhanced through additional projects and adequate funding.

Reviewers considered that education and training should remain as a priority but a much clearer statement of intent was required to ensure that activities in the area continue beyond the life of the projects, and that these activities build on the momentum established to date, as already noted in the 2011 review.

The legacy issue was noted in the question of how to keep training materials up to date for example, and how to build on these as fuel cell and hydrogen technologies were developed and demonstrated, and deployment progressed. Training of trainers and regulators and public safety officials will become increasingly important over next five plus years; these need to be prioritised. The reviewers noted that workshops with relevant representatives are a valuable means of mapping out future, and developing plans for education and training.

Reviewers also identified a need for much stronger interaction with projects within the portfolios of the other AAs. Possible standardization of training programmes developed with other AAs was raised. Although there is evidence that this is taking place it is not widespread at present. Linkages with other EU programmes, for example Marie Curie, were highlighted, as was the need to operate in tandem with the activities of Member States. However, projects themselves noted that education needs were largely met by Member States own activities, whereas harmonisation of regulator and public safety officials was European need.

Project name	Type	Description	Coordinator	EC Funding (M€)
FC-Eurogrid	Benchmark	Evaluating the performance of fuel cells in European Energy Supply Grids, by establishing technical and economic targets and benchmarks that allow the assessment of fuel cells in stationary power generation.	University of Birmingham, UK	0.58
TRAINHY	Training	Building vocational training programmes for post-graduate engineers and scientists, either at a Masters or PhD studies level of education or already employed by a company.	Forschungszentrum Jülich, Germany	0.26
HyPROFESSIONALS	Training	Development of training initiatives for technical professionals aiming to secure the required mid- and long-term availability of human resources for hydrogen technologies.	Foundation for Hydrogen in Aragon	0.37
HY-FACTS	Safety	Identification, preparation and dissemination of hydrogen safety facts to regulators and public safety officials.	TÜV SÜD Akademie	1.04
HyCOMP	PNR	Currently, the most mature technology for storing hydrogen is in compressed form in high-pressure cylinders. To improve volumetric and gravimetric performances, carbon fibre composite cylinders are currently being developed. However, current standards do not allow cylinder design to be optimized. The objective of HyCOMP is to produce improved type approval and batch testing protocols. The main outcome of the project will be a documentation of the real performance of composite cylinders to support Authorities and Industry in making enhanced RCS.	Air Liquide	1.38
FC-HyGUIDE	LCA	The project FC-HyGuide aims to develop a guidance manual for LCA of Fuel Cell and Hydrogen based systems and related training materials and courses.	PE International, Germany	0.6
HyIndoor	LCA	Safe indoor use of H ₂ ; develop knowledge base for safe handling of H ₂ indoor and issue safety guide and recommendations for RCS.	Air Liquide	1.5
HyQ	Pre-normative research	Hydrogen fuel quality requirements for transportation and other energy applications.	CEA	1.37
TEMONAS	Benchmark	Standalone assessment tool aiming to enable the FCH JU to obtain an accurate assessment of progress both towards its objectives and its position within the global field of energy technologies.	Climt GmbH	1.13

Conclusion and recommendations

Clear achievements and progress are identified in this second programme review exercise, confirming the initial outcome of the first review: the portfolio of some 70 projects arising from the first four calls 2008-2011 is aligned with the strategy identified in the Multi-Annual Implementation Plan and structured to address the challenges identified along the value chain, from basic research, through applied research to demonstrations. Gaps identified in the last programme review are being filled by projects selected from the calls 2011 and 2012.

Among these successes, the close integration between the European Union, the research and industry communities, is a valuable achievement. Over its five years of existence, the programme has structured the whole sector around ambitious, shared goals. This programme has maintained a competitive support process fully open to all interested European industrial and research entities, whilst achieving a high participation rate from innovative SMEs.

The industry-led public private partnership confirms its focus on commercialisation as the significant proportion of the budget for demonstration activities illustrates. Ene-Field, SOFT-Pact and ClearGen Demo stationary projects, and the CHIC, High V.LO city and FCGen transport projects are all excellent examples of this ambition.

Regarding *targets*, technical and economic, adjustments are required as the FCH JU moves towards another phase, and as technologies advance and markets develop. Current targets would also benefit from additional commercially relevant measures and indicators such as cost of ownership. Volumes should be assessed against the actual scope of the Multi-annual implementation plan, which goes beyond the remit of the FCH JU to encompass European activities as a whole.

For Fuel Cell Electric Vehicles and Hydrogen Refuelling Stations, although volumes and interest have increased, and good progress is being made on performance and durability or even purchasing prices as is the case for buses, the volumes required for mass production remain challenging. Stationary technologies are achieving their objectives on volume and costs and the initial gap between prototypes and pre-commercial systems is being bridged.

Sustainable hydrogen production is confirmed as a priority, with various new projects coupling water electrolysis with renewable energy sources. Efforts towards the development of centralised large scale production of hydrogen via water electrolysis are encouraged. Hydrogen storage, critical in establishing a hydrogen economy, is being addressed with the SSH2S, Bor4store projects on solid state storage, whereas HyUnder project is a welcome start to address the issue of energy storage of excess power from intermittent renewable sources. The potential of hydrogen for large scale storage of energy from renewables would further justify enlarging the scope of work to allow for larger and more ambitious projects.

As project players get closer to the market, reviews of the technology readiness requirements and market opportunities are considered valuable activities, as well as integration of end-users, at an earlier stage of project development, in order to pave a clearer way to market.

With the current funding being only available till end of 2013, a next phase of the FCH JU under Horizon 2020 would provide a timely opportunity to further develop and improve the program's effectiveness and synergies.

In particular, *learning synergies and interaction* between FCH JU projects, perhaps alongside national projects, would benefit the whole portfolio, especially should exchanges of information, centralised data banks or thematic workshops be further envisaged.

Technology transfer might also be enhanced through the use of end-users groups established to spread benefits, although this needs to be done within the constraints of IPR ownership commercial sensitivities.

More strategically, any future FCH JU programme redesign provides the opportunity to simplify the current application area structure to facilitate interaction and synergies between hydrogen fuel and usage applications, whilst also avoiding 'silo' activities and projects.

Collaboration with the activities of Member States and at the international level, is further re-affirmed. Enhanced co-ordination between National and regional programmes and the FCH JU is recommended, notably for demonstrations projects, which consume significant parts of FCH JU budget. International co-operation beyond Europe FCH JU is also considered an asset, if only to enable a better understanding of state-of-the-art with benefits to be gained from actively engaging with programmes in the USA, Canada, Japan, Australia, China, South Korea.

Cross-cutting activities, notably issues related to regulations, codes and standards, training and public awareness deserve attention with funds to match the ambitious objective to support implementation of the whole programme. These horizontal activities would also need to account appropriately for the achievements and ensure exploitation of results continue beyond the lifetime of the projects. Indeed training of trainers, regulators and public safety officials will become increasingly important as deployment progresses towards market commercialisation, and also raises the question of the legacy issue of how to keep training materials up to date.

Public awareness is increasingly important both to carefully manage expectations and prepare for consumer acceptance as fuel cells and hydrogen technologies reach a commercial reality.

The nature of the challenges ahead – the level of investment required in R&D to secure technology improvements and cost-reductions, tackling barriers to market entry and EU-wide consumer acceptance – calls for a step change in the operating strategy of the FCH JU. A sharper focus on innovative collaborative schemes, stronger integration with Member States, as well as commensurate financial support for deployment to enable returns on investment are avenues that need to be explored.

List of reviewers

Alan ATKINSON, Member of the FCH JU Scientific Committee.

Daniel CLEMENT, Deputy scientific director of ADEME (the French agency for environment and energy), expert for the French ministries, the International Energy Agency and for the European Commission

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Project funded by the FCH JU

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CHIC

Clean Hydrogen in European Cities

Key Objectives

The CHIC-Project is the next essential step leading to the full market commercialization of hydrogen powered fuel cell (FC) buses. This project will provide results from a demonstration run of more than 55 fuel cell buses. The key objectives are:

- Operation of 26 fuel cell buses and the respective infrastructure in 5 major European regions ("Phase 1 cities") for a period of 5 years
- Collaboration and transfer of key lessons learned from "Phase 0" cities (~30 fuel cell buses in operation) to "Phase 1" cities
- Assessment of the technology with a focus on environment, economy and society
- Dissemination to the general public as well as to cities and regions preparing for the technology in the next step and interested in setting up fuel cell bus and hydrogen projects ("Phase 2" cities).

Challenges addressed

26 FC buses will operate in daily public transport operations in five locations across Europe: Aargau (Switzerland), Bolzano (Italy), London (UK), Milan (Italy) and Oslo (Norway)

The project is based on a staged introduction and build-up of FC bus fleets, the supporting hydrogen fueling stations and infrastructure in order to facilitate the smooth integration of the FC buses into Europe's public transport system. Furthermore, a sustainability assessment of the use of the buses will be provided in order to analyse their impact on sustainability. Therefore, the bus operation will be accompanied by several studies analysing the performance, environmental profile, cost development and the social acceptance of the operating buses. In general, the project will identify the advantages, improvement potential, complementarities and synergies of FC buses compared with conventional and alternative technologies and will help the technology on the way to commercialisation.

Technical approach and achievements

The project aims to achieve certain technical goals regarding the fuel cell bus operation and the H₂ infrastructure. The main technical goals for the installed hydrogen infrastructures are to achieve:

- a capacity of 200kg H₂ per day or minimum 5 vehicles per hour with a minimum of 50 vehicles per day (to be upgradeable to min 100 vehicles per day)
- an average availability of 98% (based on operation time)

Furthermore, the H₂ OPEX costs are planned to be less than 10 €/kg (excl. tax) and the production efficiency for the H₂ production will be between 50-70 %. The demonstration of the FC buses and hereby the use of H₂ is supposed to replace a minimum of 500.000l diesel fuel throughout the project.

The main technical goals of the bus operation focus on ecological and economical aspects such as low fuel consumption and a high rate of availability. Therefore, the main technical goals during the project are to achieve

- a fuel cell lifetime of >6000 h of operation
- an average availability of all FC buses greater than 85% (based on operation time)
- fuel consumption less than 13 kg/100 km (depending on drive cycle)
- a minimum running distance of 2.75 Mio km and a minimum of 160,000 hours of operation of the deployed FC bus fleet.



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Expected socio and economic impact

Hydrogen and fuel cells play an important role in the reduction of local air pollutants, as well as in the decarbonisation of Europe's transport system. Fuel cells use hydrogen to generate electricity while emitting only water vapour. CHIC will reduce the 'time to market' for the technology and support 'market lift off' – two central objectives of the Joint Undertaking.

Project Information

Project reference: FCH JU

Call for proposals: 2009

Application Area: Transport

Project type: Collaborative

Topic: Demonstration

Contract type: Collaborative Project

Start date: 01/04/2010

End date: 31/12/2016

Duration: 81 months

Project total costs: € 81 894 400

Project funding: € 25 878 334

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Element Energy Limited UK	Spilett new technologies GmbH Germany
Euro Keys SPRL Belgium	Suedtiroler Transportstrukturen AG Italy
Air Liquide Hydrogen Energy France	TOTAL Deutschland GmbH Germany
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BC Transit Canada	Wrightbus Limited UK
Linde AG Germany	hySOLUTIONS GmbH Germany

DESTA

Demonstration of 1st European SOFC Truck APU

Key Objectives

The main objective of DESTA is the demonstration of the first European Solid Oxide Fuel Cell (SOFC) Auxiliary Power Unit (APU) for trucks:

- Maximum electrical power $\geq 3\text{kW}$
- Operation on conventional road diesel fuel
- Long-term tests: ~ 300 thermal cycles and ~ 3.000 operating hours
- System electrical net efficiency around 35%
- System volume and weight below 150 l and 120 kg
- CO_2 reduction of 75% compared to engine idling of a heavy-duty truck
- Start-up time of $\sim 30\text{min}$
- Noise level $\sim 65\text{dB(A)}$
- Truck integration.

Summary/overview

On 1st of January 2012, the research project DESTA started under the coordination of AVL List GmbH (Austria). It is the goal of DESTA to demonstrate the first European Solid Oxide Fuel Cell (SOFC) Auxiliary Power Unit (APU) on board of a heavy duty truck. By gathering the project partners J. Eberspächer GmbH (Germany), AVL List GmbH (Austria), Volvo (Sweden), Topsoe Fuel Cell (Denmark) and Forschungszentrum Jülich (Germany) into one consortium, a 100% European value chain for a SOFC APU is established. With an aim to reduce emissions, noise and costs, the end product will have excellent export opportunities, creating new high & clean teach job opportunities in Europe.

A significant advantage of the SOFC technology in contrast to other fuel cell technologies is its compatibility with conventional road fuels like diesel. The DESTA partners Eberspächer and AVL put a lot of effort in bringing the SOFC APU technology to the prototype level. For the market entry of this technology, the final breakthrough milestone is the demonstration of its functionality on a truck – the major goal of the DESTA project. The first phase of the project defines the requirements for the application of a SOFC APU in a Volvo heavy-duty truck for the US market. Based on test results including production costs, controllability and the manufacturability of the existing systems from AVL and Eberspächer, a benchmark will be

performed by the independent research institute Forschungszentrum Jülich. The result of this benchmark is an optimized DESTA SOFC APU combining the superior features of the individual systems. In parallel, Topsoe Fuel Cell will work on the SOFC stack optimization. The consortium is confident that the chosen technology is sufficiently mature to perform well in a truck demonstration in 2014 and will be close to the start-of-production in the coming years.

Technical approach and achievements

After the project start in January 2012, the requirement specifications for the application of the SOFC APU on a Volvo heavy-duty truck for the US market have been performed. This process was essential for the further development of the project. JE and AVL continued the optimization of their SOFC APU systems with the support of TOFC in stack improvement and supply. In line with the timeline, the project has started the benchmark phase for which the benchmark criteria have already been defined. The first 2 APU systems (one from AVL and one from JE) are already in operation. Otherwise, all deliverables and milestones have been provided and reached in time.



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AVL SOFC APU Gen 1.0 (released for publication, JR, 27.01.2012, benchmark system)

Expected socio and economic impact

Significant impact on society is expected through the fast market introduction of SOFC APU products (estimated for 2015) with all positive effects such as reduced emissions, noise and costs. With stack manufacturing (TOFC, Denmark), system manufacturing (Eberspächer, Germany) and vehicle manufacturing (Volvo, Sweden), the product value chain stays completely within the EU. The final product will enjoy excellent export opportunities to the US and other countries due to local anti-idling legislations and the great cost saving potential for truck operators.

Project Information

Project reference: FCH JU 278899

Call for proposals: 2010

Application Area: Automotive Applications

Project type: Demonstration

Topic: SP1-JTI-FCH.2010.1.5: Auxiliary Power Units for Transportation Applications

Contract type: Collaborative project

Start date: 01/01/2012

End date: 31/12/2014

Duration: 36 months

Project total costs: € 9.841.007

Project funding: € 3.874.272

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FCGEN

Fuel Cell Based On-board Power Generation

Key Objectives

The overall objectives of the FCGEN project are to develop and demonstrate a proof-of-concept complete FC-APU in a real application and on-board a truck to further develop the APU key components that are expensive or still behind the required level of maturity. The concrete system targets are (i) to reduce the system volume and mass to 300 l and 125 kg respectively; (ii) to demonstrate a system of efficiency ~ 30% and (iii) to reduce the system cost to ~1000 €/ kW.

Summary/overview

System integration and demonstration:

The focus has been on defining vehicle specifications which are necessary for the development of the APU unit; and the creation of a data set and the physical signal interface necessary for APU communication with the vehicle. Additionally, we wish to define important aspects for APU communication specifications and implementations. In addition, an analysis was carried out in order to identify the profit of electrifying the most conventional auxiliaries in terms of fuel saving during travelling and stop phases.

Complete APU system: The focus was on identification of the most important criteria for system design and integration, providing a comprehensive description of the requirements for APU control, integrating the components and sub-systems, and identifying the limitations while further developing the existing BoP components. Work has been carried out on system design and packaging optimization to meet efficiency and size targets.

Fuel processor: A system design and architecture was developed for the fuel processor system, and system units were developed and manufactured focusing on requirements related to efficiency, performance, compactness, and cost.

Control system- electrical interface and power conditioning: The focus in this work package was on defining the most optimal strategy plan for system control, both under the development phase and for the integrated APU system alike. A preliminary design based on the APU system control requirements and system control needs was developed and functional connections necessary to manage the APU was defined to make the driver able to operate the APU system.

Project management: The focus in this work package was on monitoring the progress of the project, maintain and update the project plan, administrate the project communication platform (Teamplace), keep track of the costs and financial reporting, support the work with project results dissemination and exploitation, interact with the European Commission and external parties and arrange work package leaders and steering committee meetings.

Technical approach and achievements

So far the project team has managed to develop a complete and compact system design and packaging model and define the final system architecture for the fuel processor (FP) system. The FP reactors are developed and manufactured and most of the Balance of Plant components (BOP) are identified or purchased. The specification for the vehicle integration have been addressed and completed and the exchange data set necessary for APU controls and operation is available. A Control system concept and architecture with the intermediate use of standard controllers is developed and the acquisition of basic EMC automotive standards and directives is carried out.

Expected socio and economic impact

The vision of the FCGEN project is to move the FC-based APU systems a step further towards industrialization. The project is targeting several issues which make this possible, including: system cost, improved system design for better performance, better efficiency and durability, reduced system size and weight. Efficient, durable and cost effective FC-based APU systems provide clean electricity and less noise in the driver's cabin during stand still conditions, compared to the condition when electricity is generated by engine idling.

Project Information

Project reference: FCH JU 277844

Call for proposals: 2010

Application Area: Transportation & Refuelling Infrastructure
Project type: research and Technological

Topic: SP1-JTI-FCH.1.5: Auxiliary Power Units for Transportation Applications

Contract type: Collaborative project

Start date: 01 November 2011

End date: 31 October 2014

Duration: 36 months

Project cost: €10 338 414

Project funding: € 4 342 854

Project Coordinator

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Institut fuer Mikrotechnik Mainz GMBH
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Johnson Matthey PLC. (JM)
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Modelon AB (Modelon)
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H2moves Scandinavia

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

Key Objectives

The focus of this public-private partnership is to accelerate the market introduction of hydrogen powered fuel cell electric cars. The projects ambition is to launch the latest "state-of-the-art" hydrogen fuel cell vehicles and to consolidate 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 (17 in Oslo, 2 in Copenhagen). Accompanying activities shall accelerate the commercialization of fuel cell vehicles and hydrogen refuelling infrastructure by understanding the status of certification and the needs to adapt them across all of Scandinavia. Finally, the general public in Scandinavia shall be informed and it should become obvious that fuel cell cars and hydrogen are about to enter the European market.

Challenges addressed

Obviously fuel cell vehicle and hydrogen technologies have reached a state of development allowing their deployment in mass markets soon in central Europe. Also in harsher European climates, such as in the North, performance data need to be assessed from everyday driving to understand in how far vehicles and fuelling equipment are ready for commercialisation under these conditions.

In sharp contrast it is perceived that the technical and comfort advantages of fuel cell cars have not yet been well communicated, such as rapid refuelling as well as driving range per refuelling and payloads acceptable for the customer. Hence communication activities should be an important part of the project. Time consuming and expensive vehicle and refuelling station certification procedures are one burden to their accelerated market introduction across Europe. A safety study will contribute to understand the current state-of-play of legal procedures across all of Scandinavia and to derive best practices to reduce potential burdens.

Technical approach and achievements

Next to the daily operation of 17 fuel cell cars in Oslo (and 2 in Copenhagen) using an existing hydrogen refuelling station network and one additional station conveniently located in Oslo accompanying activities study car and station performance, asses today's certification procedures in Scandinavia and communicate about the project and its achievements in the public.

To attain customer acceptance, the hydrogen station in Oslo Gaustad was publically opened in November 2011 and a Road Tour across Europe is under preparation in the summer of 2012. By organising public events, such as test drives, the public is informed about this exciting technology – sustainable fuel should be seen in normal operation as alternative to fossil fuel.

The experience from Nordic climate conditions will yield additional insights to ensure the vehicles are capable to perform within more extreme climatic markets.

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Driving into the future with FIE.

Expected socio and economic impact

A widely visible launch event in Oslo with live broadcasting on several TV channels and a ride&drive event attached to it have resulted in a sound echo in Oslo and Norway. This has contributed to a better understanding of the role of fuel cell vehicles as one type of electric vehicle, characterised by the advantage of rapid refuelling, extended driving range per refuelling in combination with zero emissions of hydrogen from hydropower and noiseless driving with high vehicle acceleration potential. The project key messages of “here today – everywhere tomorrow” and “fun to drive” were well and widely communicated. With the European Road Tour, the consortium expects to widely demonstrate that the project fuel cell car fleet extended by cars from other manufacturers can travel all across Europe already today even though refuelling infrastructure is scarce. It will also be shown that fuel cell vehicles are reaching the deserved attention in central as well as in Southern and Northern Europe.

Project Information

Project reference: FCH JU, Grant Agreement 245101

Call for proposals: 2008

Application Area: Transportation and refuelling infrastructure
Project type: Demonstration

Topic: SP1-JTI-FCH.1.1: Demonstration of Hydrogen fuelled road vehicles and refuelling infrastructure

Contract type: Collaborative Project, Large-scale demonstration of road vehicles and refuelling infrastructure

Start date: 01/01/2010

End date: 31/12/2012

Duration: 36 months

Project total costs: € 19.4 million

Project funding: € 7.8 million

The project is nationally co-funded by contributions from Transnova in Norway and EUDP in Denmark.

Project Coordinator

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Hydrogen Sweden
Sweden

SINTEF
Norway

SP
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TÜV SÜD
Germany

High V.LO City

Cities speeding up the integration of hydrogen buses in public fleets

Key Objectives

The overall objective of High V.LO-City is to facilitate the rapid deployment of the last generation FCH buses in public transport operations, by addressing key environmental and operational concerns that transport authorities are facing today. Therefore, a fleet of 14 commercial FC buses and the required refueling infrastructure will be put in place in 3 sites: San Remo (Italy), Antwerp (Belgium) and Aberdeen (Scotland). The infrastructure will support the creation of a network of 'Clean Hydrogen Bus Centers of Excellence'.

Summary/overview

Several European bus manufacturers consider the hybrid fuel cell (FCH) bus as the most promising technology to facilitate the decarbonisation of public transport. By leveraging the experiences of past fuel cell bus projects, implementing technical improvements that are meant to increase efficiency and reduce the costs of FCH buses, as well as introducing a modular approach to hydrogen refueling infrastructure build-up, the High V(Landmark).L(Liguria) O(Scotland)-City project aims to significantly increasing the "velocity" of integrating these buses on a larger scale in European bus operations.

The project addresses the following key issues:

- A) Increase the energy efficiency of the buses and reduce the cost of ownership by:
 - Taking hydrogen consumption down to 7–9 kg H₂/100km
 - Integrating the latest drive train and battery technologies
 - Ensuring the availability of 90% without the need for permanent support
 - Ensuring >12.000 hours warranty and decreased additional warranty cost
 - Increasing the lifetime of key components as fuel cells and batteries
 - Taking down investment cost <1,3 million euro
- B) Reduce the cost of hydrogen supply in:
 - Liguria: linking up with renewable hydrogen sources
 - Antwerp: using by-product hydrogen from industry
 - Aberdeen: making use of existing hydrogen production and distribution mechanisms and eventually Scotland's extensive wind energy resources
- C) Consolidate past, current and future fuel cell bus demonstration activities by creating an active dissemination network of Hydrogen Bus Centres of Excellence in collaboration with the Hydrogen Bus Alliance, Global Hydrogen Bus Platform, HyRaMP and JTI hydrogen bus demonstration projects.

More specifically High V.LO City will:

- Build on the experience of Van Hool in the USA (21 buses 2005-2010)
- Link Liguria, Antwerp, and Aberdeen with already existing activities in the United Kingdom (London), Netherlands (Amsterdam and Arnhem), Germany (Cologne, Hamburg, Berlin), Spain (Madrid, Barcelona) and Italy (Bolzano and Milano).

Technical approach and achievements

At this moment, the demonstration infrastructure is being deployed. At Van Hool, the 14 FC buses are in production and will become available in 2013. The first buses are planned to leave the factory at the end of March, with the last one departing in early 2014. All three sites are initiating the construction of the necessary infrastructure work in order to have the Hydrogen Refuelling Infrastructure ready once the buses go into commercial service. This entire infrastructure (FCB and HRI) is equipped with a data logging system to evaluate the 'Key Performance Indicators' – a set of indicators that will demonstrate the achievements of both the buses and the refuelling infrastructure.

Expected socio and economic impact

High V.LO-City intends to maximize the effect of its actions at local level, considering regional development as the key element to sustain the European FCH market takeup. Involving in each demonstration site the entire value chain of public and private stakeholders, the expected outcome is to reach Regional & Urban Mobility Plans, committing these regions to built-up long-lasting integrated policies to support FCH market enhancement. To guarantee a wide impact of the results, a clear Transferability model has been identified.

Project Information

Project reference: FCH JU 278192

Call for proposals: 2011

Application Area:

Project type: Demonstration

Topic: SP1-JTI-FCH.2010.1.1: Large scale demonstration of road vehicles and refuelling infrastructure III

Contract type: Collaborative project

Start date: 01 January 2012

End date: 31 December 2016

Duration: 60 months

Project cost: € 31.586 million

Project funding: € 13.491 million

Project Coordinator

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Solvay
Belgium

De Lijn
Belgium

Waterstofnet
Belgium

HyER
Belgium

DITEN
Italy

Regione Liguria
Italy

FIT
Italy

Aberdeen City Council
UK

Ballast Nedam
Netherlands



HyTEC

Hydrogen Transport in European Cities

Key Objectives

The HyTEC project will expand the existing European network of hydrogen demonstration sites into two of the most promising early markets for hydrogen and fuel cells, Denmark and the UK. The key objectives are:

- **Demonstrate** up to 30 new hydrogen vehicles in the hands of real customers, in three vehicles classes: taxis, passenger cars and scooters. These will be supported by new hydrogen refuelling facilities, which combine with existing deployments to create two new city based networks for hydrogen fuelling.
- **Analyse** the results of the project, with an expert pan-European research team considering full well-to-wheel life cycle impact, demonstrating technical performance of the vehicles and uncovering non-technical barriers to wider implementation.
- **Plan** for future commercialisation of the vehicles.
- **Disseminate** the results of the project widely to the public to improve hydrogen awareness.

Challenges addressed

The project will implement stakeholder-inclusive vehicle demonstration programmes that specifically address the challenge of transitioning hydrogen vehicles from running exemplars to fully certified vehicles utilised by end-users and moving along the pathway to providing competitive future products.

The results of the project will inform future commercialisation and infrastructure rollout planning by policy makers and industry players. A widespread dissemination campaign will be aimed at improving public awareness of the potential for hydrogen vehicles as a future low carbon transport solution. This will be backed up by a more targeted campaign aiming at industry players, opinion formers and key policy makers across Europe. For the first time, the project will create genuine links between the new and existing European hydrogen demonstration projects, with a view to informing ongoing strategic planning for hydrogen rollout and also ensuring a 'common voice' towards the expansion of the hydrogen vehicle fleet in Europe towards

Technical approach and achievements

The project will involve a fleet of 30 state-of-the-art hydrogen fuel cell vehicles operated for two years, in London and Copenhagen, based on:

- A fleet of state-of-the-art hybrid hydrogen fuel cell LTI 'black cab' taxis in London, to be operated by a number of end-users.
- A fleet of state-of-the-art hybrid hydrogen fuel cell Suzuki scooters in London, to be operated within the London municipal fleet.
- A fleet of state-of-the-art hydrogen fuel cell OEM passenger cars in Copenhagen, to be used by high profile public bodies in prominent roles, as well as vehicle dissemination tours around Denmark.

In addition, new networks for hydrogen refuelling in each city will be developed, including:

- A new publicly accessible London refuelling station.
- The start of a city-wide network for London with associated hydrogen delivery logistics. This deployment will represent a major step forwards in the development of an integrated citywide refuelling infrastructure, designed for high hydrogen throughput required to begin a commercial-rollout.
- A new publicly accessible Central-Copenhagen refuelling station network. The city network is to be linked with other major cities in Denmark, contributing to the efforts of securing a countrywide station network beyond 2015.

An extensive research program will assess the technical performance of the vehicles over a two year demonstration period, a life cycle impact assessment of the vehicles will demonstrate the overall well to wheels impacts and social studies will investigate the non-technical barriers.





www.hy-tec.eu

Transport and Refuelling infrastructure

Expected socio and economic impact

The expected impacts are to:

- Demonstrate a combined hydrogen vehicle and fuelling system for urban fleet operations.
- Create links between the new and existing European hydrogen demonstration projects.
- Improve public awareness of hydrogen fuel cell vehicles and their potential in tackling the problem of emissions from transport.
- Raise the profile of alternative fuel vehicles in the UK and Denmark beyond the current focus on battery electric vehicles.
- Improve industry engagement with hydrogen fuel cell technology.
- Catalyse a partnership between industry and Government in both countries, achieved through a new public-private partnership which will report on the next steps to commercialisation.
- Create two new lighthouse cities in Europe for large-scale vehicle demonstration activities, reducing the burden of responsibility on Germany and catalysing future hydrogen fuel cell vehicle markets beyond a single major European country.

Project Information

Project reference: FCH JU

Call for proposals: 2010

Application Area: Transportation & Refuelling Infrastructure

Project type: Demonstration

Topic: Large-scale demonstration of road vehicles and refuelling infrastructure III

Contract type: Collaborative project

Start date: 01/09/2011

End date: 31/12/2014

Duration: 40 months

Project total costs: € 29.5 million

Project funding: € 12 million

CENEX – Centre of excellence for low carbon and fuel cell technologies
UK

Greater London Authority
UK

hySOLUTIONS GmbH
Germany

MATGAS 2000 A.I.E.
Spain

Ludwig-Boelkow-Systemtechnik GmbH
Germany

Copenhagen Hydrogen Network AS
Denmark

Kobenhavns Kommune
Denmark

Foreningen Hydrogen Link Danmark
Denmark

Intelligent Energy Ltd
UK

BAA Airports Ltd
UK

London Bus Services Ltd
UK

Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V
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PEMICAN

PEM with Innovative low cost Core for Automotive application

Key Objectives

Reduction in the catalyst costs (gram of catalyst per kW) should contribute greatly to the industrialisation of PEMFC for automotive applications. To date much work has been carried out on the catalyst but much less on other aspects of the active layers (structure, carbon and electrolyte) even though they play a crucial role on performance. PEMICAN proposes to reduce the catalyst cost down to 0.15 gram per kW by a twofold approach: i) increase catalyst use and power density by improving transport properties of Air Liquid; ii) reduce catalyst loading by controlling its distribution. This technological approach is supported by a scientific one: i) numerical models to help defining catalyst improved distribution; ii) fundamental electrochemical experiments to improve the existing models.

Challenges addressed

The global aim of PEMICAN is to manufacture active layers with reduced catalyst loading but keeping the power density as high as possible. For this to happen, the first issue consists in developing and introducing specific electrolyte and carbon black into the active layers. These new raw materials should improve charge and gas transfers, increasing the electrical current delivered and consequently the power density. The other issue is to produce active layers with a reduced catalyst loading by locating it where it is most useful. Combination of both should allow reducing the catalyst loading with little influence on the power density. Another challenge is to improve the existing numerical modelling to better link local properties of active layers to performance of the PEMFC. For this, specific new measurements will be performed on fundamental electrochemistry, charge and gas transfers and introduced into specific models to improve the active layers.

Technical approach and achievements

Three key Milestones are defined in the project.

MEA Level 1 is planned at Month 12: reaching around 0.6 g Pt/kW and 350 mW/cm².

Focus will be on the improvement of ink formulation (electrolyte and carbon) on the cathode side and on the manufacturing of anodes by Particle Vapour Deposition (PVD). Performance models will be used to foster improvement of the active layers.

MEA Level 2 is planned at Month 24: reaching around 0.4 g Pt/kW and 500 mW/cm².

Focus will be on gradients (electrolyte, Carbon, Pt) on the cathode side and on the manufacturing of anodes by PVD or by Direct Electro Deposition. Performance models will be improved (better characterization of transport properties, experimental validation) and used to help improvement of the active layers.

MEA Level 3 is planned at Month 36: reaching the final target at around 0.15 gPt/kW and 350-700 mW/cm². Focus will be on manufacturing active layers with precise Pt/Carbon/electrolyte localisation and properties. According to Autostack project's outputs, if high power density is difficult to reach with such low catalyst loading, priority will be given to increasing the power density (up to ideally 1 W/cm²) even if higher catalyst loadings are necessary for this.



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Transport and Refuelling infrastructure

Expected socio and economic impact

PEMICAN will contribute to the cost reduction in PEMFC and consequently to its mass market development for automotive application. Whereas the project is focused on pure platinum its results will be useful also in the future when efficient non pure platinum is available to even reduce more the cost of PEMFC. Improved modelling developed in the project could also be used in the future as a baseline for design tools of PEMFC. The project will contribute to the development of a low carbon driven European Industry and is a good example of collaboration between industry (manufacturers, end-users), research centers and universities.

First results have been obtained:

- simulation has been used to analyse first modifications of cathodes to deduce the reduction in catalyst loading with minor influence on performance
- active layers with reduced catalyst loading and with new ink formulations (electrolyte, carbon black) have been manufactured and tested
- feasibility checks have been carried out on the manufacture of active layers with gradients.

Project Information

Project reference: FCH JU 256798

Call for proposals: 2009

Application Area: Automotive application

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2009.1.3
"Development and optimisation of PEMFC electrodes and GDLs"

Contract type: Collaborative project

Start date: 01/04/2011

End date: 31/03/2014

Duration: 36 months

Project cost: € 3.96 million

Project funding: € 1.86 million

Project Coordinator

**Commissariat à l'Énergie Atomique
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French Atomic and Alternative
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Opel
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Solvay
Italy

Tecnalia
Spain

Timcal
Switzerland

Imperial College
UK

ADEL

Advanced Electrolyser for Hydrogen Production with Renewable Energy Sources

Key Objectives

The ADEL project (ADvanced ELectrolyser for Hydrogen Production with Renewable Energy Sources) is developing a new steam electrolyser concept. This so-called Intermediate Temperature Steam Electrolysis (ITSE) aims at optimising the electrolyser life time by decreasing its operating temperature while maintaining satisfactory performance level and high energy efficiency at the level of the complete system including the heat and power source and the electrolyser unit.

The relevance of the ITSE is an increased coupling flexibility. Improved robustness and operability will be assessed both, at the stack level based on performance and durability tests followed by in depth post test analysis, and at the system level based on flow sheets and global energy efficiency calculations.

Challenges addressed

The challenge of the ADEL project is in the optimisation of materials for intermediate temperature operation allowing for reduced costs while maintaining sufficient performances with limited degradation. On the system level, an appropriate thermal integration of the overall devices with available electricity and heat sources is another key point. The project combines experienced partners having recognized knowledge and skills in separated fields. It particularly depends on their implementation from laboratory scale to technological scale for producing intermediate research and development tools and on their integration into a laboratory prototype constituting the final outcome of the project.

Technical approach and achievements

The project targets the development of cost-competitive, high energy efficient and sustainable hydrogen production based on renewable energy sources. For such an ambitious target the project is built on a two scales parallel approach:

- At the stack level, the adaptation and development of cell, interconnect/coating and sealing components for ITSE operation conditions (T down to 600°C) aims at increasing the electrolyser durability.
- At the system level, the development of flow sheets to analyse and quantify the coupling between the electrolyser unit and renewable heat and power sources aims at identifying the most energy efficient solutions.

The quantitative assessment of the coupling relevance of the ITSE unit with renewable energy sources such as solar or wind or with nuclear and the preliminary dimensioning of a proof of concept technology demonstrator including an operating ITSE stack constitute the final outcomes of the project.

Expected socio and economic impact

The project will contribute in developing a portfolio of sustainable hydrogen production liable to meet 10% - 20% of the hydrogen demand for energy applications from carbon-free or lean energy sources by 2015. One of the outcomes of the project is a preliminary specification of a proof of concept demonstrator that will pave the way to further demonstration and pre-commercialisation activities.

The project gathers a pool of complementary industries to bring to the market a sustainable H₂ production plant based on Steam Electrolyser coupled to renewable energy sources.

The project will prepare the ground for future large investments. So far, on the system side, a basis for understanding the different operation modes has been established and various heat and electricity sources have been inventoried for further flow sheeting work. System analysis has validated operating temperatures from 600-800°C as relevant for the electrolyser. On the electrochemical level, promising results have been obtained at 700°C both in continuous and intermittent operation, opening the door for grid-balancing operation of such units.

Project Information

Project reference: FCH JU

Call for proposals: 2009

Application Area: Area SP1-JTI-FCH.2: Hydrogen Production & Distribution

Project type: Research and Technological Development

Topic: SP2-JTI-FCH.2.3: New generation of high temperature electrolyser

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 01/01/2014

Duration: 36 months

Project total costs: € 4,373,548

Project funding: max € 2,043,518.00

Project Coordinator

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SOFCpower SPA
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Topsoe Fuel Cell A/S
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Empresarios Agrupados Internacional
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ARTIPHYCTION

Fully artificial photo-electrochemical device for low temperature hydrogen production

Key Objectives

- Improved and novel nano structured materials for photo-activated processes comprising photo catalysts, photo anodes interfaced with liquid or new polymer electrolytes
- Chemical systems for highly efficient low temperature water splitting using solar radiation
- Demonstration of solar to hydrogen efficiency > 5% with a perspective of >10.000 h lifetime
- Small to medium scale applications ranging from 100 W for domestic use (ca. 3 g/h H₂ equivalent) to 100 kW (ca. 3 kg/h H₂ equivalent) for commercial use.

Summary/overview

Leaves can split water into O₂ and H₂ at ambient conditions exploiting sun light. In photosynthesis, H₂ is used to reduce CO₂ and give rise to the various organic compounds needed by the organisms or even oily compounds which can be used as fuels. However, a specific enzyme, hydrogenase, may lead to non-negligible H₂ formation even within natural systems.

Building on the pioneering work performed in a FET project based on natural enzymes (www.solhydromics.org) and the convergence of the work of the physics, materials scientists, chemical engineers and chemists involved in the project, an artificial device will be developed to convert sun energy into H₂ with close to 10% efficiency by water splitting at ambient temperature, including: i) an electrode exposed to sunlight carrying a PSII-like chemical mimic deposited upon a suitable transparent electron-conductive porous electrode material (e.g. ITO, FTO); ii) a membrane enabling transport of protons via a pulsed thin water gap; iii) an external wire for electron conduction between electrodes; iv) a cathode carrying an hydrogenase-enzyme mimic over a porous electron-conducting support in order to recombine protons and electrons into pure molecular hydrogen at the opposite side of the membrane.

A tandem system of sensitizers will be developed at opposite sides of the membrane in order to capture light at different wavelengths so as to boost the electrons potential at the anode for water splitting purposes and to inject electrons at a sufficiently high potential for effective H₂ evolution at the cathode. Along with this, the achievement of the highest transparency level of the membrane and the electrodes will be a clear focus of the R&D work. A proof of concept prototype of about 100 W (3 g/h H₂ equivalent) will be assembled and tested by the end of the project for a projected lifetime of >10,000 h.



www.artiphyction.org

Hydrogen Production Storage and Distribution

Expected socio and economic impact

With a solar light to hydrogen conversion efficiency of 10 % and a radiation input of 1000 kWh per m², one gets 3 kg of H₂/y/m². If a 7 €/kg cost of solar-electrolytic hydrogen is considered, each panel will provide about 24 €/m²/y of H₂. Assuming a 20 years lifetime and a money capitalization of 5 %, one can afford costs up to 200 €/m² of the Artiphyction panels including installation to ensure a widespread diffusion of the technology.

Project Information

Project reference: FCH JU 123456

Call for proposals: 2010

Application Area: Hydrogen production

Project type: Research and Technology development

Topic: SP1-JTI-FCH.2011.2.6: Low-temperature H₂ production processes

Contract type: Collaborative project
Start date: 01 January 2010

End date: ongoing

Duration: 36 months

Project cost: € 4.0 million

Project funding: € 2.0 million

Project Coordinator

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Tecnologia Navarra de Nanoproductos
SL
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Pyrogenesis SA
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Bor4Store

Fast, reliable and cost effective boron hydride based high capacity solid state hydrogen storage materials

Key Objectives

BOR4STORE will develop novel cost-efficient boron hydride based hydrogen storage materials with capacities of more than 8 wt.% and 80 kg H₂/m³ for specific fuel cell applications, including:

- (a) Synthesis and modification of boron hydrides, either single or as Reactive Hydride Composites and Eutectic Mixtures;
- (b) Systematic investigation of special catalysts and additives, and;
- (c) Adaptation of nanoporous scaffolding to optimise performance. Moreover, an integrated laboratory storage - SOFC prototype will be set up, representing e.g. stationary power supplies.

Summary/overview

Only boron hydride based hydrogen storage materials exhibit the necessary high hydrogen storage capacities (more than 120 kg H₂/m³ and up to 18 wt %). It is highest among all known hydrogen storage materials suitable for gas phase loading and discharge inside the tank. To overcome their current deficits (loading and unloading times, cycling stability, cost), BOR4STORE will take the following steps:

- Synthesize **novel boron hydride based materials** (e. g. bi- and tri-metal boron hydrides, anion substituted materials) **and composites** (e.g. Eutectically Melting Composites (EMC)) with high hydrogen storage capacities >8 wt.% and >80 kg H₂/m³ and evaluate their suitability for practical application;
- **Accelerate reaction kinetics and adjust reaction temperatures** appropriately to supply a SOFC with sufficient hydrogen pressure and flow at acceptable rehydrogenation times of 1 hour or below;

- **Enhance the cycling stability** of the materials to several 1000 cycles by suitable **additives** as well as by **scaffolding** the storage material in **pore size optimized nanoporous materials** to tailor reaction pathways, prevent phase separation and retain a high storage density;
- **Decrease material cost** to reach the long term target of < 50 €/kg in large scale production, by (a) developing **cost effective materials synthesis** routes, and (b) systematically investigating the effects of impurities on storage properties to enable the use of more **cost effective raw materials** with less stringent requirements on purity, and;
- **Demonstrate the suitability, high energy and cost efficiency** of a boron hydride based laboratory prototype tank and supply a small SOFC as a model for a continuous power supply for specific applications like net independent telephone or weather stations, UPS systems for lighting and control, CHP, potentially also being a model for APU's for trains or ships and other portable applications.

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Expected socio and economic impact

High capacity hydrogen storage at low pressure <10 MPa. High overall energy efficiency due to energetic integration with fuel cell and low hydrogen compression. Cost target 500 €/kg of stored hydrogen by use of cost effective raw materials and simple tank construction.

Project Information

Project reference: FCH JU 303428

Call for proposals: 2011

Application Area: SP1-JTI-FCH.2: Hydrogen Production & Distribution

Project type: Basic Research / Research and Technological Development

Topic: SP1-JTI-FCH.2011.2.4 Novel H₂ storage materials for stationary and portable applications

Contract type: Collaborative project

Start date: 01 April 2012

End date: ongoing

Duration: 36 months

Project cost: € 4.07 million

Project funding: € 2.27 million

Project Coordinator

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Eidgenössische Materialprüfungs- und
Forschungsanstalt
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National Centre for Scientific Research
"Demokritos"
Greece

CoMETHy

Compact Multifuel-Energy to Hydrogen converter

Key Objectives

CoMETHy aims at the intensification of hydrogen production processes, developing an innovative compact steam reformer to convert reformable fuels (natural gas, biogas, bioethanol, etc.) to pure hydrogen, adaptable to several heat sources (solar, biomass, fossil, etc.) depending on the locally available energy mix. Therefore, the system will be highly flexible in terms of either the feedstock that is converted to hydrogen and the primary energy source. The objective is to provide a reformer for decentralized hydrogen production (close to the end-user).

Summary/overview

CoMETHy proposes a new "low-temperature" steam reforming technology, where a molten salt (molten nitrates mixture) at maximum temperatures of 550°C is used as the heat transfer fluid. This concept allows recovery and supply of the process heat to the reformer from different heat sources like Concentrating Solar Power (CSP) plants. The produced hydrogen is separated and purified by means of selective membranes.

First challenge is the development of advanced low-temperature steam reforming catalysts and cost-effective selective membranes in the reference operational range (400-550°C, 1-10 bar). Next technical challenge is targeted on the coupling of the membrane with the catalyst in a membrane reactor. Finally, the project involves the integration of the developed membrane reformer in a molten salts loop for proof-of-concept at the 2 Nm³/h hydrogen production scale, and the performance assessment of the whole system.

CoMETHy work plan involves five main RTD work packages (WPs 2 to 6) proceeding in parallel with project management, coordination and dissemination of results (WP1).

The 1st project year was mainly focused on the development of the two key components, catalyst and membrane (in WPs 2 and 3, respectively), to provide basic recommendation about the catalyst system and the membrane to be applied (Milestones 1 and 2, respectively). This represents input to the reformer design (Milestone 3) and validation (WP4) as key activity during the 2nd project year. Finally, after construction of the 2 Nm³/h pilot unit, the 3rd project year is mostly dedicated to the proof-of-concept (WP5, Milestones 5) and to optimization and evaluation of the whole system (WP6, Milestones 6 and 7, respectively). In the perspective of a multi-fuel application, the identification of specific catalysts for bioethanol steam reforming is required too (Milestone 4).

Technical approach and achievements

During the 1st project year research has mainly been focused on the development of the two basic components and materials for the "low-temperature" steam reforming: the catalyst and the hydrogen selective membrane. Multi-fuel catalytic materials with satisfactory performance (activity, stability and selectivity) in steam reforming of methane and/or ethanol at 400-550°C have been identified and characterized. Moreover, a structured ceramic support has been identified to enhance heat transfer and minimize pressure drops. Development and characterization of high performance hydrogen selective membranes is also in progress. Moreover, some integrated membrane reactor design concepts have been conceived.



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<http://www.comethy.enea.it>

Hydrogen Production Storage and Distribution

Expected socio and economic impact

CoMETHy leads to potential benefits on hydrogen production costs, operational flexibility and environment impact. Materials cost is reduced by operating at less than 550°C, and additional process units (water-gas-shift reactor(s) and hydrogen purifiers) avoided by the integration with membranes. The coupling with renewable sources (e.g. solar) makes production costs less sensible to the fossil fuel price and allows 40-50% reduction of CO₂ emissions, whereas the use of biofuels (biogas, bioethanol, etc.) allows totally green hydrogen production.

Project Information

Project reference: FCH JU 279075

Call for proposals: 2010

Application Area: Hydrogen production & distribution
Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.2.2: Development of fuel processing catalyst, modules and systems

Contract type: Collaborative project

Start date: 1 December 2011

End date: ongoing

Duration: 36 months

Project cost: € 4.9 million

Project funding: € 2.5 million

Fraunhofer-Gesellschaft Zur
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DeliverHy

Optimisation of Transport Solutions for Compressed Hydrogen

Key Objectives

Compressed hydrogen trailers are cost efficient for near term distribution but due to the low pressure, they require multiple daily truck deliveries, which is not often acceptable. In order to increase the transport quantities, lighter materials and higher pressure must be facilitated. The effects that can be achieved by the introduction of high capacity composite material tank trailers, allowing a payload increase from 350 to 1,000kg with respect to weight, safety, energy efficiency and greenhouse gas emissions will be assessed.

Challenges addressed

A significant increase in capacity can be achieved, in comparison to state-of-the-art pressure levels and steel technology. Delivery frequencies can be reduced by a factor of 3, compared to steel trailers, while transport-related CO₂ emissions can drop by 75%.

The optimal trailer concept for a delivery strongly depends on the HRS size and the delivery distance.

The delivery costs of new CGH₂ trailers are competitive with LH₂ delivery costs of up to at least 250km.

The analysis of regulatory requirements for the approval of hydrogen trailers arising from ADR has progressed and the process has been widely understood, with the first wave of recommendations disseminated.

Technical approach and achievements

The intended result of this project will be an optimized high-pressure storage trailer solution assisting in the optimisation of the entire supply chain regarding energy use, related emissions, product losses and supply cost while ensuring EU-wide certification. This will simplify, harmonize and speed up the safe deployment of hydrogen supply to customers.

DeliverHy intends to further develop this line of argumentation which functions to support any changes needed in the RCS framework relevant for hydrogen transport, something which can in the end, lead to harmonized requirements and approval processes in Europe.

Expected socio and economic impact

Compressed hydrogen trailers are cost efficient for near term distribution. However, with the currently used 20 MPa trailers supply of larger refuelling stations (HRS) would result in multiple daily deliveries, which often are not acceptable. In order to increase the transported quantities, lighter materials and higher pressure must be adopted. The cost increase by advanced hydrogen trailers can be off-set by the distribution cost savings from increased truck capacity. This project will assess the effects achievable through the introduction of high capacity composite materials tank trailers with respect to weight, safety, energy efficiency and greenhouse gas emissions.

The transport of compressed hydrogen today is strictly regulated by international and regional standards. New materials and product capacities available today have the potential to increase the payload of a single trailer from about 350kg of hydrogen to more than 1000 kg. Materialising this potential is of great importance for the efficient distribution of hydrogen to HRS's with high output.

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Steel Tube Trailer [Air Liquide]



www.deliverhy.eu

Hydrogen Production Storage and Distribution

This will require changes to existing Regulations, Codes and Standards (RCS) in particular for proof pressures higher than 65 MPa and tubes larger than 3000 litres. Adopting these changes is a time consuming process and will only happen if authorities are convinced that the necessary safety precautions are taken care of to achieve a level of safety at least as high as observed with today's distribution technologies for hydrogen.

The project will address these challenges by means of

- a detailed assessment of safety, environmental and techno-economic impacts of the use of higher capacity trailers,
- the development of a line of argumentation supporting the changes needed in the RCS framework,
- a preliminary action plan leading to a Roadmap for the required RCS amendments,
- communicating these needs to the authorities in charge
- facilitating a widely accepted and harmonized set of requirements and approval processes in Europe.

Project Information

Project reference: FCH JU 278796

Call for proposals: 2010

Project type: Basic Research

Topic: SP1-JTI-FCH.2010.2.6: Feasibility of 400b+CGH₂ distribution

Contract type: Collaborative project

Start date: 01 January 2012

End date: ongoing

Duration: 24 months

Project cost: € 1,247,773

Project funding: € 719,501

Project Coordinator

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Raufoss Fuel Systems (HEX)
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ELECTROHYPEM

Enhanced Performance and Cost-Effective Materials for Long-Term Operation of PEM Water Electrolysers Coupled to Renewable Power Sources

Key Objectives

The overall objective of the ELECTROHYPEM project is to develop cost-effective components for PEM electrolysers with enhanced activity and stability in order to reduce stack and system costs and to improve efficiency, performance and durability. The focus of the project is on low-cost electrocatalysts, low-noble metal loading electrodes and membrane development. The project addresses the development of PEM electrolysers based on such innovative components for residential applications in the perspective of a suitable integration with renewable power sources.

Technical approach and achievements

Nanosized Pt and Ir oxide electrocatalysts with enhanced mass activity have been developed respectively, for hydrogen and oxygen evolution reactions in PEM electrolysers. These electrocatalysts, in combination with short-side chain sulfonated perfluorosulphonic ionomer membranes performances of 2.8 A cm^{-2} at 1.8 V with hydrogen, at cross-over lower than 1 mA cm^{-2} .

The achievement of such performance is attributed to the enhanced proton conductivity of the novel membranes and the high electrochemically active surface area electrocatalysts. Interesting performances have also been obtained with fluorine-free low-cost hydrocarbon membranes. High surface area oxide supports are under development to reduce the noble metal loading in the MEA.

Expected socio and economic impact

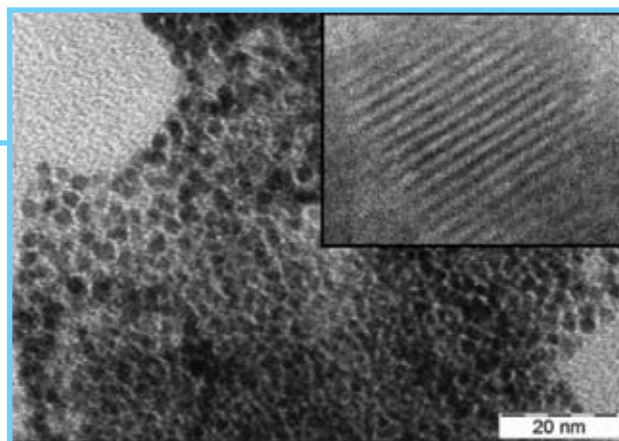
The project deals with cost-effective and enhanced durability components for PEM electrolysers which are amenable to be integrated with renewable energy sources. The decentralised hydrogen production may represent an important option for the future. This implies the use of small systems directly coupled to wind/solar sources for hydrogen generation and its storage at high pressure. The aim of the project is to contribute to the road-map, addressing the achievement of a large-scale decentralised hydrogen production infrastructure in approaches clearly oriented towards long term innovation.

The main impact concerns the enhanced performance and cost-effectiveness of PEM electrolysers, obtained through the development of novel electrocatalyst and membrane formulations.

Summary/overview

The overall objective of the ELECTROHYPEM project is to develop cost-effective components for proton conducting membrane electrolysers with enhanced activity and stability in order to reduce stack and system costs and to improve efficiency, performance and durability. The focus of the project is mainly concerned with low-cost electrocatalysts and membrane development. The project is addressing the validation of these materials in a PEM electrolyser for residential applications in the presence of renewable power sources.

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Hydrogen Production Storage and Distribution

The aim is to contribute to the road-map addressing the achievement of a wide scale decentralised hydrogen production infrastructure. Polymer electrolytes developed in the project concerned with novel chemically stabilised ionomers and sulphonated hydrocarbon membranes, as well as their composites with inorganic fillers, characterised by high conductivity and better resistance than conventional Nafion membranes to H₂-O₂ cross-over and mechanical degradation under high pressure operation. Low noble-metal loading nanosized mixed-oxides oxygen evolution electrocatalysts, highly dispersed on high surface area conductive doped-oxide or sub-oxides are developed together with novel supported non-precious oxygen evolution electrocatalysts prepared by electrospinning. After appropriate screening of active materials (supports, catalyst, membranes, ionomers) and non-active stack hardware (bipolar plates, coatings) in single cell and short stack, these components are validated in a PEM electrolyser prototype. The stack is integrated in a system and assessed in terms of durability under steady-state operating conditions as well as in the presence of current profiles simulating intermittent conditions.

Project Information

Project reference: FCH JU 300081

Call for proposals: 2011

Application Area: SP1-JTI-FCH.2:
Hydrogen Production & Distribution

Project type: Research and
technological development

Topic: SP1-JTI-FCH.2011.2.7 :
Innovative Materials and Components
for PEM electrolysers

Contract type: Collaborative project

Start date: 01 July 2011

End date: ongoing

Duration: 36 months

Project cost: € 2,842,312.00

Project funding: € 1,352,771.00

Project Coordinator

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ELYGRID

Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H₂ production from Renewable Energies to Balance the GRID

Key Objectives

The ELYGRID Project aims at contributing to the reduction of the total cost of hydrogen produced via electrolysis as it is coupled to renewable energy sources, mainly wind turbines, and focusing on megawatt size electrolyzers (from 0,5 MW and up). The objectives are to improve the efficiency related to the complete system by 20 and to reduce costs by 25%. The work will be structured in 3 different parts, namely: cell improvements, power electronics, and a balance of plant (BOP). Two scalable prototype electrolyzers will be tested in facilities which allow feeding with renewable energies (photovoltaic and wind).

Challenges addressed

The project has just completed its first year out of a total of three. Important advances have already been completed in terms of the development of new membranes, power electronics design and BOP optimization.

New materials have been developed and tested in order to assess the feasibility of the membranes. Tests and characterizations have been carried out in a membrane with a diameter of 130 mm. As for power electronics, different topologies are being assessed in order to decide the best technology available at the current time, in comparison to the traditional power electronics design for a large electrolyser (MW).

The project is also working on developing models in order to optimize BOP operation, improve manufacturing processes and assess the safety of current topology.

Technical approach and achievements

The project activities will include an assessment of the potential commercial possibilities and the participation of industrial partners also will contribute to the successful market exploitation of results. The planned dissemination activities, together with the commercial emphasis to get results to the market, will guarantee the impact of the ELYGRID project on energy efficiency, the support of renewable energy markets, and the contribution to the reduction of CO₂ emissions.

The expected results affect several areas which constitute important goals which are central to the European Union's policies such as promoting environmental protection and energy saving, fighting climate change and maximizing the use of renewable energy and the independence of fossil fuels.

Expected socio and economic impact

The ELYGRID project specifically addresses the coupling of high pressure and high capacity alkaline electrolyzers with wind energy. It is expected that the results from the ELYGRID project will have a considerable impact beyond the geographical and time scopes of the project, contributing to advances in answers related to the new typologies of electrolytic hydrogen that is adapted to ensure maximum penetration of renewable energies, especially wind energy. Application of the results should not only benefit the EU, but could specially contribute to soften serious environmental problems emerging from developing countries, which need new clean energy technologies to supply the electricity demand, support their socio-economic development and ensure that it is compatible with environmental preservation.

Besides the negative impact of fossil fuels on global warming, the increasing shortage of such energy resources will result in unstoppable increases in the costs of electricity from conventional sources. ELYGRID will optimize the electrolytic green hydrogen costs and make sure that it is able to supply clean fuel based on the maximum use of available renewable energies which can contribute to independence from traditional fossil fuels.

The ELYGRYD project has been undertaken by a well-balanced team of academic, research and industrial partners of renowned prestige with important know-how and experience in renewable energies, electrolysis (more than 40 years), energy storage, materials development, demand management and weather forecast modeling. Based on this, considerable synergies will be generated, guaranteeing the fulfillment of the project's objectives.

Project Information

Project reference: FCH-JU-2010-1

Call for proposals: 2010

Application Area: SP1-JTI-FCH.2:
Hydrogen Production & Distribution

Project type: Demonstration, Research
and Technological development

Topic: SP1-JTI-FCH.2010.2.1: Efficient
alkaline Electrolysers

Contract type: Collaborative project

Start date: 01/11/2011

End date: 01/11/2014

Duration: 36 months

Project total costs: € 3.752.760,80

Project funding: € 2.105.017,00

Project Coordinator

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Switzerland

Eidgenossische Materialprüfungs-und
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Helion S.A.S.
France

Forschungszentrum Jülich GmbH (FZJ)
Germany

Vlaamse Instelling voor Technologisch
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Lapesa Grupo Empresarial
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Instrumentacion y Componentes S.A.
(INYCOM or I&C)
Spain

INGETEAM Energy
Spain

Commissariat à l'Énergie Atomique et
aux Energies Alternatives (CEA)
France

HY2SEPS-2

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

Key Objectives

The main project goal of HY2SEPS-2 is the design and testing of hybrid separation schemes combining Membrane and Pressure Swing Adsorption (PSA) technology for H₂ purification from reformat streams. The project's focus is on small-scale PSA units operating at low feed pressures and being less flexible in operating modes in order to maintain high H₂ purity without sacrificing recovery. Various possible configurations of the hybrid system are envisioned, depending on membrane and adsorbent properties as well as on operating conditions.

Challenges addressed

Methane steam reforming is currently the major route of hydrogen production. The cost for hydrogen-derived units of energy is higher than that of energy derived from hydrocarbon fuels. One reason for the increased production cost is the low recovery rates at the PSA separation unit, which is employed for hydrogen separation and purification.

A hybrid process combining PSA with membrane separation is expected to have lower operating costs and to increase the overall H₂ recovery without sacrificing its purity, especially for small scale units. Furthermore, it provides the means for co-producing a CO₂ stream which can be ready for capture and sequestration. The development of the hybrid separation process incorporates both material development and process/system modelling. In terms of material development, the main activity refers to optimization of procedures for synthesis of carbon membranes on ceramic tubular supports tuned to being either H₂ or CO₂-selective and highly permeable in order to keep membrane production costs as low as possible. At the same time, the adopted protocols should be easily transferable to scaled-up production. An additional activity refers to the assessment of alternative, newly

developed adsorbents for the PSA unit. At the same time, the study of membranes and adsorbents will generate transport & adsorption data, which will be used in the course of the project. Mathematical models are employed in the conceptual design and optimization of a membrane – a PSA hybrid system with the goal to maximize H₂ recovery without sacrificing purity. Dynamic optimization of the overall system will be carried out for selected flowsheet configurations. Design and control issues will be considered simultaneously. The performance of optimized membranes will be evaluated under actual industrial conditions. The final stage of the project refers to the construction and testing of a membrane-PSA hybrid system at the scale of 1 Nm³ H₂ h⁻¹.

Technical approach and achievements

New types of adsorbents for the PSA unit have been evaluated in order to enhance performance. Adsorbents with improved characteristics in terms of CO₂ adsorption capacity have been identified. In the process, adoption of these adsorbents needs to take into account their respective cost compared to the existing situation. Synthesis of carbon membranes with high H₂/CO₂ separation selectivity on ceramic supports

is feasible only after a lengthy production procedure. Alternative approaches have been identified and are proposed in order to prepare membranes with a low processing cost. A mathematical model of the membrane unit has been developed for steady state simulation and optimal design of the membrane module.

Expected socio and economic impact

The expected impact of the project is in the field of "Hydrogen Production & Distribution" by enabling the more efficient clean hydrogen production in small scale units through the design of an advanced hydrogen separation and purification system. The proposed hybrid process should, in principle, also be able to produce hydrogen with almost no CO₂ emissions if it is optimized appropriately and, as a consequence, aims to improve, make more effective and reduce the cost of the fossil fuel decarbonization process.

Project Information

Project reference: FCH JU 123456

Call for proposals: 2008

Application Area: SP1-JTI-FCH.2

Project type: Basic Research, Research & technological Development

Topic: SP1-JTI-FCH.3.2: Component and system improvement for stationary Applications

Contract type: Collaborative project

Start date: 01 November 2011

End date: 31/10/2013

Duration: 24 months

Project cost: € 1,606,279.00

Project funding: € 825,321.00

Project Coordinator

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Hygear B.V.
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Ceramiques Techniques et Industrielles
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HYDROSOL 3D

Scale up of thermochemical hydrogen production in a solar monolithic reactor: a 3rd generation design study

Key Objectives

HYDROSOL-3D aims at the preparation of a demonstration of a CO₂-free hydrogen production and provision process and related technology, using two-step thermochemical water splitting cycles by concentrated solar radiation. This process has been developed within two relevant predecessor EU projects, HYDROSOL and HYDROSOL-II and through several steps of improvement has reached the status of a pilot plant demonstration in a 100 kW scale showing that hydrogen production via thermochemical water splitting is possible on a solar tower under realistic conditions. HYDROSOL-3D focuses on the next steps towards commercialisation carrying out all activities necessary to prepare the erection of a 1 MW solar demonstration plant. The project concerns the pre-design and design of the whole plant including the solar hydrogen reactor and all necessary upstream and downstream units needed to feed in the reactants and separate the products and the calculation of the necessary plant erection and hydrogen supply costs.

Challenges addressed

- Fine-tuning of materials composition and reactor configurations developed within HYDROSOL & HYDROSOL-II, in order to ensure long-term, reliable solar-aided H₂ production.
- Design & development of a solar H₂ receiver/ reactor with enhanced transport, thermal and heat recovery properties.
- Development of control concepts and procedures and pre-design of a specific process control system
- Complete pre-design of alternative plant scenario options (coupled to existing and to new solar field/ tower facilities) and selection of most promising one for further in-detail analysis
- Development of operational strategies for specific phases of the process
- Detailed design study of complete demonstration plant
- Sizing and selection of all necessary peripheral components
- Simulation of core components and standard operation phases
- Simulation of controlling the process as a whole
- Identification of investment and operational cost of a 1 MW demo plant for 2-step solar H₂ generation.
- Calculation of the cost necessary to erect a 1 MW demonstration plant, as well as H₂ production & supply costs, in a 1 MW scale on a solar tower.
- Techno-economic & market analysis to determine the feasibility of process scale-up to the MW scale.

Technical approach and achievements

The project started from fine-tuning the materials compositions and reactor designs advanced through the Projects HYDROSOL and HYDROSOL-II to ensure long-term, reliable solar-aided Hydrogen production. Emphasis was placed on improving the solar reactor performance by introducing designs and concepts that will enhance the long term thermal stability of materials and the reduction of radiation losses among others. The project then developed the control concepts, algorithms and procedures necessary for the operation of such a plant. Two alternative options were analyzed: adapting the hydrogen production plant to already available solar facilities or developing a new, completely optimised hydrogen production/solar plant. The most promising option would be analysed in detail, establishing the complete plant layout and defining and sizing all necessary components. Validation of pre-design components and process strategies by experiments (in laboratory, solar simulator and solar tower facilities) and a detailed techno-economic analysis covering market introduction complement the project.



www.hydrosol3d.org

Hydrogen Production Storage and Distribution

Expected socio and economic impact

HYDROSOL-3D responds to the necessity of developing hydrogen production processes from carbon-free sources by 2015 and the need to demonstrate the technical and economical feasibility of thermochemical decomposition of water as a potential pathway for this goal. The Project aimed at improving the technical and economic industrial-size feasibility of such processes by enhancing materials' performance, by introducing, designing and simulating real-sized components like solar reactors with enhanced efficiency and volumetric hydrogen productivity, by implementing and validating efficient solar process control strategies and schemes and by coupling of the above to hydrogen separation/purification technologies. HYDROSOL-3D aims to be the first demonstration of solar chemistry-based hydrogen production from water, with a future potential - when employed in combination with concentrated solar thermal power plants - to achieve a hydrogen cost competitive to that of non-sustainable, CO₂-emitting, hydrogen production.

Project Information

Project reference: FCH JU

Call for proposals: 2008

Application Area: SP1-JTI-FCH.2:

Hydrogen Production & Distribution
Project type: Research and Technological Development
Topic: SP1-JTI-FCH.2.3 Water decomposition with solar heat sources

Contract type: Collaborative Project

Start date: 01/01/2010

End date: 31/12/2012

Duration: 36 months

Project total costs: € 1,729,083.40

Project funding: € 984,374.80

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HyTIME

Low temperature hydrogen production from 2nd generation biomass

Key Objectives

The overall objective of 'HyTIME' is to accelerate the implementation of an industrial bioprocess for decentral hydrogen production systems using 2nd generation biomass.

The target of this project is to construct a prototype process based on the fermentation of biomass for delivering 1-10 kg hydrogen/d and to develop a biohydrogen production system as a stepping stone to pre-commercial applications.

The objective of HyTIME is to expand the unique strategy of thermophilic dark fermentation and to add an alternative approach in combining the thermophilic dark fermentation with anaerobic digestion. HyTIME builds on previous results with a focus on thermophilic fermentation to accelerate a breakthrough of fermentative hydrogen production from 2nd generation biomass including waste biomass.

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.

Challenges addressed

- Optimal utilization of 2nd generation biomass from sustainable biomass supply chains (grass, straw, residues from food-industry) in tailor-made pretreatment procedures
- developing large scale high rate bioreactors for increased H₂ productivity at low nutrient cost
- combining high yield in H₂ fermentation with increased quality of biogas from anaerobic digestion
- stimulating production by recovering dissolved H₂ from the liquid phase
- optimizing the unit-operations for upgrading H₂ at small scale, low pressure and low temperature including the development of a process for monitoring and control devices
- heat and energy integration for increasing the overall energy efficiency
- providing the design for a pre-commercial H₂ production plant to enable medium term market implementation.

Technical approach and achievements

The 9 participants, coming from small and large industries, universities and a research institutes are spread over HyTIME and addresses the entire value chain from biomass logistics and pretreatment, thermophilic hydrogen production and gas upgrading technologies. The integration of all these components of the hydrogen production system is done in order to bring progress to HyTIME beyond the state-of-the-art of current fermentative hydrogen production.

More specifically: for the production of biomass, road side grass, straw and over-date residues from supermarkets will be studied in terms of availability and suitability. Pretreatment and hydrolysis for mobilisation of sugars will be optimized by developing procedures to decrease energy demand, use of chemicals and enzymes, formation of inhibitors, and to increase fermentability, keepability etc. The hydrolysates will be tested for thermophilic fermentation and adjusted with required nutrients for optimum yield. The increase in productivity (kg H₂/ time) will be addressed by increasing the concentration of the bacteria through immobilization on carriers or by making bacterial flocs. The approach will be using designed co-cultures of Caldicellulosiruptor species and bacteria from the Thermotogales order in dedicated bioreactors based on a combination of a moving bed and trickle bed system. For the removal and capture of hydrogen, the strategy is twofold: upgrading hydrogen in the gas phase by Pressure Swing Adsorption or the application of a membrane contactor combining specific absorption and separation. Besides, hydrogen in the liquid phase will be removed by a membrane unit in an internal loop connected to the bioreactor. To guarantee proper process control and operation and, eventually, automation, dedicated measurement devices will be developed which will allow continuous detection of hydrogen or contaminants like H₂S. Finally, the effluent of the hydrogen bioreactor will be tested for methane production in an innovative continuous anaerobic membrane reactor operating at thermophilic conditions.



www.hy-time.eu

Hydrogen Production Storage and Distribution

All mass and energy balances and basic engineering data of the separate process units will be integrated and used for modelling and simulation studies to design a hydrogen production unit with maximum product output, minimum energy demand and low cost.

Expected socio and economic impact

In the EU, 118-138 million tons of bio-waste (garden waste, food and kitchen waste and waste from food processing plants) is currently produced on a yearly basis. This bio-waste could be used for methane production with a theoretical production of 2 million ton of methane. Using the same assumptions, the theoretical hydrogen production would be 0.34 million ton hydrogen with additional 1.3 million ton methane when using the technology of HyTIME. If only half of the theoretical amount of hydrogen would be produced, a production 20 PJoule/year would be the result. This would increase because of the 10% increase in bio-waste production foreseen in the EU and because the technology will grow from its infancy to full maturity after 10 years following the start of HyTIME. The impact for the EU is twofold: a significant contribution to the triple 20% by 2020' objective with green hydrogen and a contribution to improved bio-waste management.

Project Information

Project reference: FCH JU

Call for proposals: 2011

Application Area: Hydrogen production and storage

Project type: RTD

Topic: SP1-JTI-FCH.2012.2.4. Low temperature hydrogen production

Contract type: Collaborative project

Start date: 01/01/2012

End date: 01/01/2015

Duration: 36 months

Project total costs: € 2.923.818.40

Project funding: € 1.609.026.00

Project Coordinator

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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

Key Objectives

The ambition of HyUnder is to develop a European Implementation Plan, based on a detailed assessment of six individual Case Studies of the hydrogen utilization options and salt cavern storage potential across Europe. The main actions to be developed in each case study will be: regional storage prototype location analysis, economic scenario type assessment and the introduction of hydrogen underground storage into different markets. A comparative assessment of the individual case studies is expected as an outcome at the end of the project.

Technical approach and achievements

In the administrative and communication side, the kick-off meeting and the Initial Conference of HyUnder project were held during first months of the project. A website has been created to promote the project progresses.

On the scientific and technological side:

- A Methodology Approach for the Case Studies has been developed. This methodology will be the base to evaluate the different case studies of each region (Germany, Spain, UK, France, Romania and Netherlands);
- The toolkits to provide inputs for the case study development (WP2, WP3, WP4 and WP5) are in progress).

Summary/overview

Interest in the use of hydrogen as a universal energy carrier and storage medium has been growing in recent years. This is based on the insight that our energy future, which will require the integration of increasing amounts of renewable electricity generation, chemical methods offer one of the most promising options for storing large amount of energy.

In general, the project has seven major milestones:

- M1 for the setup of a Document Management System that is common for all partners;
- M2 for the development of a joint Communication Strategy at the beginning of the project,
- M3 for the development of a joint Case Study methodology;
- M4 for the development of a German Case Study serving as benchmark and providing the most detailed insights available now;
- M5 to compile basic knowledge on hydrogen energy storage;
- M6 for the development of the other Case Studies and for comparison of the individual Case Studies with each other;
- M7 for the development of a European Hydrogen Underground Storage Implementation Plan all reviewed by an external supporting partner group.

The sequence of work follows a set of work packages. WP2 to WP5 are required to provide the fundamental knowledge to carry out the detailed Case Studies (WP6), a feasibility study on the possible integration of hydrogen in each energy market is expected as an outcome of the Case Studies. The final result will be the European Hydrogen Underground Storage Implementation Plan which will top the comparison of results from the individual Case Studies. The following individual work packages are foreseen:

- WP1. Project coordination and administration
- WP2. Benchmarking of large scale hydrogen underground storage
- WP3. Assessment of geologic options for hydrogen underground storage
- WP4. Geologic mapping of European regions for underground storage of hydrogen
- WP5. Plant technologies
- WP6. Representative Case Studies with a focus on salt caverns storage
- WP7. Dissemination to improve stakeholder awareness
- WP8. Major conclusions.

Expected socio and economic impact

The Implementation Plan will be a concrete action plan to develop and move hydrogen storage from the current development phase through the demonstration and finally the deployment phase.

The expected impact of HyUnder project comprises of the following elements:

- Understand the feasibility, relevance, timelines, chances and limitations of H₂ underground storage to facilitate renewable electricity in Europe;
- Understand the different regional potentials, roles in energy systems and the commitment of H₂ underground storage;
- Understand the European Scope of H₂ underground storage;
- Understand the necessary next steps, including the financing needs and required policy measures of H₂ underground storage towards commercialization.

Project Information

Project reference: FCH JU 303417

Call for proposals: 2011

Application Area: AA5

Project type: Support Action

Topic: SP1-JTI-FCH.2011.5.1:
Assessment of benefits of H₂ for energy storage and integration in energy markets

Contract type: Coordination and Support Action

Start date: 18 June 2012

End date: ongoing (18 June 2014)

Duration: 24 months

Project cost: € 1,766,516

Project funding: € 1,193,273

Project Coordinator

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DEEP Underground Technologies (DEEP)
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E.ON Gas Storage (EGS)
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Centre of Excellence for Low Carbon and Fuel Cell Technologies (CENEX)
UK

Solvay Chemicals (Solvay)
Germany

Commissariat à l'énergie atomique et aux énergies alternatives (CEA)
France

IDEALHY

Integrated Design for Efficient Advanced Liquefaction of Hydrogen

Key Objectives

IDEALHY aims to develop a generic process and plan for the demonstration of efficient hydrogen liquefaction of up to 200 tons per day, whereby energy consumption is reduced by 50% compared to existing plants. The design is based on components that can be manufactured today and additionally, a proposal for a near future demonstration plant will be made.

Moreover, the process and the liquid hydrogen pathway will be compared to alternatives on greenhouse gas emissions, energy use and HSE implications.

Challenges addressed

A review of eight existing liquefaction plants and a similar number of literature concepts has been carried out, comparing these on the same basis and boundary conditions. From the best concepts, with the expertise on cycles and components in the consortium, a single liquefaction concept was derived and is being optimised. Discussions with equipment manufacturers indicate that the IDEALHY efficiency target is achievable considering the available equipment. In addition, lifecycle and HSE analyses have started to compare the liquid hydrogen chain with alternatives like compressed hydrogen. These show that further work is needed before the introduction of liquid hydrogen at scale.

Technical approach and achievements

High energy consumption is the main blocker for a liquid hydrogen infrastructure. Removing this would enable the following to happen:

- An increased amount of hydrogen can be transported by a truck, reducing the number of trucks on the road,
- The possibility of larger hydrogen retail stations (>500 kg/d) because of the reduced truck deliveries,
- The transport of energy over long distances via ship and rail, enabling remote energy resources (wind, solar and stranded fossil resources) to be used and thus increasing the security of energy supply.

Summary/overview

Hydrogen is expected to be an important future clean transport fuel. In the absence of a pipeline network, liquid hydrogen is the most effective way to supply larger refuelling stations. Without developing liquefaction capacity, it may be impossible to operate hydrogen stations of the same size as current liquid fuel stations.

However, liquefaction of hydrogen is expensive and energy intensive today. IDEALHY brings together world experts to develop a generic process design and plan for a large-scale demonstration of efficient hydrogen liquefaction.

The principal objectives are to:

- Reduce the specific energy consumption of hydrogen liquefaction by optimising an improved generic process design
- Prepare a strategic plan for demonstration of efficient hydrogen liquefaction at a scale of up to 200 tonnes per day.

The project will carry out a detailed investigation of different steps in the liquefaction process, bringing innovations and greater integration in an effort to reduce specific energy consumption by 50% compared to existing plants. The partners in IDEALHY believe this can be achieved by:

- Increasing plant scale
- More efficient process design
- Using more efficient components.

Furthermore, efficiency improvements are possible by integrating liquefaction with other processes such as LNG re-gasification.

IDEALHY will also perform a well-to-end-user analysis of liquid hydrogen in the energy chain, comparing it with appropriate fossil and renewable alternatives. This will include techno-economic analyses and emissions calculations and will be combined with an assessment of safety and risk mitigation.

Finally, the project will develop a proposal for a demonstration of the IDEALHY liquefaction technology in a subsequent phase. The strategic plan for a large scale demonstration will be based on the commercial partners' plans for supplying hydrogen for fuelling and will include options for location of the planned demo, with a consideration of available hydrogen supplies and nearby customer markets.

An overview of the IDEALHY project was published in "International Innovation, December 2012" by Research Media Ltd, pages 34-36.

Project Information

Project reference: FCH JU 123456

Call for proposals: 2010

Application Area: AA2

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.2.5: Preparation of demonstration of efficient large-scale hydrogen liquefaction

Contract type: Collaborative project

Start date: 01 November 2011

End date: 21 October 2013

Duration: 24 months

Project cost: € 2.5 million

Project funding: € 1.3 million

Project Coordinator

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(not part of Grant Agreement)
Japan



NEMESIS2+

New Method for Superior Integrated Hydrogen Generation System 2+

Key Objectives

The objective of this project is an on-site hydrogen production at refuelling stations from diesel and biodiesel. The NEMESIS2+ consortium aims to develop a pre-commercial, small-scale hydrogen generator capable of producing 50 Nm³ of hydrogen per hour from diesel and biodiesel. By applying pressurized steam reforming, using a "one-reformer"-concept and focusing on liquid fuels only, hydrogen production costs of < 4 Euro per kg are targeted.

Challenges addressed

A review of eight existing liquefaction plants and a similar number of literature concepts has been carried out, comparing these on the same basis and boundary conditions. From the best concepts, with the expertise on cycles and components in the consortium, a single liquefaction concept was derived and is being optimised. Discussions with equipment manufacturers indicate that the IDEALHY efficiency target is achievable considering the available equipment. In addition, lifecycle and HSE analyses have started to compare the liquid hydrogen chain with alternatives like compressed hydrogen. These show that further work is needed before the introduction of liquid hydrogen at scale.

Summary/overview

Currently, large-scale methane steam reforming is the prevailing technology for hydrogen production. In the transition towards a sustainable hydrogen economy with a fully functional infrastructure, decentralized hydrogen production at refuelling stations will accelerate the market introduction of hydrogen-powered vehicles. On-site hydrogen production at refuelling stations is economically reasonable, especially in areas where hydrogen cannot be supplied by a central production plant in a cost-efficient manner. Such technology has not yet been developed as a commercially available product fulfilling the requirements of the market in terms of cost and efficiency. The FCH JU Annual Implementation plan 2010, in which it is stated that the market introduction of hydrogen powered cars is expected within the next few years, envisions a market share between 10 and 20 % of sustainably produced hydrogen in 2015.

The NEMESIS 2+ consortium will contribute towards reaching this target by developing a pre-commercial and sustainable on-site hydrogen generator system capable of producing 50 Nm³/h H₂ from diesel and biodiesel (FAME).

Technical approach and achievements

High energy consumption is the main blocker for a liquid hydrogen infrastructure. Removing this would enable the following to happen:

- An increased amount of hydrogen can be transported by a truck, reducing the number of trucks on the road,
- The possibility of larger hydrogen retail stations (>500 kg/d) because of the reduced truck deliveries,
- The transport of energy over long distances via ship and rail, enabling remote energy resources (wind, solar and stranded fossil resources) to be used and thus increasing the security of energy supply.

Project Information

Project reference: FCH JU (GA 278138)

Call for proposals: 2010

Application Area: SP1-JTI-FCH.2
"Hydrogen Production & Distribution"

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.2.2
"Development of fuel processing catalysts, modules and systems"

Contract type: Collaborative project

Start date: 01 January 2012

End date: 31 December 2014

Duration: 36 months

Project cost: € 3.393.062 million

Project funding: € 1.614.944 million

Project Coordinator

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NEXPEL

Next Generation PEM Electrolyser for Sustainable Hydrogen Production

Key Objectives

The main objective of the NEXPEL project is a successful demonstration of an efficient proton exchange membrane (PEM) electrolyser integrated with Renewable Energy Sources. The NEXPEL project consist of a top class European consortium which is carefully balanced between leading R&D organizations and major industrial actors from 4 member states. The partners are devoted to developing new materials and stack design concepts to increase the efficiency and lifetime of PEM electrolysers and at the same time cutting costs. The three main goals for the NEXPEL project is to achieve

- Electrolyser efficiency greater than 75%
- A stack life time of 40 000 h
- A reduction in system costs to € 5,000/Nm³ production capacity.

The consortium is confident that the dissemination and exploitation of the project will create considerable impact especially in terms of Europe's energy security, reducing greenhouse gas emission and increasing Europe's competitiveness.

Challenges addressed

Centralized and decentralized sustainable H₂ production using low temperature electrolyser technology requires further improvement in performance and reduction of costs. In this context, the PEM technology particularly adapted for applications in power levels up to 0.5 MW will be considered, with a strong focus on technology improvements to make the technology fit for integration with renewable energies for electricity/ H₂ generation.

Technical approach and achievements

NEXPEL will **develop and demonstrate novel components** that are essential for cost-competitive, high-efficiency PEM electrolysis systems through five key concepts:

- lower capital costs of the main stack components; membrane, electrodes and bipolar plates / current collectors
- higher performance, in particular of the membrane electrode assembly (MEA)
- longer life time of the most crucial PEM components,
- highly efficient advanced power electronics
- novel stack design for high pressure operation and low assembly costs.

Stack design simplification and cost reduction through the use of more cost effective materials is vital to lowering capital costs. Apart from lowering the catalyst loading, a further concept to reduce the system cost down to €5,000/Nm³h⁻¹ is the use of less expensive polymers for membranes and alternative materials for current collectors, bipolar plates and end plates



Statoils Energy Park at Herøya, Porsgrunn, Norway. The energy park consists of two 6 kW wind turbines and two 2.1kW solar panels and is equipped with a 70 kWh lead acid battery storage system, and water electrolysers from NEL Hydrogen (Earlier Hydrogen Technologies).

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Expected socio and economic impact

The results obtained so far in NEXPEL are promising and demonstrate a high probability for achieving improved performance and reduced cost of PEM water electrolyzers. The main expected outcomes from the technological developments are:

- A new generation of polyaromatic membranes for PEM electrolyzers with a significant enhancement in membrane lifetime and cost.
- New oxygen evolution catalysts with significant improvement in catalytic activity and potential for noble metal thrifting.
- Novel stack design, reducing construction material costs and easing assembly.

In addition, performed market analyses of the utilization of PEM electrolyzers in different application areas (micro wind & PV for telecom, green H₂ stations and large scale H₂ production from renewable energy sources), will give a better understanding of the role of PEM electrolyzers in a future hydrogen economy.

Project Information

Project reference: FCH JU 245262

Call for proposals: FCH-JU-2008-1

Application Area: SP1-JTI-FCH-2.1:

Efficient PEM electrolyzers

Project type: RTD

Topic: SP1-JTI-FCH-2.1:

Efficient PEM electrolyzers

Contract type: Collaborative Project

Start date: 01/01/2010

End date: 31/12/2012

Duration: 36 months

Project total costs: € 3 353 549

Project funding: € 1 256 286

Project Coordinator

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PrimoLyzer

Pressurised PEM Electrolyzer stack

Key Objectives

The primary objective of PrimoLyzer is to develop, construct, and test a cost-minimised highly efficient and durable PEM-electrolyser stack with a hydrogen production capacity of 1 Nm³/h aimed for integrated with domestic μ CHPs. The objectives will be reached through a combination of the following activities:

1. Specification done by the end-user [Abengoa Hidrógeno]
 2. Basic material R&D on catalyst & membrane to increase durability & efficiency while reducing cost [FumaTech, VTT & Åbo Academy]
 3. Process development to fabricate high performance MEAs [ECN & IRD]
 4. Engineering of a durable, reliable, and robust high pressure stack [IRD & ECN]
 5. Continuous test for 2,000 hours together with a 1.5 kW μ CHP [IRD]
 6. An evaluation headed by the end-user(s) [Abengoa Hidrógeno, FumaTech & IRD]
- PrimoLyzer is phase I in a two-step development, where phase II will comprise full integration of the electrolyser with a μ CHP followed by a field test.

Challenges addressed

Stationary μ CHPs based on fuel cells are in demonstration all over the world. Almost all these systems are fed with reformed fossil fuel like natural gas. The FC-based μ CHPs are more efficient than the technologies they replace, resulting in a substantial reduction in the CO₂ emission, calculated to be \approx 1 tons CO₂/year/'single family house' when fuelled with natural gas. However, the emission reduction is *five times higher* when the μ CHPs are fuelled with hydrogen produced with excess renewable energy e.g. wind power or photovoltaics. Hydrogen production by electrolysis of water is presently associated with substantial energy losses. Furthermore, small electrolysers are prohibitively expensive while larger electrolysers with a relative smaller plant investment cost require additional hydrogen distribution grids. The primary objective of the PrimoLyzer project is to develop, construct, and test a cost-minimised highly efficient and durable PEM-electrolyser stack aimed for integration with domestic μ CHPs.

Technical approach and achievements

The PrimoLyzer key-targets are as follows:

- A) Stack capacity: 1 Nm³ H₂/h
- B) PH₂: 10 MPa
- C) U_{cell} @ BoL: 1.62 V @ 1.2 A/cm²
- D) Δ U_{cell}: <30 μ V/h
- E) Stack cost: <5,000€ in series production.

Furthermore, the stack will be liquid cooled to enhance durability and enable easy heat utilisation. This is important as a PEM electrolyser operated with renewable will run when the electricity is cheap and therefore not simultaneous with the μ CHP. The project is scheduled to last 2.5 years. The technical work is divided into six (6) Work Packages. Nineteen (19) deliverables and ten (10) milestones are defined for the project to facilitate the completion of the ambitious project targets and to enable an easy monitoring of the project progress.

The best performing MEAs are equipped with a VTT OER catalyst consisting of mixed Ir-Ru and a Fumatech PSFA-type membrane. The single cell IR-corrected polarisations of the optimised MEAs show a better performance than the project target [1.64 V @ 1.2 A/cm²] for MEAs with less than the targeted catalyst loadings [actual Anode/Cathode loading: 0.3/0.5 mg per cm²; target: Anode/Cathode loading: 1.0/0.5 mg per cm²]. The observed degradation rate is <30 μ V/h. A high-pressure stack was designed in accordance with the standard: IEC 62282-2(2005-3) FC technologies-Part 2 and successfully verified. The cost of one stack with a production capacity of 1 Nm³/h hydrogen is less than 5,000 € in production of 100 units, as targeted.



www.PrimoLyzer.ird.dk

Hydrogen Production Storage and Distribution

Expected socio and economic impact

The overall aim of PrimoLyzer is to develop a high efficiency electrolyser stack based on PEM technology. The project started with an analysis of solar and wind power followed by a specification to ensure that the stack can be integrated with Renewable Energy Sources. Experiences from this project will contribute to solving the future challenges in grid operation with balancing issues due to higher degree of distributed generation in the grid, high level of renewable energy based on wind/solar power in the grid, and the need for fast response in the activation of the distributed generation for grid balancing. The planned activities include a 2,000 hours prototype testing together with hydrogen fuelled dead-end μ CHP system. The PrimoLyzer project will assist the European Union to reach their short- to medium term target on sustainable hydrogen production and supply chains demonstrated and ready for commercialisation by 2013.

Project Information

Project reference: FCH JU 245228

Call for proposals: year 2009

Application Area:

Project type: Basic Research; Research and Technological Development

Topic: SP1-JTI-FCH.2.1: Efficient PEM Electrolyzers & SP1-JTI-FCH.3.2 Component and system improvement for stationary applications

Contract type: Collaborative Project, Small or medium-scale focused research project

Start date: 01/01/2010

End date: 30/06/2012

Duration: 30 months

Project total costs: € 2,615,270

Project funding: € 1,154,023

Project Coordinator

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RESelyser

Hydrogen From RES: Pressurised Alkaline Electrolyser with High Efficiency and Wide Operating Range

Key Objectives

The project RESelyser develops high pressure, highly efficient, low cost alkaline water electrolysers that can be integrated with renewable energy power sources (RES) using an advanced membrane concept, highly efficient electrodes and a new cell design. The project is set to develop a prototype of an improved electrolyser, wherein high efficiency and low system costs will be demonstrated. Additionally, the stability of this efficiency during long term operation in on/off cycles will be demonstrated with an extrapolation to a lifetime of 10 years.

Challenges addressed

First steps towards an alkaline water electrolyser that is better adapted to highly fluctuating current supply when connected to RES were taken. Membranes for a new concept were developed, electrodes for higher efficiency were demonstrated and a new cell design is now available.

“E-bypass separator” diaphragms with internal electrolyte bypass and properties for maximum benefit of the cell were developed with a total thickness (including the internal electrolyte channel) between 1.4 and 3.4 mm at the size of a 300 cm² electrolyser. A cell concept was also realised. Electrode coatings were demonstrated which wound up reducing the overpotential of a nickel electrode.

Technical approach and achievements

The outcome of this project will be an electrolyser that suits the requirements of operation with significantly varying loads in order to help the integration of renewable energy sources in the electrical power grid in Europe. A major market for this product is expected in the next years. Hydrogenics already produces and sells alkaline water electrolysers that are also operated when coupled to RES. However an improvement in costs, partial load operation, efficiency and life time will substantially increase the market possibilities.

Summary/overview

Alkaline water electrolysis for hydrogen production is a technique that is well established with electrolysers of a wide power range now commercially available. Hydrogen production by electrolysis is increasingly studied as a way to smooth out the fluctuating power output of renewable energy sources not correlating with the electrical energy demand. However for this purpose, present electrolysers have to be improved for fluctuating power operation and the system costs have to be decreased to reach a low cost energy conversion.

To address these challenges in the project, RESelyser has a new separator membrane with internal electrolyte circulation (“E-bypass separator”) and an adapted design of the cell to improve mass transfer, especially gas evacuation, is investigated and demonstrated.

Intermittent and varying load operation with RES is addressed by improved electrode stability and a cell concept for increasing the gas purity of hydrogen and oxygen, especially at low power operation as well as for very high pressure. Also, the system architecture is optimized for the intermittent operation of the electrolyser. To date "E-bypass separator" diaphragms with internal electrolyte bypass and properties for maximum benefit of the cell were developed with a total thickness (including the internal electrolyte channel) between 1.4 and 3.4 mm at the size of a 300 cm² electrolyser. A cell concept was realised and electrode coatings were demonstrated, reducing the overpotential of a nickel electrode by 210 mV for the cathode and 161 mV for the anode, thus increasing the efficiency. A stability of this efficiency during long term operation in on/off cycles, as needed when operated with RES, will be demonstrated with an extrapolation to a lifetime of 10 years. At the same time, low costs for the system are the target: System costs of 3.000 €/Nm³/h plant capacity for the complete system.

Project Information

Project reference: FCH JU 278732

Call for proposals: 2010

Application Area: Hydrogen Production & Distribution

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.2.1 Efficient alkaline electrolysers

Contract type: Collaborative project

Start date: 01 November 2011

End date: 31 October 2014

Duration: 36 months

Project cost: € 2.89 million

Project funding: € 1.48 million

Project Coordinator

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Denmark

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Cross section (left and middle) and top view of the E-bypass separator membrane for a 300 cm² electrolyser

SSH₂S

Fuel Cell Coupled Solid State Hydrogen Storage Tank

Key Objectives

In accordance with the requirements of the call, the main objective of SSH₂S is to develop a solid state hydrogen storage tank fully integrated with a fuel cell and to demonstrate its application on a real system. A well assessed hydrogen storage material (i.e. a mixed lithium amide/magnesium hydride system) will be considered as the active material for the tank. A new class of material for hydrogen storage (i.e. mixed borohydrides) will be also explored. The application of the hydrogen tank on a real system will be experimentally investigated with a 1 kW prototype on High Temperature Polymer Electrolyte Membrane (HTPEM) fuel cells. On the basis of the results obtained for the prototype system, an ON/OFF milestone will be considered. If suitable performances are obtained, a scale-up of the tank will be applied to a 5 kW APU. The overall aim is clearly to demonstrate the applicability of the proposed integrated system in real situations, also on the basis of a critical techno-economic evaluation.

Challenges addressed

Hydrogen storage for automotive is currently achieved by means of high pressure (about 700 atm) compressed gas. This approach has several efficiency and safety limitations, so that alternatives are necessary. Solid state hydrogen storage has already been demonstrated as suitable for stationary applications, but it requires further scientific and technological improvements for use with mobile applications. The key challenge addressed by the project is the integration of a solid state hydrogen storage tank with a HT-PEM fuel cell. This system will act as an Auxiliary Power Unit (APU) to be installed in a Light Transport Vehicle (LTV). This will require the development of new materials with high gravimetric and volumetric energy density and with technically relevant (i.e. close to ambient) sorption temperature and pressure. The loading time and the stability after several cycles will be crucial parameters with which to test the performances of the integrated system. Finally, low cost should also be obtained.

Technical approach and achievements

At the beginning of the project, the design and the synthesis, as well as the physico-chemical characterization, of existing and novel materials for solid state hydrogen storage will be undertaken. Ab-initio and thermodynamic calculations will determine the selection of materials. In fact, the materials selected should be characterized by improved capacity and efficiency, in terms of thermodynamic and kinetic properties, resistance to cycling and thermal behaviour. The synthesis of materials will be performed by ball milling. The characterisation will be performed by a combination of structural and spectroscopic experimental techniques. Two fluid-dynamic modelling of different tank concepts, as well as the experimental validation of the models in a lab-scale tank will be addressed as well as the development of a prototype tank optimized for use with the selected materials. The project and the development of the prototype tank will be undertaken by industrial partners. The results will be used to integrate the materials/tank systems with a low power HT-PEM Fuel Cell (1 kW_{el}). To this end, on the basis of the properties and simulation results obtained, a suitable material composition will be defined for a scale-up production. The final goal of the project is application of the integrated system as a 5 kW_{el} APU to be installed in a LTV. The decision about possible scale-up will be taken after a critical techno-economic evaluation.



www.ssh2s.eu

Hydrogen Production Storage and Distribution

Expected socio and economic impact

A 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 has never been developed in previous European Projects. Moreover, new concepts on the design and the coupling of solid state hydrogen tank with HT-PEM fuel cells will represent a significant achievement by the project. Finally, the development of a prototype 1 kW integrated system and the possible application to a 5 kW APU are real advances in the field. The results of the project may be of significant economic impact for large industries, as well as for SMEs' industrial partners. The possibility of coupling the HTPEM with a compact and safe hydrogen storage system will greatly increase business opportunities for SER and TD partners. The availability of safe hydrogen tanks at low pressures is expected to contribute to the social acceptance of hydrogen technologies.

Project Information

Project reference: FCH JU (GA n. 256653)

Call for proposals: 2009

Application Area: Hydrogen production and storage

Project type: Research and Development

Topic: SP1-JTI-FCH.2009.2.4: Improved solid state H₂ storage systems

Contract type: Collaborative Project

Start date: 01/02/2011

End date: 01/08/2014

Duration: 42 months

Project total costs: € 3 501 749,00

Project funding: € 1 595 685,00

Project Coordinator

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Serenergy A/S (SER)
Denmark

Centro Ricerche Fiat (CRF)
Italy

Joint Research Centre of European
Commission (JRC)
Belgium

ASSENT

Anode Sub-System Development & Optimisation for SOFC systems

Key Objectives

The objective of this project is 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. To find optimal anode subsystems to be validated, conceptual analysis and evaluation of the feasibility of the different recycle solutions for the anode subsystem will be carried out. In addition, sensing techniques are tested, evaluated, and also developed, where available techniques are not sufficient. Optimum components should be viable for mass production.

Challenges addressed

Whilst much effort and resources are devoted to cell and stack issues, less attention has been paid to the balance of plant, or components and sub-systems required for an operational system. Components and sub-systems such as fuel processing, heat and thermal management, humidification, fluid supply and management, and power electronics are as fundamental to successful commercialisation of fuel cell systems as the cell and stack. This is the main reason and basic idea which lead our consortium to propose this work. In this proposal the development work specifically addresses SOFC technology but some of the results might also support development of MCFC technology.

Technical approach and achievements

The focus of this project is on evaluating different process approaches for fuel and water management in the case of natural gas and biogas. Possible process approaches include e.g. fuel and recirculation management with a recycle blower-based approach and/or an ejector-based approach, and water circulation with condensing from the anode off-gas/exhaust gas and evaporating back to loop. Relevant process options are first evaluated on conceptual level and the results are used as a basis for detailed feasibility evaluation. The aspects taken into account in the conceptual analysis are effects on electric efficiency and process simplicity implying easiness of controllability, and requirements on diagnostics accuracy to provide insights into failure mode prevention. In detailed evaluation, the suitable approaches are analysed more thoroughly in terms of component availability and reliability, achievable diagnostics accuracy, controllability, effects on reformer, mechanical integration feasibility to whole system, safety control, failure mode prevention, cost effects etc.



<http://assent.vtt.fi/>

Stationary power production and CHP

Expected socio and economic impact

SOFC technology is immature, but is seen as having more potential than other fuel cell technologies both in terms of applications and efficiencies and costs. Based on lower cost ceramic materials SOFC technologies are believed to have the greatest potential in becoming cost competitive with incumbent technologies. High electrical and CHP efficiencies will directly impact fuel supplies, whilst low or negligible NOx and SOx emissions and no particulate matter will contribute to cleaner air. SOFC units can therefore improve fuel security, sustainability, competitiveness, efficiency and flexibility, and lower carbon emissions that will contribute to meeting the objectives of Europe's Energy Policy. Looking into the future the fuel flexibility of SOFC systems will allow units to transition from the common hydro-carbon fuels of today through to future potential fuels such as bio-fuels and hydrogen. The focus will be on technologies for SOFC units with the potential for costs less than 1500-2000 €/kW or 3000-4000 €/kW for large- and small-scale applications respectively, have 40 000 - 60 000 hours durability and efficiencies of 45-60% in power generation mode and 80% + for CHP mode.

Project Information

Project reference: FCH JU

Call for proposals: 2008

Application Area: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP-JTI-FCH.3.2: Component and system improvement for stationary applications

Contract type: Collaborative Project

Start date: 1/1/2010

End date: 31/12/2012

Duration: 36 months

Project total costs: € 4 854 760

Project funding: € 1 954 675

Project Coordinator

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Chief Research Scientist

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Finland

Hexis AG
Switzerland

Forschungszentrum Jülich GmbH
Germany

ASTERIX III

Assessment of SOFC CHP systems build on the Technology of htceRamIX 3

Key Objectives

The main objectives of this project are to further develop a micro combined heat and power (μ CHP) system based on solid oxide fuel cells (SOFC). The important parameters to be in focus are lifetime, reliability and robustness. This will include tolerance to thermal cycling and improving quality of the individual components of the system and an integrated automated control system. Also the system efficiency both thermal and electrical will be increased. Achieving these objectives will enable us to demonstrate a residential μ CHP concept fulfilling market requirements, and we can start working on the next step towards commercialization; validation of fuel cell system readiness, field trials and preparation for large scale production.

Challenges addressed

The residential μ CHP system based on SOFC technology has the potential to produce both heat and power in a very efficient way. The heat and power is produced in the private home where used and hence, transmission loss can be neglected. The units are fueled by natural gas. The high efficiency of the fuel cell will secure, that the μ CHP system will reduce the CO₂ food print of the family installing the μ CHP. The challenges of the project are to develop the μ CHP SOFC fuel cell technology to achieve proof-of-concept in order to make the technology ready for demonstration in residential environments. The important issues addressed in the project are:

- Lifetime of fuel cell stack
- Electrical and thermal efficiency
- Cost reduction
- Integration in residential environment

Technical approach and achievements

System simulations will be used to explore key Fuel cell system parameters and suggest optimized system dimensions. This will be used in the design of two generations of the Proof of Concept system. Subsequently the project focuses on the optimization of the system components such as the SOFC subsystem, the heating system and the inverter. The SOFC system will further be engineered and optimized with an emphasis on the stack, the heat exchanger, the post-combustion and the insulation. Individual components will be improved with a constant attention on their assembly. Increased stack and system performances, wider operating range, and more robustness are aimed for the SOFC subsystem. For the heating system, besides improvements on the heat storage and the inverters, a significant innovation will be aimed with the integration of a heat pump as an auxiliary heater for the micro CHP system instead of an auxiliary burner.

Ultimately, the objective is to test and validate the Asterix3 micro-CHP appliance. As a first step an experimental program will be established to test the system in various conditions. The test program will be defined with respect to the testing procedures drafted in the upcoming international standard IEC 62282-3-2 (test methods for stationary



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www.asterix3.eu

Stationary power production and CHP

fuel cell systems), which is currently under development. The testing conditions will be established to demonstrate extended continuous operation, thermal cycling, and normal and emergency shutdown conditions.

The objectives are to reach costs slightly higher than a normal condensing boiler and an electrical efficiency that is higher than to days typical large power plant.

Expected socio and economic impact

The project takes a vital step towards the commercialization of the SOFC power systems for application in private homes. The switch from traditional gas boilers to SOFC μ CHP systems will heighten the efficiency and promote decentralizing of power production. SOFC μ CHP power systems can provide energy security and independency of nuclear and large coal fired power plants. The high efficiency of the SOFC CHP systems provide once reasonably priced, a massive incentive for switching from conventional centralized power generation to decentralized heat/cooling and power production. This will lead to reduction of distribution losses and thus lower CO₂ emissions.

Project Information

Project reference: FCH JU

Call for proposals: 2009

Application Area: Research and Technology Development

Topic: R&D to achieve proof-of-concept of μ CHP fuel cell system

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 3.096.000

Project funding: € 1.361.000

Project Coordinator

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CNR-ITAE
Italy

CATION

Cathode Subsystem Development and Optimisation

Key Objectives

This project would bring improvements to the current state-of-the-art cathode side subsystem, thermal and fluid supply management of SOFC systems and may lead into the novel design solutions and optimized subsystems which will significantly increase SOFC system efficiency, reliability, controllability and lifetime, and will decrease overall cost. With this novel cathode subsystem solution the new stationary 250 kWe SOFC system should reach 55% electrical efficiency, and achieve 40000 hours of lifetime with over 90% availability. The optimization of SOFC cathode subsystem also leads into significant reduction of piping and supporting structures. With layout-wise optimized components and structural and insulation solutions, major benefits can be achieved in compactness and weight of the unit and in cost of piping and supporting structures.

Challenges addressed

Whilst much effort and resources are devoted to cell and stack degradation issues, less attention has been paid to the balance of plant, or components and sub-systems required for an operational system. Cathode side subsystem including stacks and system components such as high temperature heat exchangers, burners and blowers etc. can be significant factors decreasing the electric efficiency of the whole system. Relatively high mass flows and corresponding pressure drops together with non-optimal components, sub-system solutions and the overall system layout can decrease the total electrical efficiency many percent points, and may drop the cost-effectiveness of the whole system below commercial profitability. This can be one of the main barriers preventing commercialization of a final fuel cell system for stationary power production.

Technical approach and achievements

This project will give a thorough evaluation into alternatives for the SOFC system's cathode side subsystems (fluid and thermal management and mechanical solutions including stack/system interface) and one of them could be implemented into new ~250 kWe SOFC system demonstrations based on the development achieved in the proposed project. The optimization of SOFC cathode subsystem also leads into significant reduction of piping and supporting structures. With layout-wise optimized components and structural and insulation solutions, major benefits can be achieved in compactness and weight of the unit and in cost of piping and supporting structures. This project would bring improvements to the current state-of-the-art cathode side subsystem, thermal and fluid supply management of SOFC systems and may lead into the novel design solutions and optimized subsystems which will significantly increase SOFC system efficiency, reliability, controllability and lifetime, and will decrease overall cost. With this novel cathode subsystem solution the new 250 kWe SOFC system should reach 55% electrical efficiency, and achieve 40000 hours of lifetime with over 90% availability.



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<http://cation.vtt.fi/>

Stationary power production and CHP

Expected socio and economic impact

Even if the SOFC technology is immature compared to MCFC and PEM technologies, it can be clearly seen as having more potential than these other fuel cell technologies in terms of applications, efficiencies and cost. Based on lower cost ceramic materials SOFC technologies are believed to have the greatest potential in becoming cost competitive with conventional technologies. Thus SOFC solutions with efficiencies above 60% in power generation mode and 90% plus for CHP mode are possible for the medium to longer term. High electrical and CHP efficiencies will directly impact fuel supplies, whilst low or negligible NOx and SOx emissions and no particulate matter will contribute to cleaner air. SOFC units can therefore improve fuel security, sustainability, competitiveness, efficiency and flexibility, and lower carbon emissions. This will contribute to meeting the objectives of Europe's Energy Policy. Looking into the future the fuel flexibility of SOFC systems will allow units to move from the common hydro-carbon fuels of today, notably natural gas, through to future potential fuels such as hydrogen and biofuels.

Project Information

Project reference: FCH JU

Call for proposals: 2009

Application Area: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2009.3.4: Component and system improvement for stationary applications

Contract type: Collaborative Project

Start date: 1/1/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 7 194 680

Project funding: € 2 625 680

Project Coordinator

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Italy

CLEARgen Demo

The Integration and Demonstration of Large Stationary Fuel Cell Systems for Distributed Generation

Key Objectives

High Level Objectives:

- The development and construction of a large scale fuel cell system, developed and purpose-built for the European market.
- The validation of the technical and economic readiness of the fuel cell system at megawatt scale.
- The field demonstration and development of megawatt scale system at a European chemical production plant, running on by-product hydrogen.

Technical approach and achievements

The project has begun development to accommodate the on-site conditions and necessary implementation, however actual installation has not yet started.

Expected socio and economic impact

- To reduce the volume of flared or vented to atmosphere hydrogen by 246.4 tonnes per annum.
- Reduce carbon emission by offsetting fossil fuel generated grid electricity
- Reduce demand for centrally generated electricity.



1MWe ClearGen unit installed at Toyota, Los Angeles



Proposed installation in Kazincbarcika, Hungary

Expected socio and economic impact

- Demonstrate the deployment of a 1MW PEM Fuel Cell, developed and purpose-built for the European market, running on hydrogen generated as a surplus from a HyCo plant
- Conduct a waste hydrogen scheme and utilise it to generate no less than 7884 MW hours of electricity for use on the site or return to the grid
- The project will validate the technical and economic readiness of fuel cell systems at megawatt scale
- This project provides the site with a security of supply to the limit of the fuel cells capacity
- The electricity produced by a fuel cell is formed with a perfect sine wave

Project Information

Project reference: FCH JU 303458

Call for proposals: 2010

Application Area: Hungary

Project type: Demonstration

Topic: SP1-JTI-FCH.3.2: Component and system improvement for stationary Applications

Contract type: Collaborative project

Start date: 01 January 2010

End date: 31st December 2017

Duration: 36 months

Project cost: € 10.1 million

Project funding: € 4.6 million

Project Coordinator

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Linde Gas (To be confirmed)

Hungary

Budapest University of

Technology & Economics

Hungary

D-CODE

DC/DC COnverter-based Diagnostics for PEM systems

Key Objectives

The D-CODE project aims at developing an innovative diagnostic procedure to detect PEM fuel cell stack faults and support stack degradation level analysis. The stack electrochemical impedance spectrum (EIS) is used for on-line diagnosis during on-field operations. Thanks to both new DC/DC converter hardware and diagnosis algorithms, faults and potential failures associated with electrochemical processes, components faults (blower, power electronics, actuators) or having external origin (erroneous control, critical load) can be detected on-line while system runs.

Main Objectives:

- Innovative FC stack monitoring to change radically the concept of on-line diagnostic.
- EIS-based diagnosis-oriented DC/DC converter to be installed on low and high temperature fuel cell systems.
- Transpose EIS from lab scale to on-field for monitoring and diagnosis.
- Power stage and control strategy of a DC/DC converter to obtain the stack EIS on-board.
- A set of indicators from the spectrum to evaluate differences between the actual status and the nominal one.

Challenges addressed

The D-CODE main challenge is the on-line determination of the FCS state-of-the-health through the information provided by the impedance spectrum. Therefore, single information will guarantee a holistic analysis of the stack. To achieve this goal several technological issues are addressed, among others:

- Design and build an improved DC/DC converter; the new DC/DC hardware improves interface between power generators and load/grid.
- Implementation of power electronics controllers aimed at immunizing the stack from the load disturbance.
- Implement EIS functions on-board of the DC/DC converter.
- Develop EIS-based diagnostics for low and high temperature PEM fuel cells.
- Embed the EIS-based diagnostic tool in the electronic control unit.
- Derive FC degradation/diagnostic information while the system runs.
- Analysis of EIS to diagnose incipient failures caused by either faults or cell degradation.

Technical approach and achievements

The approach focuses on the experimental activity to characterise both low temperature (LT) and high temperature (HT) fuel cell systems and to test diagnostic hardware and related strategies. The hardware design and realization of the DC/DC power converter to perform EIS has to be achieved as well as the development of the algorithms for the diagnosis. Finally, the development of the management system is needed in order to drive the DC/DC converter for EIS purposes and to improve the FCS control strategies taking advantage of the information gathered from EIS-based diagnosis.

Expected socio and economic impact

Total performance during the life of a PEM system plays a very important role in the overall economics of the FC system. Therefore, the system needs to operate in such a way as to limit or prevent degradation and highly damaging failures. It is therefore very important for the commercialisation of PEM system to develop good diagnosis tools that can be used on board when diagnosing systems failures.

<http://www.d-code.unisa.it>
<https://dcode.eifer.uni-karlsruhe.de/>

Stationary power production and CHP

Diagnostics tools developed in D-CODE offer potential for instrumentation cost reduction, thus significantly reducing the required investment cost for PEM systems. Additionally, system on-demand servicing becomes possible by utilizing a diagnosis tool that monitors and predicts PEM system and stack failures. On-demand servicing can decrease the operation and maintenance costs of the PEM systems, as the components are serviced and replaced just prior to their end-of-life date. The lifetime of the PEM stacks can be increased by means of a diagnosis tool that identifies degrading operating conditions and provides information on a stable operating window for the PEM system. This will decrease O&M costs as the time between servicing and replacement of the stacks is extended.

Project Information

Project reference: FCH JU

Call for proposals: 2009

Application Area: SP1-JTI-FCH.3:
Stationary Power Generation & CHP

Project type: Research and
Technological Development

Topic: SP1-JTI-FCH.2009.3.3: Operation
diagnostics and control for stationary
applications

Contract type: Collaborative Project

Start date: 1/3/2011

End date: 28/2/2014

Duration: 36 months

Project total costs: € 2215767.40

Project funding: € 1173818.00

Project Coordinator

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inno TSD (INNO)
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DEMMEA

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

Key Objectives

The state of the art high temperature polymer electrolyte, PEM, fuel cell technology is based on H₃PO₄ imbibed polymer electrolytes. The most challenging areas towards the optimization of this technology are: (i) the development of stable long lasting polymer structures with high ionic conductivity and minimal cost and (ii) the design and development of catalytic layers with novel structures and architectures aiming to reduced Pt loadings and more active and stable electrochemical interfaces with minimal Pt corrosion. In this respect the objective of the present proposal is to understand the functional operation and degradation mechanisms of high temperature H₃PO₄ imbibed PEM and its electrochemical interface. The fundamental understanding of the failure mechanisms can be used to guide the development of new materials and the development of system approaches to mitigate these failures.

Challenges addressed

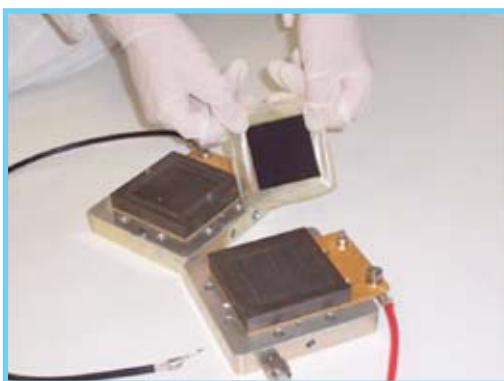
The goal of this project is to study and understand the physical origin of the degradation phenomena that take place during the operation of an MEA of a high temperature PEM fuel cell. The ultimate milestone of the project is the combined use of advanced experimental techniques that will lead to the design and development of prediction tools for the MEA's performance. Despite conventional techniques, in-situ spectroscopy and locally resolved measurements are developed and adopted for the first time for this purpose. The degradation mechanisms will be thoroughly studied. This will permit the tailor-made optimization of the MEA through the proposal of new materials (PEMs and catalysts) into a commercially reliable product for stack manufacturers.

Technical approach and achievements

For the achievements of the project's goals, ex-situ and in-situ testing methodologies must be applied for the examination of the polymer electrolytes (PEMs), the catalytic layers and MEAs.

- Two groups of HT PEMs are employed:
 - a) PBI and variants as control group and
 - b) the advanced state of the art MEAs based on aromatic polyethers bearing pyridine units. The polymer electrolytes have been prepared and characterized in terms of their chemical stability and proton conductivity under various conditions.
- Pt based electrocatalysts have been prepared using new modified carbon supports and characterized as to their physicochemical properties and electrochemical performance. The objective is to achieve a stable electrocatalytic layer with full metal electrocatalyst utilization at the electrode/electrolyte interface in order to lower Pt loadings and increase durability.
- MEAs preparation and combined in situ electrochemical and spectroscopic investigation techniques and ex-situ post mortem characterization are used in order to study thoroughly the degradation mechanisms aiming to the development of a series of diagnostic tests. MEAs are studied and tested in single fuel cells with regards to their operating conditions' effect on performance, their long term stability and the determination of Pt electrocatalytic utilization and durability. Innovative characterization methods have been developed and employed.

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- The information of the aforementioned experimental methodologies are used as a feedback for the development of a mathematical model intended as a predicting tool for the MEA's long term and transient performance.

Expected socio and economic impact

The main direct and indirect socio-economic benefits from the DEMMEA project include cost reduction of the MEA components and thus the overall fuel cell, achievement of reliable and efficient operation and therefore opening/broadening of the fuel cell market with the obvious economic (employment, rural regions) and environmental beneficial impact.

Results to date: Certain failure mechanisms of the current technology MEAs have been identified. Novel polymer electrolytes have been prepared aiming to stable structures at elevated temperature. The novel electrocatalytic systems with new architectures prepared so far seem to overcome certain limitations of current state of the art formulations towards the improvement of performance and stability of the HT MEAs. The expected outcome at the end of the project is a commercially reliable product.

Project Information

Project reference: FCH-JU-2008-1

Call for proposals: 2008

Application Area: SP1-JTI-FCH.3:
Stationary Power Generation & CHP

Project type: Research and
Technological Development

Topic: 3.3 Degradation and lifetime
fundamentals

Contract type: Collaborative Project

Start date: 01 January 2010

End date: ongoing

Duration: 36 months

Project cost: € 3.1 M

Project funding: €1.6 M

Project Coordinator

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Design

Degradation Signature Identification for Stack Operation Diagnostic

Key Objectives

The overall objective of the DESIGN project is to provide a sound diagnostic method for insidious phenomena that slowly accelerate the degradation at the commercial stack level, through understanding of the local responses of sub-stack elements. The main outcome of the project will be the identification of relevant signals monitored to diagnose full stack degradation phenomena. Data analysis methodology is to be applied to measured signals; a set of characteristic signatures for selected degradation phenomena such as high Fuel Utilisation at the local and stack level, to diagnose long-term degradation conditions; Recommendations for operation recovery, once a degradation condition is identified at the cell, SRU or stack level.

Challenges addressed

The main challenges addressed are the identification of specific signatures at the local cell /SRU / small stack level and their transposition from local signatures to full stack with limited instrumentation.

Technical approach and achievements

The DESIGN project follows the complete loop from an identified problem (i.e. the list of degradation phenomena studied), set by a group of industry partners, to the development of a solution (core study) and finally the assessment of the resulting recommendations, again with the implication of industry. After the specification and prioritisation of the different long-term degradation phenomena to be considered (Milestone M1), a test matrix and test protocols to be used will be defined. 3 iterations are scheduled encompassing test matrix definition, experiments and data analysis for the characterisation of separate phenomena and the fine-tuning the data analysis methods. Each iteration is launched by a Milestone. Up-scaling of the diagnostic method from sub-components to stack diagnostic will conclude the project with some diagnostics developed in DESIGN, applied on commercial full-size stacks.



www.design-sofc-diagnosis.com

Stationary power production and CHP

Expected socio and economic impact

During the first half of the project, the Design partners have identified and prioritized operating conditions generating degradation to be investigated in the project with the external participation of the Genius consortium. Among the three main mechanisms selected (1) Anode re-oxidation by locally increased fuel utilizations, 2) Carbon deposition and 3) Small leakages at anode side) the project has focused on the first one. Specific test matrix and test protocols have been defined and implemented iteratively at cell, Single Repeating Unit, and short stack level allowing the identification of a high FU signal at all scales. On-going work aims at assessing this signature and at validating it on large stacks. Such a result, that has never been reported elsewhere, is considered for protection.

Project Information

Project reference: FCH JU collaborative project GA 256693

Call for proposals: AIP 2009

Application Area: Stationary Power Generation & Combined Heat and Power

Project type: Applied Research;

Topic: 3.3 Operation Diagnostics and Control for Stationary Power Application

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 3,266,000

Project funding: € 1,746,000

Project Coordinator

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HyGear Fuel Cell Systems BV

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(HTC)

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Germany

European-wide field trials for residential fuel cell micro-CHP

Key Objectives

The objectives of this project are to promote practical learning, the demonstration of market potential, segmentation, and the cost and environmental benefits of micro FC-CHP while developing market-oriented product specifications and harmonised codes and standards. Additionally, we seek to set up a more mature supply chain, ready for the deployment of micro FC-CHP in 12 Member States, provide evidence base on a cost and environmental analysis that can be used to accelerate policy support from governments and a market adoption by several channels.

Summary/overview

Ene.field will deploy up to 1000 residential fuel cell Combined Heat and Power (micro-CHP) installations, across 12 key Member States. 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. The programme brings together 9 mature European micro FC-CHP manufacturers into a common analysis framework in order to deliver trials across all of the available fuel cell CHP technologies. Fuel cell micro-CHP trials will be installed and actively monitored in dwellings across a range of European domestic heating markets, dwelling types and climatic zones, which will, in the end, lead to an invaluable dataset on domestic energy consumption and micro-CHP applicability across Europe.

By learning the practicalities of installing and supporting a fleet of fuel cells with actual customers, ene.field partners will take one final step before they can begin commercial roll-out. An increase in volume deployment for the manufacturers involved will stimulate cost reduction of the technology by enabling a move from hand-built products towards serial production and tooling. The ene.field project also brings together over 30 utilities, housing providers and municipalities in order to take the products to market and explore different business models for micro-CHP deployment.

The data produced by ene.field will be used to provide a fact base for FC micro-CHP, including a definitive environmental lifecycle assessment and cost assessment on a total cost of ownership basis.

To inform clear national strategies on micro-CHP within Member States, ene.field will establish the macro-economics and CO₂ savings of the technologies in their target markets and make recommendations on the most appropriate policy mechanisms to support the commercialisation of domestic micro-CHP across Europe. Finally ene.field will assess the socio-economic barriers to widespread deployment of micro-CHP and disseminate clear position papers and advice for policy makers to encourage further roll out.

Expected socio and economic impact

To provide a detailed fact base which clearly demonstrates where in the European housing stock FC micro-CHP can provide a tangible emission savings and improvements in home energy bills. Additionally, we hope to enable key decision makers across Europe to evaluate a final commitment to the commercialisation and widespread rollout of the technology and to ensure the technology is rolled out where the economic and environmental benefits are greatest. Lastly, we want to increase the scale of deployment of FC micro-CHP and stimulate a cost reduction by allowing manufacturers to move to a series production process, with great attention to quality control.

Project Information

Project reference: FCH JU 303462

Call for proposals: 2011

Application Area: Stationary power production and CHP

Project type: Demonstration

Topic: SP1-JTI-FCH.3.7: Field demonstration of small stationary fuel cell systems for residential and commercial applications

Contract type: Collaborative project

Start date: 01 September 2011

End date: ongoing

Duration: 60 months

Project cost: € 53 million

Project funding: € 26 million

Project Coordinator

The European Association for the promotion of Cogeneration

Belgium
(COGEN Europe)

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Baxi Innotech GmbH
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Bosch Thermotechnik GmbH
Germany

Ceres Power Limited
UK

Dantherm Power A.S.
Denmark

Elcore GmbH
Germany

Hexis AG
Switzerland

Rieser Brennstoffzellentechnik GmbH
Germany

SOFCpower S.p.A
Italy

Vaillant GmbH
Germany

Dolomiti Energia SPA
Italy

British Gas Trading Limited
UK

Element Energy Ltd
UK

GDF SUEZ
France

ITHO Daalderop Group BV
Netherlands

Hydrogen, Fuel Cells and Electromobility in European Regions (HyER)
Belgium

Imperial College of Science,
Technology and Medicine
UK

Development Centre for Hydrogen
Technologies (DCHT)
Slovenia

Parco scientifico e tecnologico per
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Italy
Politecnico di Torino
Italy

DBI Gastechnologische Institut GmbH
Freiberg (DBI-GTI)
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Energy Saving Trust
UK

Gas- und Wärme-Institut Essen e.V (GWI)
Germany

Danmarks Tekniske Universitet
Denmark

European Institute for Energy Research
Germany

DONG Energy Power A/S
Denmark

EURECA

Efficient use of resources in energy converting applications

Key Objectives

EURECA is developing the next generation of micro combined Heat-and-Power (μ -CHP) systems based on advanced PEM stack technology to overcome the disadvantages of complex gas purification, gas humidification and low temperature gradients for heat exchangers with operating temperatures of 90 to 120°C. The main outcome is a less complicated, highly efficient, and therefore a robust μ -CHP system with reduced cost, meaning that the consortium is well balanced along the supply chain.

Technical approach and achievements

A public website has been designed and is available at: www.project-eureca.com. An internal website has been included and serves as an exchange server for documents. First technical meetings of the GA and in WP 2, 3, 4 have taken place to review the project's progress and define test protocols.

Summary/overview

EURECA develops the next generation of μ -CHP systems based on advanced PEM stack technology. The idea is to overcome the disadvantages of complex gas purification, gas humidification and the low temperature gradient for the heat exchangers in a heating system. EURECA will develop a new stack generation based on PEM technology with operating temperatures of 90 to 120°C. This results in a less complicated and therefore more robust μ -CHP system with reduced cost. The development of a new stack generation includes various parallel working tasks. Inside the EURECA project we will optimize materials to operate in that temperature range – including membrane and bipolar plate materials.

Also, the catalyst will be improved with a lower platinum loading – design target < 0.2 g/kW. The stack design and the flow field of the bipolar plates will be optimized for the operating conditions. All development steps will be supported by modelling. As the final step, the developed stack will be integrated in an adapted μ -CHP system to achieve proof-of-concept in the target application with validation of the design targets. The μ -CHP system – including the reformer – is expected to operate at an electrical efficiency of above 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.



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Stationary power production and CHP

A cost assessment will indicate the cost savings by the less complicated system. The consortium is well balanced along the supply chain. Component suppliers and system designer are backed by research institutions.

Expected socio and economic impact

We will simplify the design and manufacturing of cells and stacks and therefore we will search for new architectures respectively and design the specific application. Also, we will improve the tolerance to contamination and increase the performance power density efficiency reliability. In the end, we will have a system with higher robustness to cycling. We support the system engineering with a design to cost approach.

Project Information

Project reference: FCH JU 123456

Call for proposals: 2011

Application Area: Next generation stack and cell design

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2011.3.1: Efficient use of resources in energy converting applications

Contract type: Collaborative project

Start date: 01 July 2012

End date: 30 June 2015

Duration: 36 months

Project cost: € 6.314.505

Project funding: € 3.557.295

Project Coordinator

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Germany

Univerzitet u beogradu
Serbia

Commisariat à l'énergie atomique et aux énergies alternatives
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Foundation for research and technology Hellas
Greece

inhouse engineering GmbH
Germany

Celaya a emparanza y galdos internacional, S.A.
Spain

Fundacion CIDETEC
Spain

Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.
Germany

FluMaBack

Fluid management component improvement for back up fuel cell systems

Key Objectives

The project aims to develop specific components relative to fluid management that substantially affect electric efficiency and the total cost of a fuel cell system. This includes:

- a) Blower
- b) Recirculation pump
- c) Humidifier
- d) Heat exchanger.

Additionally, the project aims to:

1. Improve performance, in terms of reliability and efficiency
2. Improve lifetime singularly and at a system level,
3. Reduce cost in a mass production perspective,
4. Simplify manufacturing/ assembly processes of the entire fuel cell system.

Summary/overview

The Back project aims to improve the performance, life time and cost of BOP components of back up fuel cell systems specifically developed for emerging countries where long black-outs occur and difficult operative conditions are present. The improvement of sub-system components addressed in the project will benefit both back-up and CHP applications. The project focuses on new designs and improvement of BOP components, aimed at:

- improving BOP components' performance, in terms of reliability;
- improving the lifetime of BOP components, both at component and at a system level;
- reducing cost in a mass production perspective;
- simplifying the manufacturing/ assembly process of the entire fuel cell system.

The project consortium consists of industries working together commercially and being able to identify the critical needs based on their daily experience. It represents a real opportunity for developing a strategic alliance of industrial actors. In the future, these actors can collaborate on fostering the technological evolution of the components towards more efficient and flexible BOP components that will allow the fuel cell industry to exploit the huge opportunities both for EU market and for emerging countries.

The project is focused on the most critical BOP components with the largest potential for performance improvement and cost reduction, including:

- Air and fluid flow equipment, more specifically blowers and recirculation pumps
- Humidifiers
- Heat exchangers.

Relevant research institutes and universities support the industries in the development and evaluation of BoP components.

The project activity completely aligns with the call topic as it aims to improve availability and the cost competitiveness of balance of plant (BoP) components, as well as their suitability for mass production to meet performance and lifetime targets (up to 10 years). As the industrial partners are actively supplying the fuel cell business, the project results can be implemented rapidly, enhancing the impact of the project.

Expected socio and economic impact

- Support the implementation of the RTD priorities of the MAIP
- Disseminate the technology and its functional capabilities against current technology
- Launching of new and innovative initiatives and products
- Implementation of hydrogen and fuel cells as mainstream applications
- Improved energy efficiency
- Increased public and private RTD investment in fuel cells and hydrogen technologies
- Development of market applications and facilitation of additional industrial efforts for development of fuel cell and hydrogen technologies.

Project Information

Project reference: FCH JU 123456

Call for proposals: 2010

Application Area: SP1-JTI-FCH.3:
Stationary Power Generation & CHP
Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2011.3.3:
Component Improvement for stationary power applications

Contract type: Collaborative project

Start date: 01 July 2012

End date: 30 June 2015

Duration: 36 months

Project cost: € 4.37 million

Project funding: € 2.98 million

Project Coordinator

Electro Power Systems, SpA
Italy

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Partners

Domel
Slovenia

Tubiflex
Italy

Environment Park
Italy

Jozef Stefan Institute
Slovenia

Foundation for the Development of
New Hydrogen Technologies in Aragon
Spain

NedStack Fuel Cell Technology BV
Netherlands

Onda
Italy

University of Ljubljana - Faculty for
Mechanical Engineering
Slovenia

Joint Research Centre
Netherlands

GENIUS

Generic diagnosis instrument for SOFC systems

Key Objectives

In order to comply with the constraints of stationary generators during operation, it is necessary to develop monitoring devices that could either be used as On Board Diagnostic or as "off-line" diagnostic. In the former case, the tool sends an alarm in order to guarantee installation safety and the respect of regulations. Once a fault identified, counter measures could then be taken by the control system and a recovery strategy could be defined to limit degradations or performance drop. In the latter case, the tool helps the maintenance operations or repairs. The objective of GENIUS project is to develop a "GENERIC" approach based on different algorithms that would only use process values (normal measurements and system control input parameters) to diagnose the state of health of different SOFC systems. If the approach remains generic, the final tool will be adapted to the specificities of the different systems in which it will be integrated and validated.

Challenges addressed

In order to compete with current boilers and entering the market, SOFC systems need to reach similar reliability, lifetime and costs level:

- no inconvenience at the customer place, limited cost for operation and (at worst) yearly maintenance.
- 40 000 hrs lifetime with a degradation rate $< 0.5\%/1000\text{hrs}$.

But, these systems' state of health is currently difficult to evaluate, which makes difficult to handle faults or degradation with an appropriate counter measure. As a consequence, abovementioned requirements cannot be achieved. That's why state of health diagnostic tools are needed.

Technical approach and achievements

The purpose of this project is to develop diagnostic tools that would be validated on real systems. For this, main faults and failures that occur on a SOFC system together with their impacting parameters were identified. On this basis, test plan were defined according to the specificities of each stack/system and on each test bench. A permanent loop is established between testing, algorithm development and test plan definition, in order to create diagnostic algorithms that will be validated on three different μ -CHP systems.

Expected socio and economic impact

GENIUS contributes directly to the commercialization of the SOFC power systems. Indeed, along with costs, the reliability and lifetime of SOFC stacks remain as barriers for the market penetration of the SOFC power systems. Significant improvements in these aspects can be expected by utilizing sophisticated diagnosis tools, that just use the normal measurements and their control input parameters, for the monitoring, the prediction and the prevention of stack failures and degradation. In this way, counter measures can be taken and degradation minimized by appropriate operation even in dynamic load conditions. The implementation of such tools in real systems could therefore be of great benefit for the technology by increasing the trust of utilities.

Project Information

Project reference: FCH JU 2008-1

Call for proposals: 2008

Application Area: Stationary Applications

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.3.1 Operation diagnostics and control for stationary applications

Contract type: Collaborative action

Start date: 01/02/2010

End date: 31/01/2013

Duration: 36 months

Project total costs: € 3 928 509

Project funding: € 2 067 785

Project Coordinator

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R&D Project Manager

Distributed Energy Group

EIFER

Europäisches Institut für

Energieforschung

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Montbéliard (FCLAB)
France

Université de Franche Comté (UFC)
(third party of FC LAB)
France

Hexis AG (Hexis)
Switzerland

HTCeramix (HTC)
Switzerland

Topsoe Fuel Cell (TOFC)
Denmark

University of Genoa (UNIGE)
Italy

University of Salerno (UNISA)
Italy

Technical Research Center of Finland
(VTT)
Finland

Wärtsilä (WAR)
Finland

inno TSD (INNO)
France

KeePEMalive

Knowledge to Enhance the Endurance of PEM fuel cells by Accelerated Lifetime Verification Experiments

Key Objectives

KeePEMalive aims at establishing improved understanding of degradation and failure mechanisms, by developing and approving accelerated stress test protocols, a sensitivity matrix and a lifetime prediction model for Low Temperature Proton Exchange Membrane Fuel Cells (LT PEMFC) to enable a lifetime of 40 000 h at realistic operation conditions for stationary systems, in compliance with performance and costs targets.

Challenges addressed

KeePEMalive particularly addresses the degradation challenge by focusing on the following issues:

- Identify the relevant stressing conditions for μ -CHP by assessing data from field operations as well as laboratory tests.
- Establish a robust and efficient methodology for identification and quantification of the conditions causing degradation and failure.
- Develop ex situ accelerated ageing tests for individual MEA component, and relate results to observed degradation rates for single cell and stacks.
- Verify and validate proposed materials' improvements.
- Develop Accelerated Stress Test (AST) protocols that enable quantification of the impact of selected stressors on single cells and stacks.
- Provide validated recommendations for degradation mitigation strategies.
- Establish a model that reliably predicts lifetime on the basis of AST results.

Technical approach and achievements

The concept of this project contains the following elements (also illustrated on next page):

- Systemizing and synthesising all available information on degradation and failure mechanisms
- Designing experiments and accelerated stress test protocols
- Carrying out comprehensive cell and stack testing utilising the latest and most advanced in situ electrochemical as well as effluent analysis techniques
- Complementing the in situ tests by post mortem characterising fuel cell materials by ex situ techniques
- Analysing the data utilising powerful statistical tools
- Developing a model for prediction of lifetime and failure.

The KeePEMalive -project is of an iterative nature, initially using state-of-the-art materials and stacks supplied by European fuel cell manufacturers for detailed analyses and characterisation. As the project progresses and the understanding of degradation and failure mechanisms is enhanced, recommendations for improved materials and stack components as well as degradation mitigation strategies will be provided.



<http://www.sintef.no/Projectweb/KEEPPEMALIVE/>
Stationary power production and CHP

Expected socio and economic impact

The KeePEMalive project contributes to achieve the principal technical and economic requirements needed for PEMFCs to compete with existing energy conversion technologies (e.g., natural gas burners, resistive heating) for stationary heat generation, and in addition provide electricity by efficient cogeneration of power. The project has a strong link to the Danish Vestenskov stationary fuel cell demonstration project, where 35 PEMFC based μ -CHPs will be placed in households, utilizing hydrogen from wind in a weak grid. Real-life operation data from this demonstration project feed into the KeePEMalive project and forms, together with experimental laboratory test data, the basis for improving materials and developing a lifetime prediction model. The increased understanding of degradation mechanisms achieved in the KeePEMalive-project will eventually contribute to develop mitigation strategies, thereby ensuring longer lifetimes for PEMFCs and hence lower cost of energy (electricity and heat) compared to current state-of-the-art stationary fuel cells.

Results obtained from KeePEMalive will be of a generic nature and are thus highly relevant for all PEMFC systems, including High Temperature PEMFC and PEMFCs for automotive applications, be it that the impact on the lifetime and failure will be different and that other mitigation strategies will be required.

Project Information

Project reference: FCH JU
Call for proposals: 2008
Application Area: Stationary Power Production and CHP
Project type: Basic Research or Research and Technology Development
Topic: SP1-JTI-FCH.3.3: Degradation and lifetime fundamentals
Contract type: Collaborative Project
Start date: 01/01/2010
End date: 30/06/2013
Duration: 42 months
Project total costs: € 2,9 million
Project funding: € 1,3 million

Project Coordinator

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Vice President Marketing
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IRD Fuel Cells A/S
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France

FuMA-Tech GmbH
Germany

EIFER – European Institute for Energy Research
Germany

Technische Universität Graz
Austria

SEAS-NVE
Denmark

European Commission Joint Research Centre, Institute for Energy
Belgium

LASER-CELL

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

Key Objectives

1. Designing a novel AFC based on laser-processed substrates with optimised technical/commercial characteristics.
2. Assessing and adapting laser manufacturing techniques and incorporating their benefits in the fuel-cell design.
3. Designing an innovative fuel-cell stack to operate in industrial stationary settings, which delivers safety, mass manufacture, ease of assembly, recyclability, serviceability and optimal performance.
4. Combining the above objectives in order to establish the cost-competitiveness of the AFC technology in comparison with all competing technologies – confirming for the first time the commercial viability of AFCs in large-scale stationary applications.

Technical approach and achievements

Achievements to date fall in 4 main areas:

1. THEORETICAL MODELING
Substrate model completed and successfully used to determine optimal porosity of nickel substrates
2. LASER DRILLING
Demonstrated drilling of 4000 holes per second with single laser-source. This achievement significantly improves commercial viability of the laser drilling process
3. LASER SINTERING
Successful sintering of porous nickel samples achieved. Established that the use of innovative optics provides significant improvements in process speed
4. NANOMATERIALS
High CNT-content polymers successfully produced using compression moulding and sheet extrusion.
First trials of combined nickel and conductive polymer materials successfully undertaken.

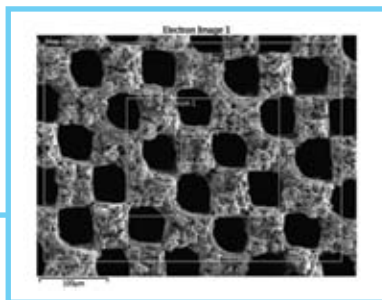
Challenges addressed

The alkaline fuel cell (AFC) is one of the most efficient devices for converting hydrogen into electricity. Project LASER CELL will develop a novel, mass producible AFC and stack design for stationary, industrial applications utilising the latest laser processing technology. This economically viable, sophisticated technology will enable design options, not previously possible, that will revolutionise the functionality and commercial viability of the AFC.

Key parameters that will dictate fuel cell and stack design are; safety, reduced part count, ease of assembly, durability, optimised performance, recyclability and increased volumetric power density in a way which achieves a cost of under €1,000 per kW. To realise this vision, proprietary cell and stack features that have never before been incorporated into an AFC system will be employed and deliver a flawlessly functioning stack. In order to achieve these ambitious objectives, the consortium comprises world leading specialists in the fields of alkaline, polymer electrolyte and solid oxide fuel cells, advanced laser processing technologies, conductive nano composites, polymer production and large scale, stationary power plants. A cell design tool, based on physical and cost models, will be produced.

This disseminated tool will provide design rationale for material selection and geometric design and will, in principle, be applicable to all low-temperature fuel cells. Commercially viable porosity forming processes developed in this project will enable organisations working with other fuel cell types to re-evaluate the fabrication and design of their core technologies. Impacts will also be felt in other sectors, including; solar cells, aviation, medical and automotive industries, for whom the partners' achievements are potentially

© laser-cell



SEM image of a laser-drilled substrate sample produced in year one of project. This optimised process achieved a much higher hole density compared to what was previously possible.

beneficial. The ability to convert 'waste' hydrogen into electricity and achieving the status of 'pull through' technology for carbon capture and storage (CCS), would enable AFCs to play a crucial role in helping the EU meet its reduced CO₂ emission targets and improve Europe's energy security.

Expected socio and economic impact

UDE's substrate model has already been used in AFC's production process, leading to improvements in fuel cell performance.

LASER-CELL results from first year have been used by a major UK university to examine the use of laser-drilled metal sheets as GDLs in PEM fuel cells.

The partners expect the improvements in laser-processing technology to significantly reduce the cost of key components in AFC's fuel cells, as well as providing benefits to other fuel cell types, and industries including aviation and emitter-wrap-through solar cells.

Project Information

Project reference: fCH JU 123456

Call for proposals: 2010

Application area: 3 – Stationary Power Generation & Combined Heat and Power (CHP)

Project type: rTD

Topic: SP1-JTI-FCH.2010.3.2: Next generation cell and stack designs

Contract type: collaborative project

Start date: 1 December 2011

End date: 30 Nov 2014 ongoing

Duration: 36 months

Project cost: € 2,9 M

Project funding: € 1,4 M

Partners

CenCorp (CNC)
Finland

Teknologian Tutkimuskeskus –
Technical Research Centre of Finland
(VTT)
Finland

Air Products
(AIRP)
UK

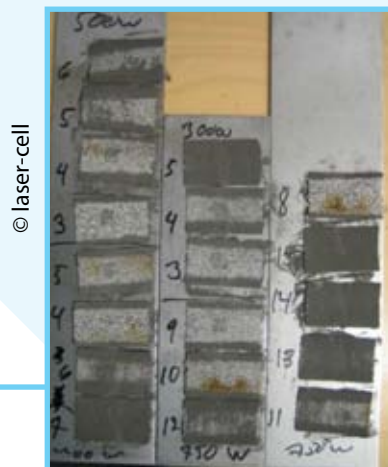
Nanocyl (NCL)
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Project Coordinator

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Sintering results using the Nd:YAG laser in combination with a cylindrical lens.

LoLiPEM

Long-life PEM-FCH & CHP systems at temperatures $\geq 100^{\circ}\text{C}$

Key Objectives

The key objective of the LoLiPEM project is to give a clear demonstration that long-life SPG&CHP systems based on PEMFCHs operating at temperatures higher than 100°C can now be developed on the basis of knowledge on the degradation mechanisms of membranes disclosed by some LoLiPEM partners. Stable perfluoro sulfonic acid (PFSA) and new stable non-perfluorinated ionomers, such as sulfonated aromatic polymers (SAPs), are the materials mostly used in this project for the membranes development for the MEAs preparation. These innovative MEAs are developed for operating above 100°C .

Challenges addressed

A PEMFCH operating in the temperature range of $100\text{-}130^{\circ}\text{C}$ is highly desirable and could be decisive for the development of SPG&CHP systems based on PEMFCHs. LoLiPEM aims to operate in this temperature range exceeding the state-of-the-art ($70\text{-}80^{\circ}\text{C}$). The lower temperature is the main drawback for PEMFCH development. Several advantages including easier warm water distribution in buildings, reduced anode poisoning due to carbon monoxide impurities in the fuel, improved fuel oxidation kinetics, etc. would be gained by operating above 100°C .

Technical approach and achievements

The key milestones and deliverables include

- The preparation of PFSA and SAPs membranes stable at a temperature higher than 100°C
- Development of new long-life catalytic electrodes and MEAs operating in the above temperature range
- Accelerated ageing tests and long-term single cell tests
- Development of a prototype of a modular SPG&CHP system based on multi-PEMFCHs also utilizing the new long-life MEAs.
- Benchmarking the single-cell and the modular prototype performance at temperatures above 100°C against the best literature results

New protocols for the evaluation of mass transport properties of membranes and MEA as well as for the testing of MEA in fuel cell have been elaborated and successfully applied.



www.LoLiPEM.eu

Stationary power production and CHP

Expected socio and economic impact

Novel PFSA and SAP membranes able to withstand temperatures higher than 100°C are prepared and successfully tested. Innovative electrodes are prepared with a new electrodeposition process which allows all the electrocatalyst nanoparticles to be in contact with both the ionically conducting ionomer and the electronically conducting electrode materials. MEAs are prepared and tested at operating temperatures above 100°C.

Project Information

Project reference: FCH JU - Grant Agreement no.245339

Call for proposals: year 2008

Application Area: SP1-JTI-FCH.3: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.3.3 Degradation and lifetime fundamentals

Contract type: Collaborative project

Start date: 01-01-2010

End date: 31-12-2012

Duration: 36 months

Project total costs: € 2.927.174

Project funding: € 1.360.277

Project Coordinator

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The University of Saarbrucken,
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EDISON SpA
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Fumatech
Germany

Matgas 2000
Spain

Cracow University of Technology
Poland

LOTUS

Low Temperature Solid Oxide Fuel Cells for micro-CHP Applications

Key Objectives

The main objective of the project will be to develop a proof-of-concept fuel cell system:

- based on state of the art Solid Oxide fuel cell technology
- operating on as low stack temperature as possible, with a target of 650°C, to solve the known failure mechanisms of HT SOFC systems
- Reducing down time by integrating a low cost, high efficient Gas Air Delivery system based on mass produced and field proven components
- integrate all needed power electronics, components and connections for a direct replacement of conventional heating appliances
- use a modular concept and design practices from the heating appliances industry to reduce maintenance and repair downtime and costs
- an electrical system efficiency of minimal
- a total system efficiency of minimal 80%.

Challenges addressed

State of the art SOFC technology runs at temperatures around 800-900°C which imposes high thermal stress on the materials used in the SOFC stack. Running at lower temperatures (650-700°C) could improve the stability of the stack and therefore increase the reliability. It has been proven on a single cell and stack level that at these lower temperatures the performance of the SOFC materials is sufficient. In the LOTUS project a micro-CHP system will be designed and a prototype built based on the 650°C operating stack which meets cost and efficiency targets. Next to the reduced temperature the biggest challenge is the integration of components to reduce parts and heat loss.

Technical approach and achievements

During the 1st year the system will be defined and modelled and materials for the stack module improved. This will lead to the delivery of a full stack at the end of year 2. In the mean time the other modules: desulfurization, external reformer, burner and heat exchangers will be developed. To reduce system costs, mass-produced off-the-shelf components will be used where possible.

In the end of year two all module developments culminate in the prototyping of a system and testing it in the last 6 month of the project.

Expected socio and economic impact

The use of distributed combined heat and power will greatly increase the energy efficiency compared with conventional power plants and boilers. When the production and transportation of the same amount of electricity and heat to a home by conventional means will take up to about 170 units, producing those with a SOFC system at the point of use, only 100 units are needed. This will reduce the energy consumption between 35 to 40% with accompanied similar CO₂ emission reductions

Project Information

Project reference: FCH JU 256694

Call for proposals: 2009

Application Area: Stationary power generation and CHP

Project type: Research and Technological development

Topic: SP1-JTI-FCH.2009.3.5: Proof-of-concept fuel cell systems

Contract type: Collaborative project

Start date: 01 January 2010

End date: 31 December 2013

Duration: 36 months

Project cost: € 2.954.984

Project funding: €1.632.601

Project Coordinator

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Partners

SOFCPower
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Domel, d.d.
Slovenia

University of Perugia
Italy

European Commission, Directorate-
General Joint Research Centre
Belgium

MAESTRO

MembrAnEs for STationary application with RObust mechanical properties

Key Objectives

MAESTRO aims to establish methods to increase the mechanical stability of state of the art low equivalent weight perfluorosulfonic acid membranes for stationary application of proton exchange membrane fuel cells (PEMFC) to increase their durability and cell lifetime. The concept will be validated by the integration of the robust, mechanically stabilised membranes into MEAs, which will be tested in realistic conditions, including stability under dynamic conditions, start/stop events and stand-by mode, in compliance with performance targets of the Multi-Annual Implementation Plan.

Challenges addressed

An issue clearly highlighted in the Multi-Annual Implementation Plan in the stationary application area is the need to address lifetime requirements of 40,000 hours for cell and stack, and the call for improved materials leading to step change improvements over existing technology in terms of performance, endurance, robustness and cost. In general, failure mechanisms of PEMFC membranes are of two main types: chemical (e.g. from attack by peroxide radicals on susceptible polymer end groups), and mechanical, which originates from weak intermolecular interactions between polymer chains. While methods of chemically stabilising the polymer end groups have been developed, failure due to insufficient membrane mechanical properties limits cell and stack lifetime. The problem is exacerbated by the trend in use of membranes of thickness only 25-30 μm (compared with the use of membranes of ca. 175 μm some 10 years ago), and the desire to employ lower equivalent weight membranes that can enable higher temperature operation, but which are inherently mechanically weaker and negatively impact membrane strength.

Technical approach and achievements

The MAESTRO project is developing solutions to the above bottlenecks through a range of approaches to improve the mechanical stability of state of the art perfluorosulfonic acid (PFSA) type PEM fuel cell membranes via improved polymer chemistries and manipulation of membrane architecture. The final project target for the membrane is to have increased the tensile strength (compared with the benchmark material at the project beginning) by 50%, with a milestone at the mid-term stage of improvement by 20-25%. In terms of the MEA integrating the mechanically stabilised membranes, the target is for 4000 hours of operation under conditions relevant to stationary application, with performance degradation less than 10% compared to beginning of life. Key technical items delivered in year 1 of the project include: Protocols for characterisation of membranes and MEAs including accelerated stress testing and long-term operation; Elaboration of benchmark MEAs and their characterisation according to these protocols; Development of membranes having elastic modulus increased by 78% compared with that of the project benchmark, while retaining conductivity of ca. 0.01 S cm^{-1} at 25 % relative humidity and 0.2 S cm^{-1} at 90 % relative humidity; State of the art report on approaches to membrane mechanical stabilisation.

Expected socio and economic impact

The long lifetime resulting from excellent chemical stability and enhanced mechanical properties, associated with sufficiently high operation temperature will contribute to reliability and costs reduction of stationary power generation systems, and improve European competitiveness in this market area. The availability of mechanically robust and performant membranes will also have positive impact on fuel cell application in other sectors such as, for example, transportation.

Project Information

Project reference: FCH JU 256647

Call for proposals: 2009

Application Area: Stationary

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2009.3.2: Materials development for cells, stacks and balance of plant

Contract type: Collaborative project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 2264765

Project funding: € 1040049

Project Coordinator

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MCFC-CONTEX

Molten Carbonate Fuel Cell catalyst and stack component degradation and lifetime: Fuel Gas **CON**Taminant effects and **EX**traction strategies

Key Objectives

Reducing the carbon footprint of our society is imperative. This can be achieved both by capturing and confining anthropogenic CO₂ emissions as by replacing fossil-based fuels with renewable or waste-derived fuels. MCFCs are unique in being able to do both these things. However, the degradation caused by the contaminants in these gases must be addressed. MCFC-CONTEX aims to tackle the problem of degradation by trace contaminants from two sides:

- 1) investigation of poisoning mechanisms caused by alternative fuels and applications and precise determination of MCFC tolerance limits for long-term endurance;
- 2) optimization of fuel and gas cleaning to achieve tailored degrees of purification according to MCFC operating conditions and tolerance.

Challenges addressed

- 1) (accelerated) experimental investigation in realistic conditions of the effects of H₂S, HCl, HF, Siloxanes on the anode, and of SO₂, NO_x at the cathode
- 2) Numerical modelling of MCFC performance and long-term behaviour under clean and poisoned conditions
- 3) Development of an industrially suited, transportable device for high-resolution real-time gas analysis and trace detection through innovative laser techniques (LIBS – laser-induced breakdown spectroscopy – and Raman)
- 4) Characterization of commercial adsorbents and catalysts for optimized cleaning in terms of cost-effectiveness, and development of a prototype cleaning system.

Technical approach and achievements

The first line of activity requires extensive long-term testing of the MCFC. It is an important step, involving harmonization of test procedures and equipment within the consortium. The gas analysis system is developed as well as the LIBS part of the device is now complete and under calibration.

The second line of investigation entails characterization and development of clean-up materials and processes, focusing on the most promising options to be selected at the start of the project. Ultimately a pilot-scale gas cleaning unit optimized for the applications considered will be developed and run.



<http://mcfc-contex.enea.it/>

Stationary power production and CHP

Expected socio and economic impact

MCFC-CONTEX actively contributes towards the development of technologies that need to take over from conventional energy supply systems in the near future, due to EU policy measures as well as mere necessity of sustainability. In particular, the results aimed at in gas analysis and biogas clean-up systems will be widely applicable across the entire field of renewable energy conversion. Optimizing the operating conditions of the MCFC allows to tap into the huge and expanding European market of small-medium-scale, anaerobic digestion waste treatment. And separation of CO₂ from power plant exhaust fumes using the MCFC (producing power instead of consuming it) has a potentially colossal global market. So far, promising results have been obtained in the determination of poisoning mechanisms by H₂S and SO₂; in the selection of adequate cleaning materials and design of a suitable gas clean-up system; in the development of the high-resolution, real-time gas analysis device, and in the set-up of the basic numerical model.

Project Information

Project reference: FCH JU 245171

Call for proposals: 2008

Application Area: S

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.3.3: Degradation and lifetime fundamentals

Contract type: Collaborative project

Start date: 01 January 2010

End date: ongoing (01 October 2013)

Duration: 36 months

Project cost: € 4,429,336.10

Project funding: € 1,841,929.27

Project Coordinator

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Joint Research Centre (JRC)
Belgium

METPROCELL

Innovative fabrication routes and materials for METal and anode supported PROton conducting fuel CELLS

Key Objectives

METPROCELL aims to develop innovative Proton Conducting Fuel Cells (PCFCs) by using new electrolytes and electrode materials dedicated to 500-600°C. The cell architecture will be optimised on both metal and anode supports, with the aim of improving the cell performance, durability and cost effectiveness. Further objectives are the development of cost-effective manufacturing routes and bringing the proof of concept of PCFCs by the set-up and validation of short stacks in relevant industrial systems.

Challenges addressed

PCFC is one of the most promising technologies to reach the requirements related to cogeneration applications, especially in the case of small power systems (1-5 kWel). The investigation in the concept of advanced thin-film ceramic fuel cell technology at operating intermediate temperatures between 400 and 700 °C aims to improve the characteristics (thermal cycling, heat transfer, current collection) as well as drastically lower the costs of the system.

The aim of METPROCELL is to develop innovative Proton Conducting Fuel Cells (PCFCs) by using new electrolytes and electrode materials and implementing cost-effective fabrication routes based on both conventional wet chemical routes and thermal spray technologies. Following a complementary approach, the cell architecture will be optimised on both metal and anode type supports, with the aim of improving the performance, durability and cost effectiveness of the cells.

Specific objectives:

- Development of novel electrolyte (e.g. BTiO₂, BCY10/BCY10) and electrode materials (e.g. NiO-BITO₂ and NiO-BCY10/BCY10 anodes) with enhanced properties for improved proton conducting fuel cells dedicated to 500-600°C.
- Development of alternative manufacturing routes using cost effective thermal spray technologies such as detonation spraying (electrolytes and protective coatings on interconnects) and plasma spraying (anode).
- Development of innovative proton conducting fuel cell configurations to be constructed on the basis of both metal supported and anode supported cell designs.
- To up-scale the manufacturing procedures based on both conventional wet chemical methods and thermal spraying for the production of flat Stack Cells with a footprint of 12 x 12 cm.
- Bring the proof of concept of these novel PCFCs by the set-up and validation of prototype like stacks in two relevant industrial systems, namely APU and gas/micro CHP.



www.metprocell.eu/about.html

Stationary power production and CHP

Expected socio and economic impact

The PCFC technology could significantly contribute to industrialise the fuel cell technology by improving the cell characteristics and drastically lowering the system costs. In this sense, METPROCELL's results will contribute to an increase the system efficiency, through a better utilization of the heat produced and a better BoP, a lower operating temperature 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).

Project Information

Project reference: FCH JU 277916

Call for proposals: 2010

Application Area: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.3.1 Materials development for cells, stacks and balance of plant (BoP)

Contract type: Collaborative project

Start date: 01 December 2011

End date: ongoing

Duration: 36 months

Project cost: € 3.4 million

Project funding: € 1.8 million

Project Coordinator

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METSAPP

Metal Supported SOFC Technology for Stationary and Mobile Application

Key Objectives

Most SOFC demonstrations with ceramic cells in real system operation have until now revealed problems regarding reliability issues. Attention to reliability and robustness has especially been paid in connection with SOFC technology for mobile application. Modelling studies as well as recent practical experience has proved how up-scaling of cells and stacks to larger more industrially relevant sizes generally leads to lower reliability in real system operation and intolerance towards system abuse and operation failures. The aim of the METSAPP project is to develop novel cells and stacks based on a robust and reliable up-scalable metal supported technology for stationary as well as mobile applications with the following primary objectives:

1. Robust metal-supported cell design, $ASR_{cell} < 0.5 \text{ ohmcm}^2$, 650°C
2. Cell optimized and up-scaled to $> 300 \text{ cm}^2$ footprint
3. Improved durability for stationary applications, degradation $< 0.25\%/kh$
4. Modular, up-scaled stack design, stack $ASR_{stack} < 0.6 \text{ ohmcm}^2$, 650°C
5. Robustness of 1-3 kW stack verified
6. Cost effectiveness, industrially relevance, up-scale-ability illustrated.

Technical approach and achievements

Metal supported cells have been scaled up to a 300 cm^2 footprint. ASR on $12 \times 12 \text{ cm}$ foot print of 0.27 ohmcm^2 has been verified. Extensive failure mode modelling has been created as a development platform for further stack design optimisation within the project. Robust seals and stack assembling has been implemented based on novel laser welding techniques. Corrosion protection of metallic interconnects by combined Co-Ce coating, which is based on a continuous PVD technology has been developed.

Summary/overview

The project is dealing with key parameters limiting the long term stability of current metal supported cells. For the metal support layers and cermet layers the type and amount of metal and ceramic components will be optimized. Compositions of Sc_2O_3 and/or Y_2O_3 doped ZrO_2 will form the ionic conducting component in the backbone structure of the anode layer. Improved nano-structured electrodes adapted to the metal-supported cell concept will be developed and tailored for high performance aiming at a 40.00 hour lifetime operated on natural gas.

Novel anode designs will be developed and fundamental studies will be conducted on La- and/or Nb-doped n-type SrTiO_3 materials. To enhance anode performance, catalysis-promoting elements such as Mn and Ga will be introduced into the titanate perovskite lattice in order to enhance oxidation activity and improve mixed ionic/electronic conductivity, respectively. Materials featuring low Cr evaporation and improved corrosion resistance will be provided by a thin film coating of Fe-22Cr strip steels with submicron Co and Co/Ce films. To ensure high cell and stack component robustness, physical models for the different governing failure modes and mathematical models for related random processes, accelerated test procedures will be validated. The electro-chemical model of the repeatable stack elements will be used for optimising the cell size and flow patterns of the interconnected components. CFD & FEM modelling will be used for minimising pressure drop across the cells and contact resistance between cells and interconnects. Small stacks with larger cells will be developed and tested with respect to electrochemical performance and mechanical robustness.

Expected socio and economic impact

The societal impact is expected to be seen along the lines of a faster and solid opening of the market related to SOFC systems for many applications, such as micro-CHP in single houses, the distributed generation of power and heat in apartment houses, hospitals, banks and office buildings and APU for the transport sector (trucks and ships). This will result in a much more efficient and clean means of utilizing our fuel resources for the production of electricity and heat, and will hence have a tremendous impact on the future. Successful integration of SOFCs into the market will thus bring the EU one step closer in achieving the targets for 2020 (20% cut in greenhouse gases, 20% increase in energy efficiency and 20% energy from renewable sources). The robust, reliable (and cheaper) SOFC systems of European players will create important high-tech, clean-tech jobs in Europe while producing sales on the global market. The potential market for micro-CHP units is a significant part of the approx. 5 million boilers that are sold in the EU (Germany: 800 000) every year.

Project Information

Project reference: FCH JU Grant agreement no: 278257

Call for proposals: 2010

Application Area: JTI-FCH

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.3.1 Materials development for cells stacks and balance of plant (BoP)

Contract type: Collaborative project

Start date: 25 October 2011

End date: ongoing

Duration: 36 months

Project cost: € 7,886,782

Project funding: € 3,396,470 million

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MMLCR

Working towards Mass Manufactured, Low Cost and Robust SOFC stacks

Key Objectives

The project addresses a novel design solution for lightweight SOFC stacks that decouple the thermal stresses within the stack and at the same time, allow optimal sealing and contacting. In this way, the capability for thermal cycling is enhanced and degradation resultant of contact, reduced.

The design is highly suitable for industrial manufacturing and automated assembly. The industrial partners will build up the necessary appliances for low cost production and automated quality control, stacking and assembly of stacks.

Technical approach and achievements

The project has been slowed down by a transfer process involving the movement of the project coordination from Juelich to the University of Birmingham.

Nevertheless, the first successful supply of parts and production of single repeating units has commenced. Laser supported glass welding has rendered promising results, and the design of a manufacturing unit has begun.

Summary/overview

Lightweight SOFC stacks are currently being developed for stationary applications such as residential CHP units, for automotive applications such as APUs and for portable devices. They supply electrical efficiency of up to 60%, a high fuel flexibility, being able to operate on syn-gas from Diesel reforming as well as LPG, methane or hydrogen, and promising cost savings due to greatly reduced amounts of steel interconnect material.

In mobile and portable applications, the requirements for thermal cycling are high. It is therefore essential that lightweight stacks have excellent thermal cycling and rapid start-up capabilities. The stack design pursued here supplies a compensation of thermo-mechanical stresses between cell and cell frame / repeating unit. Thin steel sheets with protective coating are used for the sake of cost reduction and extended stack lifetime, as well as for stationary applications. The project looks into various facets of improved components (sealing, interconnects, contacting, cells) from the point of view of mass manufacturing and automated assembly that will be cost-efficient.

Expected socio and economic impact

The design targets lower production cost, increased quality and especially shorter start-up times for SOFC stacks and thus systems.

Project Information

Project reference: FCH JU 278525

Call for proposals: 2010

Application Area: 3

Project type: Research and Technical Development

Topic: SP1-JTI-FCH.2010.3.2: Next generation cell and stack designs

Contract type: Collaborative project

Start date: 01 January 2012

End date: ongoing

Duration: 30 months

Project cost: € 4.5 Mio.

Project funding: € 2.07 Mio.

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PREMIUM ACT

PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC

Key Objectives

A general objective is to contribute to the improvement of stationary PEFC systems durability, one of the main hurdles to overcome before successful market development, knowing that the target required is 40000h.

Premium Act specific objectives are to propose a reliable method to predict lifetime, to benchmark components and to improve operating strategies of real systems, in order to reach the following achievements:

- **Relative prediction of durability** - the ranking of durability predicted between different MEAs is in agreement with ranking obtained in real conditions;
- **Absolute prediction of durability** - the method is successful in predicting the observed lifetime with reduced testing duration thanks to accelerated tests;
- **Innovative unit management strategies** - the strategies allow a measurable durability increase in the stacks and systems of the industrial partners without negative impact on the customer needs' fulfilment.

Challenges addressed

Main issue is the durability of fuel cell system for micro Combined Heat and Power applications.

It is necessary to first identify and understand the causes of fuel cells degradation in real conditions.

Degradation is mainly related to the degradation of the Membrane Electrodes Assemblies (MEAs), core of the fuel cells where electrical power is produced.

This degradation is double: decrease of the electrical power with time and degradation of the components. As multiple factors induce degradation (materials used for the catalysts or for the membrane, operating conditions such as cell temperature, gases composition), it is also necessary to understand the link between the different degradation mechanisms. The challenges of Premium Act are related to the approach which is to combine specific experimental and modelling tools to study the degradation at different scales from fuel cell performance down to microstructure of materials.

Additional issue is the consideration of two strategic fuel cell technologies for stationary markets: DMFC (Direct Methanol Fuel cell) power generators and PEMFC (Proton Exchange Membrane Fuel cell) power CHP systems fed by reformat hydrogen.

Technical approach and achievements

The technical approach has been built on technical tasks interconnected in the right way to complete the challenging objectives described above.

First step is to identify and understand the causes of degradation, particularly of Membrane Electrode Assemblies, in real conditions (with a focus on the accelerating features). These conditions are thus reproduced on small devices to estimate MEAs' lifetime. Then, analyses are conducted on the components, to elucidate how their microstructure or their properties are degraded during fuel cell operation.

In parallel, multi-physics models are developed to enable the description of the phenomena appearing during the ageing at the different scales of the cell and for different conditions, considering as well the decrease of the electrochemical performance as the alteration of the MEA materials features (catalysts, electrodes and membranes); models validation being conducted through specific single cell tests. The core technical part of the project will be to combine all the information coming from the experimental tests or analyses and from the modelling to propose and validate **relevant accelerated tests able to couple various degradation factors** and to assess different MEAs' lifetime more rapidly than with normal tests. Final expected outcomes are **operating strategies able to improve the lifetime** of the systems considered and a **methodology to predict the life time of their MEAs**.

Expected socio and economic impact

The project contributes directly to the development of the European fuel cell activities at least related to the three industrial partners involved. Premium Act aims at developing a methodology adaptable to the multiple PEFC technologies for the improvement of systems durability. In this sense, the success of the project should help to overcome one of the main bottlenecks preventing fuel cells market development for European providers of stationary fuel cell systems and will contribute to cross cutting issues relevant for European R&D and fuel cell



<https://www-premiumact.cea.fr>
www.MRTfuelcell.polimi.it/premiumact.html

Stationary power production and CHP

industry development. Thus, reliable systems corresponding to the technical specifications of the energy global market could be widespread, which will change the end-user habits towards the stationary energy management and will help to reduce greenhouse gas emission.

The project also deals with education by involving post-doctoral researchers, PhD and MSc students in activities at CEA, DLR & POLIMI. To have the best impact as possible on the PEFC early market community, results and data collected in the project will be disseminated through scientific papers & conferences. A major dissemination action has been the organization of the **Public workshop on "Characterization and quantification of MEA degradation processes" organized at CEA/Grenoble the 26 & 27th September 2012.**

This project could otherwise contribute to Safety, Regulations, Codes and Standards for future standards definition thanks to project outcomes on traditional and accelerated testing & on degradation models for both fuel cell technologies considered, PEMFC and DMFC.

Project Information

Project reference: Grant agreement n° 256776

Call for proposals: FCH JU 2009 - 1

Application Area: Stationary FC systems

Project type: Research

Topic: SP1-JTI-FCH.2009.3.1: Fundamentals of fuel cell degradation for stationary power applications

Contract type: Collaborative Project

Start date: 01 March 2011

End date: 28/02/2014

Duration: 36 months

Project cost: € 5.4 million

Project funding: € 2.5 million

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RAMSES

Robust Advanced Materials for Metal Supported SOFC

Key Objectives

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 will be developed. By considering advanced materials tailored for this application, such cells will be able to operate at 600-700°C in hydrogen and methane steam reforming is also considered. Degradation upon thermal and redox cycling is also studied.

Challenges addressed

The achievement of such performance needs several key-developments to be addressed:

- manufacturing of a durable metallic substrate
- deposition of the ceramic layers without affecting the substrate microstructure, with a special emphasis on the dense electrolyte deposition
- proof-of-concept via the integration of the cells into a short stack, supported by inspection techniques to evaluate the good quality of components at each step of the process
- testing activities to determine the performance and durability of cells and stacks, and to investigate specifically identified failure mechanisms.

Technical approach and achievements

The technical objective of this project is the development of a SOFC cell with an improved lifetime due to the low operating temperatures (600-700°C) while achieving high performances by applying advanced low-temperature electrodes and electrolyte materials. The Metal Supported Cell concept (MSC) will in addition reduce statistically based mechanical failures, since this type of cell is intrinsically more mechanically robust, and decreasing manufacturing cost by decreasing the amount of expensive ceramic materials to minimum. Cost reduction of Balance-of-Plant components will also be achieved because of the lower operating temperature (e.g. insulation, heat exchangers and recycle blowers).

Two technological objectives are targeted:

The development of a performing, durable and cost-effective Metal-Supported Cell. Metal-supported Cell development will include both the metal-substrate development and the cell development itself. The major innovative activities will be focused on the design of the cell and the development of manufacturing processes, with a major focus on the deposition of the electrolyte, which is a key issue of this project.

Manufacturing and integration of the new MSC technology into a short stack for a final proof-of-concept. For the proof-of-concept, the target is to produce full-scale cells, with the best architecture, materials and processes and to integrate them into a planar short stack (approx 100 W) and a tubular stack (approx 75 W). Performance will be evaluated at 600-700°C first with hydrogen and second with internal steam methane reforming (ISR).



**Robust Advanced Materials
for metal SupportEd
Solid oxide fuel cell**

www.ramses-project.org

Stationary power production and CHP

Expected socio and economic impact

Fuel cell applications can contribute significantly to European public policy objectives for energy security, air quality, reduction of greenhouse gas emissions and industrial competitiveness. According to the European Hydrogen and Fuel Cell Technology Platform and to the IPHE, cost and durability/reliability are the two major impediments to SOFC widespread development and commercialization. Within the EU supportive policy framework to stimulate research, development and deployment, the 3 year RAMSES project will produce a robust, highly performing and durable cell for stack manufacturers addressing the Combined Heat and Power (CHP) application. The expected impact of the project will be the availability of a stable competitive SOFC cell, with significantly improved mechanical reliability, as well as combined redox-thermal cycling, and lower manufacturing costs, particularly regarding materials. As a result it will contribute to make SOFCs more attractive and affordable, for a market entry in CHP applications at the horizon 2015 – 2020.

Project Information

Project reference: FCH JU 256768

Call for proposals: 2009

Application Area:

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2009.3.2: Material development for cells, stacks and balance of plant (BoP)

Contract type: Collaborative project

Start date: 01 January 2011

End date: ongoing

Duration: 36 months

Project cost: € 4.7 million

Project funding: € 2.1 million

Project Coordinator

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ReforCELL

Advanced multi-fuel Reformer for CHP-fuel CELL systems

Key Objectives

ReforCELL aims at developing a high efficiency PEM fuel cell micro Combined Heat and Power system (net energy efficiency > 42% and overall efficiency > 90%) based on a novel, more efficient and cheaper pure hydrogen production unit (5 Nm³/h), together with an optimized design of the subcomponent for the BoP. The target will be pursued with the integration of a reforming and purification system in one single unit using Catalytic Membrane Reactors.

Technical approach and achievements

The industrial requirements of the m-CHP system have been completed. The study identified the characteristics of state-of-the-art technology regarding reactor, PEM, BoP, raw material specifications and integrated CHP systems. The goal was to define the industrial requirements for the introduction of a CHP system in industry. Related to the Catalytic Membrane Reactor, the first Ni based catalysts, both commercial and new developments are being characterised. Besides, the process depositions for developing the membranes have been set up and first Pd based selective layers have been deposited. Studies on interdiffusion layers and support quality are on-going.

Summary/overview

Distributed power generation via Micro Combined Heat and Power systems has been proven to overcome the disadvantages of a centralized plant since it can provide savings in terms of Primary Energy consumption and energy costs. However, wide exploitation of these systems is still hindered by high costs and low reliability due to the complexity of the system.

ReforCELL aims at developing a highly efficient heat and power cogeneration system based on: i) design, construction and testing of an advanced reformer for pure hydrogen production with optimization of all of the components of the reformer (catalyst, membranes, heat management etc) and ii) the design and optimization of all the components for the connection of the membrane reformer to the fuel cell stack.

The main idea of ReforCELL is to develop a novel, more efficient and cheaper multi-fuel membrane reformer for pure hydrogen production in order to intensify the process of hydrogen production through the integration of reforming and purification in one single unit.

Additionally, ReforCELL hopes to increase the efficiency and lifetime of the reformer, create novel stable catalysts and highly permeable and more stable membranes. Afterwards, suitable reactor designs for increasing the mass and heat transfer will be realized and tested at laboratory scale. The most suitable reactor design will be scaled up at prototype level (5 Nm³/h of pure hydrogen) and tested in a CHP system.

The connection of the novel reformer within the CHP will be optimized by designing heat exchangers and auxiliaries required in order to decrease the energy losses in the system. The project aims to increase the electric efficiency of the system above 42% and the overall efficiency above 90%.

A complete lifecycle analysis of the system will be carried out and a cost analysis and business plan for reformer manufacturing and CHP systems will be supplied.



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Stationary power production and CHP

Expected socio and economic impact

A target cost of 5000 €/kW_{el} by 2020 has been proposed to enlarge the use of residential micro-CHP systems. The cost of the reformer is an important part of the overall cost, accounting for around 25 % of overall costs in domestic micro-CHP. In this context, REforCELL aims to develop an advanced reformer for CHP applications. The project will directly impact the performance of individual components of fuel cell systems, the optimization of interaction between BoP components and mature stacks, the components which are viable for mass production, lifetime, cost and recyclability.

Project Information

Project Reference: FCH JU Grant Agreement n° 278997

Call for proposals: FCH-JU-2010-1

Application Area: SP1-JTI-FCH.3: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.3.3 Component improvement for stationary power applications

Contract type: Collaborative project

Start date: 01/02/2012

End date: 31/01/2015

Duration: 36 months

Project cost: € 5,590,762

Project funding: € 2,857,211

Project Coordinator

FUNDACION TECNALIA RESEARCH AND INNOVATION

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Quantis Sàrl
Switzerland

JRC –JOINT RESEARCH CENTRE-
EUROPEAN COMMISSION
Belgium

ROBANODE

Understanding and minimizing anode degradation in hydrogen and natural gas fuelled SOFCs

Key Objectives

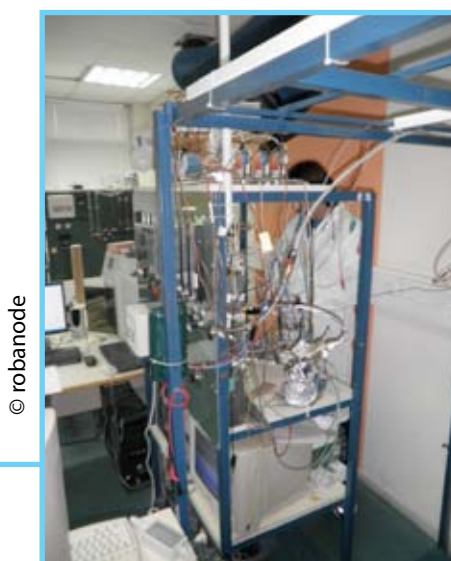
One of the main obstacles for commercialization of Solid Oxide Fuel Cells (SOFCs) is insufficient durability, which is largely due to degradation of the anode electrode. Anode degradation in hydrogen fuelled SOFCs corresponds mainly to micro-structural changes due to thermal and/or electrochemical sintering and oxidation/reduction of the anode, due to interruption of the fuel supply. Anode degradation in SOFCs using natural gas or other hydrocarbon fuels is additionally due to carbon deposition and sulphur poisoning, which result in severe decrease of both the electrocatalytic activity of the anode and its catalytic activity for internal reforming or direct oxidation of the fuel. The **key objective of ROBANODE** is the development of an integrated strategy for understanding the mechanism of anode degradation in SOFCs. This is envisaged through a combination of theoretical modelling with experiments over an extended range of operating conditions, using a large number of modified state-of-the-art (SoA) Ni-based cermet anodes.

Challenges addressed

The project's aim is to develop a detailed study of the mechanism of the anode degradation processes, through identification of similarities/differences in the degradation behaviour of unmodified and modified (via different methods and modifiers) state of the art Ni-based cermet anodes, assisted by detailed characterization of the anode materials (as-prepared and used). An important point of the proposed strategy is the development of a theoretical model for the description of the performance and degradation of the anode, with non-adjustable parameters, which will accept as input values of parameters which will be experimentally determined.

Technical approach and achievements

The main objective of ROBANODE is to understand the interrelations between the degradation factors so that targeted modifications in the structure and morphology of the Ni based anodes can be made. To achieve this objective modelling in combination with experimental observations is used, aiming at simulating the physicochemical and electrochemical process taking place at the electrochemical interface and on the catalytic surface of the anode. In this way diagnostic tools will be developed by a combination of short-term experimental observations and modelling so that the long term prediction of the functional performance of the anode can be achieved.





<http://robanode.iceht.forth.gr/>

Stationary power production and CHP

Expected socio and economic impact

The direct economic benefits that may result from ROBANODE can be summarized as follows:

- Reduction in the degradation rate of state of the art SOFCs which operate with H₂ or natural gas
- Long-term durability and reduction of the commercial cost of hydrocarbon fuelled SOFCs.

Indirect socio-economic benefits are additionally expected, since commercialization and wide use of SOFCs will result in a significant reduction of air pollution. These general socio-economic benefits which are expected to result from ROBANODE can be summarized as follows:

- Exploitation of the existing natural gas and liquid petroleum gas (LPG) network and easier introduction of SOFCs into households and public buildings.
- Easier market penetration of fuel cell and renewable energy technologies with a highly positive impact on the reduction of air pollution, health and environment.
- Development of renewable energy sources for decentralised energy supply.
- Creation of highly specialized jobs in different regions of the European Union.

Project Information

Project reference: FCH JU 245355

Call for proposals: 2008

Application Area: SP1-JTI-FCH.3: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.3.3: Degradation and lifetime fundamentals

Contract type: Collaborative project

Start date: 01/01/2010

End date: 31/12/2012

Duration: 36 months

Project total costs: € 3 394 888.00

Project funding: € 1 568 530.00

Project Coordinator

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SCOTAS SOFC

Sulphur, Carbon, and re-Oxidation Tolerant Anodes and Anode Supports for Solid Oxide Fuel Cells

Key Objectives

Solid oxide fuel cells (SOFCs) have a great advantage in their fuel flexibility compared to other fuel cells (such as PEMFC), and thus are particularly suited for stationary cogeneration of heat and power based on natural gas or other hydrocarbon fuels. The aim of the project is to demonstrate a new more robust type of solid oxide fuel cell for application in small scale, combined heat and power systems (micro CHP). Thus, the project is a material based approach to increase micro CHP robustness, simplify operation strategies and thus reduce system costs. It addresses in particular critical issues in the StartUp/Shut Down phase and during grid outage/system failures.

Challenges addressed

The metal nickel is a major material in today's SOFCs and commonly used together with ceramic as a composite material for the fuel electrode and support. Although it performs satisfactory and is stable at the reducing conditions and operating temperatures of SOFCs, the choice of nickel makes the fuel electrode very sensitive to carbon deposition at low steam / oxygen contents, deactivation by traces of sulphur present (e.g. as odorants in pipeline natural gas) and mechanical failure of the electrode during re-oxidation caused by loss of fuel during operation. These three major failure mechanisms have to be addressed today at the system level. The project will demonstrate a new full ceramic SOFC cell with superior robustness as regards to sulphur tolerance, carbon deposition (coking) and re-oxidation (redox resistance). Having a more robust cell will thus enable the system to be simplified, something of particular importance for small systems, e.g. for combined heat and power (CHP).

Technical approach and achievements

Oxide ceramics based on strontium titanates have been investigated in previous EU projects (Real-SOFC and SOFC600) and developed up to button cell sizes. The approach in this project is to integrate three of the most promising compositions into a full cell and thus evaluate their performance under application relevant conditions.

Key milestones have been the selection of three candidate compositions and the evaluation of test routines within the first year of the project and the selection of the best suited materials for anode and support structures at mid term. The final assessment of the cell concept will take place at stack level according to test conditions specified by the industrial partners. At the end of the project a 1 kW stack built on these new cells is scheduled to be tested in a real micro CHP system, namely the Galileo system from Hexis AG.

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Expected socio and economic impact

It is expected that the outcome of the project will be improved anode and anode support materials, which improves the performance in regards to the identified failure mechanisms for fuel tolerance (sulphur and carbon) and re-oxidation resistance in SOFCs. Thus, the project can contribute significantly to fulfilling the electrical efficiency, lifetime and target costs requirement for SOFCs used with the relevant types of fuels and applications. A further socio-economic factor is the replacement of nickel (nickel oxide during fabrication) by a more environmentally friendly ceramic as a major element in the fuel electrode and support structure. The project has so far proven that sufficient performance levels can be reached and technically relevant cell sizes be fabricated. At present optimisation of the cell fabrication for systematic cell and stack testing is on focus.

Project Information

Project reference: FCH JU 256730

Call for proposals: 2009

Application Area: Stationary Power Generation & Combined Heat and Power (CHP)

Project type: Research and Technological Development

Topic: SP2-JTI-FCH.3.2: Materials development for cells, stacks and balance of plant (BOP)

Contract type: Collaborative Project

Start date: 01/10/2010

End date: 30/09/2013 (ongoing)

Duration: 36 months

Project total costs: € 4.4 million

Project funding: € 1.7 million

Project Coordinator

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Topsoe Fuel Cell A/S
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SOFC-Life

Solid Oxide Fuel Cells – Integrating Degradation Effects into Lifetime Prediction Models

Key Objectives

The project addresses the quantification and understanding of the details of major Solid Oxide Fuel Cells' (SOFC) continuous degradation effects. The goal is to isolate effects occurring on the anode and cathode side of SOFC and **develop descriptions of the degradation mechanisms** as functions of distinctive operating parameters (mainly temperature, atmosphere and current density). These functional descriptions are meant to represent the physical and chemical changes of basic materials and layer properties over time. **This information will be integrated into higher level models** that are then capable of predicting single degradation phenomena and their combined effect on SOFC cells and single repeating units.

Challenges addressed

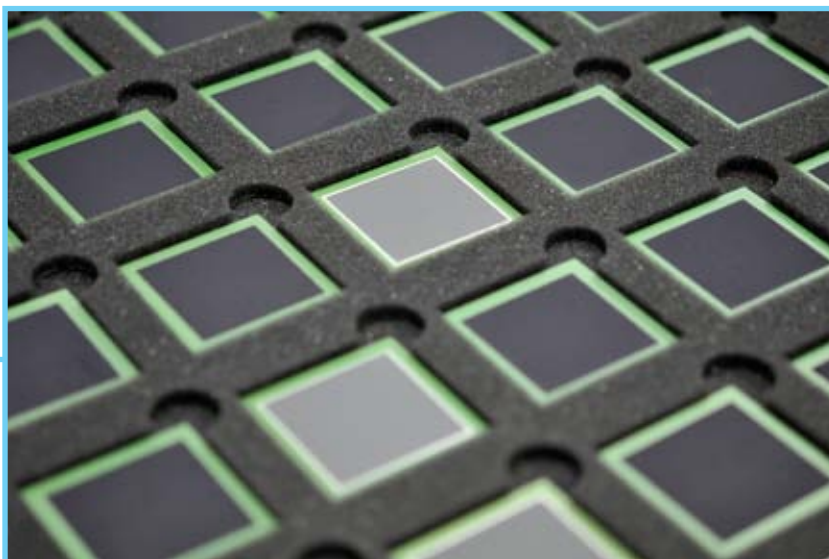
Long-term stable operation of Solid Oxide Fuel Cells (SOFC) is a basic requirement for introducing this technology to the stationary power market. Electricity generating equipment is usually designed for lifetimes of 10 years and above, corresponding to between 40 000 to over 100 000 hours of operation. The continuous degradation of fuel cell voltage commonly observed has to be reduced so that the loss of power remains within acceptable limits during the lifetime. **The project aims at a better understanding of the degradation phenomena as a tool for mitigating these effects and as a first step towards developing accelerated testing methods.**

Technical approach and achievements

The project follows a systematic approach to analysis of some of the most important degradation mechanisms. It concentrates on the 'continuous' (baseline) degradation phenomena determining stack behaviour in the long term. By deconstructing the SOFC stack into isolated elements and interfaces, these are exposed to the physical conditions found in typical SOFC system operation (and beyond). At regular intervals, specimen are taken from the experiments and thus a time series of the gradual development of degradation effects are recorded. This time-lapse photography type approach is designed specifically to allow the modelling of physical change over time.

Key milestones, deliverables

Anode sub-model
Cathode sub-model
Integrated model(s) for predicting cell and SRU level degradation
Identification, Assessment and Simulation of Major Degradation Parameters - Concluding report (M36).



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Stationary power production and CHP

Expected socio and economic impact

The project aims at **improving the longevity of SOFC** and as such contributes towards the market introduction and economic development of the stationary fuel cell sector.

Achievements/Results to date

First experiments have been conducted and the evaluation is under way.

Project Information

Project reference: FCH JU 526885

Call for proposals: 2009

Application Area: 3 (Stationary)

Project type: Basic Research

Topic: SP1-JTI-FCH.3.1: Degradation and lifetime fundamentals

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 5.700.000

Project funding: € 2.400.000

Project Coordinator

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Eidgenössische Materialprüfungs-
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Institute of High Temperature
Electrochemistry
Russia

Teknologian tutkimuskeskus VTT
Finland

Ecole Polytechnique Fédérale Lausanne
Switzerland

Imperial College
UK

Electricité de France
France

Zürcher Hochschule für Angewandte
Wissenschaften
Switzerland

SOFCOM

SOFC CCHP with poly-fuel: operation and management

Key Objectives

The proposal is an applied research project devoted to demonstrate the technical feasibility, the efficiency and environmental advantages of **CCHP (a three product plant based on cogeneration of cooling, heat and power) based on SOFC (solid oxide fuel cell technology) fed by different typologies of biogenous primary fuels (biogas and bio-syngas, locally produced), also integrated by a process for the CO₂ separation from the exhaust gases.**

The activity will be devoted to the scientific improvement of SOFC fed by biofuels, but especially to the technical and economical management of two demonstration of complete energy systems based on SOFCs. Several issues will be addressed: the impact of the fuel pollutants on the SOFC and fuel processing units, and consequently the necessity of gas cleaning; the operation of the integrated plants in CCHP configuration; the design and optimization of the carbon sequestration-management modules; the analysis and implementation of maintenance and repair strategies of those plants. Finally, the lessons learned from the demonstration will be used for pre-normative issues and scale-up analysis of this typology of integrated plants.

Challenges addressed

The general aim is the technological improvement of a virtual combination of fuel and technology: biogenous fuels (biogas, bio-syngas) as renewable fuels in high efficiency electrochemical CCHP generators (solid oxide fuel cells), able also to effectively separate and reuse the CO₂ contained in its exhaust streams. To achieve this, the project foresees the design, installation and optimization of two demonstration plants, with the aim of facing and solving all the technical problems correlated to the coupling of biogenous fuels and SOFC, with CO₂ removal. In particular, the following target will be faced: (1) *Fuel issues* considering detailed poisoning mechanisms, advancing in cleaning and processing technologies; (2) Define and operate *new proof-of-concept fuel cell systems* fully integrated with *biomass processing units and carbon sequestration and handling technologies*; (3) *Maintenance, safety, repair and de-commissioning* of fuel cell systems on a *demonstration scale*.

Technical approach and achievements

The research activity will be devoted to the scientific, technical and economical management of two demonstration of complete energy systems based on SOFCs.

A first proof-of-concept SOFC system (Torino, Italy) will be able to operate with biogas produced in an industrial waste water treatment unit (WWTU).

The plant will be in operation as CCHP plant, with heat recovery from the exhaust for the production of hot services (e.g. hot water) and conditioning services (through an adsorption chiller). Also, the plant will be completed with a CO₂ separation from the anode exhaust and with a section of CO₂ management (and disposal) integrated with the primary fuel processing system.

A second proof-of-concept SOFC system (Helsinki, Finland) will be demonstrated considering a SOFC stack operating with a syngas from biomass gasification. This second demonstration plant will be concentrated on the operation of a SOFC stack with a lean gasification fuel; all the concerns related to a proper fuel gas cleaning for fuelling the fuel cell system.

Expected socio and economic impact

The main impact of the project will be the 'proof-of-concept' demonstration of two SOFC units integrated with biogas or bio-syngas, respectively. Such fuels have a wide potential in terms of availability and diffusion over the territory. The fuels considered are not only of interest because of their carbon neutrality, but also for certain peculiarities. In the case of biogas coming from the sewage plant, it represents a by-product of a dedicated process of waste-water treatment. Such plants have already a large diffusion over the territory (especially in urban areas where the continuously collected sewage has to be treated - only in Italy, more than 120 large plants in urban areas exist), with a mature technology already developed behind.

Therefore it already subsists a huge biogas potential ready to be exploited, and therefore a large market potential for such SOFC integrated systems. The bio-syngas option is another interesting one, investigated within the project, which will face different BoP integration and cleaning issues. Again the market potential of such integrated systems is high, especially for those areas where the biomass feedstock is ready available.

Another relevant impact accomplished by the project will be represented by the CCS capability of the integrated systems studied and tested during the project. Plants with a negative carbon emission balance will be then the focus and objective of our project, with an interest of such architectures of plants also in terms of energy economy and energy policy.

Finally a major impact will be represented by the CCHP mode of the tested demonstration units. Such operational mode will permit to achieve not only high electrical efficiency (>45% with biogenous fuel), but also global efficiencies exceeding values around 80-85%. Therefore, the project foresees the design, installation and optimization of demonstration plants, with the aim of facing and solving all the technical problems correlated to the coupling of biogenous fuels and SOFC (with CO₂ removal), with an optimization of their technological structure to achieve a optimization of their economic revenues.

Project Information

Project reference: FCH JU "SP1-JTI-FCH.2010.3.4: Proof-of-concept and validation of integrated fuel cell systems"

Call for proposals: year 2010

Application Area: Area SP1-JTI-FCH.3: Stationary Power Generation & CHP

Project type: Demonstration

Topic: Proof-of-concept and validation of integrated fuel cell systems

Contract type: Collaborative Project

Start date: 01/11/2011

End date: 31/10/2014

Duration: 36 months

Project total costs: € 6,219,613

Project funding: € 2,937,753

Project Coordinator

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Institut Energtyki (IEN)
 Poland

Ecole Polytechnique Federale de Lausanne (EPFL)
 Switzerland

Technische Universitaet Muenchen (TUM)
 Germany

Universita degli Studi di Torno (UNITO)
 Italy

SOFT-PACT

Solid Oxide Fuel Cell micro-CHP Field Trials

Key Objectives

SOFT-PACT has been established to undertake a large scale field demonstration of a Solid Oxide Fuel Cell (SOFC) generator that can be utilised in residential applications. The objectives are to:

- Design, develop and deploy integrated fuel cell mCHP systems
- Facilitate the training and re-skilling of installation and maintenance engineers
- Provide remote control and diagnostics of all the systems from a central point in real time
- Identify and quantify benefits to the homeowner
- Ensure long-term reliability and life data from the systems.

Technical approach and achievements

So far, an EU Market Study has been published, showcasing the most favourable EU member countries for the deployment of Fuel Cell technology, based microCHP (Combined Heat and Power).

Expected socio and economic impact

As of now, the project has been successful in contributing towards mitigating the effects of climate change through a more efficient use of energy. Specifically, the BlueGen unit used in the pathfinder field trial displaces 4.5 Tonnes of CO₂ p.a. (in the UK), using electricity made at 60% net efficiency. These field trials will discover real world issues in their deployment.

European leadership in fuel cells will play a key role in creating high-quality employment opportunities, from strategic R&D to production, craftsmen and installers; the number of employees will be increase throughout the consortium and supply chain due to this project.

Expected socio and economic impact

Key outputs from the project (an EU market study, data from two field trials, building of installation capability and the completion of the development of a optimised integrated FC system) address the major hurdles / barriers that are limiting a full scale system of fuel cell deployment, which are namely: the reduction in the total cost of the system, compared to other microgeneration devices; development of the supply chain for key components (inverters, filters, etc) to enable cost reduction and statistical proof of the system's reliability and maintenance requirements from gathering long-term field test data which will provide the manufacturer with the confidence to offer long-term product warranties. However these alone will not place the product in homes as these systems require qualified and specialized hybrid (electrical, mechanical and IT) installation and maintenance engineers. Aware of this gap, this project endeavours to begin the creation of this capability, while also validating its ability to safely control and operate a multitude of systems at multiple locations in real time and ensuring the ability to avoid the need for maintenance call outs.

This project aims to prove that a series of fuel cell appliances can be installed into occupied residential locations and show that at least 50% of its fuel can be turned into electrical energy – something which has been originally only demonstrated in a laboratory. It will then gather sufficient real time data on system performance to show the generating efficiency and the life of a system is within the manufacturer's targets: 40,000 hours on key components.

Designing the final version of an integrated system will take the findings from the pathfinder field trial into consideration in order to enhance reliability and serviceability while miniaturising the current prototype in order to meet acceptable size constraints for domestic installation.

Cost and performance analysis of the systems sub-components will be performed and redesigned as necessary to meet the JTI AIP commercial system cost target of €4-5k per kWe in mass production (post 2015).

Project Information

Project reference: FCH JU 278804

Call for proposals: 2010

Application Area: Stationary power production and CHP

Project type: Demonstration

Topic: SP1-JTI-FCH.2010.3.5

Contract Type: Collaborative Project

Start date: 07 July 2011

End date: 07 July 2014

Duration: 36 months

Project cost: € 10.4 million

Project funding: € 3.95 million

Project Coordinator

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STAYERS

STationary PEM fuel cells with lifetimes beyond five YEaRS

Key Objectives

Economical use of PEM fuel cell power for stationary applications demands a lifetime from the fuel cells of at least a minimum of 5 years, or more than 40,000 hours of continuous operation. This, in contrast to the large scale application for automotive use, which has dedicated PEM research on low cost production techniques with practical lifetimes of the fuel cells of 5,000 hours. The main objective of STAYERS is materials research leading to the production of a full size, 10 kW prototype PEM fuel cell stack, capable of operating continuously during 40,000 hours in a system for stationary power generation in a chlor-alkali plant. The lifetime of the 40,000 hours will be proven by extrapolation over a long duration data. The initial phase of the project consists in establishing the dominant degradation mechanisms of the state-of-the-art MEA and setting up the initial framework for the theoretical model.

Challenges addressed

The PEM fuel cell consists of several alternately stacked components, such as membrane-electrode-assemblies (MEAs) and bipolar plates, pressed together by housing. The MEA consists of subcomponents like gas diffusion layers, catalyst layers and a thin membrane, separating reactant gases. The bipolar plate is a carbon composite, electrically connecting neighbour cells and distributing reactant gases throughout the MEA electro-active area.

All these components face harsh conditions imposing chemical and mechanical stress that during operation, change the structure and composition, thereby lowering the power output of the fuel cell and limiting the lifetime. operating conditions like temperature, gas humidification and gas feed play a role in the fuel cell lifetime.

Within the project it will be attempted to determine the dominant degradation mechanisms in a real life stationary PEM Power Plant. Subsequently these components and operational parameters will need optimising to reach the goal of 40,000 hours of continuous operation.

Technical approach and achievements

The project foresees the following steps:

1. Duration experiments in a real-life stationary fuel cell plant from Nedstack and at SINTEF and SolviCore at lab-scale with stacks composed of the state-of-the art reference materials, like the membrane provided by Solvay Specialty Polymers Italy.
2. Model improvement and analysis of on-line and off-line measurements by JRC. Post-mortem analysis on stacks returning from durability experiments yields data on the degradation processes. Based on these results improved MEA's and stack components will be produced as well as a fine tuned model.
3. Subsequent series of duration experiments are started and SINTEF will also perform accelerated lifetime tests.
4. The final period starts with the most promising stacks. From the model and from data extrapolation the lifetime can be predicted.



Expected socio and economic impact

One of the main aims of the FCH-JU is: "... placing Europe at the forefront of fuel cell and hydrogen technologies worldwide and enabling the market breakthrough of fuel cell and hydrogen technologies ...". To reach this goal, it is essential that the durability of the stack and its components is significantly improved and at a well mature and cost competitive level. STAYERS will contribute to this by developing a stationary PEMFC stack with 40,000 hours lifetime.

The project will also strengthen the knowledge about degradation mechanisms in PEM fuel cells. At the same time STAYERS will create business opportunities, not only for its partners, but also for the whole of the fuel cell community. Commercial prospects for PEM FC-generators are very promising if a guaranteed stack lifetime of 5 years can be given. Society will benefit by less CO₂-emission, pollution-free, low noise transport, and clean silent generators.

Project Information

Project reference: FCH JU 256721

Call for proposals: 2009

Application Area: Stationary power

Project type: Research and Technology Development

Topic: SP1-JTI-FCH.2009.3.2: Materials development for cells, stacks and balance of plant (BoP)

SP1-JTI-FCH.2009.3.1: Fundamentals of fuel cell degradation for stationary power application

Contract type: Collaborative project

Start date: 01 January 2011

End date: 31 December 2013

Duration: 36 months

Project cost: € 4.1 million

Project funding: € 1.9 million

Project Coordinator

NEDSTACK FUEL CELL TECHNOLOGY

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SOLVAY SPECIALTY POLYMER S.P.A.
Italy

SINTEF
Norway

JRC-JOINT RESEARCH CENTRE-
EUROPEAN COMMISSION
Belgium

DURAMET

Improved durability and cost-effective components for new generation solid polymer electrolyte direct methanol fuel cells

Key Objectives

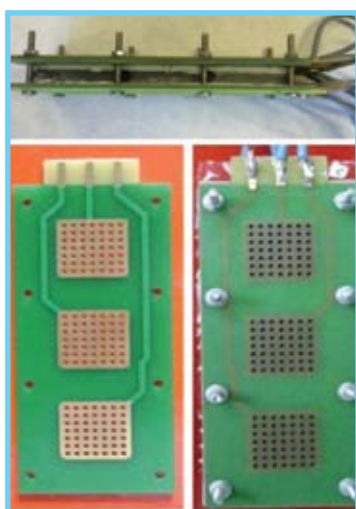
Direct Methanol Fuel Cells (DMFCs) have been postulated as suitable systems for power generation in the fields of portable power sources, remote and micro-distributed energy generation and auxiliary power units (APU). The main objective of the DURAMET project is to develop cost-effective components for DMFCs with enhanced activity and stability in order to reduce stack costs and improve performance and durability. The project deals with the development of DMFC components for application in auxiliary power units and portable systems.

Challenges addressed

Specifications and protocols for assessing direct methanol fuel cells components and devices such as membranes, catalysts, MEAs and stacks have been delivered. These are available to the public through the project website. Low temperature membranes with improved conductivity and reduced methanol cross-over have been developed. Enhanced anode and cathode electro-catalysts as well as catalytic layers including specific promoters have allowed for the achievement of an increase in performance with respect to baseline formulations. Proton conductivity values as high as 180 mS/cm at 150 °C have been obtained with high temperature membranes. These results appear promising in relation to the development of high temperature DMFCs with enhanced reaction kinetics.

Technical approach and achievements

The market segments for DMFCs deal with portable generators, UPS, back-up power systems and portable micro-fuel cells. The project results regarding enhanced performance and cost reduction materials and devices will be of interest for an emerging European fuel cells industry in the short term. The materials are demonstrated in devices which are technically representative of power ranges and application requirements for which DMFCs can be used in early-market applications. Moreover, this technology provides the potential to reduce pollution, energy use, and greenhouse gases.



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Monopolar plates and DMFC ministack operating under passive mode for portable applications

Summary/overview

Direct Methanol Fuel Cells (DMFCs) working at low and intermediate temperatures (up to 130-150 °C) and employing solid protonic electrolytes have been postulated as suitable systems for power generation in the field of portable power sources, remote and micro-distributed energy generation as well as auxiliary power units (APU) in stationary and mobile applications. DMFCs utilize liquid fuel to deliver continuous power and they have lower fuel storage and handling constraints than hydrogen fuelled fuel cells. In order to be competitive within the portable and distributed energy markets, the DMFCs must be reasonably cheap, characterised by high durability and capable of delivering high power densities. Before these technologies can reach full scale production, specific problems have to be solved especially the high cost and the short term stability. The activities of this project are focused on new cost-effective membranes with better resistance than Nafion to methanol cross-over as well as the drag of Ru ions. Improved durability electro-catalysts are developed with the aim to reduce costs, degradation and noble metals content. To validate the new membranes and electro-catalysts materials, the specific development of membrane-electrode assembly will be carried out with tailored hydrophobic-hydrophilic electrode characteristics. The new developed components will thus be validated in short stacks to assess their performance and durability under practical operation. Specific attention will be devoted to the exploitation, dissemination and training of young researchers.

Project Information

Project reference: FCH JU 278054

Call for proposals: 2010

Application Area: Early market

Project type: Research and technological development

Topic: SP1-JTI-FCH.2010.4.4: Components with advanced durability for Direct Methanol Fuel Cells

Contract type: Collaborative Project

Start date: 01/12/2011

End date: ongoing

Duration: 36 months

Project cost: € 2,956,874.00

Project funding: € 1,496,617.00

Project Coordinator

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PRETEXO (PXO)
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FCpoweredRBS

Demonstration Project for Power Supply to Telecom Stations through FC technology

Key Objectives

The objectives of this project are as follows:

- Demonstrate the advantages of hydrogen and fuel cells with the supporting hydrogen re-fuelling infrastructure for delivering the expected power supply service, compared to the solutions used today
- Demonstrate a significant number of sites which are based on sufficient maturity levels of fuel cell systems & hydrogen supply solutions. Benchmarking of different technical configurations for fuel cells integrated with renewable sources.

Summary/overview

- The first prototype based on the Dantherm FC is fully operating in the UNIROMA2 Lab where system optimization activities have been running
- The test protocol definition is still under development at research centres
- All the TELCO Operators sites have been chosen and related surveys have been executed. A wide shortlist of potential sites has been selected to be prepared to eventually change some trial sites under the customer's request.
- The permit procedure contracts have been signed with Telecom Italia (negotiation on going for WIND and H3G)
- Training session preparation and dissemination activities are ongoing.

Technical approach and achievements

- Deliverables D2.1 *Energy profile for Radio base Station* released.
- Deliverable D2.2 *Target Specification* released which includes the details of the system solution architecture and specifications of the single components.
- Deliverable D5.2 - *Installation and permitting procedure* released.
- Deliverable D10.1 - Project web-site up and running

Expected socio and economic impact

- The activities on solution definition were longer than expected to fulfil the customer's requirements and improve efficiency. Additional development was needed to best integrate the different equipment in the system
- The project will manage to minimize impacts on the field activities in order to avoid affecting the final project dates
- An amendment will be requested for a change in the DOW without including impacts on the overall project budget (two additional sites with Methanol to replace the two sites Natural Gas that will be not delivered)

Project Information

Project reference: FCH JU 278921

Call for proposals:
2010 (FCH-JU-2010-1)

Application Area: Early Market

Project type: Demonstration Project

Topic: SP1-JTIFCH. 2010.4.2

“Demonstration of industrial application readiness of fuel cell generators for power supply to off-grid stations, including the hydrogen supply solution”

Contract type: Collaborative project

Start date: 01 January 2012

End date: ongoing

Duration: 36 months

Project cost: € 10,591,649

Project funding: € 4,221,270

Project Coordinator

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FITUP

Fuel cell field test demonstration of economic and environmental viability for portable generators, backup and UPS power system applications

Key Objectives

The project aims to increase the visibility of fuel cell systems as a potential alternative to conventional backup power sources (batteries and diesel generators) and prove to potential customers in different industrial sectors their advantages. The technical objectives to meet with these systems are:

- Reliability of greater than 95%
- Durability of more than 1500 hours (real-time or extrapolated)
- Response time of <5ms
- More than 1000 cycles (real time or extrapolated).

Summary/overview

A total of 19 market-ready fuel cell systems from 2 suppliers (ElectroPS, FutureE) have been installed as UPS/ backup power sources in selected sites across the EU. Real-world customers from the telecommunications are using these fuel cell-based systems, with power levels in the 1-10kW range, in their sites. A level of technical performance (start-up time, reliability, durability, number of cycles) that qualifies them for market entry is under evaluation, with the aim of accelerating the commercialisation of this technology in Europe and elsewhere. The demonstration project involves the benchmarking of units from both

fuel cell suppliers according to a test protocol developed within the project. Test protocol is used to conduct extensive tests in field trials in sites selected by final users in Italy, Switzerland and Turkey. The performance is logged and analysed to draw conclusions regarding commercial viability and degree to which they meet customer requirements, as well as suggesting areas for improvement. A lifecycle cost analysis using data from the project will be carried out to determine economic value proposition over incumbent technologies such as batteries or diesel generators. The system producers use the results to obtain valuable first hand feedback from customers, optimise their systems as needed, and demonstrate commercial viability. On the other hand, final users from the telecommunications will experience first-hand the advantages of fuel cells for their applications under real world conditions. The optimisation potential is expected from the production process itself, from the installation of a significant amount of fuel cell systems and from the testing. The project will also develop a certification procedure valid in the selected EU countries under the lead of TÜV Süd.

Technical approach and achievements

The achievements of the project since its beginning are:

- 19 fuel cell systems produced and installed across Europe: 13 systems in selected final user sites and 6 systems in R&D centres for benchmarking;
- Initialization of benchmarking and field testing of the fuel cell systems
- Initialization of a proposal for the LCA analysis of the systems installed and tested
- Initialization of the proposal for the unique certification procedure
- Development of a definitive version of website and different dissemination activities.

Expected socio and economic impact

- Demonstrate the readiness of the FC UPS systems to compete in the marketplace with conventional systems in the short term.
- To show the functional capability of the new technology and to motivate European operators to handle it.
- Support the development of cleaner and more efficient technologies through the substitution of batteries and diesel generators.
- Create an on-field testing bed database that will provide useful data in light of the commercialisation process.
- Provide the means to jump over the technical barriers that hinder the extensive penetration of hydrogen technologies: reliability, lifetime.
- Enhance sustainable development by the promotion of hydrogen technologies which are closely linked to the penetration of renewable energies.
- Contribute to the development and application of codes and standards related to hydrogen safety.

Project Information

Project reference: FCH JU 256766
Call for proposals: 2009
Application Area: Early Markets - SP1-JTI-FCH.4
Project type: Research and Technological Development
Topic: SP1-JTI-FCH.2009.4.2: Portable generators, backup and UPS power systems
Contract type: Collaborative project
Start date: 01 November 2010
End date: 31 October 2013
Duration: 36 months
Project cost: € 5.41 million
Project funding: € 2.47 million

Project Coordinator

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 Joint Research Centre
 Netherlands
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 Swisscom (Schweiz) AG
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 Wind telecomunicazioni s.p.a.
 Italy
 Anton Nidwalden
 Switzerland



Site in Switzerland
 Polycom - EPS

©fitup

HyLIFT-DEMO

European demonstration of hydrogen powered fuel cell material handling vehicles

Key Objectives

The overall purpose and ambition of HyLIFT-DEMO is to conduct a large scale demonstration of hydrogen powered fuel cell material handling vehicles, which enables a following deployment and commercial market introduction starting no later than 2013. The detailed HyLIFT-DEMO project objectives are the demonstration of at least 30 material handling vehicles as well as the demonstration of the corresponding hydrogen refuelling infrastructure at end-user sites.

The project partnership will conduct accelerated laboratory durability tests and validate the value proposition of the technology and the reaching of the commercial and environmental targets. Further objectives are to plan and to secure the initiation of Research and Development (R&D) of the 4th product generation. Finally, the project will contribute to the establishment of an appropriate Regulations, Codes and Standards (RCS) framework which enables smooth commercialisation as well as to the motivation of European, national and regional stakeholders by performing adequate dissemination activities.

Challenges addressed

The project is conducted by a consortium of European companies that for several years have invested significantly in developing and testing hydrogen and fuel cell technology for material handling vehicles.

The technology is now advanced to a 3rd generation level that allows for a large scale demonstration before commencing market deployment. Also extensive market analyses have encouraged the partners to focus on the market segments of 2.5-3.5 tons forklifts and airport tow tractors, as these segments provide the strongest value proposition for fuel cell vehicles in the material handling sector within Europe. Thus the demonstration activities can lead directly to a following market deployment with a solid and proven value proposition for the vehicle end-users.

Technical approach and achievements

The fuel cell system is to be demonstrated in material handling vehicles from three vehicle manufacturers, representing various market segments and system integration approaches. The demonstration is expected to be handled in fleets of at least 3-4 vehicles; end-users envisaging larger fleets will be preferred. Larger fleets would lead to a more viable business case for the supporting hydrogen refuelling infrastructure, but also to an efficient service and maintenance set up. As well as minimizing the final number of demonstration sites, the project will endeavour to place these as close as possible to each other as this lowers costs both for maintenance trips and for hydrogen distribution.

The supply of hydrogen for the sites will either be from local sources or through commercial subcontracting tendering from local gas suppliers. The refuelling infrastructure will either be owned and / or operated by project partners, the end-user or other local partners or projects.

Expected socio and economic impact

HyLIFT-DEMO addresses a specific and proven value proposition where hydrogen and fuel cells replace use of diesel/LPG in 2.5-3.5 ton material handling vehicles where batteries cannot provide a satisfying solution. The higher energy efficiency of the fuel cell compared to the combustion engine enables the end-user to gain savings on fuel costs that lead to a payback time of 3 years, at commercial price targets.

The ambition and driving force of the HyLIFT-DEMO activities and partners are to enable a following deployment and market introduction starting no later than 2013. Therefore the targets to be reached within the project as well as the demonstration model and relations to end-users are set-up with a future commercial value chain in mind. One work package within the project will be dedicated to planning the commercialisation and ensure initiation of market deployment.

Project Information

Project reference: FCH-JU-2009-1, Grant Agreement Number 256862

Call for proposals: AIP 2009

Application Area: SP1-JTI-FCH.4: Early Markets

Project type: Demonstration

Topic: SP1-JTI-FCH.4.1 Demonstration of fuel cell-powered materials handling vehicles and infrastructure

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 7,077,942

Project funding: € 2,881,245

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IRAFC

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

Key Objectives

Polymer Electrolyte Membrane Fuel Cells (PEMFCs), which typically consume H_2 and O_2 , operate at 80-100°C and produce electricity without polluting the environment, seem to be the most technically advanced energy conversion system for stationary/mobile applications and have the highest potential for market penetration. However, the absence of a worldwide infrastructure for transport and distribution of pure hydrogen, in addition to the presence of well-established and developed fossil fuel-based network, favors the short term solution of on-site (stationary) or on-board (mobile) hydrogen production from reforming of various hydrocarbons (e.g. natural gas, gasoline) or alcohols (e.g. methanol, ethanol).

Therefore, the ultimate goal of the project is to provide High Temperature PEM Fuel Cells, which operate up to 210 C°, and to combine them with a methanol reformer operating at the same temperature range and deliver a compact internal alcohol reformer-high temperature PEM fuel cell (IRAFC) device that can be fed with liquid methanol.

Challenges addressed

The complexity of the balance of plant of a **fuel cell-fuel processor** unit challenges the design and development of compact and user friendly fuel cell power systems. The main concept in this project is the incorporation of an alcohol reforming catalyst into the anodic compartment of the fuel cell, so that methanol reforming takes place inside the fuel cell stack. The development of an **Internal Reforming Alcohol - High Temperature PEM Fuel Cell (IRAFC)** poses an ambitious technological and research challenge which requires the effective combination of various technological approaches regarding materials development, chemical reaction engineering and stack design. The proposed fuel cell comprises of

- A high temperature membrane electrode assembly (HT-MEA), able to operate at temperatures of 190-220°C.
- A steam reforming catalyst, which can either be (i) present together with the Pt-based electrocatalyst in the anode, (ii) deposited on the gas diffusion layer or (iii) deposited on the surface of monolithic structures, which should be functional at the operating temperature of the fuel cell.

Technical approach and achievements

The main objective of the proposal is the development of an internal reforming alcohol high temperature PEM fuel cell. To achieve this, the following goals should be accomplished:

- Design and synthesis of robust polymer electrolyte membranes for HT-PEMFCs, which enable operation within the temperature range of 190-220°C.
- Development of alcohol, (methanol or ethanol) reforming catalysts, for the production of low carbon monoxide content hydrogen, in the temperature range of HT-PEMFCs, i.e. at 190-220°C.
- Integration of steam reforming catalyst and high temperature MEA in a compact **Internal Reforming Alcohol - High Temperature PEMFC**. Integration may be achieved via different configurations as related to the position of the reforming catalyst.

The proposed compact system differs from conventional fuel processors and allows for efficient heat management, since the "waste" heat produced by the fuel cell is in-situ utilized to drive the endothermic reforming reaction. The targeted power density of the system is 0.15 W/cm² at 0.7 V.

Expected socio and economic impact

- Internal alcohol reforming - Fuel cell development will intensify the mass production of renewable fuels (like methanol by the CO₂ reduction) with positive economic effects.
- The reduction on oil dependence will increase economic security.
- Energy produced by a fuel cell will be characterized as high quality energy because of the high conversion efficiency from chemical to electrical energy (~50%) almost twice as high compared to internal combustion engines, and because of the zero emissions of pollutants and greenhouse gases (due to the recycling of CO₂ to produce renewable fuels) to the environment.
- The extensive use of fuel cells will reduce air pollutants in metropolitan areas.

Project Information

Project reference: FCH-JU-2008-1

Call for proposals: 2008

Application Area: SP1 Cooperation

Topic: SP1-JTI-FCH-4.2: Fuel supply technology for portable and micro FC

Contract type: Joint Technology Initiatives – Collaborative Projects (FCH)

Start date: 01 January 2010

End date: ongoing

Duration: 36 months

Project cost: € 2.5 million

Project funding: € 1.4 million

Project Coordinator

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ISH₂SUP

In situ H₂ supply technology for micro fuel cells powering mobile electronics appliances

Key Objectives

The key objective of the project is to develop a fuelling system for micro-fuel cells. The concept is based on in-situ production of hydrogen. Two novel solutions are proposed: one is based on using NaBH as the fuel and the other one on utilizing catalyzed electrolysis of methanol. The primary application area is fuel cell based power sources of mobile and portable electronic appliances. The ISH₂ project concentrates on research and development of the hydrogen cartridge technology and the electrical system. Development of micro-fuel cells is excluded, validation of the fuelling system will be performed with commercially available small fuel cells. The main practical targets are to prove the feasibility of each fuelling technology and to fulfill the RCS requirements of mobile/portable electronic appliances in consumer markets, and to scheme a logistics system for disposable or recyclable cartridges used for fuelling the proposed system.

Challenges addressed

The targeted power range is 5 – 20 W. Within this range there are many electronic appliances for mobile use, like phones, laptops, cameras, etc, which suffer short operation time caused by easily draining batteries. We like to develop fuel cartridges for the chargers or use-extenders of those devices. Challenges are related in addition to safety issues, to technical design making the cartridges usable for common people and finally to environmental issues making them recyclable or disposable. Borohydrid (NaBH₄)-technology to make hydrogen producing cartridges is already well known, but needs still studying and development to make it functioning well in small scale and for a long use period. Catalyst based electrolysis of methanol is a new method, which needs more basic studies. In the project we have studied use of two catalysts, platinum and an enzyme. At present state of the project the platinum catalyst has been chosen for further development because of problems to obtain high enough energy efficiency in hydrogen production when the enzyme catalyst is used.

Technical approach and achievements

The technical approach adopted by the project is to develop the two cartridge technologies in parallel and test them in two application devices during the last project year. The test devices chosen are a smart mobile phone and a laptop computer. Both these devices are standard commercial appliances for which the project will build a specific hydrogen driven non-grid charger or use-extender. The key targets in the development phase are:

- Prototype of 20 Wh NaBH₄-cartridge for a mobile phone charger (CEA, myFC).
- Prototype of 120 Wh NaBH₄ container for a fuel cells power pack (CEA, Hydrocell).
- Electrolyser cartridge-fuel cell system prototype for a non-grid long term power source for 10 W devices(Aalto, Hydrocell).
- Electrolyser-PEM fuel cell system prototype with a better methanol conversion (Wh/ml) than DMFCs (Aalto)
- Control electronics for the both fuelling concepts

The project will produce reports as well three different cartridge prototypes as the deliverables.



<http://autsys.tkk.fi/en/ISH2>

Early Markets

Expected socio and economic impact

The project is targeting to prototypes, which will open up possibilities for further product development. Decisions to that direction will be made during 2013.

Both of the concepts of in-situ production of hydrogen are not limited to the small power range. Preliminary investigation to enlarge the area to 100 W – 1kW will be done during the project. This will open applications e.g. to portable tools, small backboard motors etc.

As a future perspective, electrolysis by the aid of enzyme opens up interesting possibility to produce hydrogen from different kind of bio-decomposable wastes including alcohols or sugars. The energy level around 3 W/l H₂ can be reached, which is considerably lower than that of water electrolysis. Simultaneously the BOD value of the waste water could be decreased. This is one way to continue the study made in the project with biocatalyst.

Project Information

Project reference: FCH JU

Call for proposals: 2008

Application Area: Early Markets

Project type: Research and Technological Development

Topic: Early Markets 4.2. Fuel Supply technology for portable and microfuel cells

Contract type: Collaborative Project

Start date: 01/01/2010

End date: 31/03/2013

Duration: 36 months

Project total costs: € 1,7 million

Project funding: € 1 million

Project Coordinator

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MobyPost

Mobility with hydrogen for postal delivery

Key Objectives

MobyPost aims to implement hydrogen and fuel cell technology systems in material handling vehicles, according to an environmentally respectful strategy. The approach is generating significant data which will prove the viability of the technology and, initiate its commercialization in this specific niche market. MobyPost aims to develop electric vehicles powered by fuel cells using hydrogen locally produced by renewable energy means: solar panels installed on the roofs of the buildings. MobyPost will implement low pressure storage solutions for hydrogen in two fleets of five vehicles on two different sites for postal mail delivery. Development of the vehicles and the associated refueling stations will be carried out, in line with all certification processes required and, taking into account public acceptance of this mobility system.

Challenges addressed

MobyPost addresses the following challenges:

- Complete solar-to-wheel solution developing an innovative concept for fuel cell electric vehicles and incorporating hydrogen production into existing postal buildings for its utilization on the spot.
- Fuel cell electric vehicle used every day on heavy duty cycle and under demanding climatic conditions (including summer and winter time).
- Autonomous energy production - Hydrogen is produced on-site by coupling an electrolyser to solar panels at the different MobyPost sites.
- Implementing metal hydride tanks for hydrogen storage - to guarantee safety, MobyPost will use low pressure storage which considerably improves on-board safety.

Technical approach and achievements

2011 Designing

- Vehicle Power train Mechanical structure Ergonomics and style
- Infrastructure Dimensioning of equipment & monitoring system Safety and regulation analysis

2012 Building

- Vehicle Power train final test Manufacturing of 10 FCEV Homologation
- Infrastructure PV generator Electrolyser On-site storage Refueling station Certification

2013 Testing

- Vehicle Postmen training Deployment of the FCEV Performance monitoring
- Infrastructure Performance monitoring Dissemination and knowledge transfer

The first year dedicated to the design of both infrastructure and vehicle has allowed for clearly defining the requirements for both sub-systems (hydrogen production and fuel cell electric vehicle). The consortium partners have already started to design their components in order to adapt them to the project needs (Fuel cell, tanks, electrolyzers), in parallel with the creation of the model and first level of simulation. The first models for vehicle framework and ergonomics have been issued. As defined, the final design should be achieved during 2012, in parallel with the modification of the buildings and sites for welcoming the MobyPost experiment.



www.mobypost-project.eu

Early Markets

Expected socio and economic impact

The MobyPost project will first and foremost contribute to the achievement of 2020 EU's objectives in terms of sustainable development by demonstrating the reality of a real-life existing decarbonized mobility system whose development will rapidly accelerate in the near future.

The expected outcomes are:

- Favor the transferability of developed technologies to other delivery services.
- Accelerate and effectively support the emergence and consolidation of the Fuel Cell Electric Vehicle industry.
- Disseminate the project outcomes at local and European levels in order to promote innovative and sustainable transportation means.

The second main impact is the acceleration of social acceptance for novel technologies. The MobyPost concept will be tested directly by professionals who are in daily contact with the public - The Postmen. This will increase the project's visibility and knowledge that people have on this technology.

Project Information

Project reference: FCH JU 256834

Call for proposal: 2009

Application area: Early Markets

Project type: Demonstration

Topic: SP1-JTI-FCH.2009.4.1

Demonstration of fuel cell powered materials handling vehicles and infrastructure

Contract type: Collaborative project

Start date: 01-02-2011

End date: 31-01-2014

Duration: 36 months

Project total costs: € 8,209,872

Project funding: € 4,262,057

Project Coordinator

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SHEL

Sustainable Hydrogen Evaluation in Logistics

Key Objectives

The overall purpose of the SHEL project is to demonstrate the market readiness of the technology and to develop a template for future commercialization of hydrogen powered fuel cell based materials handling vehicles for demanding, high intensity logistics operations.

This project will demonstrate 10 Fuel Cell ForkLift Trucks (FC FLT) and associated hydrogen refuelling infrastructure across at least 4 sites in Europe. Real time information will be gathered to demonstrate the advantages of using fuel cells to current technologies and fast procedures will be developed to reduce the time required for product certification and infrastructural build approval. Moreover, to ensure the widest dissemination of the results, the project will build a comprehensive Stake Holder Group of partners to pave the way for wider acceptance of the technology.

Challenges addressed

Up to now analysis of the current State of Art across various FC FLT international demonstration has been done. According to the FC system, the consortium is now in the phase of purchasing the FC systems and assembling the fleet.

Related to the demonstrations, the site assessments and preparation for demonstrations have been carried out following the AMFE methodology, and main Codes & Standards have been reviewed in order to obtain the certification procedure.

Technical approach and achievements

This project will show 10 FC FLT and associated hydrogen refuelling infrastructure across 4 sites in Europe: Turkey, UK, Spain and Greece. The Turkish site will be within the Petkim Petrokyma (Turkey's largest chemical complex), where the demonstration will use industrial off-gas hydrogen for 1 year; the UK demonstration will be at the Port of Felixstowe for 6 months, the Spanish demonstration will be at the CEGA Logistics site in Vitoria for one year and the Greek demonstration will be placed at the new central logistic centre of AB Vassilopoulos supermarket chain during at least 1 year. The demonstration will therefore be used to investigate commercial operation of the trucks in three likely early market sectors under real conditions.

Key milestones

The project, started on January 2011, has a well defined strategy to demonstrate 10 FC FLT and associated hydrogen supply mechanisms across a minimum of 4 countries. Each site will demonstrate a different type of infrastructure based upon future possible commercial hydrogen resources available in Europe.

The main objective of the project is the delivery of 9 optimised FC FLT for the demonstration, using an existing FLT FC prototype design developed by UNIDO-ICHET and their partner CUMITAS. Two types of vehicles will be used to the demonstration: counterbalanced and reach type, will utilise an existing Fuel Cell Module but will investigate the development of next generation energy saving technologies which can greatly improve the fuel cell operation lifecycle.

Achievements/ Results to date

- Both FC purchasing bids have been launched.
- The site assessment study has been carried out following a FMEA methodology. For the FMEA top level hazards/events related to equipment/ components/processes have been identified, potential failure modes and effects defined, and inherent safety and potential prevention and/or mitigation corrective actions designed.
- Main codes and standards have been revised and checked with local authorities in order to define the certification process.
- Each site preparation works have been commenced.

Expected socio and economic impact

The consortium brings together a strong cluster of partners from Europe's hydrogen and fuel cell sector with key industrial partners -a gas company (AP), a Fork Lift truck OEM (Cumitas) and a logistic company (CEGA)-.



'Sustainable Hydrogen Evaluation in Logistics'

www.shel.eu

Early Markets

The project contributes to achieving the following impacts:

Impact 1: Demonstration of two types of FC-based vehicles (10 vehicles in total) across four different sites in Europe. The demonstration will give the participant partners in-depth field experience to accelerate medium term commercialization of FC vehicle across the EU member states.

Impact 2: Prove durability of fuel cell concept, functionality of hydrogen refuelling infrastructure and demonstrate end user acceptance of the project.

This demonstration of pre-commercial products will confirm system specifications, lifecycle costs and training needs for product installation and use, and demonstrate public acceptance.

Impact 3: Development of certification procedures

It will identify and improve the speed of certification from the relevant European Agencies, promoting international standards and developing procedures for certification within the European member states.

Project Information

Project reference: FCH JU
Call for proposals: FCH-JU-2009-1
Application Area: SP1-JTI-FCH.4: Early Markets 10.3
Project type: Demonstration
Topic: SP1-JTI-FCH-2009.4.1
Demonstration of fuel cell-powered materials handling vehicles and infrastructure
Contract type: Collaborative Project
Start date: 01/01/2011
End date: 30/06/2014
Duration: 42 months
Project total costs: € 4,645,500.00
Project funding: € 2,443,095.00

Project Coordinator

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Hygear BV (HYGEAR) Netherlands
CEGA Logistics (CEGA) Spain
Cukurova Makina Imalat ve Ticaret (CUMITAS) Turkey



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SUAV

Microtubular Solid Oxide Fuel Cell Power System development and integration into a Mini-UAV

Key Objectives

The objectives of the project is to design, optimise and build a fuel cell power generator for small Unmanned Aerial Vehicles (mini-UAV). The stack to be developed will be integrated together with the required fuel processor and mechanical as well as electrical balance of plant components. The fuel cell generator will be packaged and placed into a mini-UAV. The advanced mini-UAV will be tested in a flight mission with the goal to achieve a flight endurance that is three-times longer than batteries.

Challenges addressed

Firstly, the top level requirements (TLR) for the packaged system were defined, resulting in the demand of weight and volume limitations. The restrictions for the fuel cell generator, including all balance of plant components are 3.88 kg with respect to weight and 3.32 litres with respect to the volume. These specifications include the fuel that is to be carried throughout the flight. Based on the Top Level Requirements, the development of the mSOFC stack was performed. The stack will consist of several microtubular cells connected to each other in parallel to achieve the required stack power of 250 W (end of life power). This will ensure long flight missions with a total runtime of 600 h. The present status of the cells is a power of 0.23 W/cm² at 60% fuel utilization feeding pure hydrogen (cell temperature 750 °C and hydrogen volume flow of 60 ml/min).

The stack development is accompanied by system modelling with respect to the desired power output of 250 W (end of life). The system modelling considers all parts of the power generator as a SOFC stack, heat exchangers and fuel processing. Results of system modelling and stack development are exchanged between the two work packages to improve both development tasks – stack development targeting to the required end of life power of 250 W (or 600 h runtime) and system models validated with real data from stack development.

Technical approach and achievements

This project aims to produce fuel cell components of longer cycling lifetimes at a reasonable price, thereby allowing SOFCs to be used in portable and other applications. Widespread adoption of SOFC technologies will give the environmental benefits of reduced fossil fuel usage (via increased efficiency) and reduced emissions. Because of the improved efficiency of SOFC microgeneration, the consumption of fuel will decrease. This represents a large saving of fuel cost, which in the future will result in a savings of imported fuel. Two other economic benefits follow from this: first, there is an export market in Europe and overseas, which will reward the first successful introduction of this technology; and second, the reduction in pollution will likely lead to significant health improvements and a drop in medical costs.

Summary/overview

SUAV aims to design, optimise and build a 100-200W mSOFC stack, and to integrate it into a hybrid power system, comprising of a stack and a battery. Additional components are, a fuel processor to generate reformat gas from propane and other equipment for the electrical, mechanical and control balance of the plant. All these components will be integrated into a mini Unmanned Aerial Vehicle. The project intends to optimise the mission duration, making efficiency less of a concern at the time. All these components will be constituents of an entire fuel cell power generator, which will first be tested in the lab and, after further optimisation and miniaturisation, in a mini UAV platform. The achievement of these objectives will result in an improvement in mini-UAV endurance by a factor of 3 over conventional battery power.

A single microtubular cell with a power of 0.23 W/cm² was achieved, with a fuel utilization of 60% (pure hydrogen). The next step is to perform tests with synthetic reformat gas comprised of components as they form in an effluent of a CPOX reactor (hydrogen, carbon monoxide, oxygen and unconverted propane). From the fuel processor development, the real composition of the CPOX effluent is to be transferred to the stack development (WP3) and system modelling (WP5).

Project Information

Project reference: FCH JU 278629

Call for proposals: 2010

Application Area:

RTD on new portable and micro Fuel Cell solutions

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.2010.4.5

Contract type: Collaborative Project

Start date: 01/12/2011

End date: 30/11/2014

Duration: 36 months

Project total costs: € 4,187,100

Project funding: € 2,109,518

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FC-EuroGrid

Evaluating the Performance of Fuel Cells in European Energy Supply Grids

Key Objectives

The main objective of the project is to establish technical and economic targets and benchmarks that allow the assessment of fuel cells in stationary power generation. The fuel savings and CO₂ emission reductions will be a function of the electricity grid structure and the fuels employed. Using these results it will be possible to determine, whether a fuel cell installation effectively improves fuel use and improves the CO₂ footprint, amongst other criteria. This leads up to a more focused allocation of research funding, identification of R&D gaps and objective comparison of fuel cell with competing technologies. The project will discuss the methodology adopted with EU and worldwide stakeholders in order to establish a recognised assessment and benchmarking frame of reference.

Challenges addressed

Stationary fuel cells operate under a variety of constraints which are defined by the energy supply grid they are integrated into and the application they serve. Generally, stationary fuel cells offer the advantages of high efficiency operation with low emissions, low noise and modular design. Nevertheless, it must be acknowledged that the GHG savings from a fuel cell operated on the German grid will very much differ from those of a fuel cell producing electricity in France – due to the difference in carbon footprint of the French electricity supply system. Different fuel cell types (PEFC, HT-PEFC, MCFC, SOFC) display different efficiencies in electricity production from natural gas.

As a result of this complex situation there is no simple means of predicting the advantages a stationary fuel cell system will offer in any given energy supply environment. The task of setting minimum benchmark targets for projects to be awarded funding under the FCH JU scheme was therefore abandoned since there was no sensible way of setting general conditions that would apply independently of technology and system integration across the whole of Europe.

Technical approach and achievements

The project will establish pertinent application categories (among them: μCHP, CHP, decentralised electricity production, etc.), establish benchmarks from the performance of competing power generating technology (in the different EU countries), identify the technical and economic targets for the key applications, and review the potential of the different fuel cell technologies to fulfil them. The goal is to collect all data necessary in evaluating the performance of stationary fuel cells in the European energy markets (predominately heat and electricity) and paving the way to objective criteria of best practice and minimum standards, as well as an appraisal of the type of applications that actually lead to reductions in gross energy consumption, emissions and depletion of fossil energy resources.

Key milestones, deliverables

The main milestones refer to the finalisation of project work and the onset of discussion with the FCH JU and stakeholders from approx. month 16 onwards.

Key deliverables include data collections ('atlas') of European electricity grids, handbook of methodology and benchmarking, and the status and gap analysis for stationary fuel cell systems.



Cross-cutting activities

Expected socio and economic impact

The project will supply

- a quantifiable technical understanding of the interaction of stationary fuel cell technology with various European electricity supply grids with respect to greenhouse gas abatement and improved economy of fuel,
- associated benchmarks and indicators suitable to describe the superiority (or inferiority) of specific fuel cell concepts vis à vis competing technologies with respect to efficiency, emissions, economic and operational data etc.,
- targets for fuel cell development and criteria for the selection of best performing project proposals, and
- status reports on the development status of stationary fuel cells and the technology gaps that remain to be shut, along with indications for the focus of future development work.

Achievements/Results to date

The cataloguing and benchmarking data have been compiled and the development of the methodology of technology comparison is under way.

Project Information

Project reference: FCH JU 256810

Call for proposals: 2009

Application Area: 3 (Stationary)

Project type: Support Action

Topic: SP1-JTI-FCH.2009.3.8:

Applications specific targets for stationary power generation and related technology benchmark

Contract type: Coordination and Support Action

Start date: 01/10/2010

End date: 30/09/2012

Duration: 24 months

Project total costs: € 849.684

Project funding: € 588.982

Project Coordinator

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FC-HyGuide

Guidance document for performing LCAs on Hydrogen and Fuel Cell Technologies

FC-HyGuide includes two autonomous projects and consortia: HyGuide and FC-Guide.

While FC-Guide focuses on fuel cell technologies, HyGuide addresses hydrogen production systems.

The two consortia, led by PE INTERNATIONAL resp. ENEA agreed during the project negotiation phase to collaborate closely over the course of the project. The collaboration included a common work programme, interlinked work packages, and mutual choices on key overall LCA methodological topics. The advisory board / review panel and the technical expert group were also shared by both consortia. The reason for the collaboration between the two consortia was to produce more value for the FCH JU funding and to avoid contradictory results. For that reason, the only public domain used, is FC-HyGuide.

Key Objectives

The overall goal of the project is to develop a specific guidance document(s) for application to hydrogen and fuel cell technologies, and related training material with courses for practitioners in industry and research. These documents (one on hydrogen supply technologies, one on fuel cells) are based on and in line with the International Reference Life Cycle Data System (ILCD) Handbook, coordinated by the European Commission's JRC-IES. The main objective of the FC-HyGuide project is the development of guidance documents and accompanying LCA report templates to evaluate the environmental benefits of new technologies in the field of fuel cell and hydrogen applications. It is foreseen that the guidance documents developed within FC-HyGuide will be applied in all on-going and future FCH JU projects calling for Life Cycle Assessment (LCA).

Challenges addressed

The challenge of FC-HyGuide is to provide consistent, widely accepted and applicable rules (following the ISO 14025 approach: product category rules) for performing LCA of hydrogen and fuel cell systems. The guidance documents (HyGuide and FC-Guide) can serve as these rules, which define "how" LCA must be conducted within projects funded by the FCH JU.

Technical approach and achievements

The guidance documents were developed in a multi stage stakeholder approach. In the first stage a draft version of the guidance documents were developed by the project consortia and introduced to the technical expert group of the project. Feedback gained during the expert group workshop was integrated and advanced versions of the guidance documents were prepared. In the following stage they passed a second consultation round. This consultation was public. Before the documents were finally released, an independent external third party review process was performed to ensure the quality of the documents. Dissemination and communication were core elements which were performed during the entire project period. Two training courses on the developed guidance documents completed the project. A graphical overview of the concept of stakeholder involvement within FC-HyGuide is given in the following graph.

Expected socio and economic impact

The FC-HyGuide project is finalized. The outcome of the project can be used in all hydrogen and fuel cell application areas (horizontal approach) asking for LCA. FC-HyGuide facilitates a more effective policy evaluation and decision making by providing guidance for evaluating the environmental performance of fuel cell and hydrogen systems.

Project Information

Project reference: FCH JU Grant

Agreement No.: 256328

Call for proposals: 2009

Application Area: Cross-Cutting Issues

Project type: Support Action

Topic: SP1-JTI-FCH.2009.5.5
LIFE CYCLE ASSESSMENT (LCA)

Contract type: Coordination and
Support Action

Start date: 01/10/2010

End date: 30/09/2011

Duration: 12 months

Project total costs: € 366.318

Project funding: € 366.318

Project Coordinator

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HyCOMP

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

Key Objectives

Currently, the most mature technology for storing hydrogen is in compressed form in high-pressure cylinders. To improve volumetric and gravimetric performances, carbon fibre composite cylinders are currently being developed. However, current standards do not allow cylinder design to be optimized. In particular, the safety factor relative to the burst pressure ratio appears to be conservative, which results in the cylinders being oversized and thus costly.

In this context, this project aims at:

- To develop a better understanding of the damage accumulation processes in composite cylinders and the degradation rate as a function of the type of load and environmental conditions,
- To enhance design requirements for composite cylinders for storage or transport of compressed hydrogen,
- To improve the full set of requirements defined for ensuring the structural integrity of the cylinders throughout their service life,
- To improve procedures for type approval and batch testing.

Challenges addressed

Current regulations do not allow exploiting the full potential of carbon fibre materials. New and revised standards are in process, but the work is done based on a traditional and conservative way of determine the performance of a cylinder. Furthermore, the requirements in these standards are often not based on degradation processes in composite materials, but have been adapted from standards covering metallic cylinders.

Therefore a potential clearly exists to enhance the standards for achieving further improved levels of safety while avoiding overly conservative construction requirements, in particular through a better understanding of the degradation mechanism actually occurring in carbon fibre composite materials. The objective of HyCOMP is to bring this potential to fruition for producing improved type approval and batch testing protocols.

The main outcome of the project will be a documentation of the real performance of composite cylinders to support Authorities and Industry in making enhanced RCS.

Technical approach and achievements

HyCOMP is based on an experimental and numerical approach that will provide a comprehensive scientific basis of damage accumulation mechanisms that occur in the composite wrapping under typical loads in service.

The final objective of HyCOMP is to improve the full set of requirements while ensuring the structural integrity of the cylinders. For that, the following technical approach is performed.

Damage mechanisms and failure modes of composite vessels are first identified at a material scale on plate specimens and then at a structural scale on cylinders, under cyclic, static and hybrid loads, representative of service conditions for three different applications: stationary, transportable and automotive uses. The most relevant parameters characterizing service life in terms of gas pressure-related loads and temperature are identified in order to check that the critical operational loads have been properly characterized in the test program.

Knowing that carbon fibre reinforced plastic (CFRP) materials mainly damage by fibre breakage, a non-destructive test based on acoustic emission has been preferred to quantify the level of damage produced in the composite wrapping. Nevertheless, a destructive burst test is finally performed to estimate the influence of damage on the cylinder residual strength. Furthermore, a particular attention is paid on material and manufacturing parameters that should be subjected to a quality assurance plan because they strongly impact cylinder performances (initial strength as well as long-term properties of cylinders). Numerical models are then developed in agreement with experimental results and observations in order to predict damage accumulation in the composite wrapping and then cylinder failure. The estimation of the probability of failure for a required lifetime will be used to define the acceptable safety factor.

Based on the findings from the experimental work, appropriate testing protocols will be defined to demonstrate the cylinder fitness for service and resistance to its anticipated service life. Finally, findings and recommendations will be summarized and disseminated so that they can be used by the international hydrogen and fuel cell community, in particular for Regulation, Codes and Standards initiatives.

Expected socio and economic impact

The outcome of the project will have a direct economic and social impact on high pressure composite cylinders intended for the storage of hydrogen. First, the project will provide all the data necessary to argue in favour of a decrease of the cylinder safety factor. A direct consequence is then a decrease of the composite thickness, so a decrease of the quantity of carbon fibre. Knowing that carbon fibre represents the largest part in the final cost of a cylinder, a decrease of the cylinder cost is thus expected.

Furthermore, the structural integrity of high pressure composite cylinders will be demonstrated during the project by determining appropriate testing protocols and defining pass/fail criteria to ensure the cylinder fitness for service and resistance to its service life. These results will contribute to a better social acceptance of hydrogen as an energy vector.

Project Information

Project reference: FCH JU 256671

Call for proposals: 2009

Application Area:

Hydrogen production and storage

Project type: Research and

Technological Development

Topic: SP2-JTI-FCH.1.5 – Pre-normative
Research on Composite Storage

Contract type: Collaborative Project

Start date: 01/01/2011

End date: 31/12/2013

Duration: 36 months

Project total costs: € 3 802 542

Project funding: € 1 380 728 (36 %)

Project Coordinator

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HyFacts

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

Key Objectives

The HyFacts project aims **to develop and disseminate fully up-to-date contemporary material** for customized 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. The training material will focus on the fundamental **aspects of hydrogen safety** and on the safety approaches and criteria developed in standards and according to which hydrogen systems are engineered for the safe use of hydrogen under all circumstances.

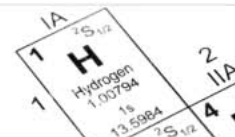
Challenges addressed

Main goal of the HyFacts project is the gathering, analysis, synthesis and dissemination of the technical content identified in the first stage of the project by providing an adequate format which can easily be absorbed by the target group. Depending on the different target groups, the material will be delivering a different depth of information, reflecting on the needs of the respective persons representing different levels of one regulating institution.

In order to achieve a good learning result, short courses have proven to be one of the adequate means of spreading excellence to specific target groups along with distance learning.

Expected socio and economic impact

Fuel Cell and Hydrogen Technologies shall be implemented in Europe in order to gain specific knowledge in applying these technologies and bringing them to a breakthrough by reaching the necessary "critical mass". Only if the number of fuel cell cars, refuelling stations, small and large centralised and decentralised hydrogen systems in operation, the necessary impact on public acceptance and involvement can be achieved. For reaching this aim, **the regulators**, which sometimes hold up approval of systems prior to their implementation, **need to be trained in understanding and safe use of hydrogen and its related technologies much better** and should even be brought to a supportive attitude.



Up to date several deliverables could be finalized.

The general structure of the training material has been defined and most of the content has been finalized. Questionnaires have been sent out to the target audience in Germany, UK and France. The answers have been analysed and the scope of the training material as well as the training structure has been adopted to their specific requirements. A poster as well as hand out brochures have been produced and the project website is online with a lot of information on the project. The first short course will be conducted soon and the first draft training material will be tested.

Project Information

Project reference: FCH JU
Call for proposals: year 2010
Application Area: Cross cutting
Project type: Coordination and Support Action
Topic: Fuel cells and Hydrogen
Contract type: Coordination and support action
Start date: 01/02/2011
End date: 01/07/2013
Duration: 36 months
Project total costs: € 1 million
Project funding: € 1 million

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Hyindoor

Pre Normative Research on the in-door use of fuel cells and hydrogen systems

Key Objectives

The aim of Hyindoor is to develop the capability to specify practical means and strategies that will prevent or mitigate the potential consequences of a hydrogen release indoors. This will be implemented with a risk-based approach: i.e. the higher the expected frequency of the release, the more stringent the acceptance criteria.

Summary/overview

Hyindoor addresses knowledge gaps regarding indoor hydrogen accumulations, vented deflagrations, and under-ventilated jet fires. This includes improved criteria for indoor HFC systems to avoid hazards; sizing of openings for natural ventilation and specification of forced ventilation systems; and sizing of the vent area for deflagration mitigation.

Analytical, numerical and experimental studies in Hyindoor will be guided by the expectable, foreseeable or conceivable release conditions for fuel cells (FC) systems in early markets' power range and building or FC cabinet characteristics.

The generated knowledge will be translated into safety guidelines, including specific engineering tools supporting their implementation. Recommendations for normative / regulatory requirements are expected to lead to the adoption of the results by the wider stakeholder community and their introduction into RCS. Envisaged unique results can give Europe a leading position in the sector. The benefits of optimised design and RCS upgrade are expected to significantly improve the prospects of hydrogen as an energy carrier.

Technical approach and achievements

- Development of the **knowledge base** required in order to be able to predict H₂ behavior indoor and consequences in the case of early or late ignition (*results expected January 2013 – June 2014*)
- Definition of **improved criteria for allowing hydrogen and FC systems indoors** (*recommendations for RCS – September 2014*)
- Issuing of **safety guidelines** (*to be published on Hyindoor website by August 2014*)
 - Sizing of enclosure openings or forced ventilation in the function of H₂ release parameters
 - Sizing of the vent area for deflagration mitigation in relation to the accumulated inventory and obstruction in the enclosure
- Dissemination of the **project outputs through H₂ safety community and industrials** (*Advanced Research Workshop envisaged in Brussels for September 2013 and Stakeholders dissemination workshop in December 2014*).



©hyindoor

Example of HFC indoor application – Forklift

Expected socio and economic impact

Hydrogen Fuels Cells (HFC) technology is expected to constitute a major contribution for environmental protection and rational use of energy. However, hydrogen as an energy carrier requires a sound safety framework of harmonized Regulations and Codes and Standards (RCS) to reach commercialisation.

The generated knowledge of Hyindoor will feed into safety guidelines. The experimental work will significantly enhance the understanding of hydrogen dispersion and combustion; the increased predictive ability of Computational Fluid Dynamics (CFD) modelling will enable its applicability to particular settings and simple models will be proposed for industrial use to size mitigation means.

Project Information

Project reference: FCH JU 278534

Call for proposals: 2010

Application Area: Early markets

Project type: Research and

Technological Development

Topic: Priority 4.6 of the call FCH-
JU-2010-1

Contract type: Collaborative project

Start date: 1 January 2012

End date: 31 December 2014

Duration: 36 months

Project cost: € 3,657,760

Project funding: € 1,528,974

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(HFCS)

Netherlands

University of Ulster

(UU)

UK

Joint Research Centre

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LGI Consulting

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HYPROFESSIONALS

Development of educational programmes and training initiatives related to hydrogen technologies and fuel cells in Europe

Key Objectives

Today's technicians and students are the next generation of potential fuel cell users and designers and education is now a critical step towards the widespread acceptance and implementation of hydrogen fuel cell technology in the near future. Development of training initiatives for technical professionals aiming to secure the required mid- and long-term availability of human resources for hydrogen technologies will be started. The work will be carried out for vocational education, including industry, SMEs, educational institutions and Authorities. Coordination and cooperation are key factors to fulfil the objective of developing a well-trained work-force which will support technological development.

Challenges addressed

The main challenge is to find the right guidelines in order to establish hydrogen technologies at current vocational training. In order to do that, existing training programs related to hydrogen and fuel cells in the EU were identified to provide a good base for educational activities and also the gap between educational trainings and industry needs. After that, specific initiatives, proposals, guidelines and projects were developed to get consolidated educational programs for technical training at different levels, implementing the results of the project and involving different stakeholders (industry, SMEs, educational entities, authorities...). Furthermore, the dissemination of the results at different target audiences for the purpose of facilitating the acceptance and implementation of these technologies by means of education has been achieved (2 workshops developed) as well as several pilot actions involving different European countries have been done.

Technical approach and achievements

Mapping of existing training programs

- What has been done so far in H₂FCs?
- How is innovation in vocational training funded?
- How does vocational training evolve?

Proposals for initiatives

- Who are the "offer and the demand"?
- What will be the mismatch of "the offer and demand"?
- What could be done? At what time?

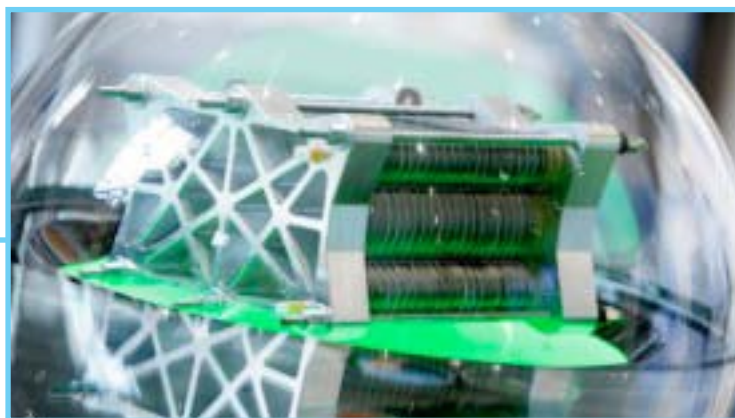
Testing and implementation of initiatives

- Pilot actions within the project
- Seed for new steps (broader initiatives outside the scope of the project)

Dissemination plan

- Workshops with Target Groups. Bringing together industry education, authorities...
- Website, media...

@hyprofessionals





www.hyprofessionals.eu

Cross-cutting activities

Expected socio and economic impact

The socio and economic impact of the project is anchored in setting up the road map for conventional educational systems in order to add the new hydrogen technologies to educational programs. This way, industry and SMEs will have a well-trained work-force in the medium term. In the short-term, a library with educational resources about hydrogen and fuel cells is available on the project website. This way, some pilot actions took place for teaching different target groups like vocational training students, graduates, technicians and teachers. Spread among several fields such as automotive, maintenance or renewable energies, the information sessions give a clear picture of the diverse aspects of hydrogen technologies, what they do and why they are useful and important.

Project Information

Project reference:

Grant Agreement n°: 256758

Call for proposals: FCH-JU-2009-1

Application Area: AA5 –
Cross-cutting issues

Project type: Support Action

Topic: SP1-JTI-FCH.2009.5.1:
Development of educational
programmes

Contract type: Coordination and
Support Action

Start date: 01/01/2011

End date: 31/12/2012

Duration: 24 months

Project total costs: € 432.116,00

Project funding: € 373.537,00

Project Coordinator

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Association PHYRENEES
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Environment Park
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CPI, Centre for Process Innovation
UK

HyQ

Hydrogen fuel Quality requirements for transportation and other energy applications

Key Objectives

HyQ consists of pre-normative studies to provide a strong support to Regulation Codes and Standards organizations in order to normalize an acceptable fuel quality for PEMFC for automotive application. Depending on the way to produce and purify hydrogen, it can contain different kind of pollutants which impact the performances and the durability of PEMFC.

To facilitate the emergence of the potential mass market represent by the automotive application, a standard hydrogen quality is becoming a necessity. One of the objectives of HyQ is to increase knowledge on the impact of pollutants commonly find in the hydrogen produced by economically sustainable industrial processes. Thus, relevant scientific results from HyQ will give strong arguments in the discussion on the fuel quality for PEMFC. Another objective of the project is to improve the analytical methods used to guaranty the quality specified in the standard.

Challenges addressed

One of the challenges addresses in HyQ is to evaluate the impact of pollutant on the PEMFC performance in the condition as representative as possible of the real application conditions. To the best of our knowledge, the results discussed for the determination of the standard had been obtained in conditions that are not representative of the real automotive application. Indeed, the impact of pollutant can be dramatically different depending on the conditions in which the test has been performed.

Another issues addressed in HyQ is to be able to propose standards that could be used to certify the purity level of hydrogen by assurance quality. By example, if no method exists (or are very expansive) to prove that the amount of an impurity in the hydrogen fuel is low enough to follow the standard, it is problem to certify the quality of the gaz. Formaldehyde and sulphur compound are in this case and their impact are addressed in HyQ to see if a so low level (respectively 0.01 ppm and 4 ppb) recommended in the actual standard are justified or not.

Technical approach and achievements

The approach developed in HyQ can be divided in two parts. The first one deals with the determination of the highest acceptable amount of impurities in H₂ which does not impact the fuel cell performance. To do that, 4 institutes are performing tests, in both identical conditions(reproducibility) and then in different conditions to obtain maximum of results. The impact of impurities (CO, H₂S, HCHO) is checked under single cell and stack configuration, with and without recirculation. In another part, partners specialized in gas analysis are improving analytical method to quantify the amount of impurities in H₂. The problem with the actual standard is that it's difficult to certify that H₂ reaches the quality requested and/or are costly. At the end of the project, after inter-laboratories comparison, report on the best measurement method and gas sampling will give input for the establishment of unified protocols.



Cross-cutting activities

Expected socio and economic impact

To sum up, HyQ results will give strong inputs to the Regulation, Code and Standard organisation. Accepted standards based on consensus between the actors of the hydrogen economy for automotive application will give strength to the development of a mass market. Of course, a special emphasis is put on the automotive application. Indeed, even if the potential widespread distribution of fuel cell vehicles could not reach the actual fleet of more than 1 billion cars all over the world. The money and matter flow that could be generated by this sector will be huge and an approved international standard will facilitate the negotiation processes between the actors of the hydrogen economy and will help also in unifying the links of the chain from gas producer to end-users. In the same way, results obtained here will be very helpful for the stationary application.

Project Information

Project type: Support action
Project reference: FCH JU 256773

Call for proposals: 2009-1

Application Area: pre-normative research on hydrogen quality

Project type: Support Action

Topic: SP1-JTI-FCH.1: Transportation and Refuelling Infrastructure; SP1-JTI-FCH.2009.1.6: Pre-normative research on fuel quality

Contract type: Collaborative project, small or medium scale focused research project

Start date: 01 March 2011

End date: on-going

Duration: 36 months

Project cost: € 3,718,853.00

Project funding: € 1,385,219.00

Project Coordinator

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VSL Dutch Metrology Institute (VSL)
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CCS Global group Ltd (CCS)
UK

Shell Downstream Services
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Linde (Linde)
Germany

VTT Technical Research Centre of
Finland (VTT)
Finland

TEMONAS

TEchnology MONitoring and ASsessment

Key Objectives

TEMONAS will enable the FCH-JU to obtain an accurate assessment of progress, both towards its objectives and in terms of its position within the global field of energy technologies.

TEMONAS is an advanced TEchnology MONitoring and ASsessment tool for the R&D area. It enables decision makers and project managers to continuously monitor the progress of their projects against their own targets and against developments in the market. It also allows for benchmarking with worldwide innovations. TEMONAS is designed for hydrogen and fuel cells as first application but can also be used for several other kinds of complex innovation.

Challenges addressed

The main innovative aspect of TEMONAS is the supply of a smart Technology Monitoring and Assessment (TMA) tool, beyond what is commercially available and based in transparent, yet well-designed and implemented IT, therefore allowing for accessible methodology, specifically designed for project and programme evaluation purposes.

1. TEMONAS is an integrated IT based tool for a well-documented, highly automated, objectified technological data set and also a tool for benchmark management, technology assessment as well as a wide range of technology monitoring with selection mechanisms based on a variety of commercialisation parameters.

2. The first-of-its-kind, TEMONAS complements technology assessments (internal viewpoint) with an equally strong technology monitoring (external viewpoint) system and the possibility to combine these two aspects of technology management into one integrated application while producing a single integrated summary result.

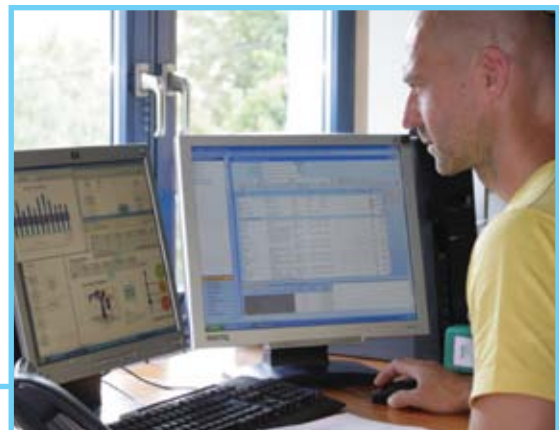
3. TEMONAS focuses on monitoring analyses, the performance or structural changes in their time dependency and in both technical and social domains.

4. Advanced methodologies are applied to each of the modules' functions, such as Multi-Criteria Decision Aid tools which allow the treatment of complex, multi-dimensional, nonlinear evaluations necessary for TMA.

5. TEMONAS features a largely automated Report Generator for various outputs such as MS Power Point presentations and written reports to be processed in word processing packages.

Technical approach and achievements

There has been a preceding phase of intensive ascertainment of all the necessary features in detail, based of the extensive experience of the partners working in international R&D projects. The results have already been implemented and the software is in the testing phase. Practical work with real data is currently taking place in order to learn about possibly necessary improvements. The final version of the software package will be produced in due time.



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Expected socio and economic impact

The main expected impact of the TEMONAS project is the provision of an advanced management tool for the FCH-JTI. If all functionalities required by the call specifications can be fully implemented in an integrated tool, then we expect that it will enhance the JTI's capacity to make decisions on the basis of repeatable and objective information.

The FCH-JU will profit from this enhanced information base in terms of:

- Performance-monitoring of individual projects vis-a-vis benchmarks and overall program objectives
- Overall assessment of program performance in comparison to international benchmarks
- Provision of rationale for discussions about program/ call structure and enabling the strategic steering of decisions.

Project Information

Project reference: FCH JU 278862

Call for proposals: 2010

Application Area: Fuel Cells and Hydrogen

Project type: Cross Cutting

Topic: Technology Monitoring and Assessment

Contract type: Coordination and Support Action

Start date: 01 September 2011

End date: 28 February 2013

Duration: 18 months

Project cost: € 1,8 million

Project funding: € 1,3 million

Project Coordinator

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 (SYN-HW)
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TrainHy

Building Training Programmes for Young Professionals in the Hydrogen and Fuel Cell Field

Key Objectives

The project aims at:

- deriving specifications for a Fuel Cell and Hydrogen education and training curriculum for post-graduates (young professionals, master of sciences and doctoral students) from the review of existing training programmes specific to FCH in Europe (with respect to scope, effectiveness, structure and cost),
- designing a curriculum and organisational structure to supply high-level professional training to the above mentioned group of students in the areas of Fuel Cell and Hydrogen technologies,
- building a financing scheme and business model oriented at a long-term sustainable performance of such a curriculum,
- initiating such a structure and performing first test elements of these courses,
- evaluating the suitability and success of the initiated activities, suggesting further action and presenting an action plan with organisational and financial information.

Challenges addressed

Post-graduates are offered the opportunity to improve and complete the skills most relevant to their current occupation without interrupting their professional life – therefore making the curriculum and education & training structure valuable for businesses and academic institutions alike since it does not remove the trainees from their ongoing assignments.

The course content and the choice of course elements by the student can interact with the necessities of her/his main profession.

The course programme offers ECTS points to those who desire to obtain them, especially university students. It will also offer 'Continuous Programme of Development' (CPD) credits.

The project intends to introduce a coherent coordination between different suppliers of training courses. In order to achieve the highest quality of these measures, the cooperation will be performed on the basis of stringent quality control and compatibility with the educational goals and general acceptance of the course(s) in the academic world.

Technical approach and achievements

The approach of the project is to develop a curriculum for the field of Fuel Cell and Hydrogen technologies aimed at post-graduate students and young professionals. Elements of this curriculum, namely summer school events, will be held in 2011 and 2012. They will be used to verify and evaluate the applicability of the curriculum concepts and develop a course and e-learning structure within which the educational programme can be organised. Universities will be invited to adopt the curriculum and the courses offered within their training programme, including grant of ECTS points. The developed programme and organisational structures are intended to be further sustained after termination of the project.

The key deliverables include a data collection ('atlas') of European Training Measures for Young Professionals in the field, presentation material, handouts, experimental material for trainers (experimentation materials and textbooks) and two summer school courses.

Expected socio and economic impact

- The project directly addresses the problem of building suitable human resources for the unrestricted development of European Fuel Cell and Hydrogen businesses. It contributes to enforcing the competitiveness of the European economic area.
- It develops a concept for an educational system across a number of post-graduate educational levels.
- It establishes selected course elements and assesses their potential to increase hiring rates of course participants.
- It will lead to the establishment of the developed curriculum concept within the European post-graduate educational system and the programmes of life-long learning in the framework of vocational Continuous Development Programmes.

The 1st Joint European School on Fuel Cell and Hydrogen Technology took place in Viterbo, Italy, from 22.8-02.9.2011. It consisted of four separate courses:

- A Primer on Hydrogen and Fuel Cell Technology, 21 August - 27 August 2011



www.hysafe.org/TrainHyProf

Cross-cutting activities

- An Introduction to Solid Oxide Fuel Cell Technology, 21 August - 27 August 2011
- An Introduction to Low Temperature Fuel Cell Technology, 28 August - 02 September 2011
- Solid Oxide Fuel Cell Design and Modelling, 28 August - 02 September 2011.

The 2nd Joint European School on Fuel Cell and Hydrogen Technology took place in Iraklio, Crete, from 16.-29.09.2012. It consisted of a total of nine 'modules', each lasting one week:

- Low Temperature Fuel Cells
- SOFC
- Fuel Cell Modelling
- Safety of Hydrogen Technologies
- Electrochemistry for fuel cells and electrolyzers / Characterisation methods
- Hydrogen technology
- SOFC Systems & Balance of Plant Components
- Electrolysis
- System modelling.

Project Information

Project reference: FCH JU 256703

Call for proposals: 2009

Application Area: 5 (Cross Cutting)

Project type: Support Action

Topic: SP1-JTI-FCH.20095.1:

Development of educational programmes

Contract type:

Coordination and Support Action

Start date: 01/10/2010

End date: 30/09/2012

Duration: 24 months

Project total costs: € 345.722

Project funding: € 269.105

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European Commission

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