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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING (FCH JU)
THEME SP1-JTI-FCH.2013.3.5
Field demonstration of large scale stationary power and CHP fuel cell system

GA No. 621256

DEMCOPEM 2MW

Demonstration of a combined heat and power 2MWe PEM fuel cell generator and integration into an existing chlorine production plant

	DEMCOPEM-2MW - Periodic Report	
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PROJECT PERIODIC REPORT

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Project title: **Demonstration of a combined heat and power 2 MWe PEM fuel cell generator and integration into an existing chlorine production plant**

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Periodic report: **1st X 2nd ☐ 3rd ☐ 4th ☐**

Period covered: **from 01/01/2015 to 30/06/2016**

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate) [3]:
  - X has fully achieved its objectives and technical goals for the period;
  - ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations.
  - ☐ has failed to achieve critical objectives and/or is not at all on schedule.
- The public website, if applicable
  - X is up to date
  - ☐ is not up to date
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Nick Miesen

Date: 29./ 08./ 2016

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism and in that case, no signed paper form needs to be sent

[3] If either of these boxes below is ticked, the report should reflect these and any remedial actions taken.

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1 Publishable Summary

1.1 Summary description of project context and objectives

1.1.1 Project concept

The Concept of DEMCOPEM-2MW is to explicitly demonstrate the feasibility, reliability, and availability of PEM fuel cells in a large scale stationary application of at least 2 MWe in China. The demonstration will take place in the industrial environment of a chemical factory.
In the chlorine industry hydrogen of high quality is often available at low or zero cost, and the heat and electrical power from hydrogen can be directly fed into the plant's production process. PEM fuel cell power and heat will be delivered at the industrial level of 2 MW electrical power (MWe) and 1.5 MW of heat. It is clean, silent, and non-polluting. The exhaust product, pure water, is also utilized in the process. The commercial viability of PEM fuel cells in competition with thermal machines is best demonstrated in the chlor-alkali industry in China because in this industry the value of the PEM fuel cell electrochemical power is highest. This is due to the relatively high electricity prices in most areas in China. These are up to 2 times higher than in Europe and rising; *i.e.* 550- 600 Chinese RMB/MWh (~ Eur 68-75/MWhe) and the abundant availability of hydrogen that is vented by many of the ca. 180 chlor-alkali plants (~50% chlorine world production) in China. Also, the common shortage of electricity supply in China in certain periods of the year contributes positively to the business case via the contribution margin of additional chlorine production in these periods. However, to create real interest for the PPP in China a successful demonstration of PPP in China is needed. After a successful demonstration 20-50 PEM Power Plants of at least 2 MWe for H_2 conversion from chlor-alkali plants in the coming 5-8 year is a realistic scenario for the market introduction phase in China.

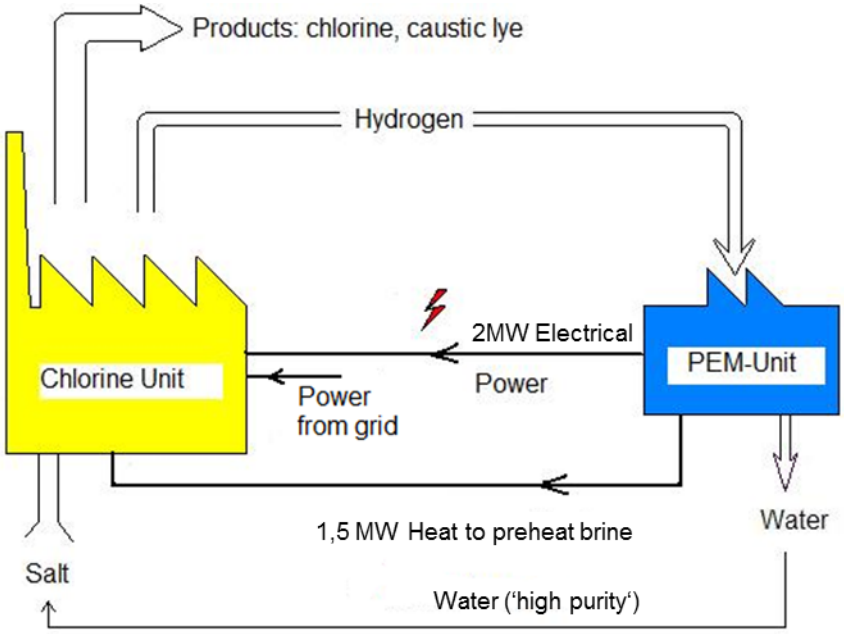

Figure.1-1 DEMCOPEM-2MW Concept. On the left, chlorine production plant; and on the right, the PEM fuel cell plant.

1.1.2 Objectives

The main objective of the four years DEMCOPEM-2MW project is to design, build and operate a 2 MW power generator, with the following attributes:

- Full integration of heat and power with an existing chlorine production plant
- High net conversion efficiency, i.e. > 50% electric energy on system level and > 85% for combined heat and power

- Long lifetime of system and fuel cells, i.e. over 2 years (16,000 hrs) for fuel cell stacks without any need for repair or maintenance of the membranes. The long-term target is 5 years (40,000 hrs) for fuels cell stacks
- Fully automated way of operation and remote control
- Economical design to reach a competitive price, i.e. < €2,500 / kWe with potential for reaching < € 1,500/kWe in 2020. With membrane lifetime of 5 years and high volume series (> 25 MWe/y) production the cost price of the electricity produced with a PEM power plant is estimated to drop from 0,075 to below 0,04 Euro/kWh.
- Demonstration of power and heat generation for over 2 years i.e. on-stream availability of > 95% for over 16,000 hours, in line with the Annual Implementation Plan 2013 objectives
- Contribute to the general goals of the JTI FCH, as stated in the revised Multi Annual Implementation Plan, to have > 5 MW @ € 3,000/kW installed fuel cell capacity in 2015 and > 50 MW @ € 1,500/kW installed fuel cell capacity in 2020.

1.2 Description of the work performed since the beginning of the project and the main results achieved so far

1.2.1 Main technical Achievements/results

The most relevant result for this first period of the DEMCOPEM project is the design and building of the power plant with all related components and systems.

In particular the following technical results have been achieved by the specific categories (RTD and DEMO) / work packages:

RTD

WP3: The simulation model for the whole PEM power plant has been defined and validated (by simulation and preliminary testing. In addition, alternative lay-outs and operating conditions were investigated for the management of the plant.

WP6: More than 27,000 MEAs for the preparation of the stacks for the PEM unit have been prepared, tested and delivered. The MEA performance in NFCT test hardware, both at beginning of life and after 1000hr, gives good confidence that MEA1306 produced in high volume fulfils the project's aim of producing a high quality MEA.

WP7: Result so far is the work plan for improved MEA types but the most significant outcome of the WP is still to come (improvement in MEA durability in the Delfzijl or Ynnovate plants).

DEM

WP2: Most of the work for this WP has been already finalised; the complete process and lay-out design of the PEM plant, including the planning and set-up of the operating system have been prepared and submitted.

WP4: This WP focuses on the actual design and construction of all connections between the chlorine unit and the PEM system, all activities which could be performed in Europe have been completed. In addition, preliminary training and maintenance manuals and workshops have been prepared and planned.

WP5: activities or this WP are almost completed since the construction of the PEM power plant and its components has been finalised. The test phase for the unit was completed (this activity involved also the Chinese end user Ynnovate). The packing and shipment of the complete unit took place in May 2016.

The complete overview of the work undertaken and the results for the different WPs are reported in the Core Part of this report.

1.2.2 Other Achievements

1. Constant communication and collaboration with end user Ynnovate via email, telephone conference and several physical meeting (both in Europe and in China)
2. MS18: Final review by the Advisory Board achieved (draft documents for Final and Second Periodic Report sent)
3. Newsletter(s) published
4. Continuous update of mailing list for the newsletter and project information
5. Preparation of dissemination video available online
6. Dissemination activities: presentations at conferences (more details provided further in the report)

1.3 Expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far)

1.3.1 Expected Final results

The application area of the project DEMCOPEM-2MW is "Field demonstration of large scale stationary CHP fuel cell systems", Topic SP1-JTI-FCH.2013.3.5. The proposed PEM fuel cell power plant is to be demonstrated at a chlor-alkali plant in China, and will serve as showcase for the prospected roll out of the PEMFC technology in China/Asia. Several chlor-alkali plants have shown serious interest and signed LOI's for a PEM power plant and at least 25 show an attractive business case for the next series PEM power plant. The final selection of the chlor-alkali plant for the demonstration will be based on the attractiveness of the business case and the suitability to act as showcase.

Based on the attractiveness of the business case and the suitability to act as showcase, the selected candidate has been Ynnovate Sanzheng (Yinkou) Fine Chemical Co. Ltd. In total 24,000 Nm^3/hrs of H2 purged (of which 4,400 Nm^3 very pure from Chlor Alkali).

DEMCOPEM-2MW will provide and demonstrate:

- An industrial fuel cell system, rated at 2 MW_e fully integrated into the chlorine plant.
- Conversion to power of the by-product/waste hydrogen.
- Restitution of the energy content of the by-product/waste hydrogen to the production process
- The employment of technology perfectly matched to a production process that is also based on membranes and operates on similar pressures and temperatures. Demonstration of the lifetime of PEM fuel cells well beyond 16,000 hours is one of the main objectives. The MEAs for this stationary application will be applied with reinforced membranes and stabilized cathodes. To generate a nominal electric power of 2 MW 336 stacks with 75 cells are planned and 24 spare stacks. The total number of cells is 360 x 75 = 27,000.
- Automatic operation with remote monitoring, backed-up by an advanced data-acquisition system that will enable improvement of parameters during the period of demonstration.
- Contribute to the general goals of the JTI FCH, as stated in the revised Multi Annual Implementation Plan, to have > 5 MW @ € 3,000/kW installed fuel cell capacity in 2015 and > 50 MW @ € 1,500/kW installed fuel cell capacity in 2020.
- A lifetime of the system that exceeds the 40,000 hours, as required in the 2013 Annual Implementation Plan.

To create real interest for the PPP in China a successful demonstration of PPP in China is needed. After a successful demonstration building 20 - 50 additional PEM power plants of at least 2 MWe each for H_2 conversion from chlor-alkali plants in the coming 5-8 year in China is realistic. With the expected development of the lifetime of the membrane to 5 years, the further reduction of the investment to below 1,500 Euro/kWh, the cost price will become well below 0,04 Euro/kWh making the technology economically feasible for all chlor alkali plants in the world and also the Chlorate production process (see also Chapter 3).

Worldwide the amount of hydrogen produced by chlor-alkali plants would be sufficient to produce about 3,000 MWe/h with a PEM power plant. The ultimate target would be to have at least 1,000 MWe/h produced via a PEM power plant worldwide.

1.3.2 Expected Impact

DEMCOPEM-2MW aims to design, build and integrate a 2 MW PEM fuel cell power generator in an existing chlorine production plant in China; and to demonstrate combined heat and power generation for over 2 years with the one set of 360 fuel cell stacks and over 95% on-stream availability. Further, it develops MEAs and fuel cell stacks with improved performance and lifetime that will be validated in the ANIC's PEM pilot plant in Delfzijl (and in the PEM demo plant in China) and a roll out plan (exploitation plan) for the Market Entry.

In the figure below a scheme of the project exploitation plan as well as DEMCOPEM-2MW's position in respect to the road map towards full implementation of PEM power plant in 2020 onwards.

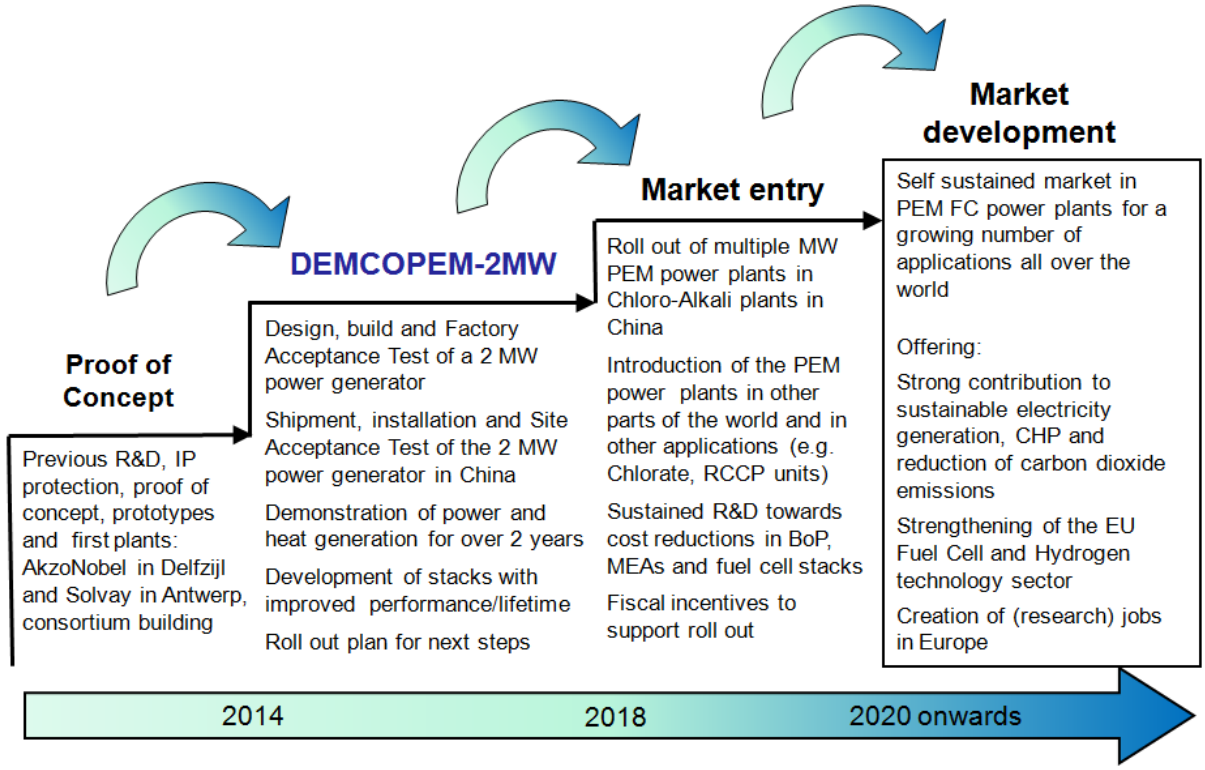

Figure 1-2 DEMCOPEM-2MW's position and roadmap towards full implementation in 2020 onwards.

For the **Market Entry** phase the plan is to roll out multiple PEM power plants in Chlor-Alkali plants in China together with Chinese partners. ANIC has already made an inventory of potential customers and locations that will be informed of the demonstration and its results during the demonstration period through newsletters, workshops and site visits.

To understand the potential of the list of potential customers and locations presented in the table one should realize that a 2 MW PEM Power Plant requires a hydrogen capacity of 1,300 Nm^3/h. In other words, **the list cumulates at least 25 plants and in total over 100 Megawatts**.

The manufacturing possibilities in Europe are as follows:

- JMFC will produce and sell improved MEAs to NFCT;
- NFCT will purchase MEAs from JMFC and produce and sell improved fuel cell stacks
- MTSA will develop and build series of the PEM Power Plants, integrate the fuel cell stacks, and ship the plants to China.

Socio-economic Impact

At the moment commercialization is most interesting for cases where hydrogen is a waste product, vented to the atmosphere. Large reduction of CO_2-emission is possible when the energy content of the otherwise vented hydrogen is used. To enter the market the production of electricity with by-product hydrogen should be competitive with the price from the local grid, taking into account the avoided CO_2-emission. The chlor-alkali industry, and to a lesser extend the chlorate industry, generally has favourable contracts with electricity companies as cost of electricity is crucial. In Europe, these tariffs can be as low as € 40/MWh and sometimes even less. Therefore, China has been selected as in this strongly growing economy; the electricity prices can be as high as € 70 to € 80/MWh. Moreover, rationing of energy is common practise in various regions of China as the build-up of power plants does not keep pace with the economic growth and growing energy demand. In these situations, *i.e.* a high electricity prices and rationing of electricity, the business case for a PEM power plant is economically viable as showed in the beginning of this section.
Chlorate plants in the world produce a quantity of hydrogen that would enable PEM fuel cells to generate 300 MW of power continuously. Three molecules of by-product hydrogen are released for every molecule of sodium chlorate. These plants are connected to wood pulp factories, associated with the paper industry. They are often positioned in remote areas with limited possibilities for the utilization of hydrogen. Technically a multiple MW PEM-unit can readily be fitted, but commercial criteria for cost and lifetime, similar to those of the chlor-alkali industry, must also be met.

Some years ago AkzoNobel developed Remote Controlled Chlorine Production units (RCCP units) as an environmentally friendly alternative for chlorine transportation and as an economic and environmental alternative for smaller plants based on the mercury electrolysis process. The coupling of a PEM FC power unit to an RCCP unit is promising as the hydrogen is freely available in most cases. The size of 1-3 MW is a perfect match for the RCCP-unit as it takes all by-product hydrogen, reducing the intake from the grid by 20 %. The utilization of the heat from the PEM-unit means extra savings in fossil fuels.

The specific benefits of the DEMCOPEM-2MW fuel cell stack are in particular interesting in the following applications (in China, Europe and worldwide):

- Range extension in EV's; this market has gained substantial traction in Europe and in Asia. TCO and lifetime are essential and will be outcomes of the DEMCOPEM-2MW project
- Grid-balancing and reduction of CO_2 emission in electricity production. Fuel cell technology can play an important future role here and relevant companies as State Grid should be made aware of the advancements and reliability of fuel cell technology for large scale power supply
- Base-load power or extended back-up in telecom and utility market. These units typically provide < 10 kW power and with ongoing developments in reformer-technology these markets become within reach. Especially in the larger Southeast Asian region exists a huge demand for reliable (implying very long lifetimes) and clean power supply.

Wider Societal Implication

In December 2015, at the Paris climate conference (COP21), 195 countries adopted the first-ever universal, legally binding global climate deal in order to avoid dangerous climate change by limiting global warming to well below 2°C. This agreement is due to enter into force in 2020.
Before that date countries need to work on their 'National Climate Action Plans' (already prepared before the Paris conference).
One of the most important possible solutions for limiting global warming is to reduce or completely eliminate the use of fossil fuel. With this vision in mind the renewable energies became/ will become main actors.
The technology developed in the DEMCOPEM project will provide main advantages in this direction.
The climate will benefit by the reduction in CO_2-emission.

The PEM power plant technology, developed within the DEMCOPEM project, will be introduced in other parts of the world and in other applications (e.g. Chlorate, RCCP units). In this phase it is important that sustained R&D efforts are taken to realise continuous cost reductions in Balance of Plants, MEAs and fuel cell stacks. Incentives for supporting the roll out, *e.g.* subsidies or fiscal measures for customers will be useful in the Market Entry phase.

The next step is the **Market Development** phase. In this phase, the market in PEM FC power plants has become self-sustained and cost-efficient for a growing number of applications all over the world.

The chosen project structure and approach ensures that the technology value chain in Europe now gets the opportunity to launch and develop as the business case for a PEM power plant in China is economically favourable. A successful field demonstration will pave the way for commercial introduction of PEM power plants in China (over 20 sites and potential for over 50 similar sized PEM power plants), will open up opportunities for introduction of the PEM power plant technology in other parts of the world and in chlorate and RCCP processes and will enable sustained research and development efforts to achieve cost reductions in fuel cell stacks and BoP, improved performance and longer lifetimes.
Demonstrating in China means a continuation of the development of the PPP technology. As soon as the PPP technology becomes cost competitive in Europe, it is ready for introduction in the EU.

1.3.3 External factors that may determine whether the impacts will be achieved

Tax on CO_2-emission would raise the price of electricity from the grid appreciably and would make the PEM-unit more competitive. Electricity produced with the most efficient natural-gas-fired units (50 % efficiency) leads to an emission of 0.4 tons of CO_2 per MWh. A charge of € 50 per ton of CO_2 raises the electricity price by € 20/MWh. Power produced with coal-fired units would be more expensive by € 60/MWh.

Further, the possibilities will be assessed at the Chinese Government to acquire subsidy for the introduction of this type of sustainable and energy saving technology; especially after a successful demonstration.

For fuel cell stacks also outside the chemical industry important opportunities in China and the Southeast Asian region are imminent.
The DEMCOPEM-2MW fuel cell stack (commercialized as XXL stack) is designed for high efficiency and exceptionally long lifetime. The actual demonstration of these features in the power plant will help to convince potential Chinese stack customers of the benefits of this specific stack technology over other suppliers.

1.4 Address of the project public website, if applicable

www.demcopem-2mw.eu

2 Acknowledgment

This project is co-funded by the 7th FP (Seventh Framework Programme) – Fuel Cells and Hydrogen Joint Undertaking

http://www.fch-ju.eu/
http://ec.europa.eu