**Stack testing with renewable energy sources**
The planned field testing will take place in 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. It can operate as a standalone unit or be connected to the main grid for export. The facility can be used for testing the combination of renewable power sources with water electrolysis. Other applications include testing of control systems for wind power production as well as testing of components for energy conversion and energy storage systems. The hydrogen can be utilized at the adjacent hydrogen station, and serve as fuel for the 10 hydrogen powered Toyota Prius cars in the region.

In order to achieve efficient operation of the NEXPEL stack, a new DC/DC converter is being designed and constructed, based on PCB with control of power, current and voltage for a safe operation. The concept and system layout of the DC/DC converters for integration in the field test has been completed. Laboratory tests indicate that an efficiency of 98.3% is possible. A first prototype of the converter has been produced and functionalities such as power supply, communication and measurement have been tested and calibrated. The housing has been prepared for the assembly of the modules, main controller, connection bars and user interface devices. In the next step the modules will be paralleled in the housing and communication to the main controller will be tested.

The laboratory located in the garage in the Energy Park has been completed, and is now ready to accommodate the NEXPEL stack.

The demonstration is scheduled to begin in the second part of 2012. The field test will give valuable experience on wind-hydrogen systems. Integration of such systems, and can provide input for future projects/demonstrations.

**Dissemination activities**
Dissemination activities have a high focus in the project and the consortium acknowledges the importance of promotion of the development of technologies for sustainable hydrogen production. Our public webpage (www.nexpel.eu) is continually updated with news from the project, the latest dissemination activities and scientific presentations and papers.

## Expected final results and potential impacts and use

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

- 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.
- A new generation polyaromatic membranes for PEM electrolysers with significant enhancement in membrane lifetime and cost.

In addition, performed market analyses of the utilization of PEM electrolysers in different application areas (micro wind & PV for telecom, green $H_2$ stations and large scale $H_2$ production from renewable energy sources), will give a better understanding of the role of PEM electrolysers in a future hydrogen economy.

More information can be obtained by contacting the
project coordinator
Magnus Thomassen
e-mail: magnus.s.thomassen@sintef.no

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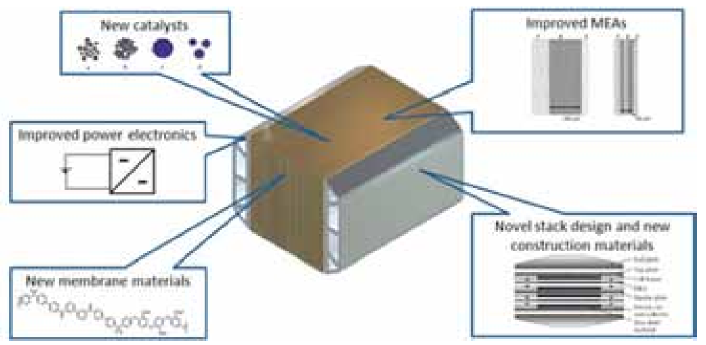
# NEXPEL

## Next Generation PEM Electrolyser for Sustainable Hydrogen Production

2nd YEAR PUBLISHABLE SUMMARY

CEA LITEN - Fraunhofer ISE - FuMA-Tech GmbH - Helion Hydrogen Power - SINTEF - Statoil ASA - University of Reading




## Project overview

The main objective of the NEXPEL project, a successful demonstration of an efficient PEM electrolyser integrated with Renewable Energy Sources, supports the overall vision to establish hydrogen as an energy carrier in a large range of applications in the near future.

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 develop 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 targets 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

## 24 month summary

The development of new membrane materials and electrocatalysts are coming to an end and has resulted in prototypes with promising properties. The development of MEAs and bipolar plates as well as stack design activities is on-going and a first short stack for component testing and verification of the stack design has been completed.

### System design, marked analysis and cost studies

A detailed cost break down of key components has been performed by Fraunhofer ISE. Costs of membrane, electrodes, catalyst, current collectors and bipolar plates made from titanium and frames, sealing gaskets, and finally end plates have been investigated. These data have been used to establish a complete cost break down model for the stack. This model allows comparing different stack designs against each other. Cost break down was performed for stacks in conventional design with a production capacity of 10 and 25 Nm³/h, respectively. Results were compared with the new design as developed for the NEXPEL project (see Figure 1). With the new design cost targets can be reached for quantities > 100 stacks produced.

Initial system design studies have been performed and a design for a PEM electrolysis plant with a hydrogen production rate of 100 Nm³/h has been developed. A smaller system design for distributed applications with < 10 Nm³/h has been evaluated as a benchmark. High pressure operation (up to hundreds of bar) through an analysis of optimized system pressure have been evaluated in terms of hydrogen production costs.

Optimum operation pressure appears to be between 30 and 60 barg, but is closely linked to future performances to be achieved at higher pressure.

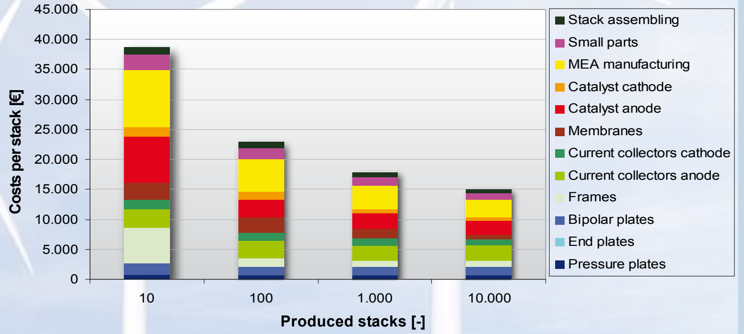



*Figure 1: Cost break down of NEXPEL PEM electrolyser stack.*

### Membrane development

An investigation into a series of polyaromatic materials has been completed. Both parts of the polymer, hydrophilic and hydrophobic, have been considered resulting in the most effective monomers being selected. Scale up of the synthesis of the in-house hydrophobic monomer has been achieved and a commercially available hydrophilic monomer used. Polymerization has been achieved on a large scale (~10 g) and to high molecular weight (Mn ~100,000). The high molecular weight of the polymer enabled efficient conversion to the ionomer. The polymer exhibited good thermo-mechanical properties with a glass transition temperature 195-197 °C potentially allowing for higher temperature operating conditions. The ionomer is soluble in suitable organic solvents such as N-Methyl-2-pyrrolidone and has been cast from a 15 % solution to affect a membrane across the desired thickness range of 60-100 µm.

The University of Reading has supplied polymer for a 5.5 m² pilot scale production at FuMaTech of the membrane with homogeneous- morphology in thickness of ~50 micron (Figure 2)

*Figure 2: 5.5 sqm sPEEK membrane cast from UoR onomer*

### Electrocatalyst development

SINTEF has synthesized both oxygen and hydrogen evolution catalysts on supported materials to reduce the total noble metal content. For the HER catalysts, Pt/C was synthesised by both the polyol method and the impregnation method. Several of the catalysts are showing higher activity than comparable commercially available Pt/C catalysts.

For the OER catalyst, Ir and Ir/Ru alloys on ATO as support were synthesised by the polyol method showing good reproducibility regarding metal loading, homogeneity of the dispersed nanosized (<2 nm) catalyst and performance (Figure 3). A 200% increase in performance was observed with the Ir supported NEXPEL OER catalyst system, compared to commercial Ir black catalysts.  MEAs with NEXPELs OER catalyst and commercial HER catalysts showed performance of 0.80 A/cm² for 0.4 mg Ir/cm² at 1.65 V and 80 °C, using a Nafion 115 membrane.

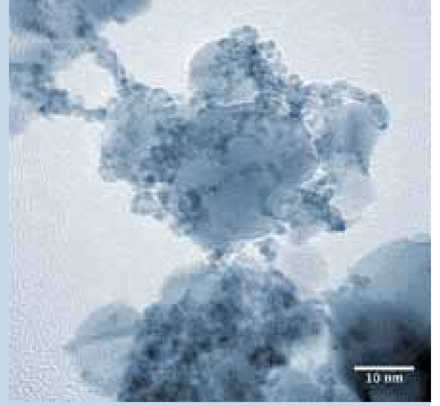



*Figure 3: TEM (right)micrograph of Ir/ ATO electrocatalyst*

Up scale of the synthesis have been successfully completed, and a batch size of 10g without any influence on reproducibility or performance has been achieved. Alloying the catalyst with Ru has further increased the catalytic activity significantly, showing 500% increase of mass activity at 1.5 V with a nominal composition of $Ir_{0.85}Ru_{0.15}O_2$ /ATO compared to the Ir/ATO.

### Membrane electrode assembly

Fumatech has supplied four different kinds of standard-type CCM to the partners involved in CCM tests

1. CCM fumea®EF-10 is based on 180 micron reinforced membrane. This type of membrane shows high conductivity so the CCM offers good performance, with a pressure limit of 10 bar.
2. CCM fumea®EF-30 is based on 250 micron reinforced membrane. This type of CCM is capable to pressures up to 30 bar.
3. CCM fumea@EF-40 based on a 240 micron reinforced membrane using a different polymer and reinforcement film compared to EF-30. It offers the same performance as EF-30, but with higher gas purity and a pressure range up to 40 bar.
4. CCM coded as EF-50 based on a 360 micron reinforced membrane. This membrane offer very high purity of gases on account of performance which has a limit of 0.8 A/cm².

Fumatech has completed investigation of production parameters of CCM based on developed Ir/ATO catalysts for the anode side. Ir/ATO has been coated on EF-40. After an optimisation of coating parameters the results showed that Ir/ATO has almost comparable performance to the anode layer in commercial EF-40, see Figure 4 . The loading of Ir in the Ir/ ATO catalyst layers represents about 40% of the loading in standard EF-40.

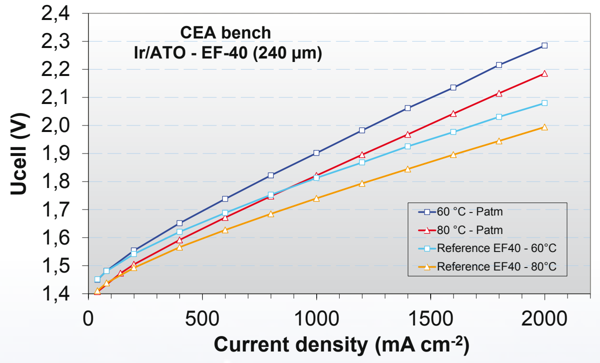



*Figure 4: Comparison of Ir/ATO with standard EF-40. Loading of Ir in Ir/ATO-layer represents about 40% of the one in standard EF-40. Data recorded in CEA-cell.*

### Bipolar plates and stack design

At the beginning of the project a bibliographic review to define suitable materials or coating strategies for the titanium replacement was performed. A benchmark of possible solutions started in the middle of the first year, consisting of an evaluation of the corrosion resistance and electrical contact resistance of the most promising materials. Several titanium grades and coated stainless steel samples have been evaluated in conditions representative of PEMWE operation for hundreds of hours.

A two-phase fluid transport modeling tool including electrochemical reactions and thermo-hydraulic transport has been developed. Fluidic transport and electrical conductivity of various current collectors has been evaluated by ex-situ characterization and real PEM water electrolysis tests were performed for model validation. Performance and electrical characterization for different physical properties of current collectors (thickness, porosity, wetting angle…) were compared. A first generation of current collectors was developed at small scale (25 cm² single cell). Then several improved generations were evaluated and the first large surface area samples (150 cm²) were supplied at the end of the second year.

The stack design activity was started by a literature survey on conventional stack design, to identify possible areas for cost, durability and performance improvement and subsequently, to define the specifications of the novel stack design. Based on the specifications from this study and a series of in-house brainstorming sessions with experts on stack construction, a final design and sealing concept for the first generation 2-cell NEXPEL short stack was conceived.  A mathematical stiffness model, taking into account the elastic and compression behavior as well as the mechanical property of each component in the stack, was used to determine the optimal clamping load. A 3-D FEA Solid Mechanics model was used to optimize contact pressures and the design and thickness of the endplate. The constructed 2-cell NEXPEL short stack (Figure 5) is now being tested at Fraunhofer ISE in a fully automated 10 kW test rig adapted to high pressure operation.

The final result from this activity will be a 10-cell stack design for PEM electrolysis with a production rate up to 10 Nm³/h for high pressure operation. Stack components will be designed for life-time up to 40.000 hours. Potential impact is given by the novel design which allows cost effective production of PEM electrolysis stacks according to the implementation plan of the JU FCH.

*Figure 5: NEXPEL 2 cell short stack*