1 PUBLISHABLE SUMMARY

1.1 Project overview

The main objective of MEGASTACK is to develop a cost efficient stack design for MW sized PEM electrolysers and to construct and demonstrate a prototype of this stack. The prototype will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (HHV) at a current density of 1.2 Acm^{-2} with a stack cost below €2,500/Nm^3h^{-1} and a target lifetime in excess of 40,000 hours (< 15 μV^{h-1} voltage increase at constant load). In the project we aim to take advantage of the existing PEM electrolyser stack designs of ITM power as well as novel solutions in the low-cost stack design concepts developed and further refined in the FCH-JU projects NEXPEL and NOVEL. In order to successfully up-scale the design concept from a 10-50 kW to a MW-sized stack, we will in the MEGASTACK project perform integrated two-phase flow and multi-physic modelling together with optimization of stack components such as MEAs, current collectors and sealings which are important for stack scale up.

To reach these ambitious objectives, MEGASTACK will develop and demonstrate an enhanced stack design essential for cost-competitive, efficient and dynamic PEM electrolysis systems through the following key concepts:

- The stack design process will have an integrated approach, involving stack manufacturers, component and MEA suppliers as well as PEM electrolyser experts from research institutes.
- Evaluation and adaptation of existing solutions and commercially available components for use in large format stacks and increased ease of stack assembly by the reduction of stack part count.
- Advanced multiphase flow modelling coupled with multi-physics models for electrochemical kinetics, heat and momentum transport will be used as detailed design tools for cell and stack components.
- Implementation of quality control measures and supply chain evaluation of all components will be performed in order to reduce costs and minimise technology and manufacturing risks.

1.2 Description of the work performed and main results of the 1st period of MEGASTACK

During the first 12 months of the MEGASTACK project, the consortium has performed a study on the cost and performance targets for large scale PEM electrolysers, including the organisation of a cost reduction strategy workshop. The technical work has involved development of multi-scale and multiphysics models for PEM electrolysers, performance and lifetime evaluation of CCMs and stack design and prototyping.

Cost and performance analyses

This activity has during the first year mainly been focused on establishing cost targets for large-scale PEM electrolysers and establishing a robust cost reduction strategy. As part of this activity, the consortium organised a cost reduction strategy workshop in conjunction with the 2nd IEA ANNEX 30 Electrolysis Meeting at the Hydrogen Centre of Excellence in Herten, Germany. Within this workshop, the commonly accepted view on the market application for large scale (PEM) electrolysis systems and possible/preferred cost reduction strategies by manufactures were presented and discussed. In general, the cost reduction strategies can be classified into the categories of (i) technology related cost reductions, (ii) design and process savings, and (iii) manufacturing related cost reductions. Mostly cost reduction strategies of different PEM electrolysis manufactures comprise:

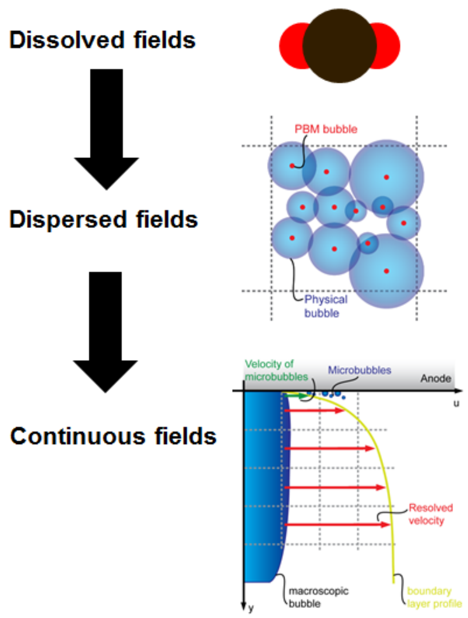
- (i) Aiming at higher current density operation through improved catalyst systems
- (i) Increasing the operating temperature (through novel membranes)
- (ii) Development of stack platforms with larger active area
- (ii) Design improvements, e.g. reduction of stack parts, material reduction through improved stack design
- (iii) Decreasing labour costs through higher automation and improved quality control methods

Mathematical modelling and verification

The main objective of this activity is to develop and use multiscale and multiphase models as engineering tools for stack design and up-scaling. The models will be verified and validated using advanced experimental set ups such as distributed current mapping and flow visualization.

During the first period, Fraunhofer has commissioned a single test cell for I-V-characterisation in order to study different combinations of MEAs, current collectors and flow fields. An electrical and electrochemical model has been developed to study local current density in catalyst layer/current collector interface and to calculate I-V-curves.

At SINTEF, a two-phase flow model has been developed in order to study the gas-liquid flows during water electrolysis process. Relevant experiments have been designed to validate the two-phase flow model. A high speed camera is used to capture images of gas bubbles which then are analyzed by means of advanced image processing. The results from numerical simulations will also be processed in a similar way.



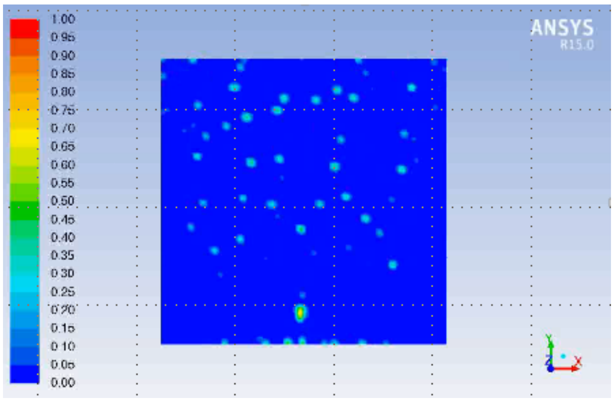


Figure 1: Multiphase flow model framework (right) and simulated bubble flow in PEM electrolyser (left).

CEA has during the first 12 months adapted their PEMFC code PS++ to PEM electrolyser conditions. The software structure is now operational after the necessary code changes and debugging work. The simulated results have been validated against experimental polarization curves and water crossover measurements. Proof of concept on the use of acoustic emission

(AE) measurement to characterize diphasic flow within the cell was set up and the absolute energy was found to follow the various current regimes.

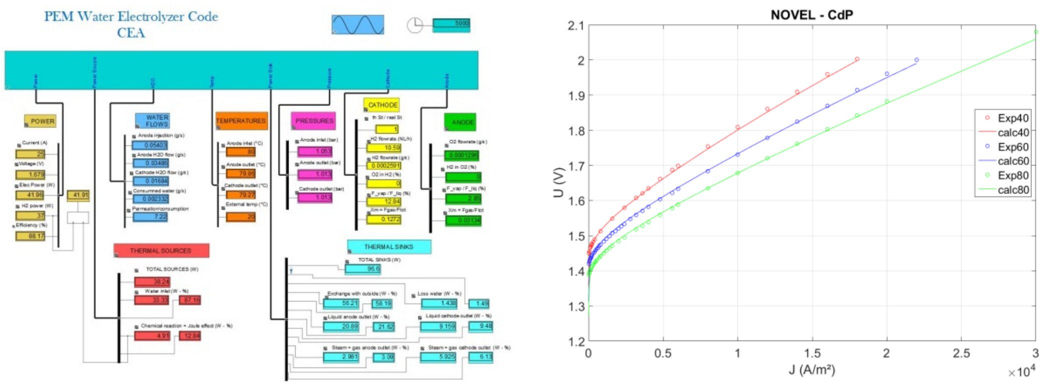


Figure 2: Multi-physic stack model framework (right) and simulated polarization curve (left).

Membranes and MEAs

In the period, a screening and selection of MEAs for the project has been performed. The evaluation of MEAs was based on multiple criteria, such as cell voltage at high current density, resistance to ITMs proprietary accelerated stress tests (AST) and the hydrogen crossover rate at differential pressures. More than four suppliers of MEAs have been tested and it was found that MEAs with low loadings of PGMs (2-3.5 $mgcm^{-2}$) gives the best balance between cost, performance and durability.

Stack design and manufacturing strategies

The main objective of this activity is to develop a large scale stack design for a PEM electrolyser in the MW range. To reach the main objective, activities such as comprehensive testing of cell and stack components and evaluation of concepts and components will be performed, using a multi-criterion (e.g. technical/economical risk, supply chain strength, cost reduction potential) decision matrix. During the first 12 months, a comprehensive design and review of stack components such as sinters, meshes, cell plates, frames and bipolar plates and the associated supply chains have been performed. A first revision of a stack design is complete and manufacturing templates have been produced for testing of assembly, tolerances and pressure tightness.

Large scale stack prototype construction and testing

The goal of this activity will be to construct and test short stacks based on the stack design developed in the project. Technical validations of the stack design, the efficiency and stack performance will be performed under real life data cycles and the capability of the stack to operate in different applications such as HRS or direct coupling to renewable energy sources will be evaluated. This activity has during the first year been limited to establishing the necessary test bays for the upcoming stack evaluation.

1.3 Expected final results and potential impacts and use

The results obtained in the first period of MEGASTACK 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:

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.s.thomassen@sintef.no)