PEMBeyond

PEMFC system and low-grade bioethanol processor unit development for back-up and off-grid power applications

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Summary This public report will present the current status after the first year of the implementation phase of PEMBeyond project. Information in this document may be used for dissemination purposes to different project stakeholders. Similar brief status reports will be given after every year of the project.	
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1. Project overview

Main objective of PEMBeyond project (http://pembeyond.eu/) is to develop an integrated PEM fuel cell based power system for stationary back-up and off-grid power generation, that is:

- Using crude (80-95%) bioethanol as primary fuel
- Cost-competitive (complete system < 2 500 €/kW @ 500 units)
- Energy-efficient (> 30% overall system efficiency)
- Durable (> 20 000 hours system lifetime in continuous operation)

Back-up and off-grid power is one of the strongest early markets for fuel cell technology today. Wireless communication systems are rapidly expanding globally, and the need for reliable, cost-competitive and environmentally sustainable back-up and off-grid power is growing, especially in developing countries.

Fuel cell technology has already proven to be competitive with conventional technologies - diesel generators or batteries - in these applications in terms of total cost of ownership (TCO). However, the growth of the fuel cell industry in this sector has been modest at least partially due to high initial investment cost and fuel logistics problems. Cost-competitive PEMFC power system compatible with crude bioethanol would allow direct use of easily transported and stored, locally produced sustainable and low-emission fuel also in developing countries, further adding value and increasing the number of potential applications and end-users for fuel cell and hydrogen technology.

The PEMBeyond system will basically consist of the following functions integrated as a one complete system:

1. Reforming of crude bioethanol,
2. Hydrogen purification,
3. Power generation in PEMFC system.

Optimized overall system design combined to use of improved system components and control strategies will lead to improvements in cost, efficiency and durability throughout the complete system. Latest automotive reformate compatible PEMFC stacks will be used, possessing high potential to reducing stack manufacturing costs. On top of this, the stacks as a part of a low-grade H2 compatible fuel cell system design will allow both FC system simplifications (e.g. no cathode humidifier needed) and complete system simplifications (e.g. higher CO ppm and lower H2% allowed) leading to decreased cost. Optimizing the target H2 quality used will be an important task with the regard to overall system cost, efficiency and durability. An extensive techno-economic analysis will be carried out throughout the project to ensure attractiveness of the concept. A roadmap to volume production will be one of the main deliverables of the project. Overall concept developed in PEMBeyond is presented in Figure 1 and an overview of project schedule is given in Figure 2.

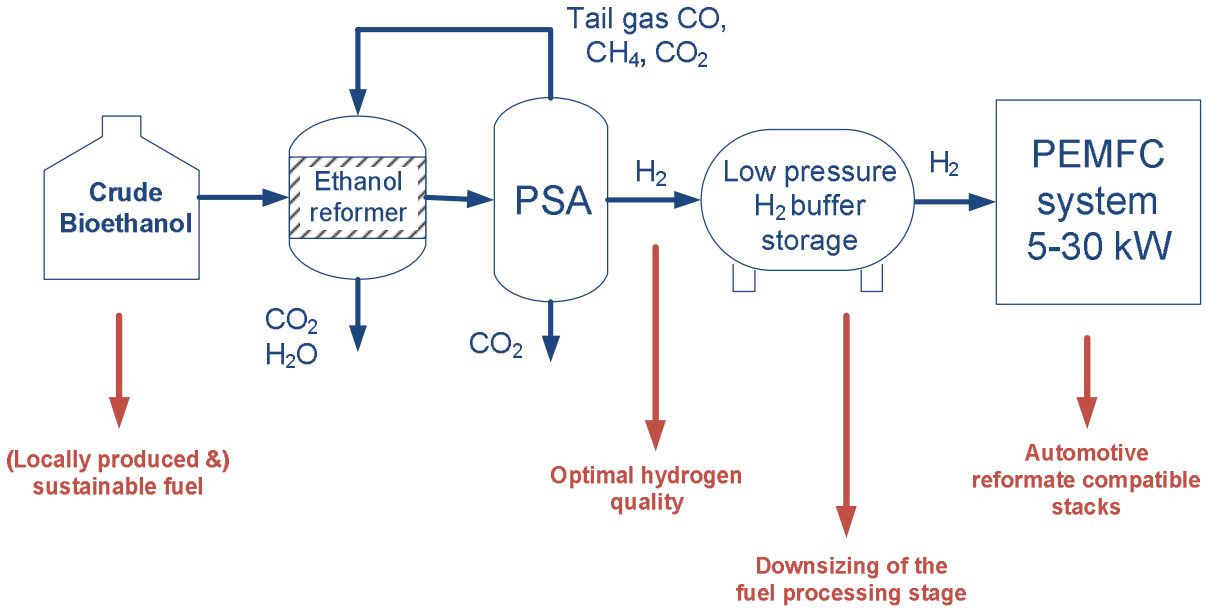

Figure 1: Overall concept developed in PEMBeyond project.

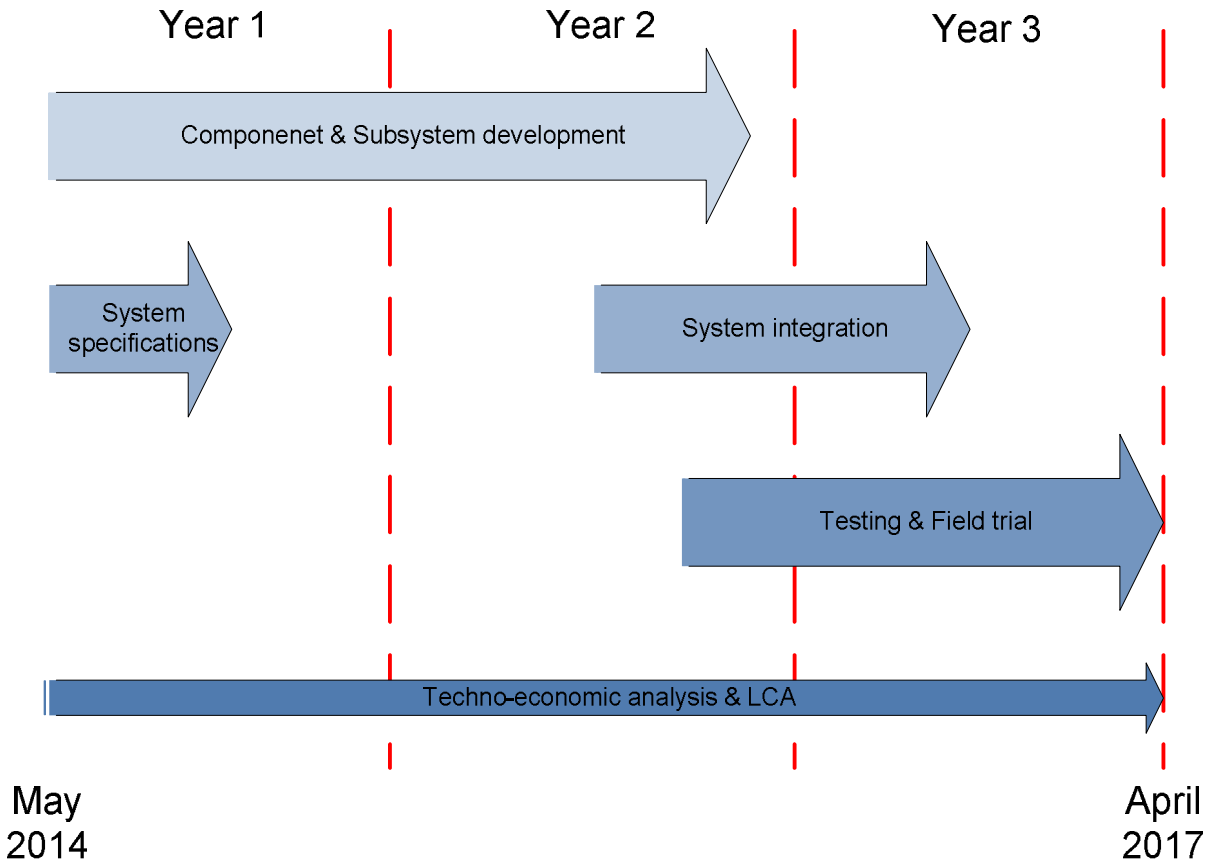

Figure 2: Overview of PEMBeyond project schedule.

In addition to the complete system, development of separately utilizable subsystems is another main outcome of the project. This includes PEMFC system for back-up and off-grid application using low-grade hydrogen directly as a fuel, low-cost state-of-the-art PEMFC stack for various applications, crude bioethanol processor unit for distributed hydrogen generation (e.g. at hydrogen refilling stations).

Serious market penetration of fuel cell technology and renewable fuel into back-up and off-grid power generation will have a high impact on energy consumption, and particulate and greenhouse gas emissions worldwide. Use of crude bioethanol as fuel would enable the use of low-cost, easily transported and stored, and locally produced sustainable and low-emission fuel also in developing countries.

PEMBeyond consortium consists of five partners from 5 different European countries:

1. VTT Technical Research Centre of Finland (VTT) – coordinator
2. PowerCell Sweden Ab (PCS)
3. Genport srl (Genport)
4. Fraunhofer ICT-IMM (Fraunhofer-IMM)
5. University of Porto (UPorto)

2. Progress to date

In the early stages of the project the system specifications to steer the subsystem and system development were defined. Partners are currently working on development of different subsystems and main components to be integrated as the complete system. System integration work has been started with hydrogen quality optimization work. Techno-economic and environmental analyses are ongoing throughout the project duration to give feedback on competitiveness andattractiveness of the developed concept.

Overview of project progress by work package during the first year:

- WP2 – Fuel cell stack development (WP leader: PCS)

  First generation of the fuel cell stack BoS (blance-of-stack) has been completed and tested. Corrective actions following the testing were taken into the next generation that has also been completed and the validation testing is ongoing. Two prototype version stacks have been delivered to project partners Genport and VTT so far, and three product version stacks will be delivered before summer.

- WP3 – Fuel cell system development (WP leader: Genport)

  Fuel cell system (FCS) simulation tool has been developed and it has been used for dimensioning of the system. FCS design has been decided for the first lab prototype. All the components for the first bench FCS were purchased, assembled in subsystem, tested and characterized separately. Control electronic and software architecture have been developed. A feasibility test on digital controlled power electronics is ongoing. Also the test benches at Genport have been updated to enable full characterization of the FCS.

  Fuel cell stack and system test benches have been completed at VTT to facilitate the stack and system testing. Low-pressure ejector study for anode recirculation has been started at VTT with simulations and experimental characterization of commercially available ejectors. For experimental studies a new test bench has been developed and built. Additionally, a custom ejector with optimized dimensions was purchased for characterization and validation of the ejector model.

- WP4 – Reformer development (WP leader: Fraunhofer-IMM)

  Bioethanol (crude and purified) samples from different sources have been acquired and analysed at Fraunhofer-IMM and VTT. At Fraunhofer-IMM, testing of modified bimetallic catalysts under expected PEMBeyond conditions regarding activity, long term stability and low selectivity towards methane formation has been made. A model of the fuel processor (reformer + PSA) has been set up using ASPEN Plus. Detailed engineering of the microstructured components, and development of reformer control strategy has started.

  At UPorto, preliminary physicochemical characterization of Cu-based catalysts for low temperature water gas shift (LT-WGS) has been completed.

- WP5 – PSA development (WP leader: UPorto)

  Negotiations with a commercial PSA supplier regarding purchase of their PSA unit for the project have been successful, but certain legal aspects are delaying completion of the purchase. The unit will be delivered in 6 months after the acquisition process is completed and the unit should be ready for tests at VTT at M24. The characterization of activated carbons for hydrogen purification was performed and the most promising of them was deeply characterized. The lab-scale PSA unit (Figure 3) was designed and assembled and preliminary tests conducted using a binary feed mixture (70 % H2 and 30 % CO2). A stream of 99.99+% purity of H2 and 78 % of recovery was obtained.

  VTT has completed a literature study on use of Pd-membranes for hydrogen purification in PEMBeyond applications. They are considered as an possible future option, but not used within this project.

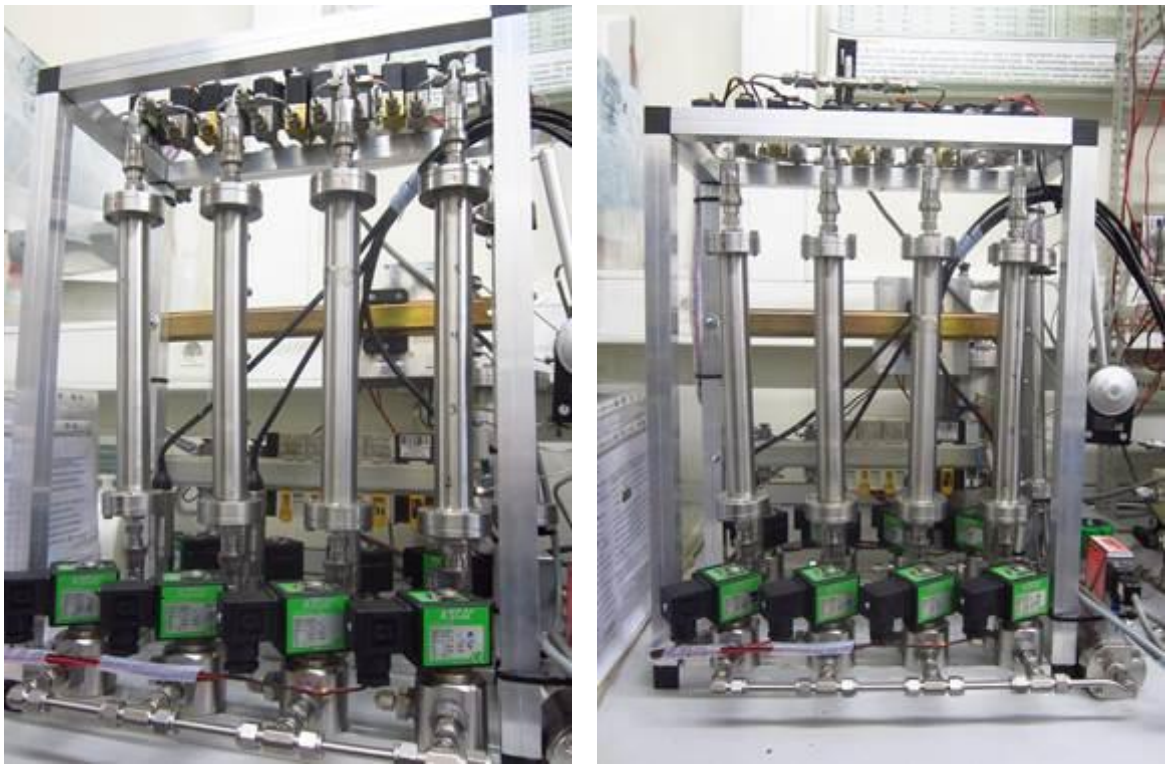

Figure 3: Lab scale PSA unit

- WP6 – Complete system integration (WP leader: VTT)

  Overall system specifications have been set (main specifications found inTable 1 below). At VTT, experiments studying CO concentration effects in a single cell setup with anode recirculation are close to being completed, and the next step is to verify the results on stack level. Mapping and purchasing of system integration related auxiliary components have been started. Also development of the higher level control system has been started.

  Table 1: Main target system specifications

Fuel Cell System:	
Electric net output	7 kW / 48 V DC
Start-up time	few ms (buffered by Li-ion battery)
Efficiency	> 45%
Bioethanol processor:	
Product H_2 feed to buffer storage	0.135 kg/h (corresponds to ~2 kW net electric output)
Expected product gas characteristics	> 98 % H_2 and < 20 ppm CO, at 40 °C / 10 bar
Start-up time	< 45 min (buffered by hydrogen storage)
Complete system prototype:	
Electric net output	> 5 kW / 48 V DC (for 3.3 h hydrogen buffer storage capacity, after that limited to 2 kW)
Efficiency	> 30%
Fuel consumption	1 kg/h bioethanol
Back-up time	7 days (with 160 liter ethanol vessel)
Physical footprint	10ft. ISO container (not including the hydrogen buffer storage)
Ambient temp range	-20 to + 40 °C
Start-stop cycles	> 1000
Availability / reliability	> 98%

- WP7 – Testing and field-trial (WP leader: VTT)

  This work package has not been started yet. Work is scheduled to be started in M20 when first subsystems are delivered to VTT from other partners.

- WP8 – Techno-economic and environmental analysis (WP leader: Genport)

  Genport is responsible for the techno-economic analysis, and VTT for the environmental analysis (LCA). A market research has been conducted for the global fuel cell telecom backup market. A techno-economic tool has been developed and further improved to be used in studying attractiveness of PEMBeyond system in the backup market. Collecting data for both techno-economic analysis and life-cycle analysis has been started.

- WP9 – Dissemination (WP leader: VTT)

  The project website has been launched (http://pembeyond.eu/) and is kept up-to-date, a dissemination plan has been developed and an Industrial Advisor Group (IAG) has been

formed. IAG will consist of stakeholders from telecom and energy industry. Annual workshops will be organized to disseminate project results and receive feedback from industry. The first workshop was held in September 2014 at VTT in Finland, and the second one at Genport in Italy in May 2015.