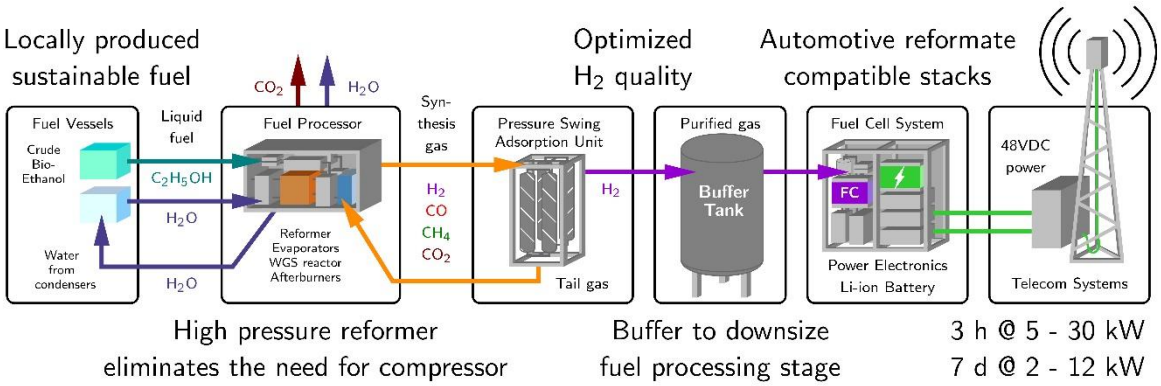

Figure 1: Overall concept developed in PEMBeyond project.

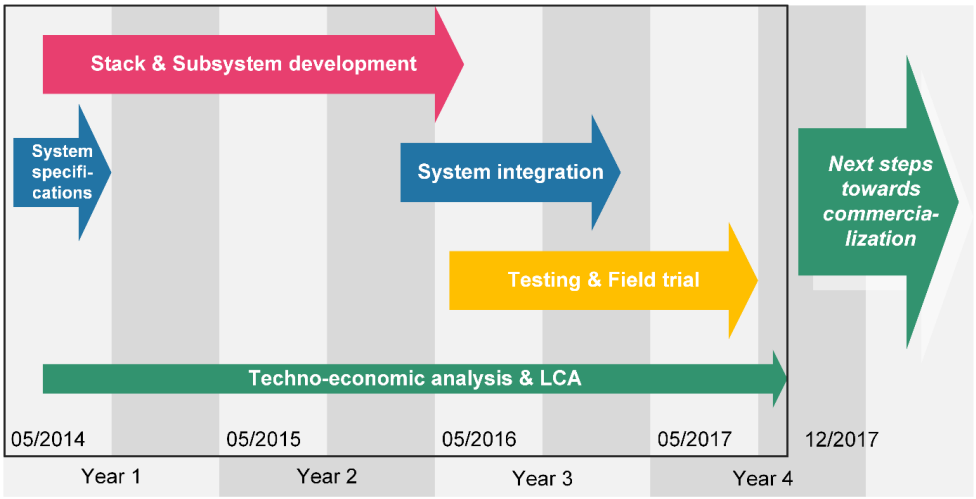

Figure 2: Overview of PEMBeyond project schedule.

Table 1: Initial specifications for the reformed ethanol fuel cell system (REFCS).

Fuel Cell System:	
Net electric output	> 7 kW at 48 VDC
Start-up time	few ms (buffered by Li-ion battery)
Efficiency	> 45 %
Bioethanol Fuel Processor (FP) & PSA unit:	
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 H_2 storage)

Complete REFCS Prototype:	
Net electric output	> 5 kW / 48 VDC (3 h with H_2 buffer, then limited to 2 kW)
Efficiency	> 30 %
Fuel consumption	1 kg/h bioethanol
Back-up time	7 days (with 190 liter ethanol vessel)
Physical footprint	10 ft. ISO container (not including the H_2 buffer storage)
Ambient temp. range	-25 °C to + 40 °C
Start-stop cycles	> 1000
Availability / reliability	> 98 %

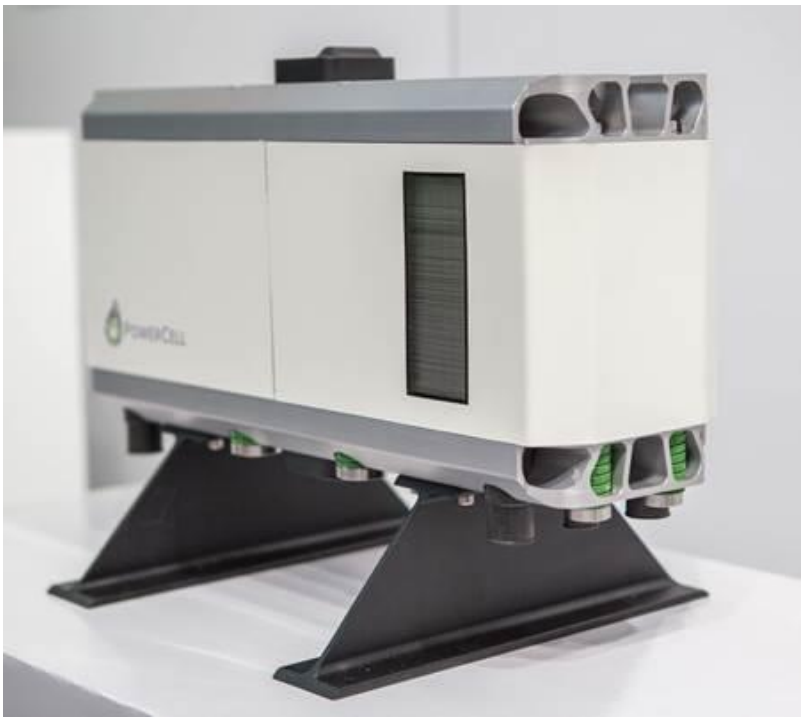

Figure 3: Product version of the S2 stack employed in the project, with 100-cells and 9 kW nominal power.

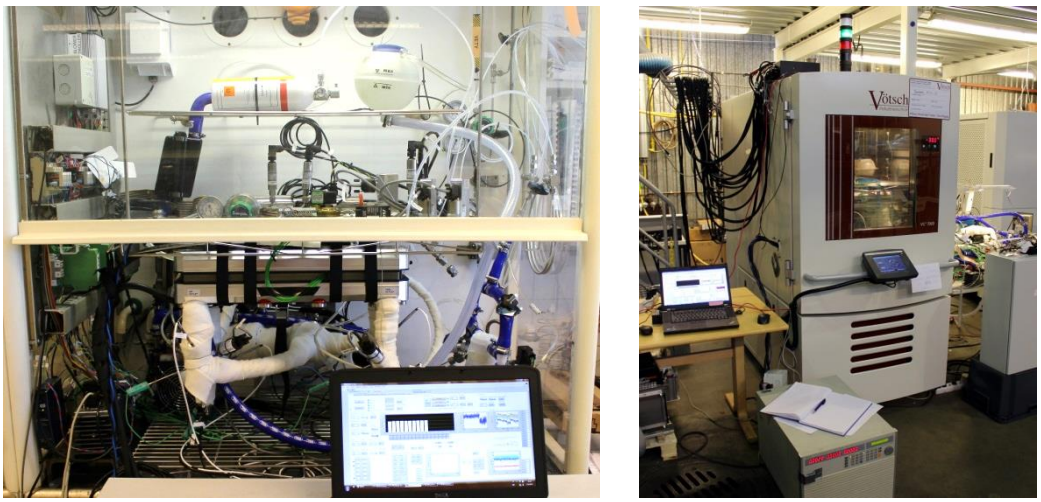

Figure 4: The S2 stack on impurity tolerance measurements (left) and under thermal stabilization preceding freeze start-up (right).

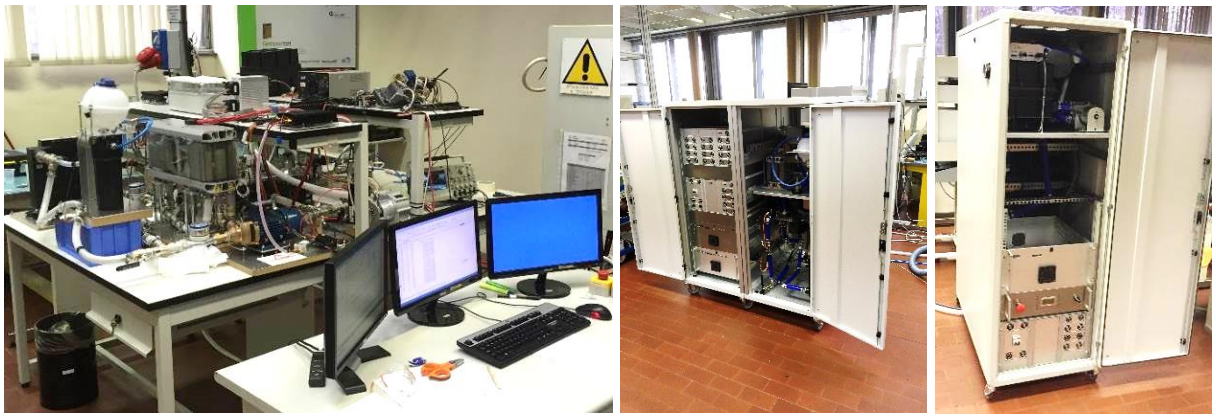

Figure 5: Breadboard FCS prototype (left), industrial FCS prototype used in REFC system (middle), and cost-optimized FCS prototype (right).

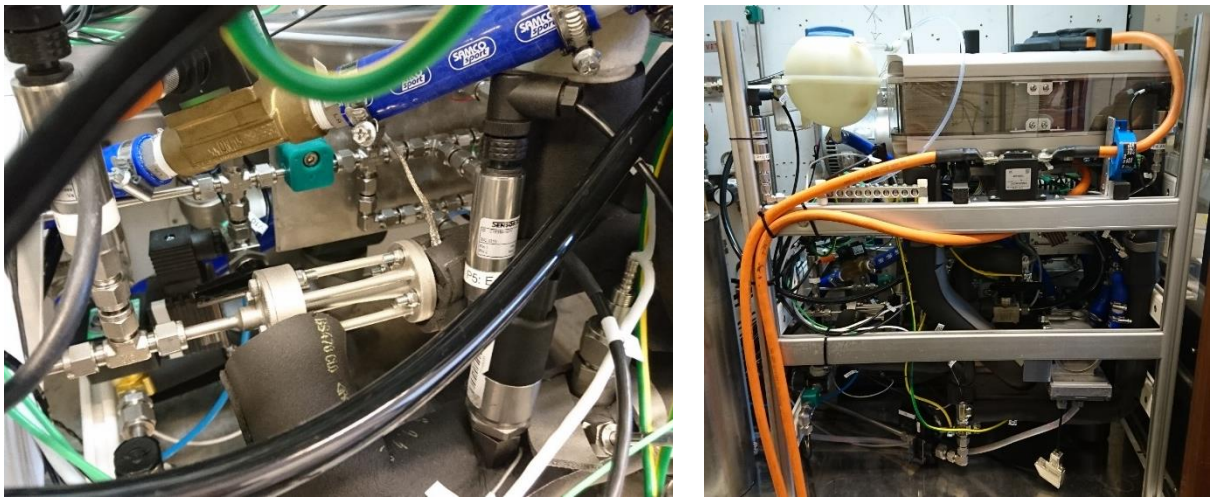

Figure 6 - Fuel cell system operated with 3D-printed ejector and discrete controller.

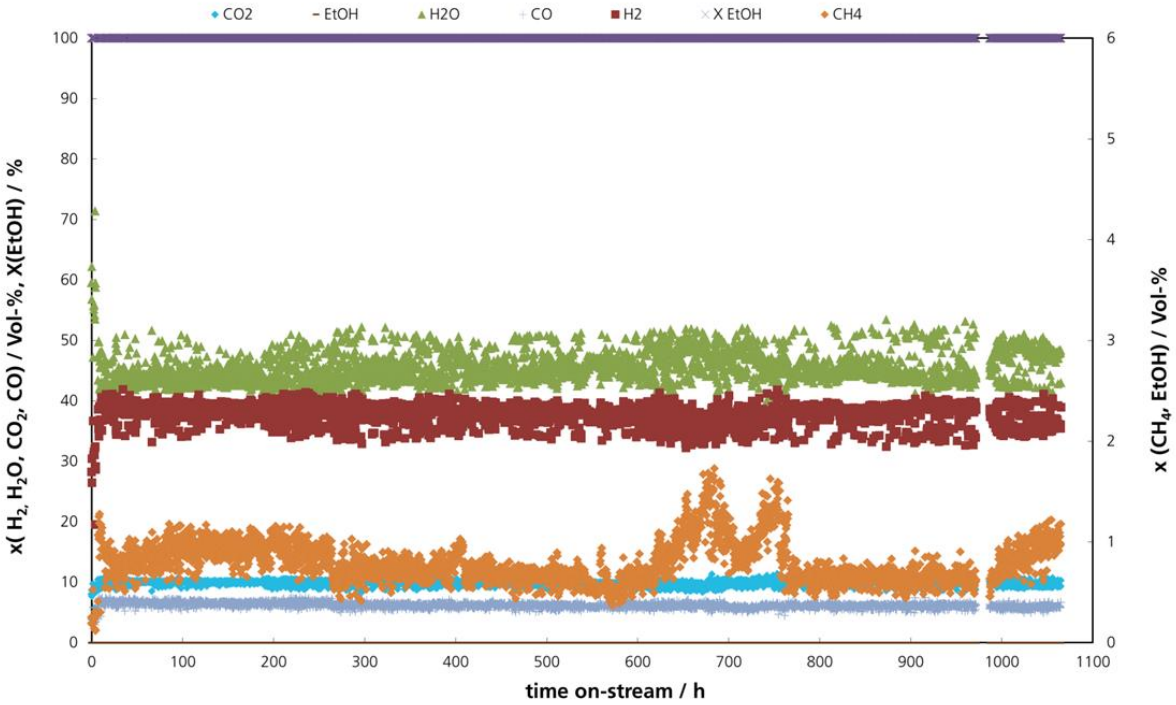

Figure 7: Stability test of ETAX-B crude bioethanol steam reforming over catalyst IMM 1474e. Species concentrations in the reformate: pressure, 8 barg; temperature, 750 °C; feed S/C ratio, 4.1; feed flowrate 100 mL/min; mass of catalyst in screening reactor, 17 mg.

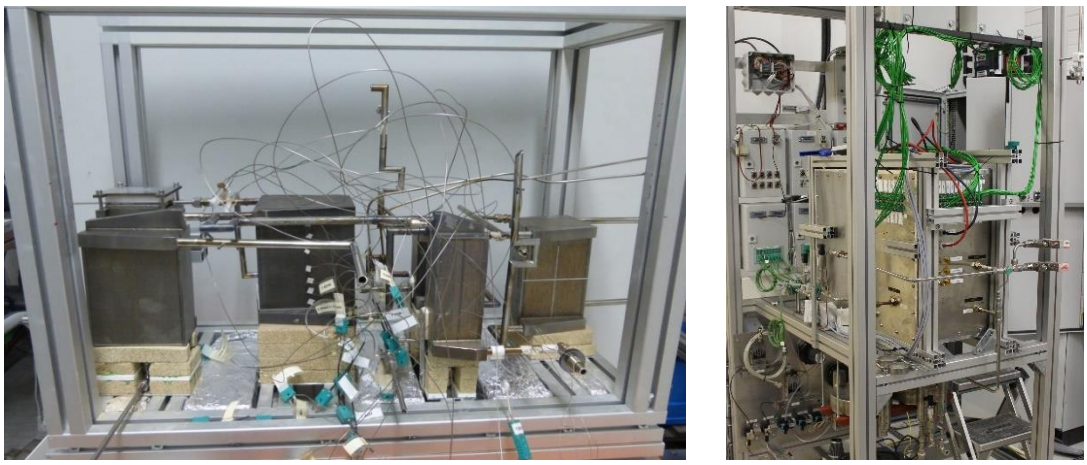

Figure 8: Fuel processor during installation of reactors and thermocouples at Fraunhofer IMM (left), and fuel processor installed to test bench at VTT (right).

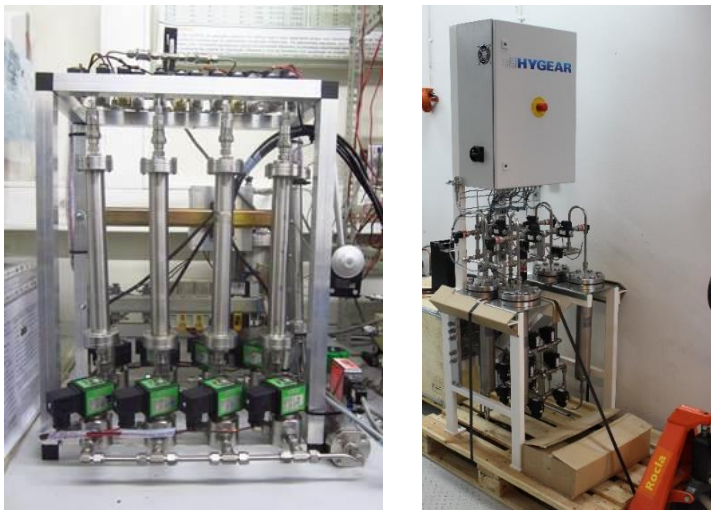

Figure 9: Lab scale PSA unit at UPorto (left) and prototype PSA unit by HyGear (right).

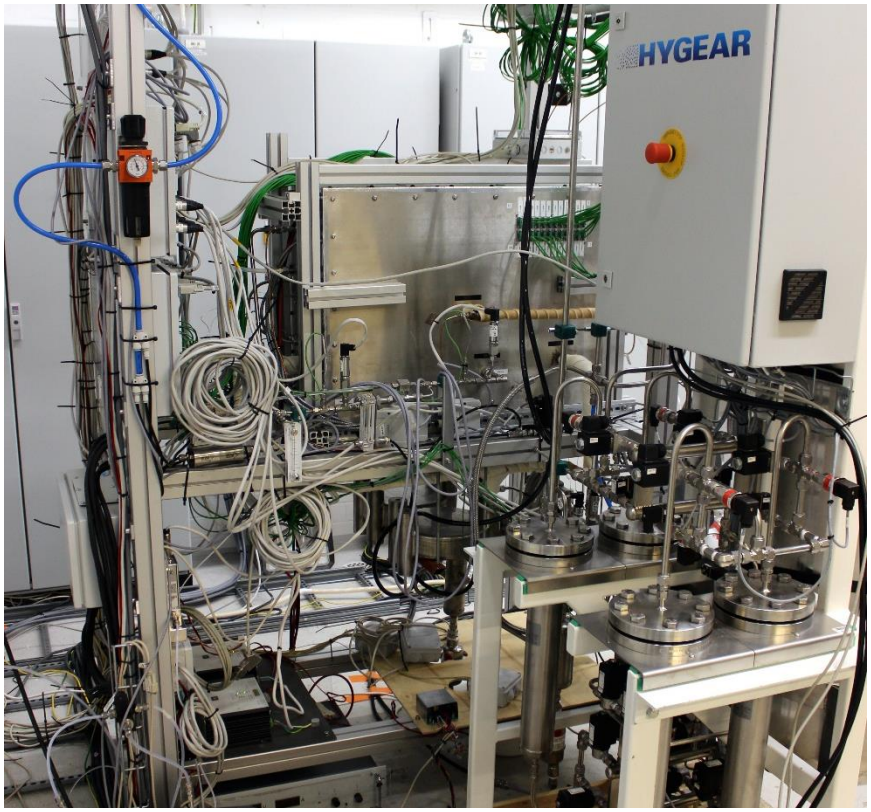

Figure 10: FP and PSA during initial testing.

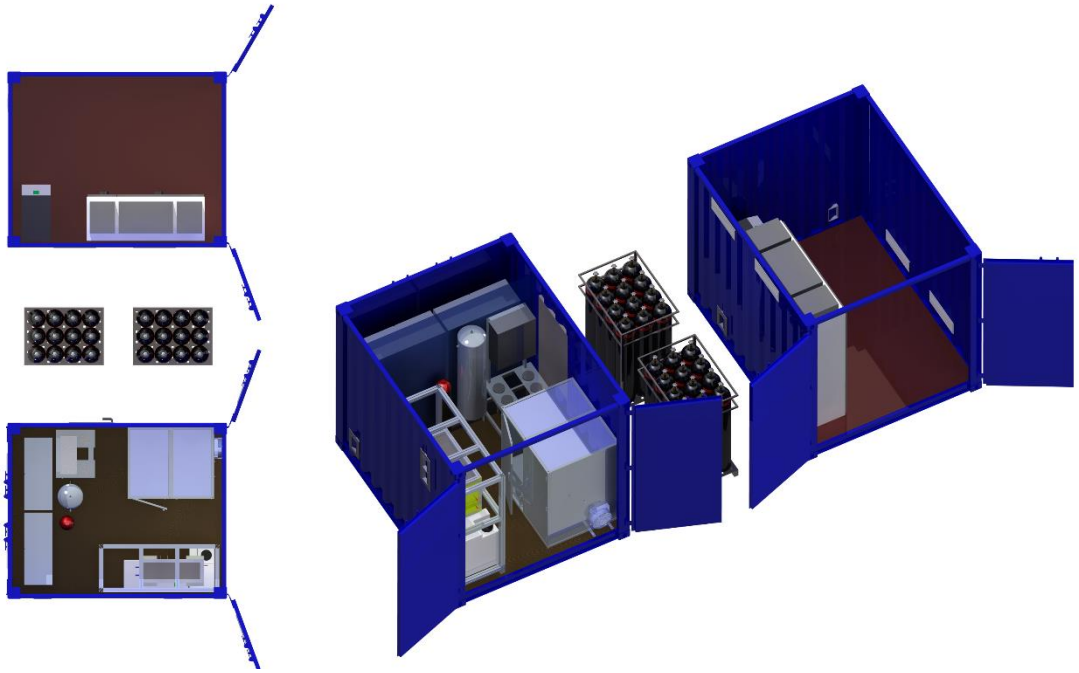

Figure 11: Rendered images of CAD model from REFC system container, H_2 buffer tanks, and control room container.

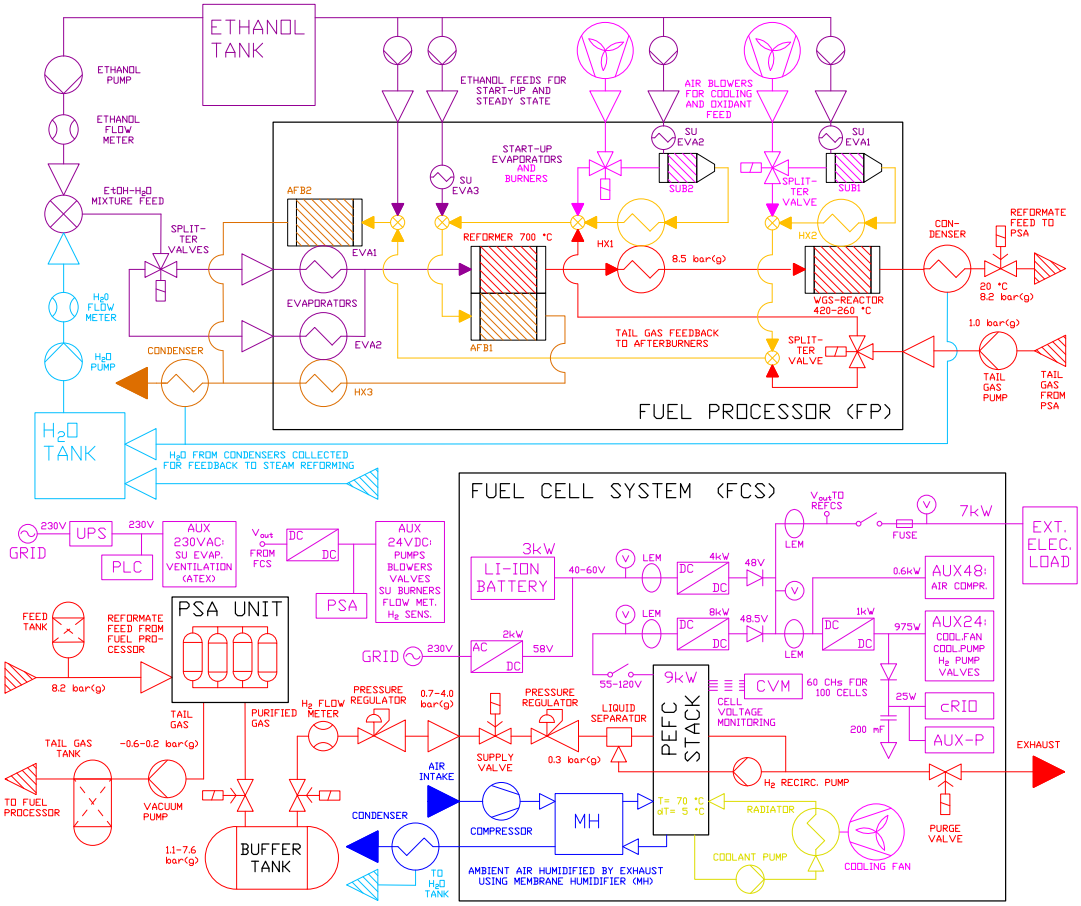

Figure 12: Simplified process flow diagram of the reformed ethanol fuel cell (REFC) system.

Figure 13: Integrated REFC container layout during commissioning.

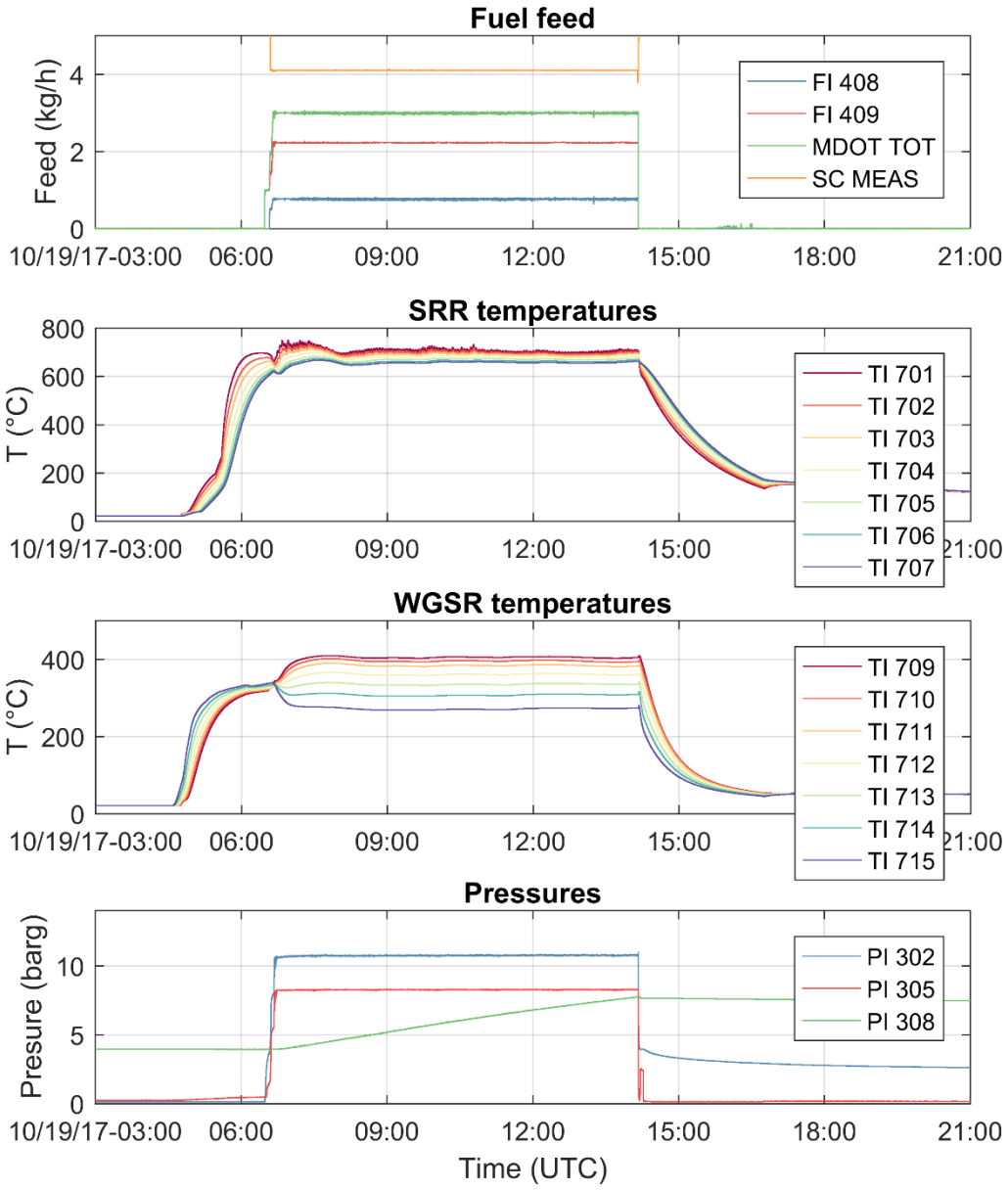

Figure 14: Data showing fuel feed, reactor temperatures, and pressure during 7.5 hour run.

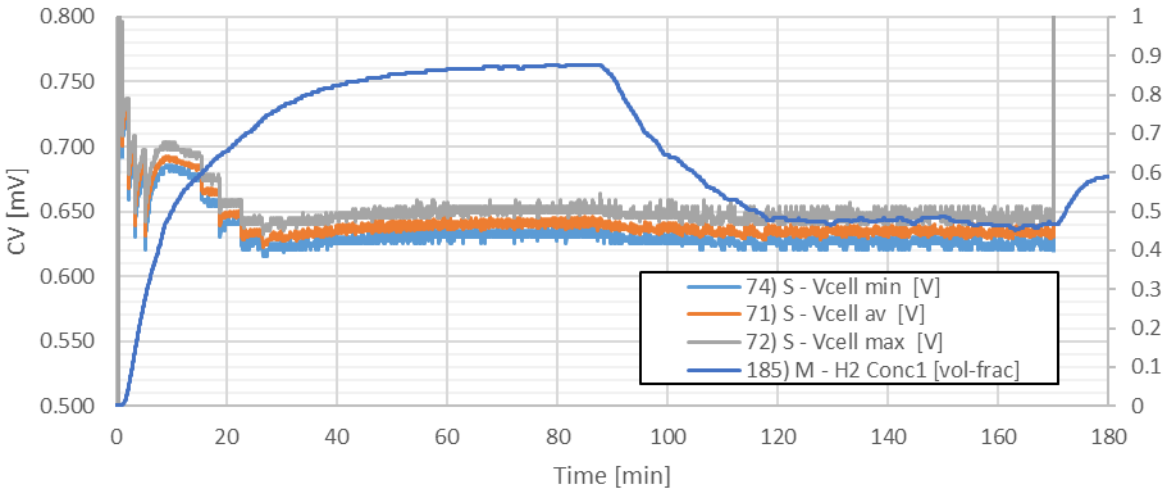

Figure 15: FCS cell voltages during operation at 117 A current with pure H_2 2.5 and H_2 produced from EtOH starting from 90 minutes onwards.

Project logo:

PEMBeyond