Project
EXPLOITATION OF THE RESULTS

Development of new technologies at ITM Power

The materials and concepts developed in CREATE have the potential to decrease the capital cost and meet the operating cost of the competing PEMEL technology, while drastically reducing the content CRMs (especially PGMs) in such systems. Since the CREATE project is a low technology readiness level activity, the next step in terms of exploitation of the results will be projects developing solutions closer to market. Gradual scale-up and parallel development of AEMEL and PEMEL technologies is foreseen. The work undertaken in this project forms the basis for future product development, having a long-term perspective to meet the technoeconomic challenges for hydrogen generation from AEMEL as an alternative to generation from fossil fuels.

New membranes for the FUMATECH's product catalogue

In the CREATE project FUMATECH has developed new AEM and BM using improved formulations, new chemical stabilizer and suitable reinforcements. These membranes were successfully produced on the FUMATECH continuous production line with the aim to obtain high-quality and highly reproducible membranes for evaluation, sampling and MEA production. The process of the pilot-scale production of the novel membranes is fully compatible with the standard large-scale membrane production enabling the rapid transfer and integration of the new formulations into the standard operation of manufacturing processes. This allows the subsequent commercialisation of project results on a long-term perspective when AEMFC and AEMEL technologies have been developed. Although the project is aiming to AEM-based fuel cells and electrolysers, the new formulations are useful for other electrochemical applications where alkaline stable AEMs are required which may enter the FUMATECH's product catalogue on a mid-term perspective.

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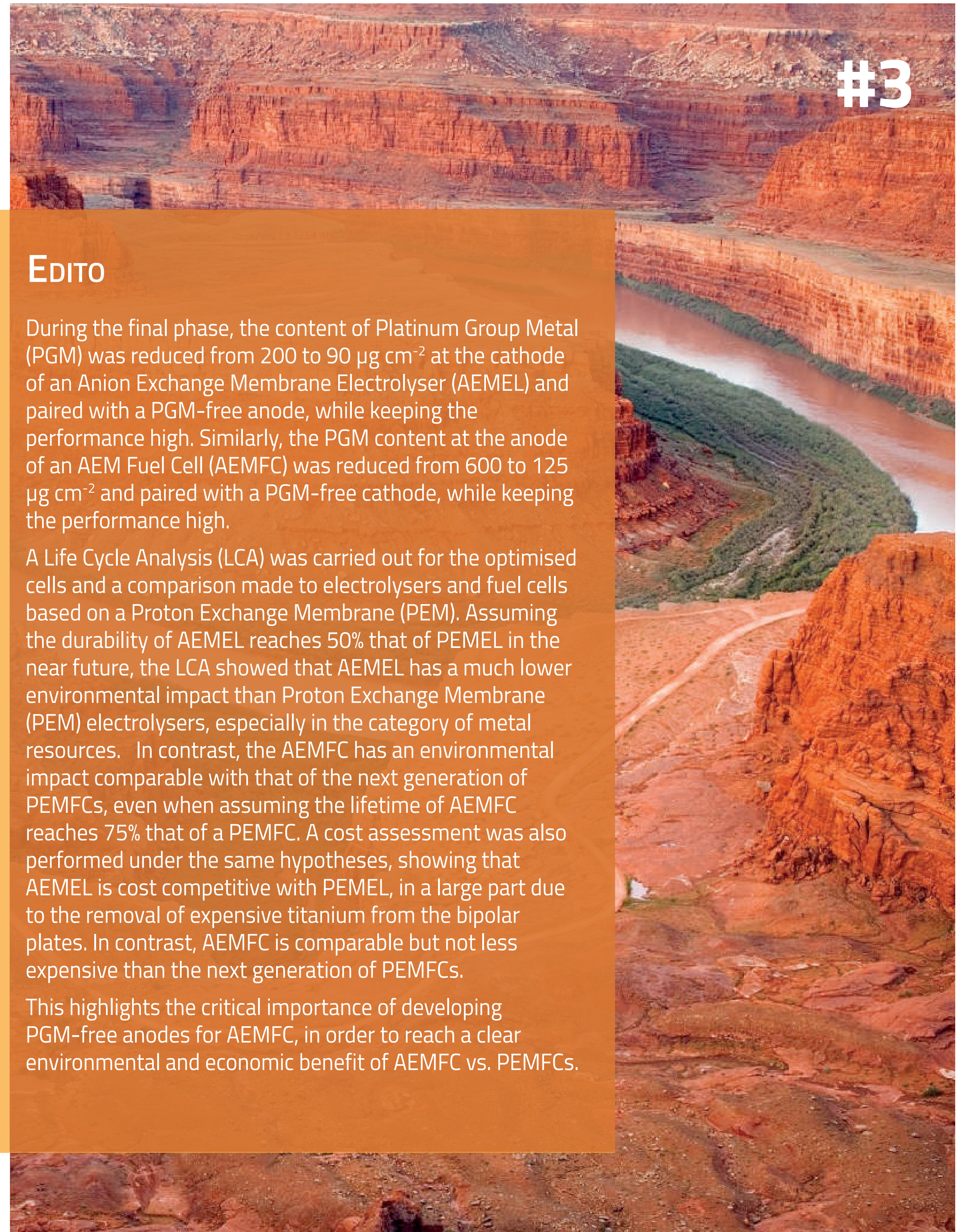


Edito

During the final phase, the content of Platinum Group Metal (PGM) was reduced from 200 to 90 μg cm^{-2} at the cathode of an Anion Exchange Membrane Electrolyser (AEMEL) and paired with a PGM-free anode, while keeping the performance high. Similarly, the PGM content at the anode of an AEM Fuel Cell (AEMFC) was reduced from 600 to 125 μg cm^{-2} and paired with a PGM-free cathode, while keeping the performance high.

A Life Cycle Analysis (LCA) was carried out for the optimised cells and a comparison made to electrolysers and fuel cells based on a Proton Exchange Membrane (PEM). Assuming the durability of AEMEL reaches 50% that of PEMEL in the near future, the LCA showed that AEMEL has a much lower environmental impact than Proton Exchange Membrane (PEM) electrolysers, especially in the category of metal resources. In contrast, the AEMFC has an environmental impact comparable with that of the next generation of PEMFCs, even when assuming the lifetime of AEMFC reaches 75% that of a PEMFC. A cost assessment was also performed under the same hypotheses, showing that AEMEL is cost competitive with PEMEL, in a large part due to the removal of expensive titanium from the bipolar plates. In contrast, AEMFC is comparable but not less expensive than the next generation of PEMFCs.

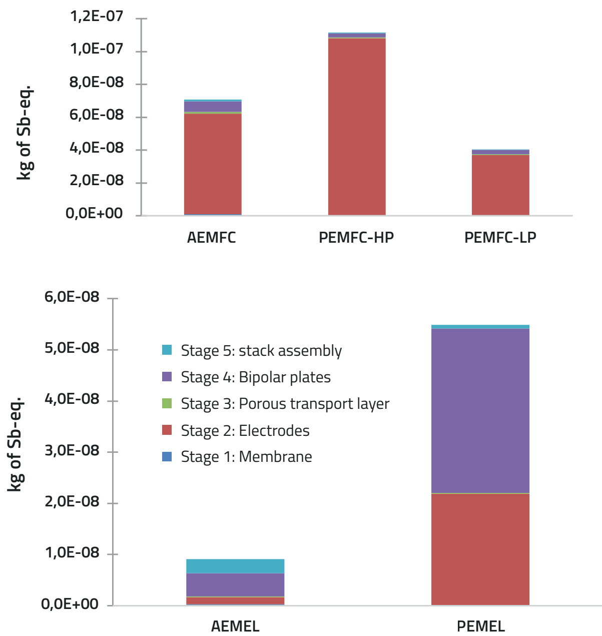
This highlights the critical importance of developing PGM-free anodes for AEMFC, in order to reach a clear environmental and economic benefit of AEMFC vs. PEMFCs.

Critical Raw materials Elimination by a top-down Approach To hydrogen and Electricity generation

Life Cycle Assessment

In Work Package 2, a full-scale LCA was completed. In general, LCA aims at characterising a product's environmental performance over its entire life cycle (cradle to grave). In CREATE, systems with the newly developed, most promising AEM membrane electrodes assemblies were compared to typical PEM-based systems in fuel cell and electrolyser mode. In line with CREATE's purposes, the focus was on the materials used in the manufacturing stage.

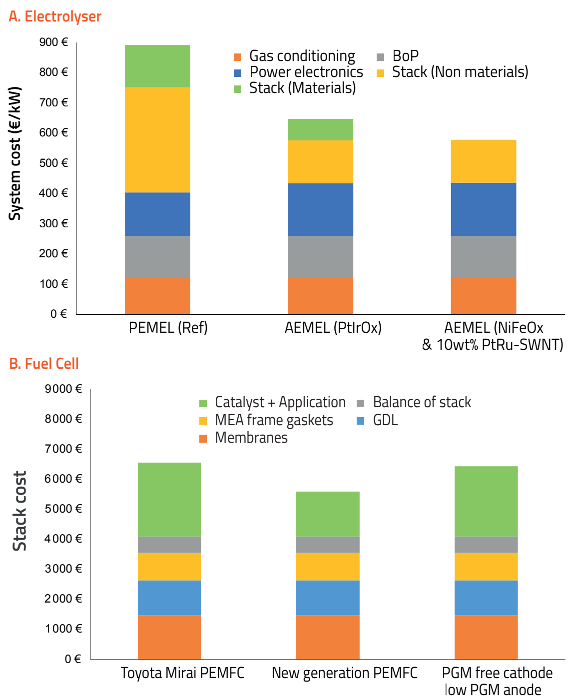
Results show that the low PGM loading in AEMFC and AEMEL has a substantial influence on their environmental impact. Under the assumptions taken, the AEMFC has a lower impact than the PEMFC-HP in 6 out of 27 impact categories. AEMEL has a lower impact in 24 out of 27 impact categories. The figures exemplary show the results for the impact category "resources, minerals and metals".



Results for the impact category "resources, minerals and metal" comparing fuel cell and electrolyser applications for AEM and PEM. PEMFC-HP"2018" high platinum 0.365 mg/cm², PEMFC-LP"2022" low platinum 0.125 mg/cm²

Cost Assessment

In Work Package 2, we also have estimated the costs of the AEMEL and AEMFC technologies based on the performance of the project's optimised cells an the current prices of the materials. We then compared the estimated costs to those of state-of-art PEMEL and PEMFC systems.



Cost comparison between different electrolysers (A) and fuel cells (B). A: BoP = balance of plant. "Stack non materials" ~ machining + manpower. B: Stack cost for 96 kW fuel cell stacks.

Regarding the electrolysis, the cost of the system is already reduced by 28% when switching from PEMEL to AEMEL, even when standard PGM contents are used in the AEMEL electrodes (Fig. A, 1^{st}-2^{nd} columns). This is due to less expensive stainless steel as bipolar plate materials in AEMEL compared to Platinum-coated titanium in PEMEL and the easier machining of steel. Switching from high- to low-PGM (PGM-free anode and low Pt cathode) MEAs in AEMEL further reduced the cost by 10% (Fig. A, 2^{nd}-3^{rd} column)

Regarding fuel cells, we assumed that the balance of plants is similar and therefore considered that the cost difference between PEMFC and AEMFC systems is only related to the stack. In commercial PEMFC stacks, ~2/3 of the cost is related to membrane + catalysts (Fig. B, 1^{st} column). From our analysis, it appears that the AEMFC MEA developped in the project is cost competitive with the PEMFC technology existing in the Toyota Mirai fuel cell car (Fig. B, 1^{st}-2^{nd} columns), but not yet competitive with the coming generation of PEMFCs with decreased PGM content (Fig. B, 2^{nd}-3^{rd} columns). Increase in AEMFC performance with decreased PGM loading (i.e., at the anode) are still needed to make AEMFCs competitive.

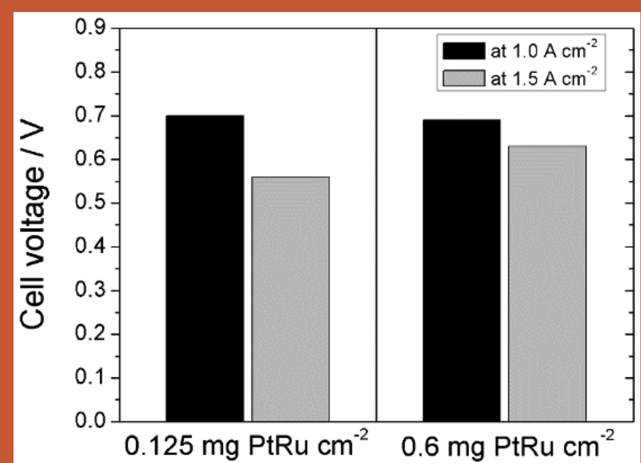
Project OUTPUT AND HIGHLIGHT

Cell assembly and cell testing

In Work Package 5, the MEAs comprising a Fe-N-C cathode were optimised, and the peak power in H_2/O_2 AEMFC was increased from 1.05 to 1.75 W cm^{-2}. This advance was achieved with a reduced Fe-N-C loading at the cathode and a thinner AEM. The durability was investigated and a restricted decrease of ca 33% was observed for the catalytic activity of Fe-N-C, in line with an irreversible change in iron speciation that was observed by end-of-test spectroscopy. A slight increase in the cell resistance was also measured (+ 10 mΩ cm²), assigned to dehydration or chemical attack of the AEM. These two effects lead to ca 15% decrease in the cell performance over 100 h of operation.

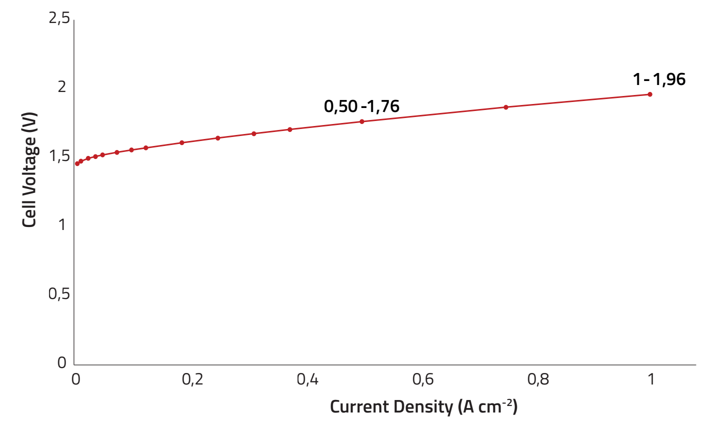
The good initial performance was however achieved with a high content of PGMs at the anode, 0.6 mgPtRu cm^{-2}.

In a next step, the anode was re-designed and the anode PGM loading could be reduced from ca 0.6 to ca 0.13 mgPtRu cm^{-2} without any loss in AEMFC performance at cell voltages > 0.67 , while some performance loss was observed at even higher current density (see figure). An important target of the project was to achieve 0.7 V fuel cell voltage at 0.5 A cm^{-2} for an H_2/air AEMFC, and this was almost achieved with the low-PGM anode (125 μgPGM/cm²), reaching 0.69 V at 0.5 A cm^{-2}. The full economic and environmental sustainability promise of AEMFCs will however be achieved only with PGM- and CRM-free anodes.



In Work Package 5, an AEMEL has been developed with CRM-free anode. With a low loading of PtRu/C at the cathode, this produced excellent performance at a temperature of 45°C. The optimised electrodes gave a cell voltage of 1.76 V at 0.5 A cm^{-2} at 45°C with only 90 μg cm^{-2} PGM.

This is similar to the previous best result at a higher temperature of 60°C and using PGM catalysts. In the initial benchmarking, an AEMEL with 0.2 mg cm^{-2} Pt at cathode and 1.5 mg cm^{-2} IrO_2 at the anode showed 1.75 V cell voltage at 60°C and 0.5 A cm^{-2} and 1.83V at 45°C at the same current density.



Polarisation curve at 45°C, fumapem® FAA-3-30 membrane with CRM-free anode and low CRM cathode with 0.1M NaOH electrolyte at the anode. Anode: 4.5 mg cm^{-2} Ni-foam/Ni2P/Fe(PO3)2/Ionomer 0.54mm Aged, Cathode: 0.09 mg cm^{-2} PtRu (PtRu20%/C, fumasep® AE Resin, fumion® FAA-3 post-coat on carbon paper)

List of abbreviations

AEM	Anion Exchange Membrane
AEMEL	Anion Exchange Membrane Electrolyser
AEMFC	Anion Exchange Membrane Fuel Cell
BM	Bipolar Membrane
CRM	Critical Raw Material
LCA	Life Cycle Assessment
MEA	Membrane Electrode Assembly
PGM	Platinum Group Metal
PEM	Proton Exchange Membrane
PEMEL	Proton Exchange Membrane ELectrolyser
PEMFC	Proton Exchange Membrane Fuel Cell
PEMFC-HP	PEFMC – High Platinum content
PEMFC-LP	PEFMC – Low Platinum content
TRL	Technological Readiness Level