# Project NEXT STEPS

### Membrane Electrode Assembly (MEA) Optimization

The electrode structure will be further optimized in WP5 for already identified CRM-free catalysts at the anode of AEM electrolyzer (bi- and trimetallic oxide) and at the cathode of AEM fuel cell (Fe-N-C). The effect of e.g. electrode thickness, porosity and ionomer type will be investigated for each device, while a series of membranes with different thickness and mechanical properties from WP4 will be tested in combination with these optimized electrodes.

The two test stations at EIFER (Figures) will be used to evaluate electrodes and membranes developed in CREATE, at single cell level, under operating conditions that are representative of automotive applications for fuel cell and for $H_2$ production for a refuelling station for the electrolyzer.

### CRM-free and CRM-lean catalysts

In parallel, groundwork is still pursued in WP3 to increase the activity of CRM-free catalysts for hydrogen oxidation and hydrogen evolution in alkaline medium. In the risk mitigation approach, the synthesis of catalysts with low PGM content will investigate approaches to further reduce the amount of PGM needed.

### Bipolar Membranes

The novel bipolar membranes with much lower through-plane resistivity achieved during the last year will be scaled-up and their preparation modified in order to allow their easier implementation in novel MEA types.

### Cost and life cycle

Cost and life cycle analyses will be conducted on the optimized MEAs developped in CREATE that will have provided the best combination of performance and durability when tested in single-cell fuel cell and electrolyzer. The goal is to evaluate the economic and environmental performance of the most promising cells, which will be benchmarked against the PEM-based cells.

*After 30 months of project, the progress is in track with the initial schedule. Two milestones were reached during the second period (MS1 on AEM conductivity & stability and MS2 on bipolar membrane conductivity) while MS3 on AEMFC performance (0.5 W $cm^{-2}$ peak power with air feed & PGM loading < 80 µg $cm^{-2}$) has been achieved in terms of power performance but at PGM loading above the target, due to the need for PGM at the anode. The advent of CRM-free HER/HOR catalysts with high activity is now key to realize the full potential of AEM-based devices.*

**Contact**

*Dr. Frédéric Jaouen*
*Project Coordinator*
*ICGM - Equipe AIME*
*Université de Montpellier*
*Place E. Bataillon - CC1502*
*Montpellier 34090 France*

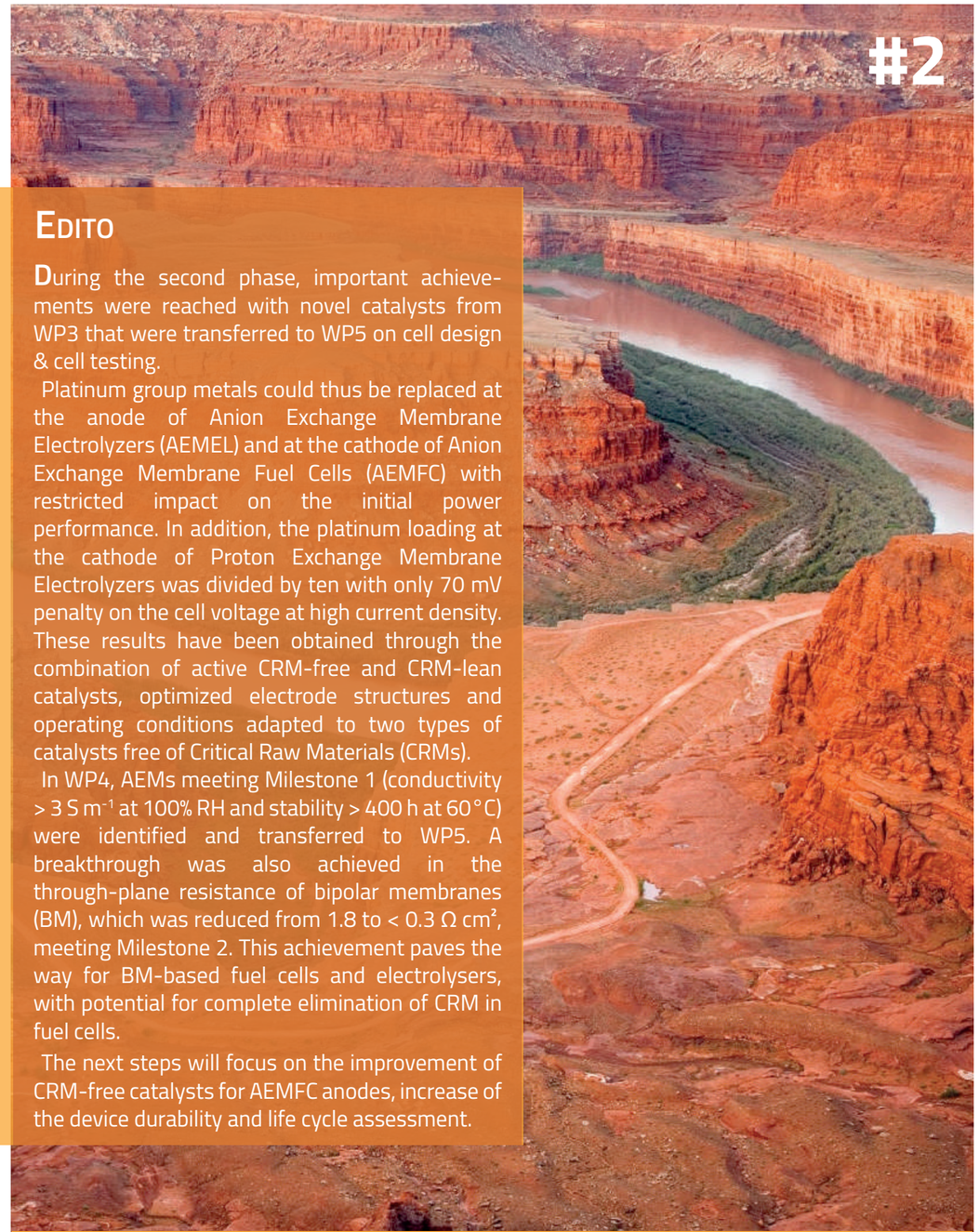
*www.create-energy-h2020.eu*

*The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement CREATE No. 721065*

Horizon 2020
European Union funding
for Research & Innovation

# Newsletter

September 2019




## Edito

During the second phase, important achievements were reached with novel catalysts from WP3 that were transferred to WP5 on cell design & cell testing.

Platinum group metals could thus be replaced at the anode of Anion Exchange Membrane Electrolyzers (AEMEL) and at the cathode of Anion Exchange Membrane Fuel Cells (AEMFC) with restricted impact on the initial power performance. In addition, the platinum loading at the cathode of Proton Exchange Membrane Electrolyzers was divided by ten with only 70 mV penalty on the cell voltage at high current density. These results have been obtained through the combination of active CRM-free and CRM-lean catalysts, optimized electrode structures and operating conditions adapted to two types of catalysts free of Critical Raw Materials (CRMs).

In WP4, AEMs meeting Milestone 1 (conductivity > 3 S $m^{-1}$ at 100% RH and stability > 400 h at 60 °C) were identified and transferred to WP5. A breakthrough was also achieved in the through-plane resistance of bipolar membranes (BM), which was reduced from 1.8 to < 0.3 Ω $cm^2$, meeting Milestone 2. This achievement paves the way for BM-based fuel cells and electrolysers, with potential for complete elimination of CRM in fuel cells.

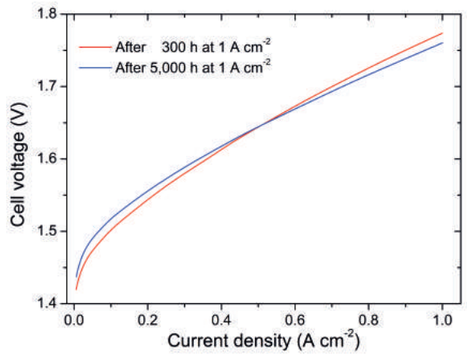
The next steps will focus on the improvement of CRM-free catalysts for AEMFC anodes, increase of the device durability and life cycle assessment.

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

# Project
# MAIN ACHIEVEMENTS

*The European project CREATE aims at developing new concepts of hydrogen fuel cells and water electrolysers based on polymer electrolytes with lower acidity than the ones currently in use. This approach will allow the use, combination and/or development of novel anode and cathode catalysts that are free of CRM (and especially free of PGM), or contain a much reduced CRM amount compared to today's electrolysers and fuel cells based on proton-conducting polymer-electrolyte membranes.*

In **WP3** a novel electrocatalyst has been developed to enable efficient utilization of Pt. In this material, Pt forms nanowires on the sidewalls of thin single walled carbon nanotubes resulting in a catalyst with low Pt content of 4 wt%. The benefits of this novel ultra-low Pt electrocatalyst have been demonstrated for electrocatalysing hydrogen evolution reaction in acidic media. With the notably lower Pt loading, a catalytic activity of 10 mA $cm^{-2}$ at –18 mV vs. RHE was reached. When implemented at the cathode of a proton exchange membrane electrolyzer, a stable voltage of ca 1.77 V was reached for 5,000 h at a high current density of 1 A $cm^{-2}$, with only 0.02 $mg_{Pt}$ $cm^{-2}$ at the cathode. This successfully competes with PEM electrolyzer results obtained with state-of-art Pt nanoparticles highly loaded on a carbon support as a cathode. With 20 wt % Pt/C and ten times higher Pt cathode loading (0.2 $mg_{Pt}$ $cm^{-2}$), the cell voltage was indeed lowered by only 70 mV at 1 A $cm^{-2}$, partly due to improved kinetics but also reduced Ohmic resistance.




*PEM electrolyser polarisation curves recorded after 300 and 5,000 h at 1 A $cm^{-2}$ using Nafion membrane and pure water. Cathode: 0.02 $mg_{Pt}$ $cm^{-2}$ with CREATE Pt/SWNT catalyst. Anode: 2.4 $mg_{IrRu}$ $cm^{-2}$ (commercial IrRuOx).*

*The CREATE partnership involves partners from both academia and industry who will jointly advance novel catalysts and membranes, test in industrial conditions the most promising materials in hydrogen fuel cells and electrolysers, and perform cost and life-cycle assessment of the most promising systems.*



# Project
# OUTPUT AND HIGHLIGHT

In **WP6,** the international workshop **Electrolysis and Fuel Cell Discussions 2019**, focusing on Critical Raw Materials free devices for electrochemical energy conversion, was held on 15th-18th September 2019 in La Grande Motte, France.

EFCD 2019, jointly organised with the European project CRESCENDO, has brought together more than 150 researchers from 24 different countries. Contributions received provided and interesting programme with:

- 34 oral presentations
- 10 keynotes lectures
- 81 posters

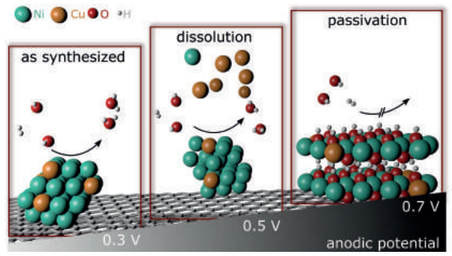
In this second period, the consortium has also released 17 publications, among them:

- **Direct magnetic enhancement of electrocatalytic water oxidation in alkaline media**, *Nature Energy* 4, 519–525, 2019.

- **Stability limits of Ni-based hydrogen oxidation electrocatalysts for anion exchange membrane fuel cells,** *ACS Catalysis*, 2019, 98, 6837-6845

- **Effect of Pyrolysis Atmosphere and Electrolyte pH on the Oxygen Reduction Activity, Stability and Spectroscopic Signature of FeNx Moieties in Fe-N-C Catalysts**, *Journal of The Electrochemical Society*, 166 (7) F3311-F3320, 2019

In **WP3**, synthesis and characterization of platinum group metal (PGM)-free hydrogen oxidation reaction (HOR) catalysts was carried out by Technion. In close collaboration with Jülich, we were able to identify stability windows of binary NiM catalysts. On one hand, we detect dissolution of some alloying materials, which leads to a high surface area, possibly more active Ni enriched catalyst. On the other hand, however, we found that high anodic potentials can lead the irreversible oxidation to Ni hydroxides, which are no longer active for HOR. While the former can be managed by finding a suitable stable dopant, the latter is more intrinsic to the Ni catalysts. Therefore, high anodic potentials need to be avoided in fuel cell application.




In **WP5**, a Fe-N-C catalyst free of critical raw materials successfully replaced a platinum-based cathode in Anion-exchange membrane fuel cell (AEMFC) device. The Fe-N-C catalyst was down-selected from WP3 and its active sites were shown to be atomically dispersed Fe cations ligated by nitrogen atoms. Compared to a cathode with 450 $\mu g_{Pt}$ $cm^{-2}$, the cathode with 1.5 $mg_{FeNC}$ $cm^{-2}$ (only ca 30 $\mu g_{Fe}$ $cm^{-2}$) shows a higher activity in AEMFC at potentials above 0.85 V and only slightly lower power performance at high current densities. The peak power reach with 450 $\mu g_{Pt}$ $cm^{-2}$ was, in the same testing conditions, ca 1.5 $W \cdot cm^{-2}$ while 1.05 $W \cdot cm^{-2}$ was reached with Fe-N-C (Figure). Short term durability testing also shows promising results for the sustainable application of Fe-N-C in AEMFC environment.

Future efforts will focus on reducing or eliminating noble metals at the anode side, and in optimizing the Fe-N-C cathode structure to close the gap with highly-loaded Pt-based cathodes.

- **AEM electrolysis**: during the second phase the cell voltage of 1.76 V was reached at 0.5 A $cm^{-2}$ with a Ni-Fe anode, almost matching the results obtained with IrOx during the previous phase, and approaching the project target of 1.70 V at that current density.

*Polarisation and power density curves for an AEMFC with an Fe-N-C cathode (1.5 mg FeNC/$cm^2$) and Pt-Ru/C anode (0.9 mgPGM/$cm^2$). $H_2$ and $O_2$ gas at anode and cathode, cell temperature 60 °C*