Project NEXT STEPS

Membrane conductivity and stability

The key steps during the second period of the project will be the milestone of Anion Exchange Membrane (AEM) conductivity and stability (MS1 at M20, conductivity ≥ 3 S m^{-1} at 100% RH and stability > 400 hours at 60 °C), continued optimisation of electrolyser Membrane Electrode assembly (MEA) comprising the novel CRM-free Oxygen Evolution Reaction (OER) catalyst and low-PGM Hydrogen Evolution Reaction (HER) catalyst developed in WP3, and similar optimisation for the MEA for AEM-Fuel Cell.

CRM-free catalysts evaluation

In parallel, groundwork is pursued on the synthesis and evaluation of CRM-free catalysts for catalysing the Hydrogen Oxidation Reaction and HER in alkaline medium with high-throughput methods. The approach with bipolar membranes is also being investigated in parallel, with a Go/No-Go decision at M36 for assembling the final cells with AEM or Bipolar Membrane approaches, with implications on the catalyst selection and final PGM loading in the cells.

EFCD 2019 September 2019

The international workshop - Electrolysis and Fuel Cell Discussions 2019, focusing on Critical Raw Materials free devices for electrochemical energy conversion, will be held on 15th-18th September 2019 in La Grande Motte, France.
EFCD 2019 is jointly organised with the European project, CRESCENDO.

2019 EFCD

www.efcd2019.eu

After 18 months of project, the progress is in track with the initial schedule. The focus will progressively shift from the independent optimisation of materials to the integration of novel catalysts, ionomers and membranes in complete MEAs for electrolyser and fuel cells.

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Newsletter

October 2018

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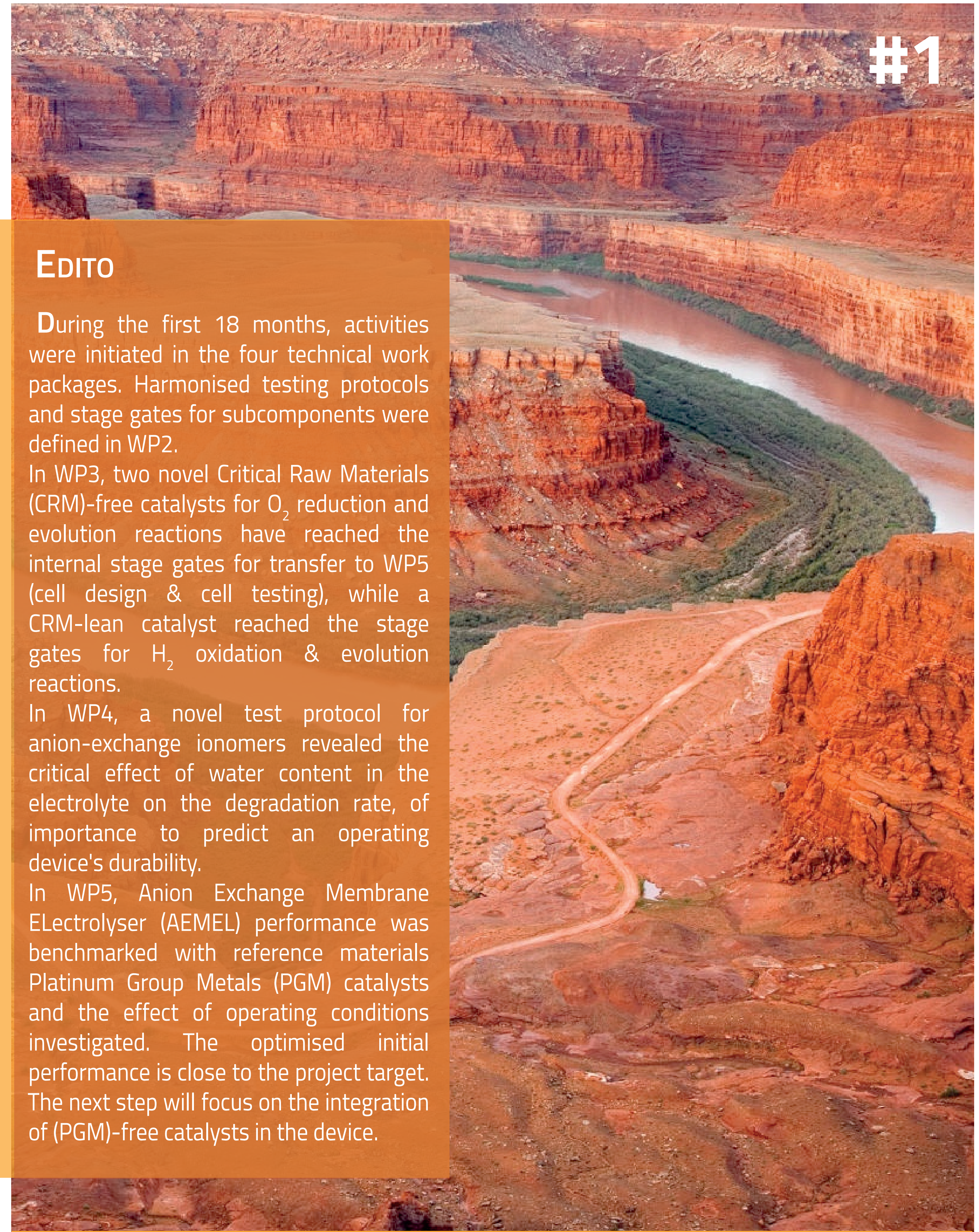


Edito

During the first 18 months, activities were initiated in the four technical work packages. Harmonised testing protocols and stage gates for subcomponents were defined in WP2.
In WP3, two novel Critical Raw Materials (CRM)-free catalysts for O_2 reduction and evolution reactions have reached the internal stage gates for transfer to WP5 (cell design & cell testing), while a CRM-lean catalyst reached the stage gates for H_2 oxidation & evolution reactions.
In WP4, a novel test protocol for anion-exchange ionomers revealed the critical effect of water content in the electrolyte on the degradation rate, of importance to predict an operating device's durability.
In WP5, Anion Exchange Membrane ELectrolyser (AEMEL) performance was benchmarked with reference materials Platinum Group Metals (PGM) catalysts and the effect of operating conditions investigated. The optimised initial performance is close to the project target. The next step will focus on the integration of (PGM)-free catalysts in the device.

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

Horizon 2020
European Union funding
for Research & Innovation

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.

During the first 18 months period, activities were initiated in the four technical work packages of CREATE, ranging from the technical specifications of the device's subcomponents, catalyst synthesis, ionomer synthesis and membrane preparation to cell assembly and cell testing.

Technical specifications were identified for catalysts and membranes, with functional properties established for down-selecting and transferring the materials to the work package on cell testing. Harmonised testing protocols were established and used by the various partners, enabling an easy comparison of the properties of catalytic and ionomeric materials across the different partners.

The period achievements for the cell subcomponents are:

- Three catalysts passing the CREATE activity and stability stage gate for transfer to cell design: a CRM-free catalyst for O_2 evolution, a CRM-free catalyst for O_2 reduction and a CRM-lean catalyst for H_2 oxidation.
- Novel method developed to investigate the stability of anion-exchange ionomers in conditions closely simulating an operating device.
- Anion Exchange Membrane (AEM) reaching the conductivity target combined with reduced swelling.

Commercial membrane and commercial PGM catalysts have been benchmarked in AEM electrolyser at ITM, and replacement of PGM-based by CRM-free and CRM-lean catalysts initialised.

Optimisation of membrane-electrode assemblies will be necessary for materials passing the stage gates. Groundwork will in parallel continue on ionomeric and catalytic materials, especially for the challenge of catalysing the hydrogen oxidation in alkaline medium without resorting to CRM.

WP3	Activity stage-gate	Stability stage-gate	Transferred to WP5
ORR	200 µg cm^{-2} 0.5 mA cm^{-2} at 0.9 V vs RHE	< 40 mV shift after 5,000 cycles between 0.6-1.0 V vs RHE	AEMFC
HOR	200 µg cm^{-2} 2.2 mA cm^{-2} at 0.05 V vs RHE	< 40 mV shift after 5,000 cycles between 0.0-0.4 V vs RHE	AEMFC
OER	500 µg cm^{-2} 10 mA cm^{-2} at 1.55 V vs RHE	< 80 mV shift after 5,000 cycles between 1.3-1.7 V vs RHE	AEMEL
HER	200 µg cm^{-2} 2.2 mA cm^{-2} at -0.05 V vs RHE	< 80 mV shift after 5,000 cycles between -0.4-0.0 V vs RHE	AEMEL

Activity stage-gate for each reaction , at a given catalyst loading to be reached in Roating-Disk-Electrode setup

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

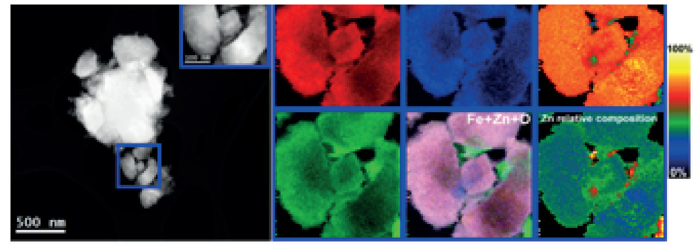
In **WP2**, EIFER defined in collaboration with WP3 partners harmonised protocols for measuring the activity and for assessing the stability of catalysts for each of the four electrochemical reactions occurring in electrolysers and fuel cells.

The activity stage-gates were defined by reverse engineering, starting from the desired performance of each electrode in the final device and assuming a maximum active-layer thickness of 100 µm, in order to define the minimum activity to be reached in rotating-disk electrode (RDE) setup. The scheme on page 2 shows the activity stage-gate for each reaction, to be achieved at a given catalyst loading in RDE setup. This approach is akin to that of the definition of a volumetric activity target, a key criterion for CRM-free catalysts.

Stability criteria were also established, defining accelerated stress tests (AST) of load-cycling protocols for each reaction, and the maximum shift of potential allowed after the AST. Only catalysts passing both the activity and stability stage gates will be transferred to WP5 for integration in fuel cell or electrolyser (scheme on page 2).

In **WP3**, a library of binary and ternary metal oxides of Earth-abundant elements have been synthesised and evaluated in RDE setup at ICIQ.

The synthesis of the most promising ternary metal oxide (NiZnFe) was then modified for nanostructuration, and this allowed reaching the Oxygen Evolution Reaction (OER) activity stage-gate. In addition, the activity after the AST was higher than the initial one (14.7 and 11.4 mA·cm^{-2} at 1.55 V versus RHE, respectively), a promising result for long-term stability in a device.



TEM and STEM analysis of a screened binary metal-oxide OER catalyst

In **WP4**, a novel protocol has been developed that allows setting the Anion exchange Ionomer (AEI), hydroxide and water concentrations independently. This revealed the critical importance of the water content in setting the degradation rate of AEI. The latter is strongly enhanced with decreasing water content, which has been assigned to a decreased solvation of hydroxyl anions, resulting in increased nucleophilic attack of cationic groups.

These results are of importance to predict the degradation rate of novel AEI in a non-fully hydrated environment, which is expected to occur especially at the cathode of AEMFC during operation.

These findings were published in *Chemistry of Materials 29 (2017) 4425-4431.*

In **WP5**, ITM has benchmarked the performance of AEMEL with reference materials and investigated the effect of operating conditions. PGM-based commercial catalysts (Pt at the cathode and Ir-Ru oxide at the anode) and commercial AEM and ionomers from FUMATECH have been tested. The best initial performance has showed a cell voltage of 1.75 V at 0.5 A·cm^{-2}, close to the performance target at beginning-of-life for the project, but that must be reached ideally with no CRM, or with a maximum PGM content of 20-40 µg·cm^{-2}.

Electrolyser stack testing at ITM