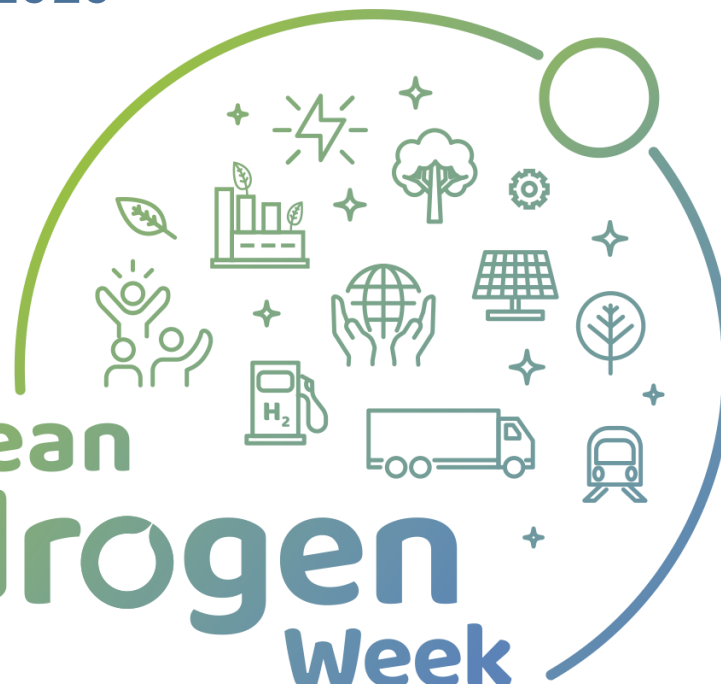


CRESCENDO

Critical Raw material Electro-catalysts  
replacement ENabling Designed pOst-2020  
PEMFC



European  
Hydrogen  
Week



Deborah Jones

CNRS

[www.crescendo-fuelcell.eu](http://www.crescendo-fuelcell.eu)

[Deborah.Jones@umontpellier.fr](mailto:Deborah.Jones@umontpellier.fr)

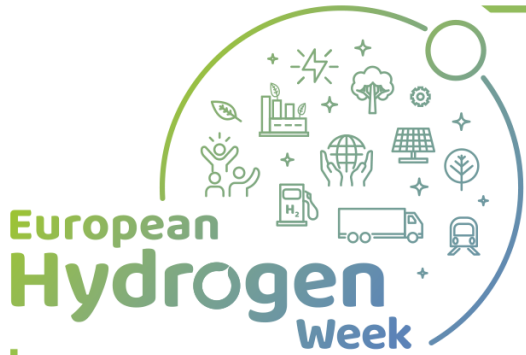


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#EUResearchDays  
#PRD2022  
#CleanHydrogen



# Project Overview

Critical Raw material Electro-catalystS replacement  
ENabling Designed pOst-2020 PEMFC

**Call year:**  
2017

**Call topic:**  
1.2 Towards next  
generation of  
PEMFC: non-  
PGM catalysts

**Project dates:**  
1<sup>st</sup> January 2018  
- 30<sup>th</sup> June 2021

**Total project budget:**  
2 739 602 €

**CRESCENDO**

**% stage of implementation**  
01/11/2022: 100 %

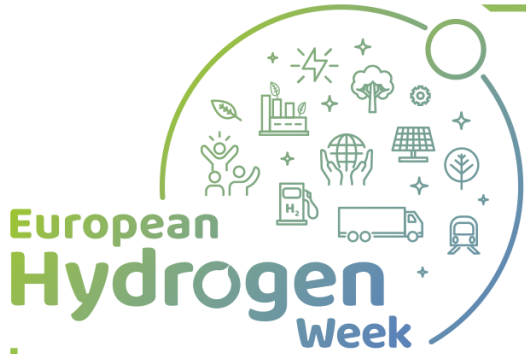
**FCH JU max. contribution:**  
2 739 602 €  
**Other financial contribution:**  
0 €



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# Partners

Critical Raw material Electro-catalystS replacement  
ENabling Designed pOst-2020 PEMFC

**JM** Johnson Matthey  
Inspiring science, enhancing life

Imperial College  
London

**cnrs**  
Centre National de la Recherche Scientifique

**cea**  
Commissariat à l'énergie atomique et aux énergies alternatives

**PRETEXO**

**TU** berlin  
**BMW GROUP**

**UNIVERSITÀ DEGLI STUDI DI PADOVA**

Clean Hydrogen  
Partnership

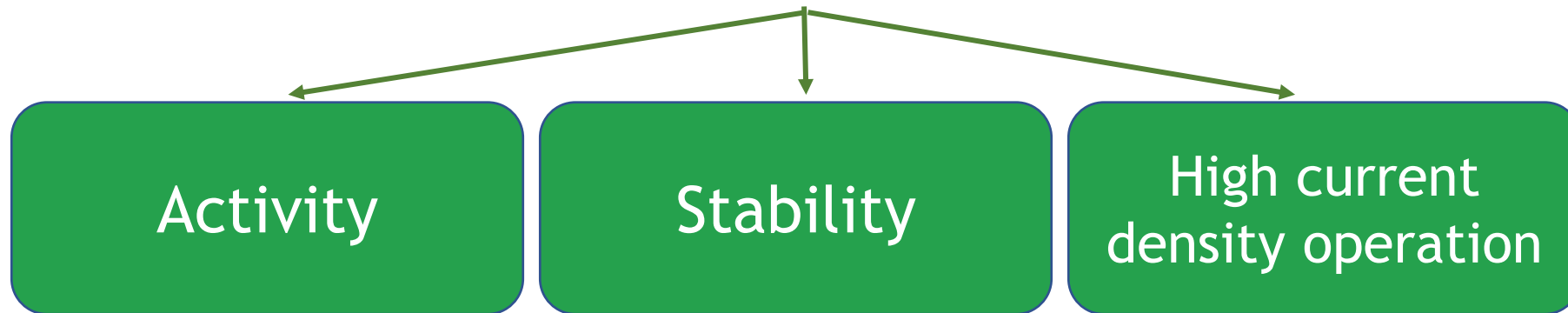
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# Project Summary

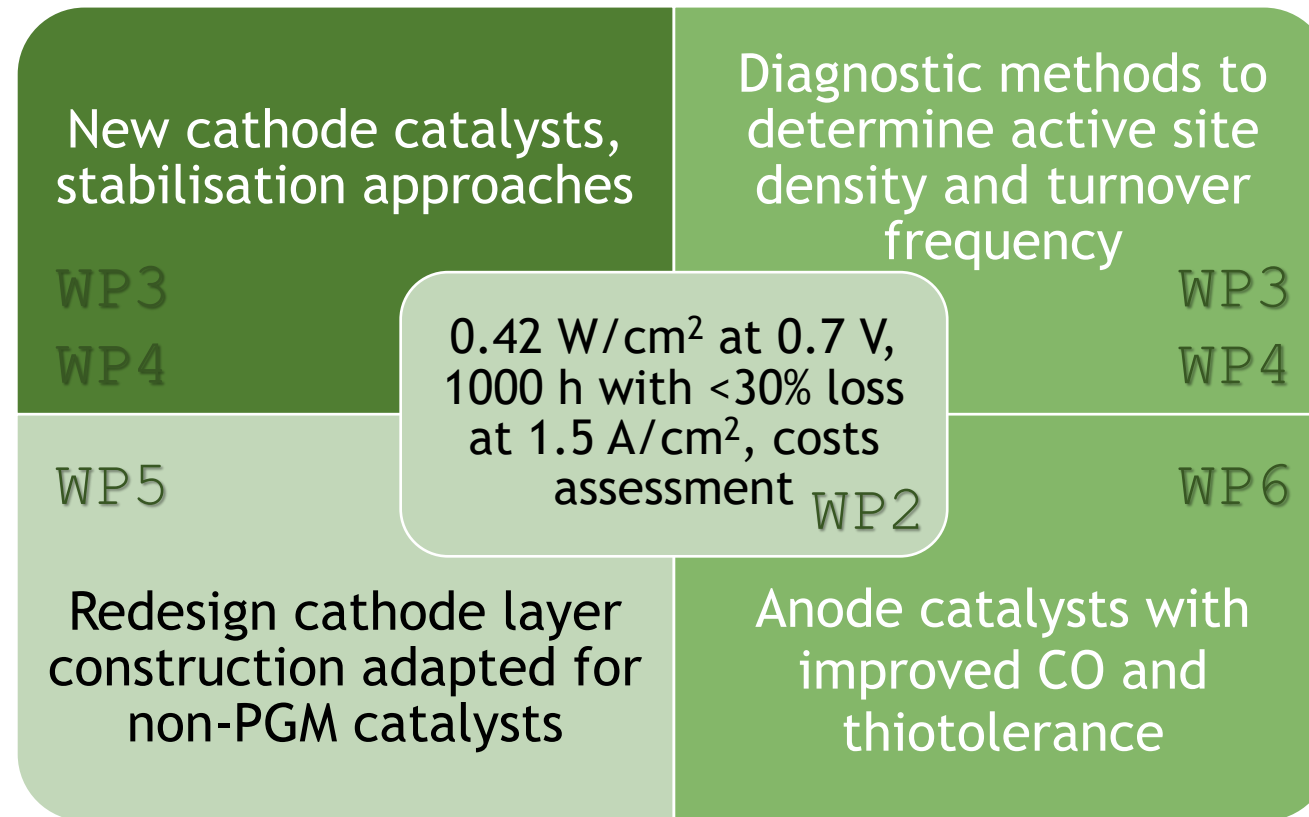
## CRESCENDO Objectives

- CRESCENDO responded to the 2017 call for proposals of the H2020 Fuel Cells and Hydrogen Joint Undertaking for PGM-free automotive MEAs, with the final targets to:
- Demonstrate the ability of the finally configured MEA to achieve  $0.42 \text{ W/cm}^2$  at  $0.7 \text{ V}$  ( $\text{H}_2$  - air) and 1000 h operation with less than 30% power degradation at  $1.5 \text{ A/cm}^2$  over an operationally-relevant drive cycle.



# Project Summary

## CRESCENDO Approach



# CRESCENDO Project Progress (1)

## H<sub>2</sub>-air PEMFC performance

Achievement to-date

Project start  
0.06 W/cm<sup>2</sup> @ 0.7 V

25%

50%

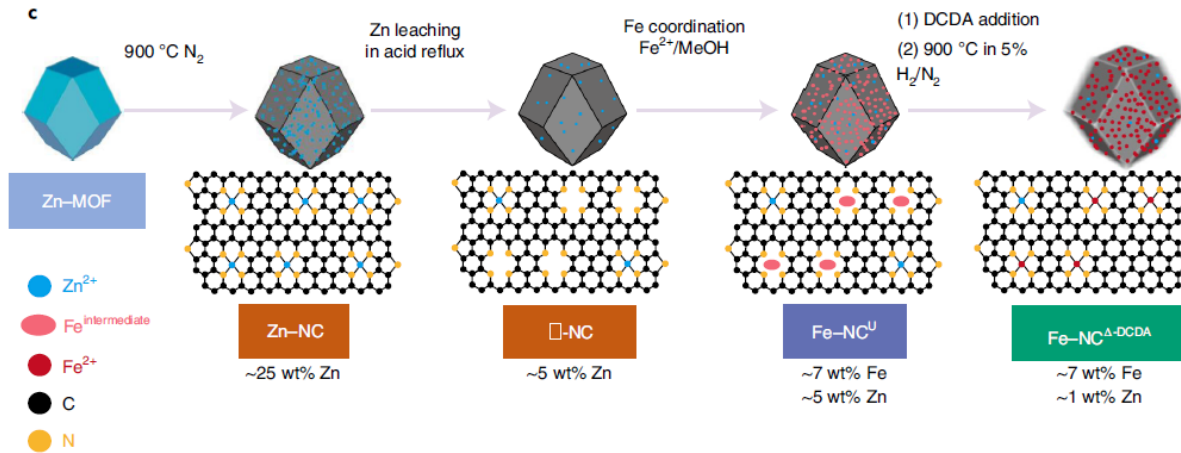
75%

Target

0.42 W/cm<sup>2</sup> @ 0.7 V

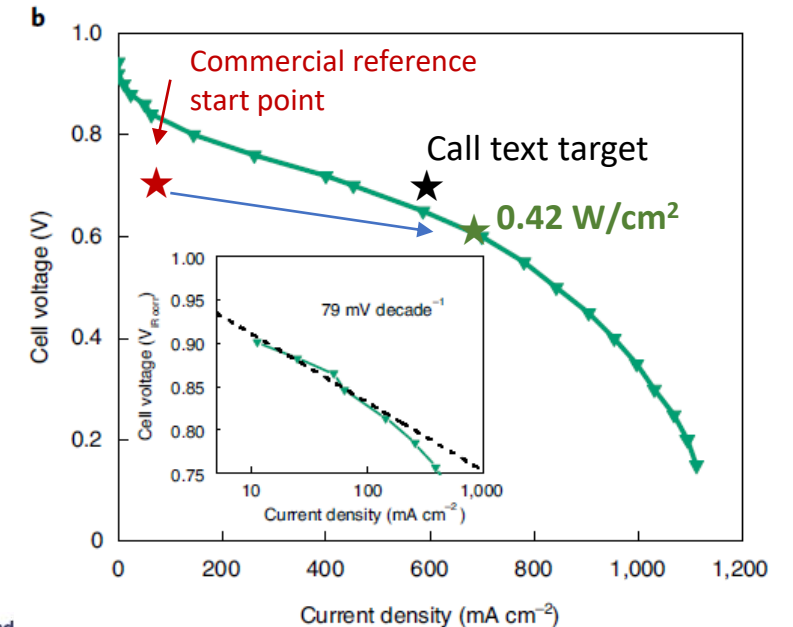
Achieved

0.42 W/cm<sup>2</sup> @ 0.6 V



High loading of single atomic iron sites in Fe-NC oxygen reduction catalysts for proton exchange membrane fuel cells, A. Mehmood, M. Gong, F. Jaouen, A. Roy, M.-T. Sougrati, M. Primbs, A. Martinez Bonastre, G. Drazic, P. Strasser, A. Kucernak, *Nature Catal.* 2022, **5**, 311-323, doi.org/10.1038/s41929-022-00772-9

Target power density was achieved with a non-PGM cathode on H<sub>2</sub>/air at 0.6 V with a high content single atomic iron site electrocatalyst



# CRESCENDO Project Progress (2)

## Bio-inspired non-PGM anode catalyst

Achievement to-date

Project start:  
25 mA/cm<sup>2</sup>

25%

50%

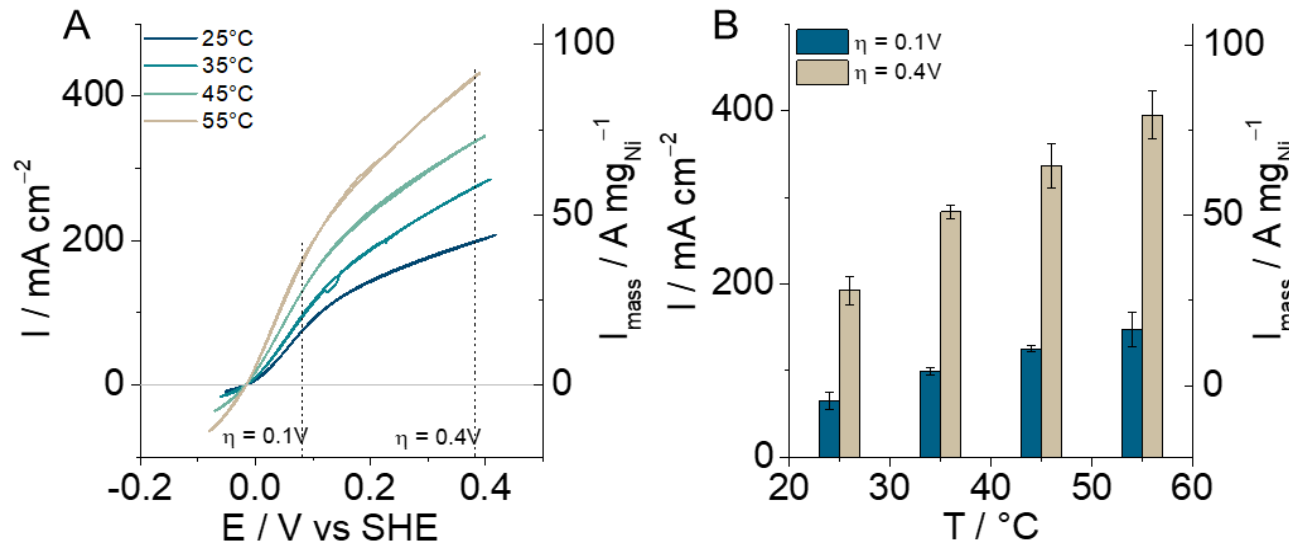
75%

Target

75 mA/cm<sup>2</sup> at 0.1 V

Achieved:

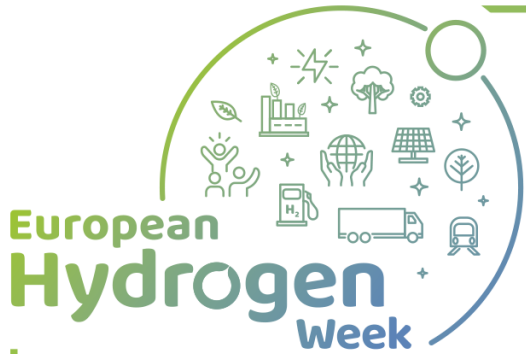
150 mA/cm<sup>2</sup> at 0.1 V



Target current density with non-PGM anode at 0.1 V was exceeded by a factor 2 at 55 °C

A) CV and B) average current densities taken from CVs at 0.1 and 0.4 overpotential for NiArg|PyCO<sub>2</sub>H|MWCNTs|GDL electrodes (10 mM PyCO<sub>2</sub>H, 10 mM NiArg) under H<sub>2</sub> feed in 0.5 M H<sub>2</sub>SO<sub>4</sub>, pH 0.3 at 25; 35; 45 and 55 °C ( $v = 20 \text{ mV/s}$ ).

Approaching Industrially Relevant Current Densities for Hydrogen Oxidation with a Bio-inspired Molecular Catalytic Material, J. Schilda, B. Reuillard, A. Morozan, P. Chenevier, E. Gravel, E. Doris and V. Artero, *JACS*, 2021, **143**, 43, DOI: 10.1021/jacs.1c07093



# Dissemination and Communication Activities

- 25 conference presentations
- 15 publications, including

***Establishing reactivity descriptors for platinum group metal (PGM)-free Fe-N-C catalysts for PEM fuel cells***, M. Primbs, Y. Sun, A. Roy, D. Malko, As. Mehmood, M.-T. Sougrati, P.-Y. Blanchard, G. Granozzi, T. Kosmala, G. Daniel, P. Atanassov, J. Sharman, C. Durante, A. Kucernak, D. Jones, F. Jaouen and P. Strasser, *Energy Environ. Sci.*, 2020, 13, 2480-2500, DOI 10.1039/D0EE01013H

***Sulfur Doping versus Hierarchical Pore Structure: The Dominating Effect on the Fe-N-C Site Density, Activity, and Selectivity in Oxygen Reduction Reaction Electrocatalysis***, G. Daniel, M. Mazzucato, R. Brandiele, L. De Lazzari, D. Badocco, P. Pastore, T. Kosmala, G. Granozzi, and C. Durante, *ACS Appl. Mater. Interfaces* 2021, 13, 42693-42705 - DOI 10.1021/acami.1c09659



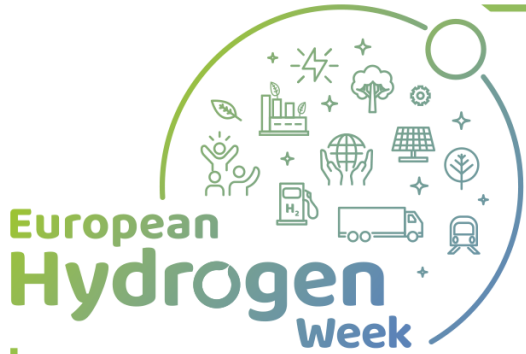
## Dissemination event & international conference, September 2019



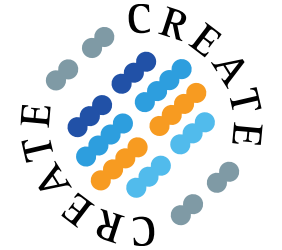
## CRESCENDO communication via:

- Project [brochure](#)
- Two newsletters at [M18](#) and [M30](#)
- Public deliverables are accessible through the CRESCENDO website



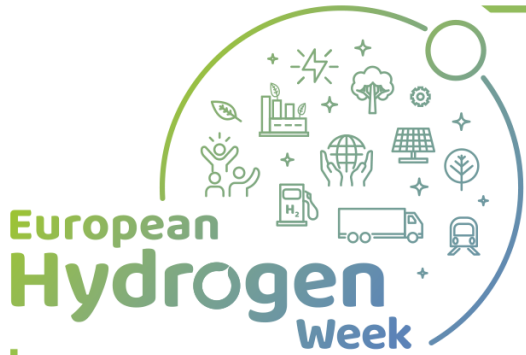


# Synergies With Other Projects And Programmes



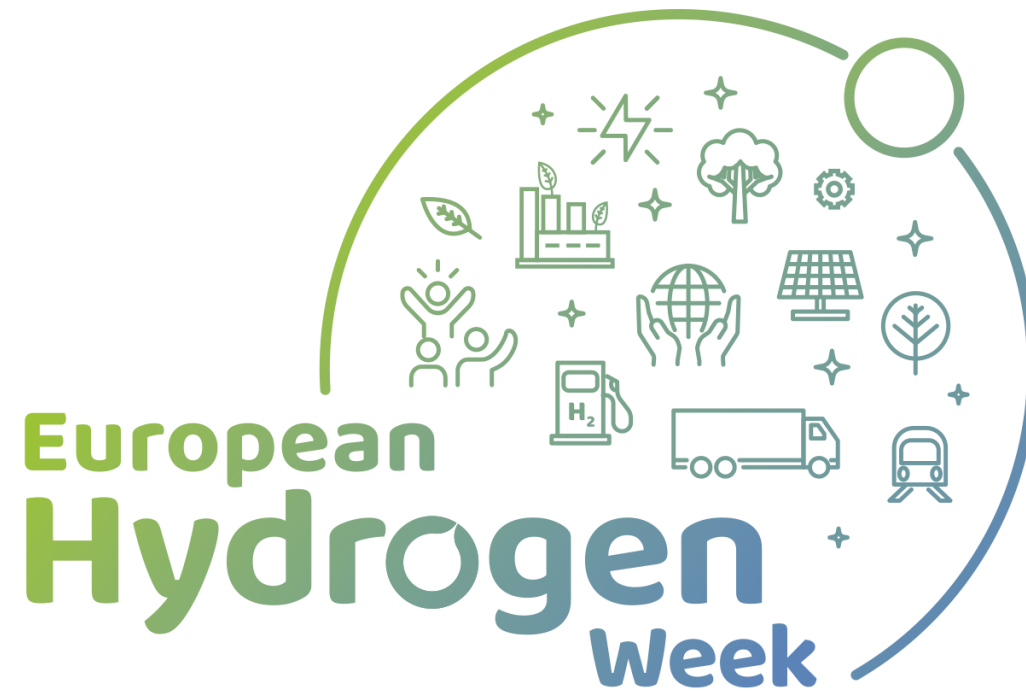
- **Synergy with programme NMBP, project CREATE**
  - Co-organisation of the international conference “Towards Catalysts Free of Critical Raw Materials for Fuel Cells and Electrolysers”, Sept. 2019, 160 participants
  - Joint session with FCH JU PEGASUS
- **Synergy with FCH JU PEGASUS**
  - Joint session at EFCD 2019 international conference
  - Participation in PEGASUS final online event, June 2021, with an overview presentation of final results
- **Synergy with DOE ElectroCat, UC Irvine, Kyushu University, Israeli fuel cell consortium**
  - Methodologies, test protocols, characterisation





# Risks, Challenges and Lessons Learned

Risks, Challenges, Lessons Learned	Measures taken
Catalyst scale-up	Different synthetic chemistries might require different approaches or modifications in order to enable scale-up of catalyst production
The modest power density (0.42 W/cm <sup>2</sup> at 0.7 V), and durability at high current density targets were challenges for MEAs with non-PGM cathodes	Applications other than automotive transport to be considered: lower power, and for which longer lifetime is not essential



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