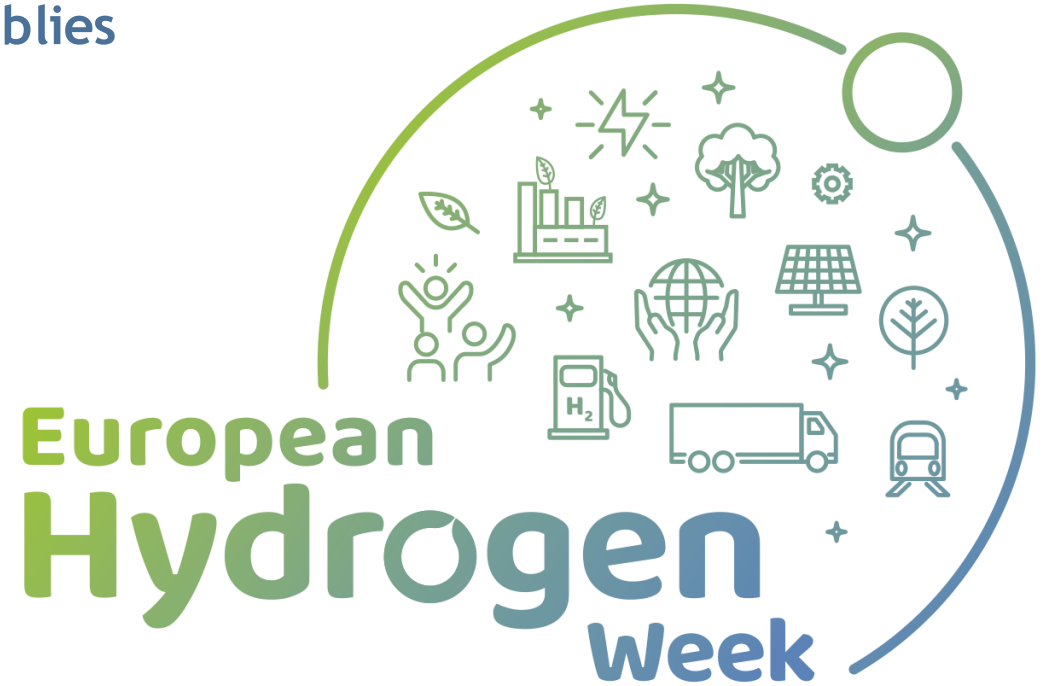
GAIA

next Generation Automotive membrane electrode Assemblies



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#PRD2020
#CleanHydrogen

European Commission

Project Overview

next Generation Automotive membrane electrode Assemblies

Call year:
2018

Call topic:
1.5 Next generation automotive MEA development

Project dates:
1st January 2019
- 31st December 2021

Total project budget:
4 493 025 €

GAIA

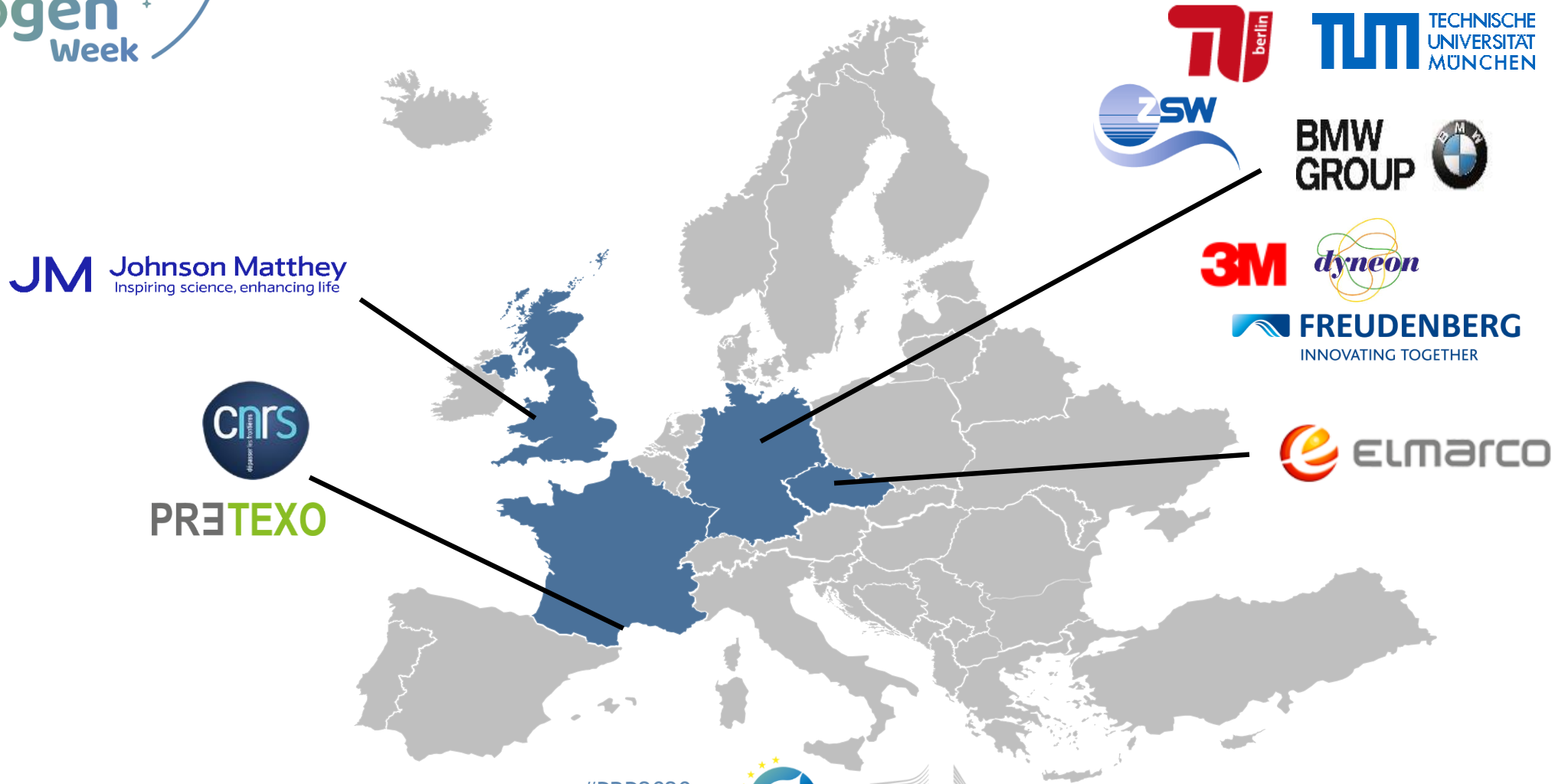
% stage of implementation
01/11/2019: 60 %

FCH JU max. contribution:
4 493 025 €

Other financial contribution:
0 €

Partners

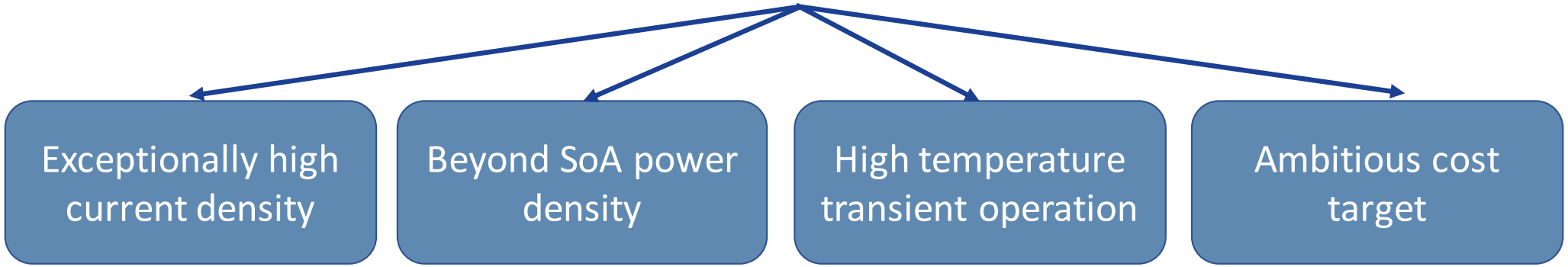
next Generation Automotive membrane electrode Assemblies



Project Summary

GAIA Objectives

- Step-change in beginning of life (BOL) power density to 1.8 W/cm^2 at 0.6 V, as tested in 10-cell short stacks with active area ≥ 200 cm^2, conditions within the call operation window
- Expectation of 6,000 hours of operation (<10% power decay), from extrapolation of ≥ 1,000 hours drive cycle testing
- Increased operating temperature i.e. MEA capable of operation at coolant outlet temperature of 105 °C and current densities of 1.5 A/cm^2 @ 0.67 V for 5% of the lifetime (approx. 300 h)
- Decreased MEA cost, with MEA cost of 6.0 € / kW based on a production volume of 1 million m^2 per year, assuming Pt spot price of 1,200 €/ Troy oz.



Project Summary

GAIA Approach

- **Develop materials** – catalyst supports, electrocatalysts, ionomers, reinforcements, membranes, gas diffusion and microporous layers with improved activity, performance, durability
- **Develop new deposition methods** for CCMs for improved quality
- **Validate iterations of CCMs** integrating novel materials in short stacks
- **Associate the most promising components** to achieve 1.8 W/cm^2 at 0.6 V and predicted <10% voltage loss in automotive drive cycle over 6,000 hours
- **Analyse any gap** between the GAIA MEA cost and 6 €/kW target and identify critical components requiring further improvement or costs reduction

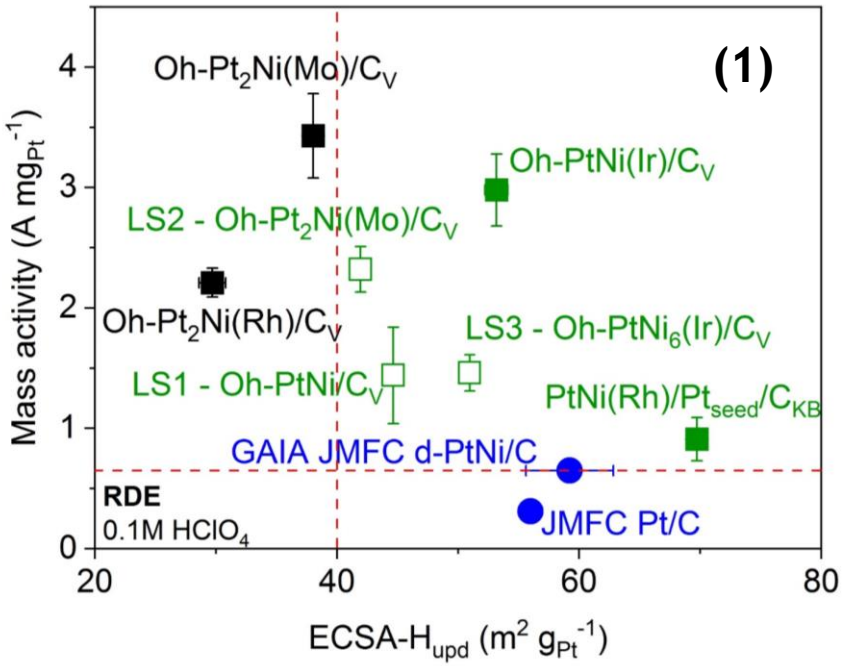
GAIA Project Progress (1)
Catalyst Mass Activity in RDE and MEA

Achievement to-date

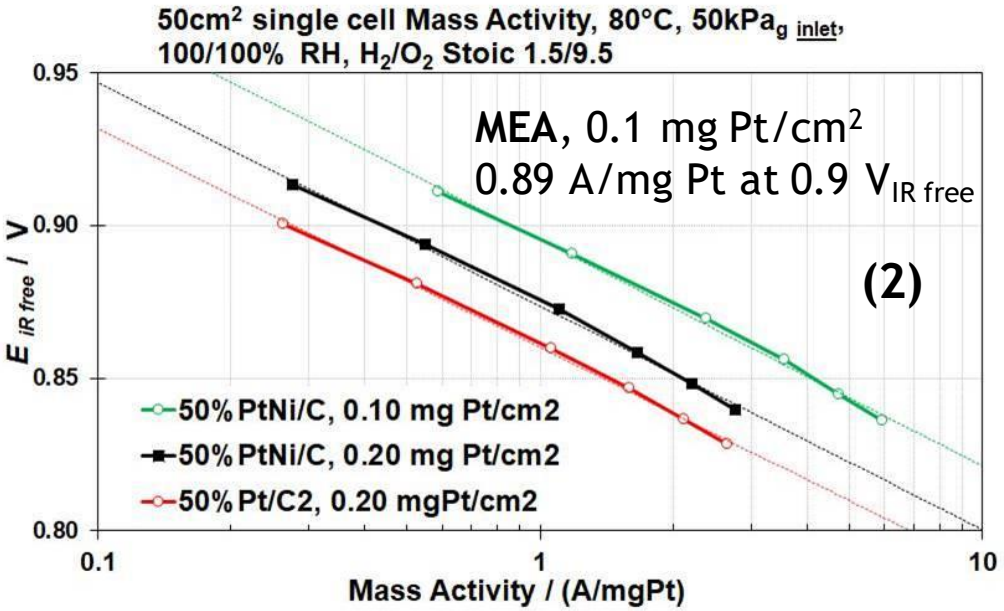
Project start
0.6 A/mg Pt

25% 50% 75%

Target
0.7 A/mg Pt
Achieved
0.89 A/mg Pt



(1) Five catalysts exceeding MS1 mass activity and ECSA targets in RDE and (2) mass activity of 0.89 A/mg Pt in MEA



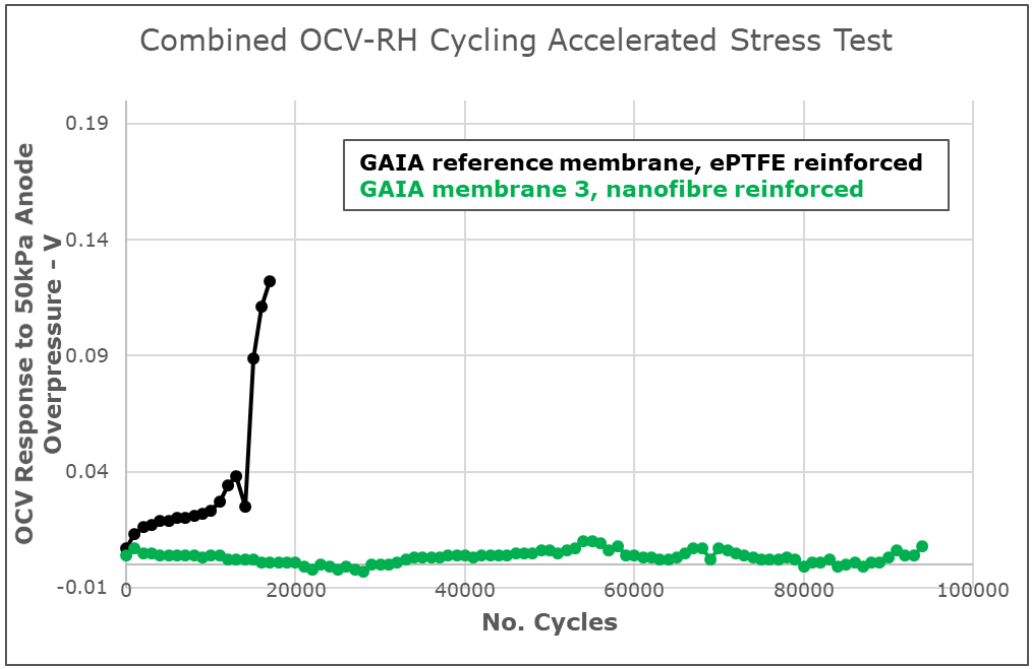
GAIA Project Progress (2)
Membrane durability in MEA on AST

Achievement to-date

Project start
18 000 AST cycles

25% 50% 75%

Target
20 000 AST cycles
Achieved
95 000 AST cycles



(1) Accelerated stress test combining Open Circuit Voltage hold + Relative Humidity cycling (dry/wet) at 90 °C cell temperature

(2) Electrospun nanofibre-reinforced membrane in MEA reached 95 000 cycles without failure

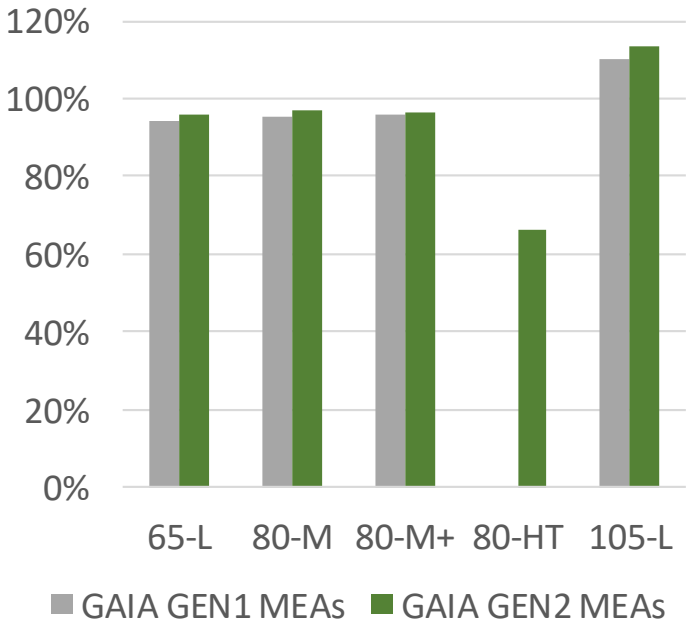
GAIA Project Progress (3)
Improved MEA performance and high temperature stability

Achievement to-date

Project start
Low, mid and high power at low, mid, and high temperature operating points

25% 50% 75%

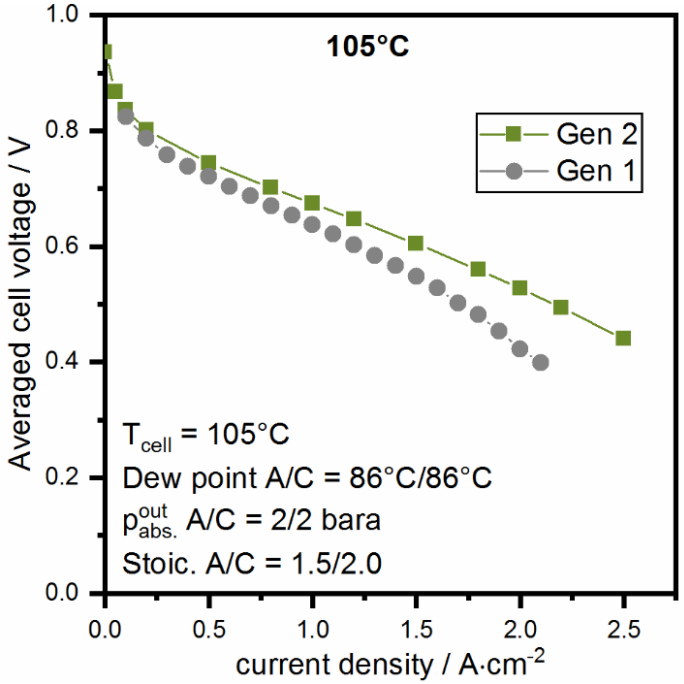
Target
7 operating points
Achieved
5 operating points



10-cell stack measurements

(1) GEN2 MEAs provide higher cell voltage at GAIA operating points

(2) GEN 2 MEAs have greater high temperature performance, >1 A/cm² at 105 °C, 49% RHA, 49% RHC



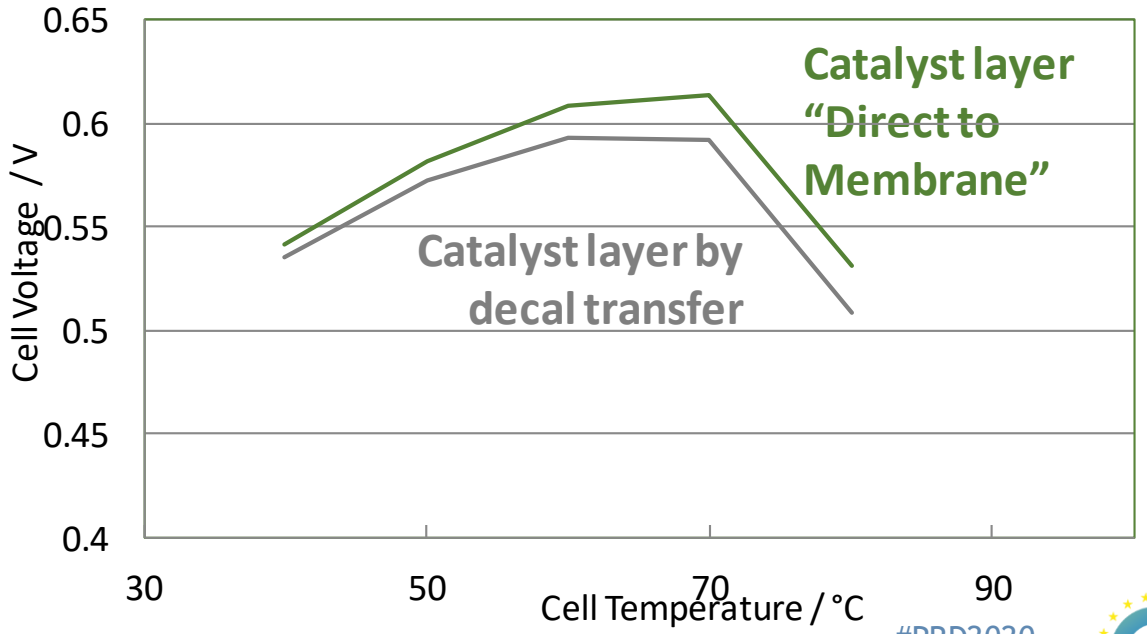
GAIA Project Progress (4)
Alternative coating methods

Achievement to-date

Project start
Decal transfer

25% 50% 75%

Currently
22 mV improvement at 70-80 °C with DTM transfer



- **Significant improvement in performance of MEAs produced by an alternative direct to membrane coating method over a wide range of operating conditions from cool/wet to hot/dry**

Humidity Sweep at 1.2 A cm^{-2}
Ambient Outlet Pressure, Anode/Cathode Stoich 1.5/2.0,
Dew point Anode/Cathode 50°C

Communication Activities

GAIA has communicated through:

- **Project brochure**
- **Two newsletters at M12 and M23**
- **A video on catalyst preparation and characterisation by RDE and catalyst integration into MEAs, testing/diagnostics**

Dissemination Activities

- GAIA has attended 2 international conferences with 4 presentations in total to date

Dissemination activities were affected by COVID-19

- Two conference presentations are programmed for 2021

- GAIA has published one review paper to date

Current challenges related to the deployment of shape-controlled Pt alloy ORR nanocatalysts in low-Pt loaded cathode layers of Proton Exchange Membrane Fuel Cells (PEMFC), Pan L., Ott S., Dionigi F., Strasser P., Current Opinion in Electrochemistry, 18,61-71 (2019)

- Possible patent filings are being considered

- Public deliverables are accessible through the GAIA website

Risks, Challenges and Lessons Learned

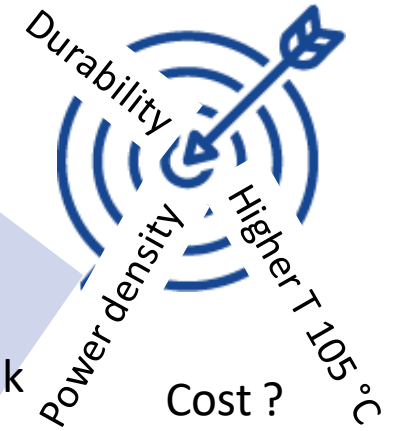
Risks, Challenges, Lessons Learned	Measures taken
Thermostable polymer used for nanofibre reinforcement gave slow electrospinning throughput, defects at scale, and cost incompatible with target	Successful reformulation of thermostable polymer
Benefits seen separately with novel MEA components are not always additive. The many new materials developments of GAIA that warrant investigation at larger scale would require more short stack iterations than planned.	Ideally, increased full size cell testing to screen in/out the best combinations. COVID-19 on-site working restrictions make this challenging.
High power operating points at high temperature are not yet achieved	Future MEA generations to incorporate thinner membranes, higher MA catalysts, novel catalyst layer structures and improved MPL/GDL

Exploitation Plan

Exploitation Plan Item	Partner	Exploitation Activity
Product commercialisation	Freudenberg, 3M-Dyneon, Elmarco	Increased product portfolios for MPL, GDL and ionomer Increased sales
Use of components in next generation MEA products	JMFC	Will introduce GAIA components in next generation MEAs
Technology improvement	JMFC	Will use improved manufacturing technology to produce products to automotive quality with increased performance and durability
Further R&D	CNRS, TUM, TUB, ZSW, JMFC	Continue the development, scale-up and qualification of fuel cell components materials, their characterisation, testing and diagnostics
Methodology standardisation	BMW	Requirement specifications applicable for fuel cell and MEA industrialisation, standard methodology for test protocols and data analysis, and spec-sheets for next generation vehicle series development

Expected Impact

Project and MAWP targets



Exceptional membrane durability giving 6 µV/h loss in 2700 h drive cycle

Mass activity target for 0.11 g Pt/kW exceeded by 30%

Fewer deposition-related defects and lower interface resistances

MEAs GEN1 / GEN2 reach intermediate 1.5 W / cm^2 target and 105 °C operation

Ionomer, reinforcement, membrane architecture

Stable, exceptionally high mass activity catalysts on novel carbons

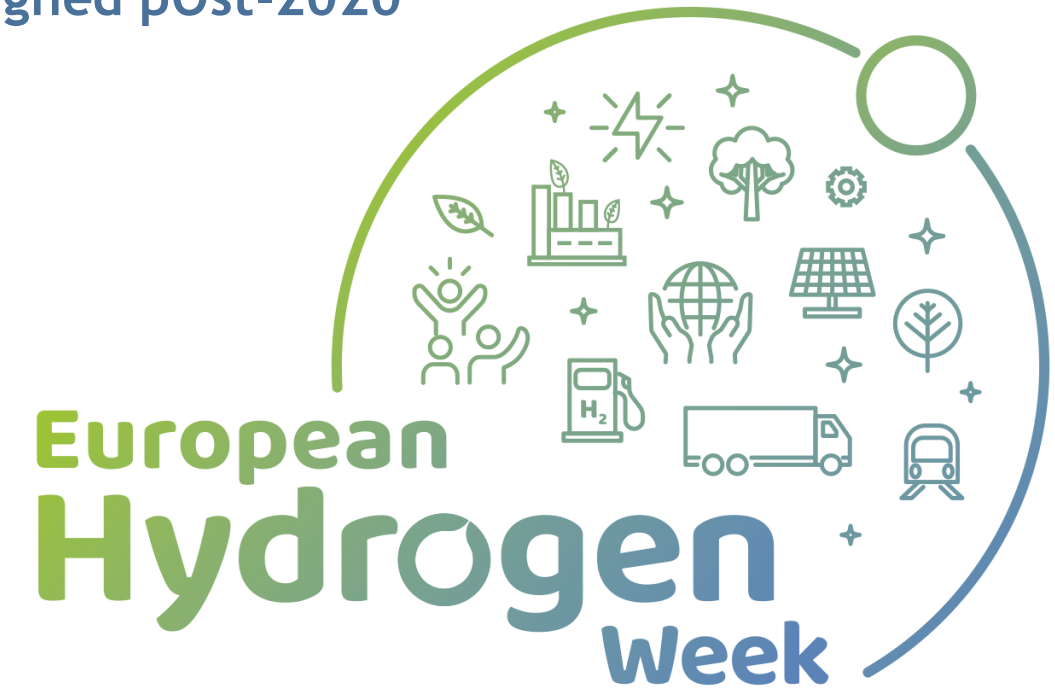
Breakthrough alternative deposition methods

Microporous and gas diffusion layers tailored for high T and high current density operation

Short stack iterations integrating GAIA new materials

CRESCENDO

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



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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:
1st January 2018
- 30th June 2021

Total project budget:
2 739 602 €

CRESCENDO

% stage of implementation
01/11/2019: 80 %

FCH JU max. contribution:
2 739 602 €

Other financial contribution:
0 €

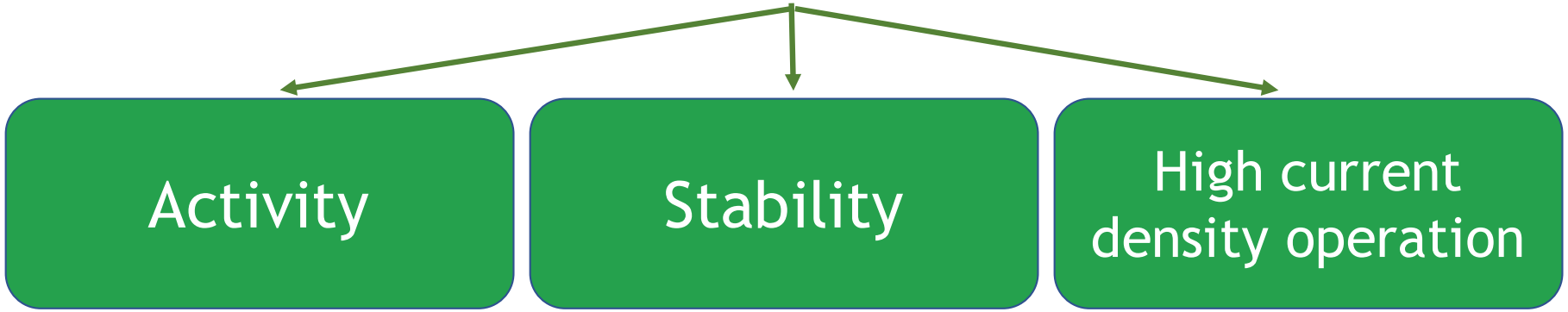
Partners

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

Project Summary

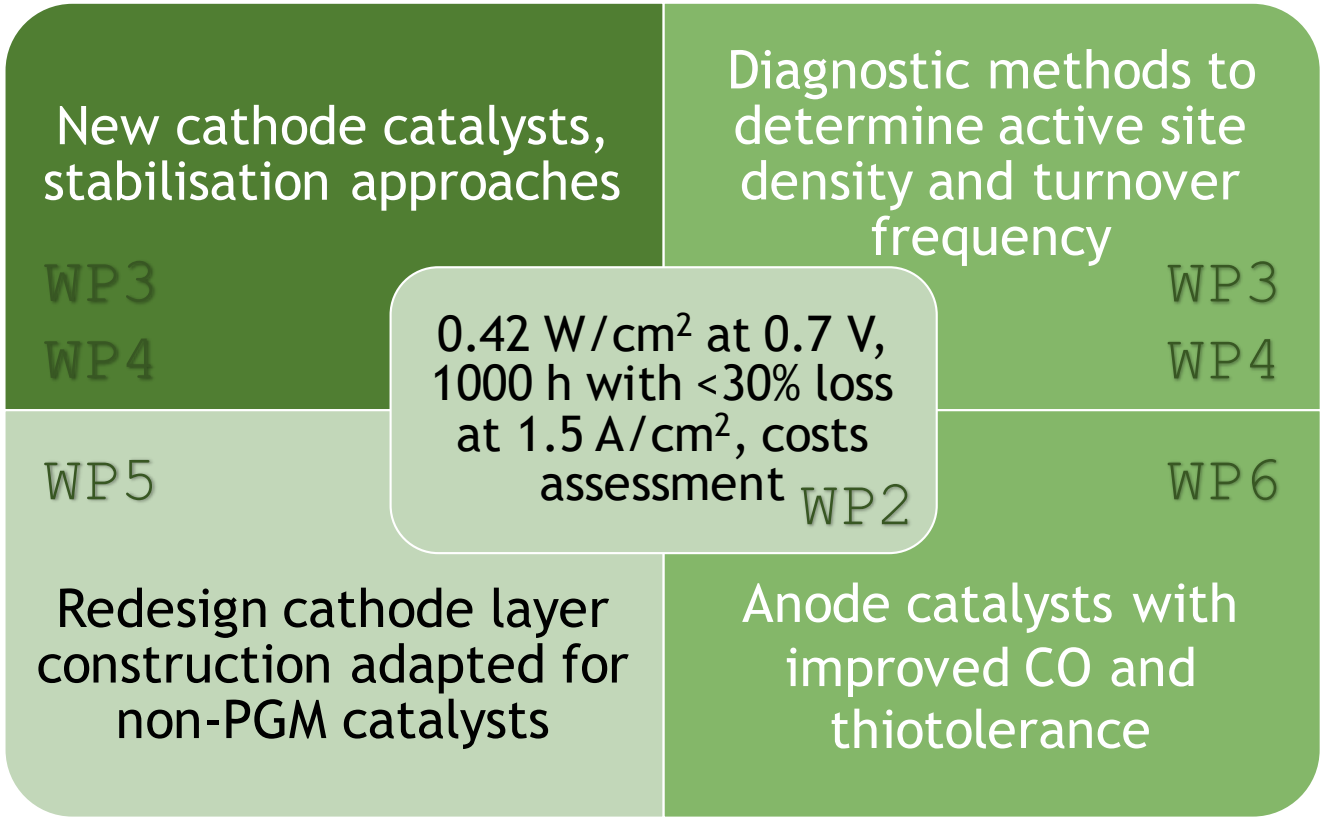
CRESCENDO Objectives

- 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 W/cm^2 at 0.7 V (H_2 – air) and 1000 h operation with less than 30% power degradation at 1.5 A/cm^2 over an operationally-relevant drive cycle.



Project Summary

CRESCENDO Approach



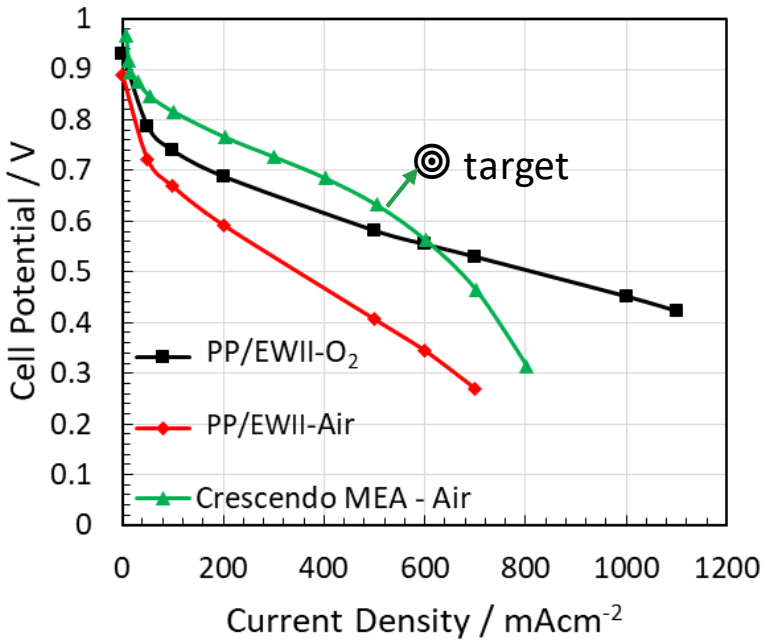
CRESCENDO Project Progress (1)
H_2-air PEMFC performance

Achievement to-date

Project start
0.12 W cm^{-2}

25% 50% 75%

Target
0.42 W cm^{-2}
Achieved
0.34 W cm^{-2} with non-optimised cathode layer



Commercial non-PGM catalyst (Pajarito Powder), CCM prepared at EWII

- <50% of the target cell voltage at 0.6 A/cm^2

Project Fe-NC catalyst (unoptimised layer)

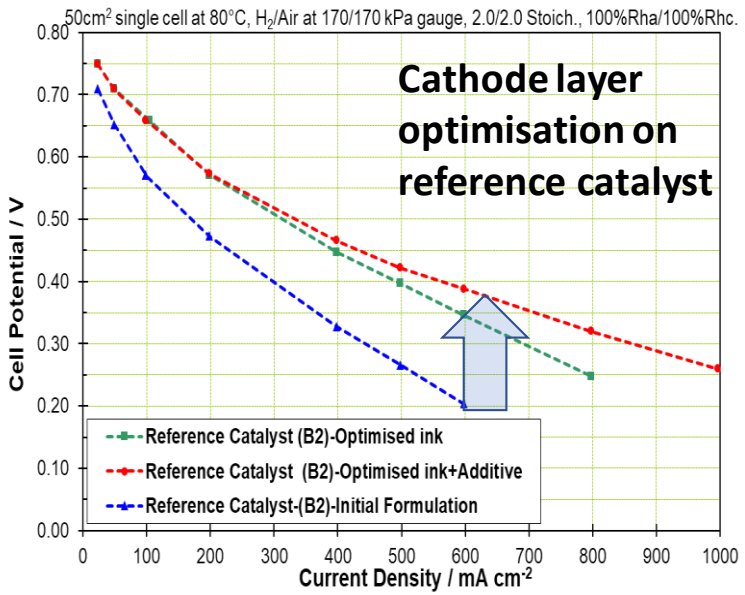
- 78% of target cell voltage at 0.6 A/cm^2

Cathode layer optimisation

- brings +190 mV performance improvement with reference catalyst @ 0.6 A/cm^2

Current work

- Catalyst layer optimisation with upscaled project catalyst



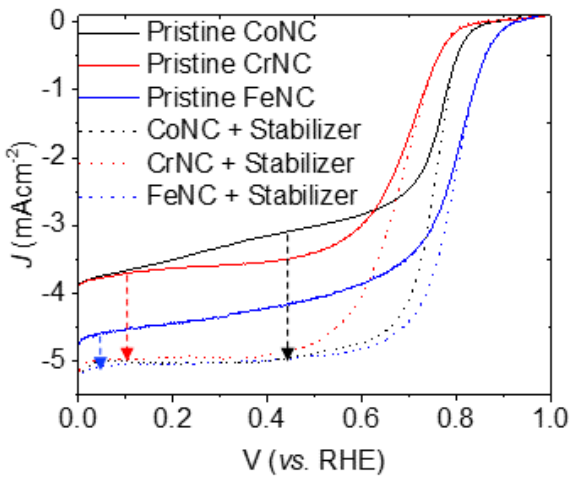
CRESCENDO Project Progress (2)
Cathode catalyst stabilisation

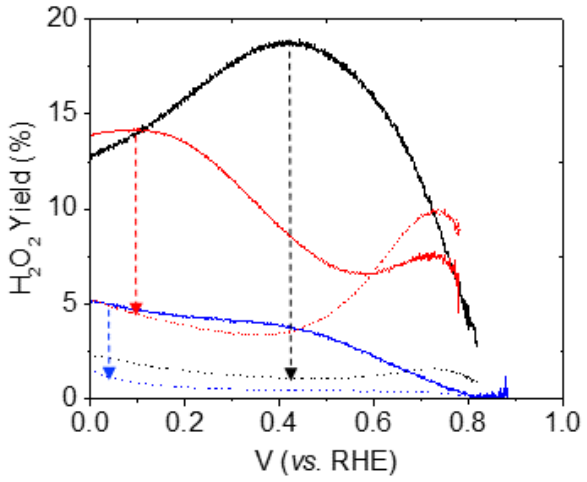
Achievement to-date

Project start: Stabilisation with ultra-low Pt%

25% 50% 75%

Achieved: Factor 5 times lower H_2O_2 yield





PGM-free co-catalysts have been developed that greatly reduce the side production of H_2O_2 during ORR and improve PEMFC stability

- **Innovation Title:** Novel stabilizers and stabilization techniques for non-PGM catalysts for PEMFCs;
- **Market Maturity of the Innovation:** 'Exploring' (based on a method described in this paper);
- **Market Creation Potential of the innovation:** Addresses needs of existing markets.

Dissemination and Communication Activities

- >30 conference presentations - Dissemination activities in 2020 were affected by COVID-19
- 7 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, DOI 10.1039/D0EE01013H

- Organisation, with NMBP CREATE, of an international conference on in Sept. 2019, 160 participants

- Possible patent filings on non-PGM stabilisation of non-PGM catalysts

CRESCENDO communication via:

- Project brochure
- Two newsletters at M18 and M30

- Public deliverables are accessible through the CRESCENDO website

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