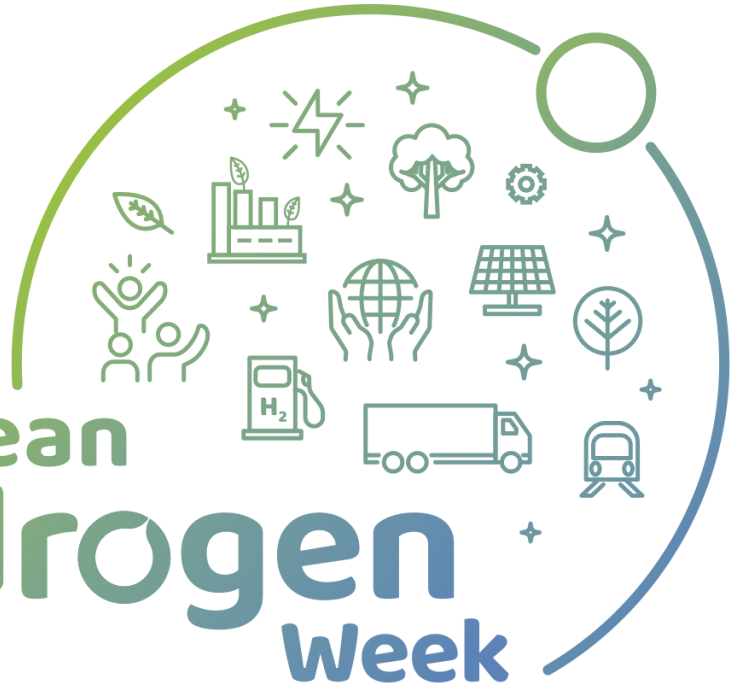
GAIA

next Generation Automotive membrane electrode Assemblies



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#EUResearchDays
#PRD2022
#CleanHydrogen

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
- 30th June 2022

Total project budget:
4 493 025 €

GAIA

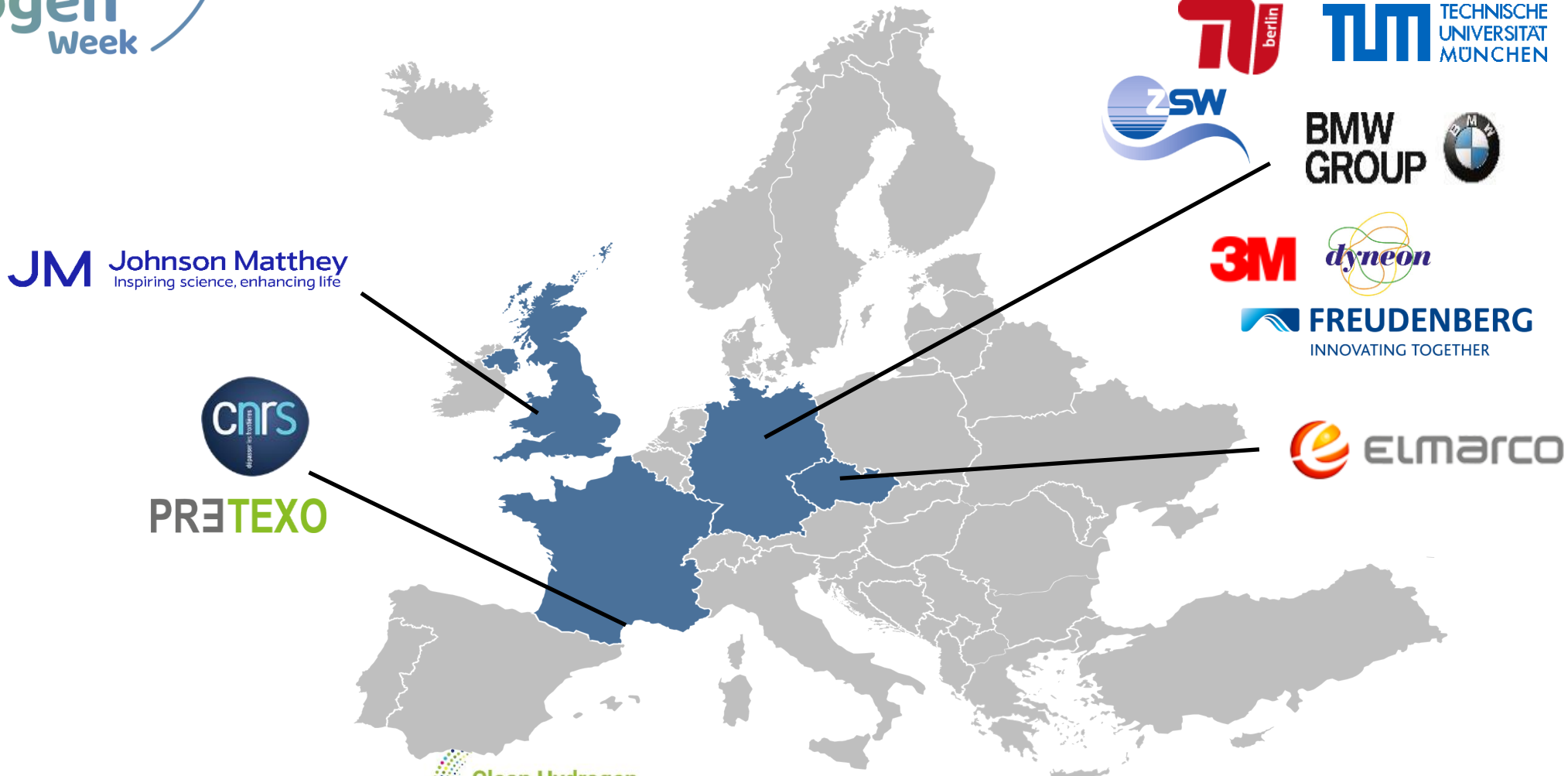
% stage of implementation
01/11/2022: 100 %

Clean Hydrogen JU contribution:
4 493 025 €

Other financial contribution:
0 €

Partners

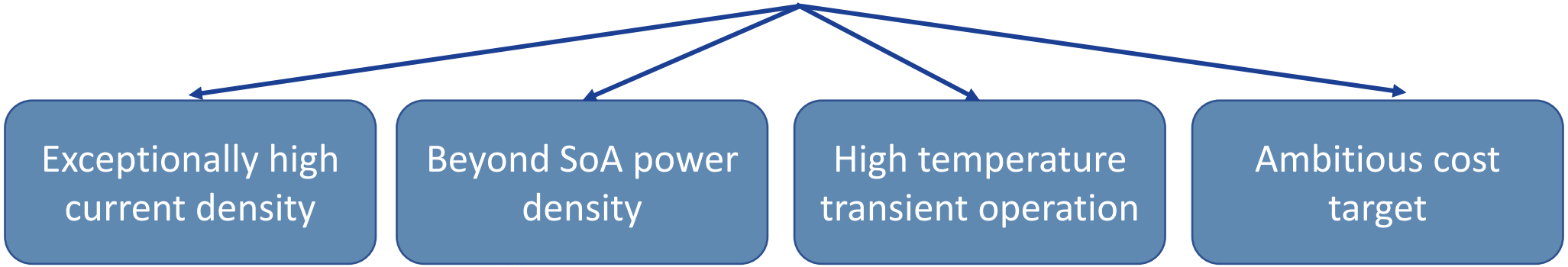
next Generation Automotive membrane electrode Assemblies



Project Summary

GAIA Main 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.



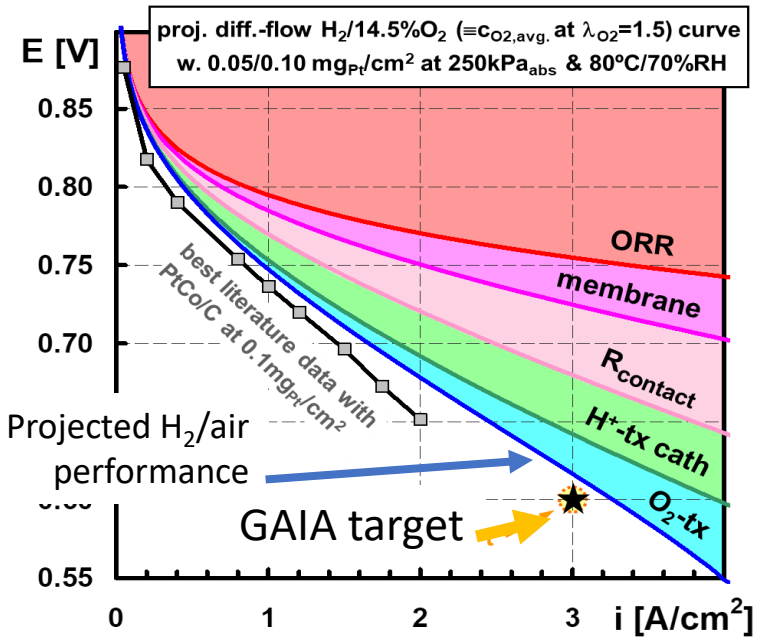
Project Summary

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

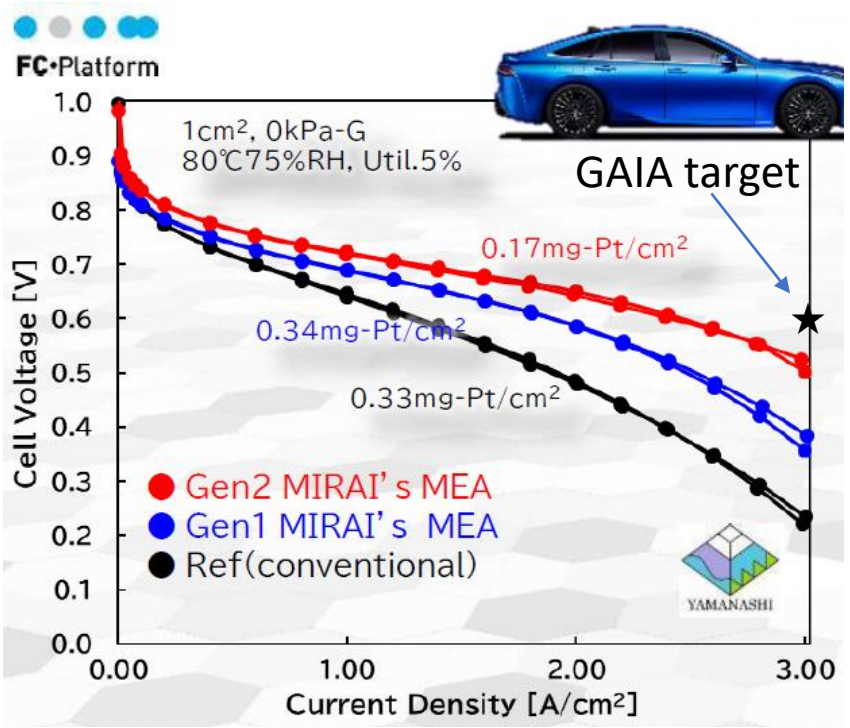
Positioning vs state of the art
Application and market area: Transport, automotive

(1)



- Best literature data[1] (grey dots/line) data under comparable conditions (94°C/65% RH, 250 kPa_{abs}, $\lambda_{H2}/\lambda_{air}$ = 1.5/2.0 at anode/cathode loadings of 0.05/0.10 mg_{Pt}/cm^2) do not reach GAIA target
- Projection[2] from voltage loss analysis[3] also does not reach the GAIA target

(2)



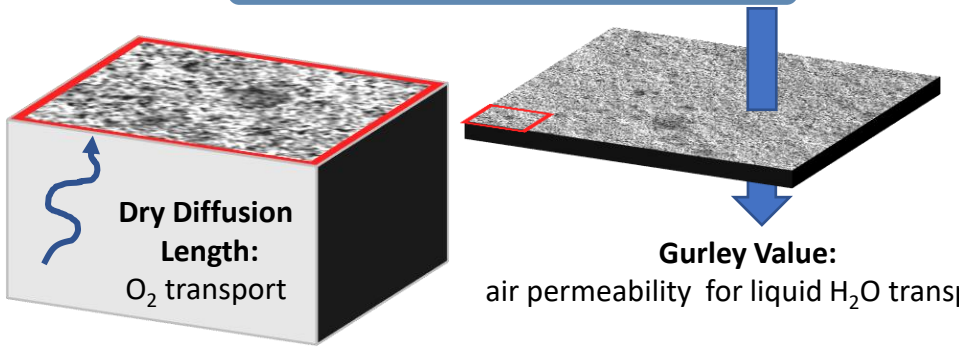
K. Amemiya, et al., *Gen2 MIRAI Analysis at FC Platform* iDWG Meeting Feb. 17th 2022

[1] Y. Yarlagadda, et al., *ACS Energy Lett*. 3 (2018) 618-621.
[2] GAIA Description of the Action
[3] Using I_m 0.6 A/mg Pt (PtCo), $L_{an/ca}$ 0.05/0.1 mg Pt/cm^2, $t_{membrane}$ 10 µm (0.1 S/cm), $R_{contact}$ 15 mΩ cm^2, $\rho_{H+,Cath}$ 60 Ω cm (10 µm thick), R_{O2-tx} 0.9 s/cm (DM only), η_{HOR} 10 mV at 3 A/cm^2 (linear)

2018 Call target of 3 A/cm^2 at 0.6 V beyond SoA

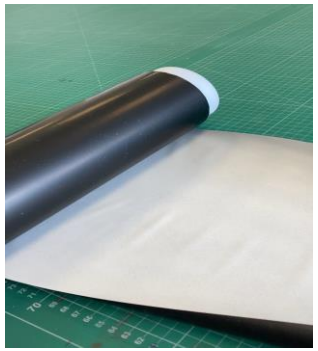
GAIA Project Progress
Materials

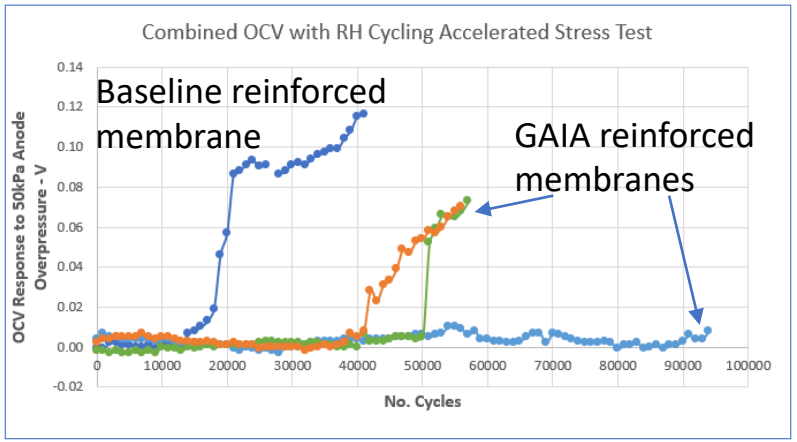
MPL and GDL



Gurley Value:
air permeability for liquid H_2O transport

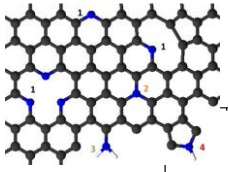
Reinforcement, ionomer and membrane

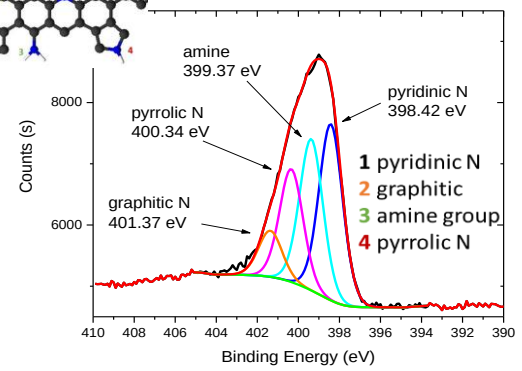


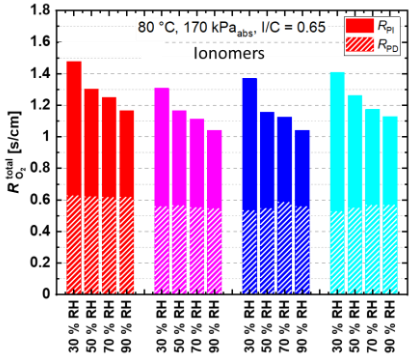


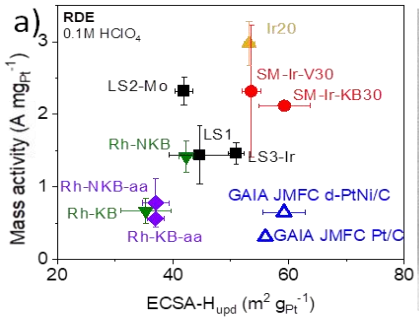
- Modified supports, shape- and location-controlled Pt and Pt-alloy catalysts
- Improved ionomers for the membrane, high oxygen permeability ionomers for the cathode catalyst layer
- Improved nanofibre membrane reinforcements
- Diagnostics developments and new characterisation methodologies

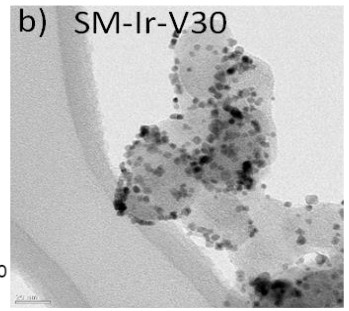
Supports, Catalysts and Layers

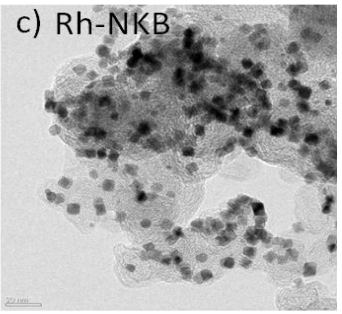












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GAIA Project Progress

High power density, high current density

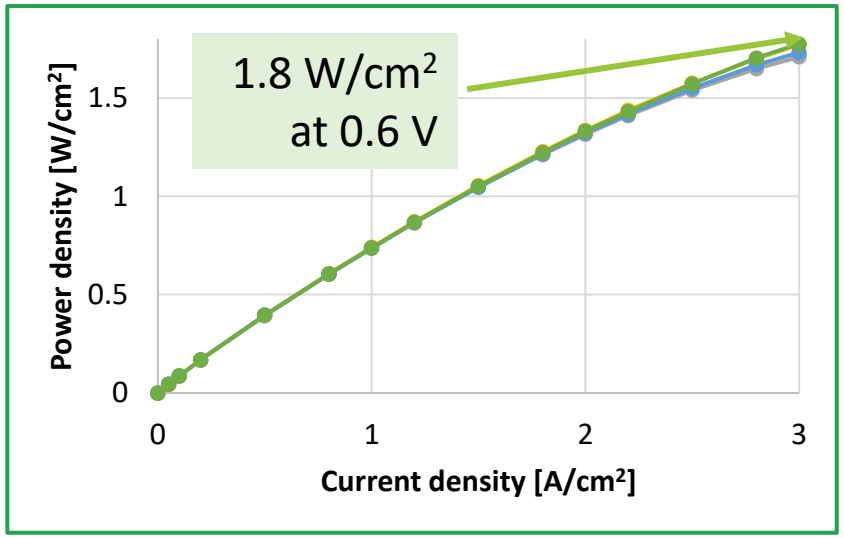
Achievement to-date

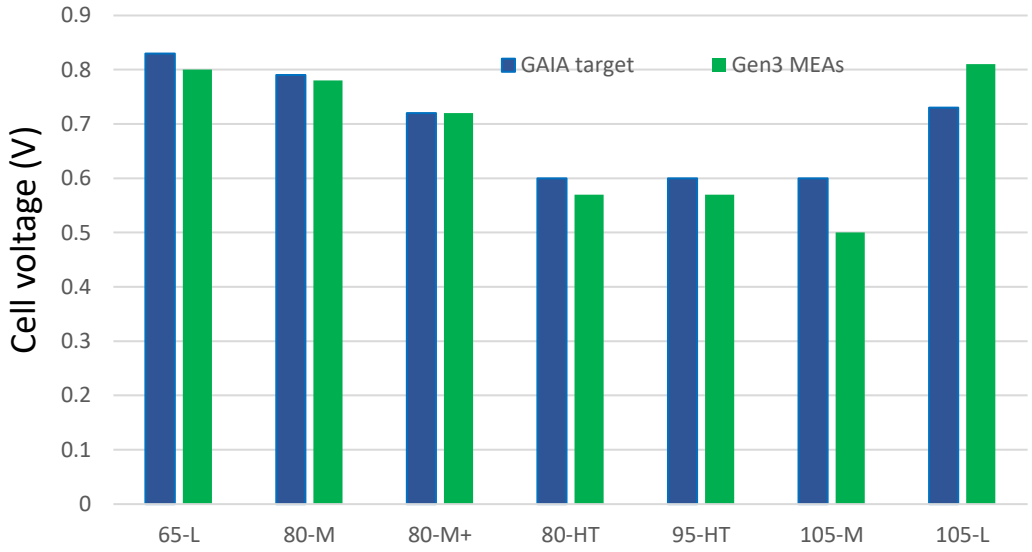
Project start
1.5 W/cm² at 0.6 V
2.5 A/cm² at 0.6 V

25% 50% 75%

Target
1.8 W/cm² at 3 A/cm²
Achieved
MAWP 2024 target

Gen3 and Gen4 MEAs **reached the power density target of MAWP 2024** in 4 and 10-cell stacks





GAIA Project Progress
Durability

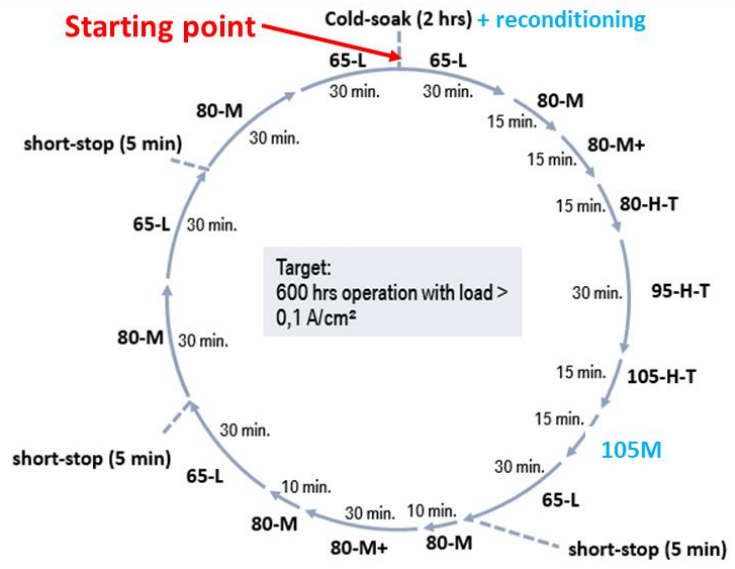
Achievement to-date

Voltage loss (600 hours) on drive cycle operation: Gen1 MEAs -71 µV/h at 65-L operating point

25% 50% 75%

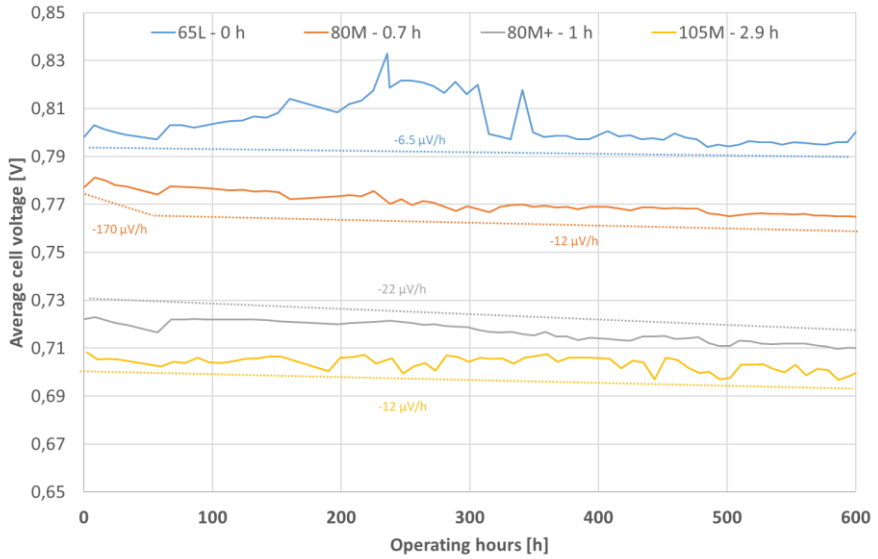
Voltage loss (600 hours) Gen4 MEAs
-6.5 µV/h at 65-L
-12 µV/h at 105-M

Low voltage loss with Gen4 MEAs at several operating points over 600 hours of automotive drive cycle



Voltage loss within range for 6000 hours operation over the first 600 hours of drive cycle for several operation points.

Notable stability at 105 °C stack temperature.



GAIA Project Progress

High performance reduces MEA cost/kW

Performance

1.8 W/cm²

Pt loading

0.25 g Pt / kW

Lifetime

Target voltage loss over 600 hours of drive cycle

Cost

Approaches 6 €/kW target, once Pt and ionomer recycling are included

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Communication Activities

GAIA has communicated through:

- **Project brochure**
- **Three newsletters at M12, M23 and M34**
- **Two videos on catalyst preparation and characterisation by RDE and catalyst integration into MEAs, testing/diagnostics, and on the fabrication of nanofibre web reinforced composite PFSA membranes**

Dissemination Activities

- 10 international conference presentations during GAIA project lifetime
  - Conference presentation activities were affected by cancellations due to COVID-19
  - Further presentations still being made on GAIA results (ECS Fall Meeting 2022)
- 8 published articles, others being drafted for publication
- Possible patent filings are being considered
- Public summaries of all deliverables are accessible through the GAIA website

Risks, Challenges and Lessons Learned

Risks, Challenges, Lessons Learned	Measures taken
The many new materials developments of GAIA that warranted investigation at larger scale required more short stack iterations than were planned.	Ideally, more full size cell testing to screen in/out the best combinations. COVID-19 on-site working restrictions made this challenging.
The short stack with Gen4 MEAs came tantalising close to reaching performance AND durability targets. A further iteration of post-mortem analysis/mitigation measures/MEA fabrication and testing would have been needed.	None possible in GAIA – project end. Lesson learned to be carried forward into other work on MEAs for LDV/HDV.

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	JM	Will introduce GAIA components in next generation MEAs
Technology improvement	JM	Will use improved manufacturing technology to produce products to automotive quality with increased performance and durability
Further R&D	CNRS, TUM, TUB, ZSW, JM	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

Post-mortem analysis of Gen2 MEAs

Improved mitigation measures against degradation

Optimisation of conditions at all operating points

Ionomer, reinforcement, membrane architecture

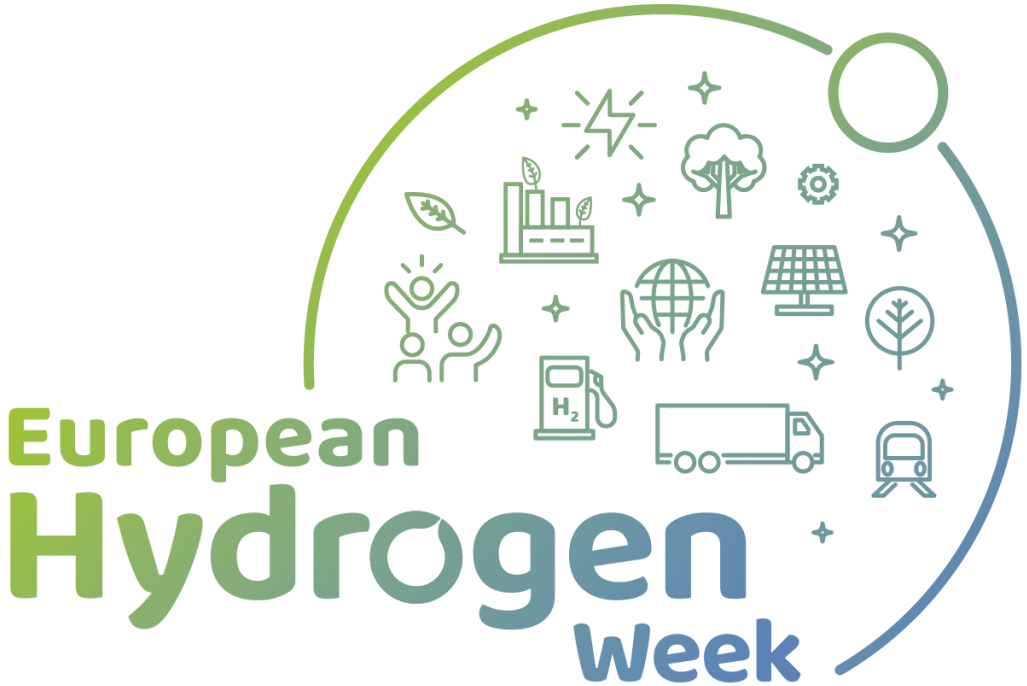
Stable, exceptionally high mass activity catalysts on novel carbons

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

Project and MAWP targets



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