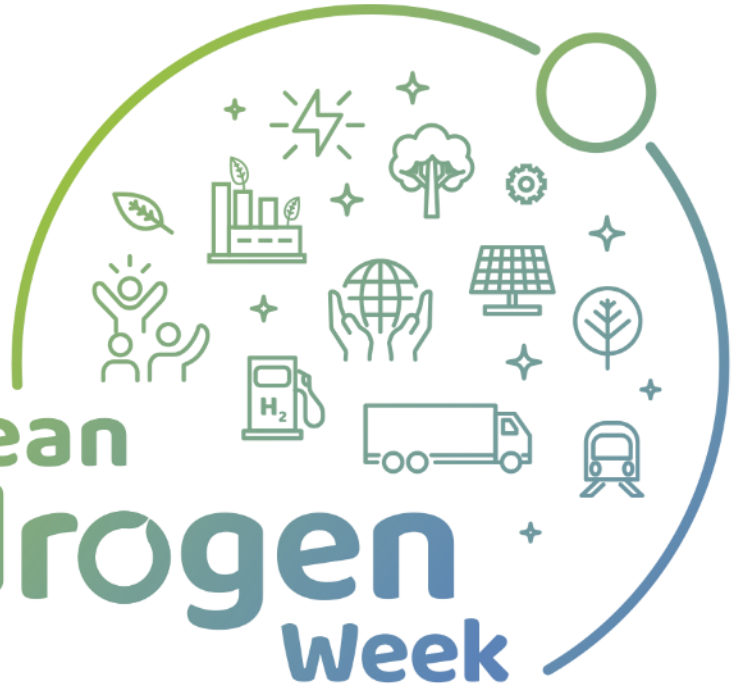
GRASSHOPPER

GRid ASSisting Modular HydrOgen PEM PowER Plant



GRASSHOPPER

Grid Assisting Modular Hydrogen PEM Power Plant

Germán Nieto Cantero
FC Systems Engineer
Nedstack

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#EUResearchDays
#PRD2022
#CleanHydrogen

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European Hydrogen Week

GRASSHOPPER
Grid Assisting Modular Hydrogen PEM Power Plant

SUMMARY

- Overview of the project
- Testing and Results so far
- The pilot plant and its future operation
- Further developments after GRASSHOPPER

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PROJECT OVERVIEW

GRASSHOPPER
Grid Assisting Modular Hydrogen PEM Power Plant

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Next-generation FCPP targeting stationary application for grid stabilisation

Construction of a 100kWe plant to be operated for 5+ years

- Flexible and dynamic operation
- Demand-driven
- Fast response

mFRR market

- Long-lasting PEM FC
- Increased power density (Both active area and cell count)
- Pressurised operation

> 20.000h
> 55% efficiency

- Important cost reductions both in Stack and Plant Manufacturing

CAPEX < 1500 €/kWe

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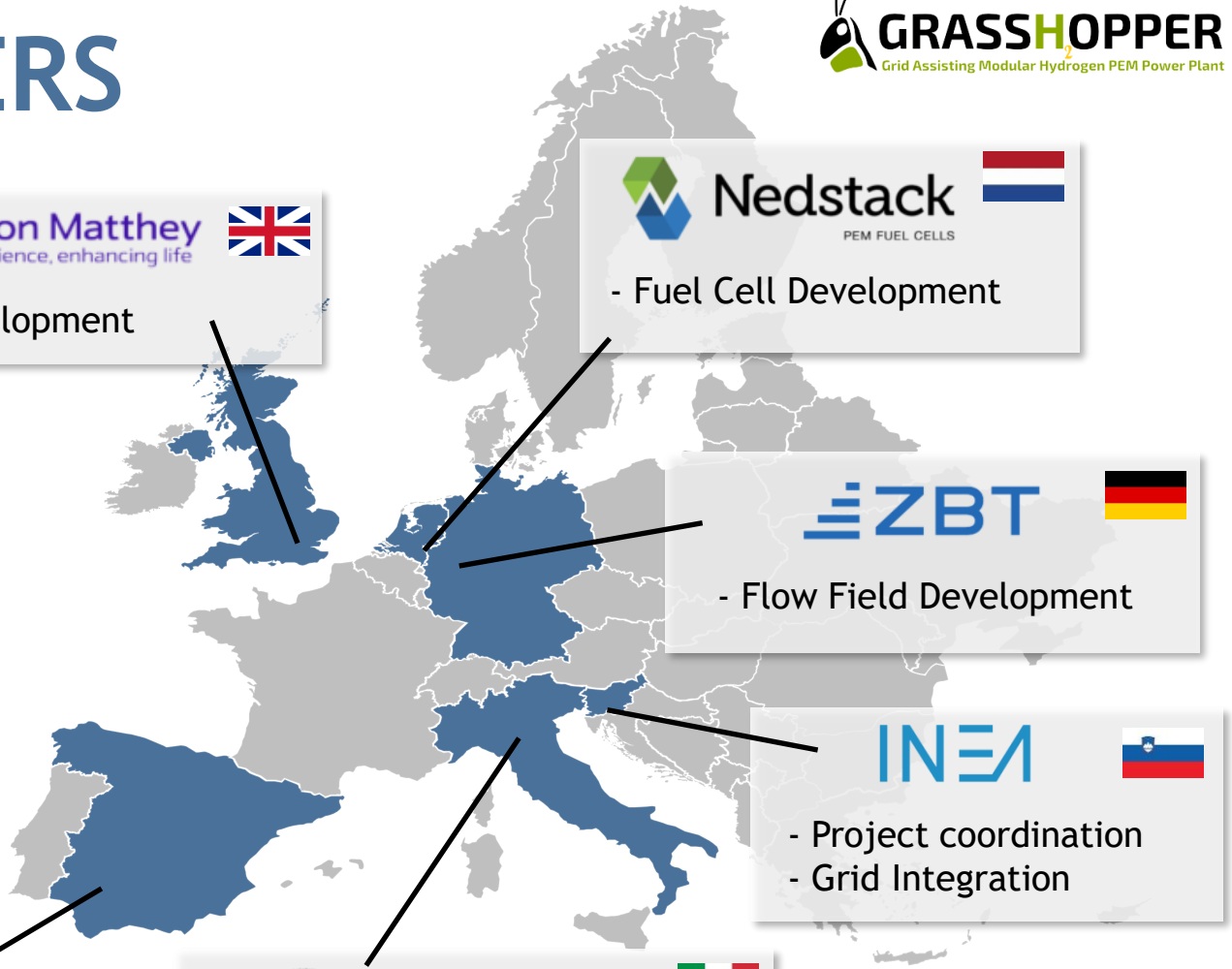
PARTNERS

- Start date: 1 January 2018
- Final date: 31 March 2022
- Total budget: 4,4 M€
- EC funding: 4,4 M€
- EC contract: 779430



Johnson Matthey (Inspiring science, enhancing life)
- MEA Development

Nedstack PEM FUEL CELLS
- Fuel Cell Development

ZBT
- Flow Field Development

INEA
- Project coordination
- Grid Integration

ABENGOA
- Power Plant Development
- Dissemination & Exploitation

POLITECNICO MILANO 1863
- Modelling and optimization

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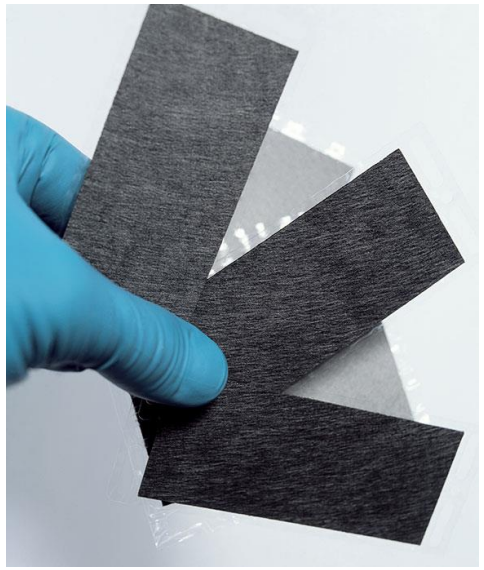
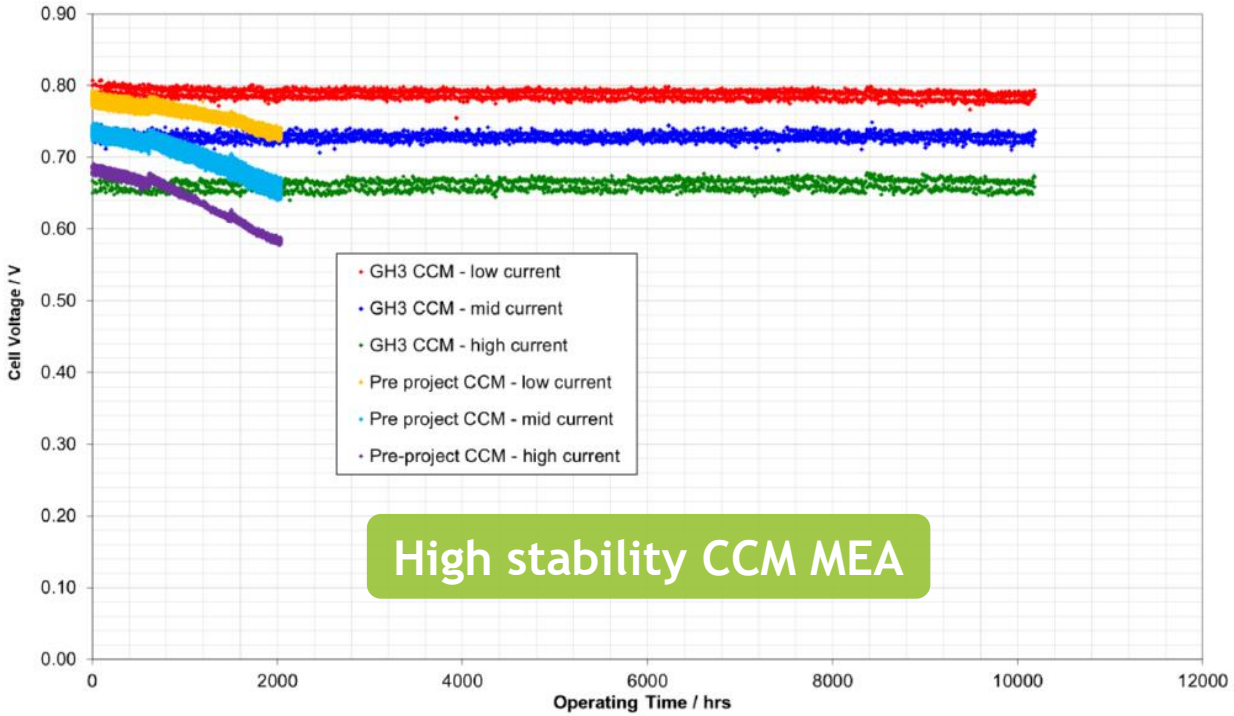
MEA DEVELOPMENT

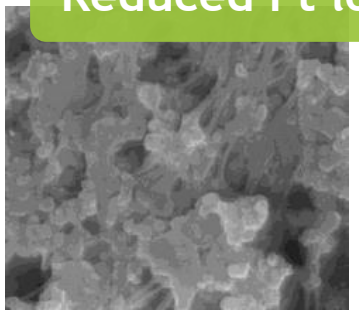
COMPLETED



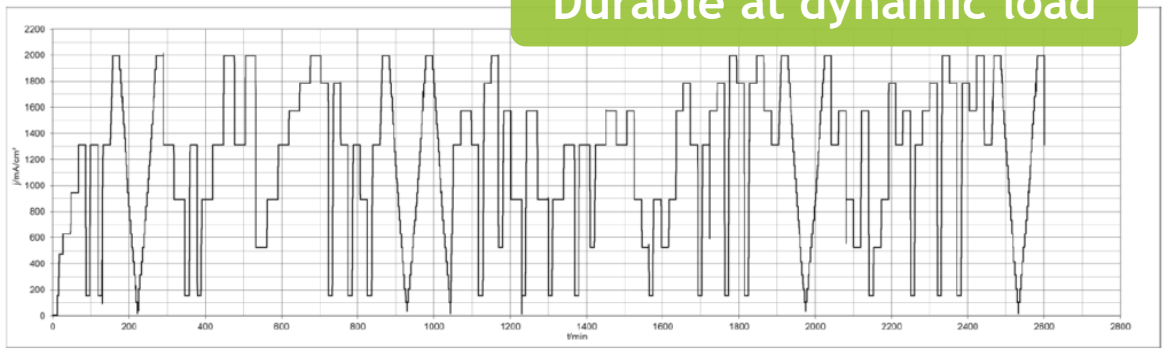


High stability CCM MEA

Reduced Pt loading



Durable at dynamic load



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STACK DEVELOPMENT

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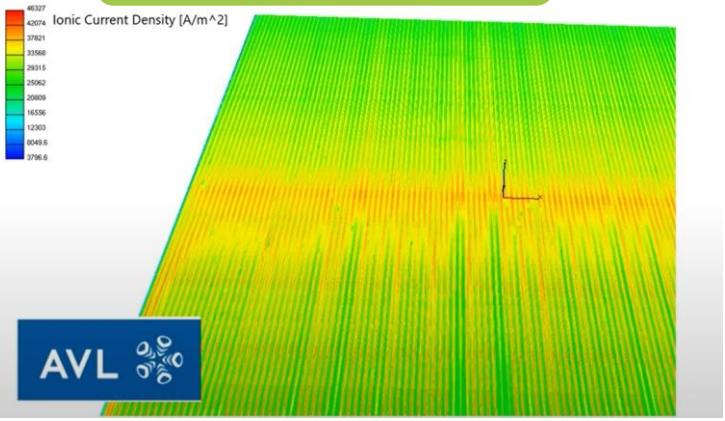
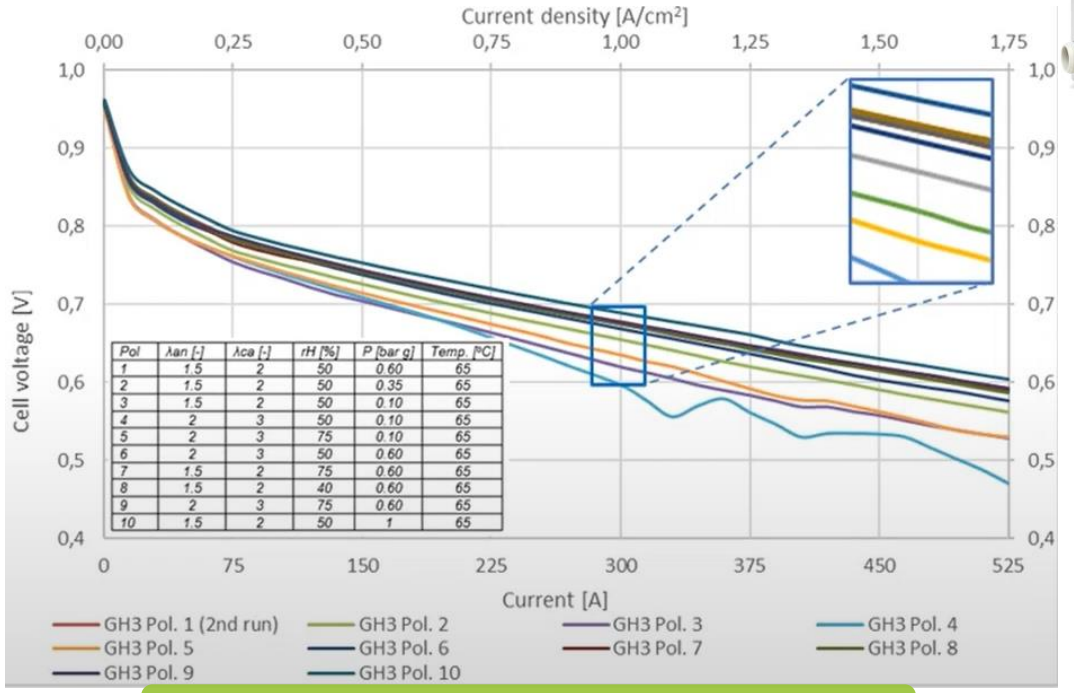
IN PROGRESS

Homogeneous flow distribution





Pol	λan [-]	λca [-]	rH [%]	P [bar g]	Temp. [°C]
1	1.5	2	50	0.60	65
2	1.5	2	50	0.35	65
3	1.5	2	50	0.10	65
4	2	3	50	0.10	65
5	2	3	75	0.10	65
6	2	3	50	0.60	65
7	1.5	2	75	0.60	65
8	1.5	2	40	0.60	65
9	2	3	75	0.60	65
10	1.5	2	50	1	65

Higher pressure -> Higher efficiency

Increased active area

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POWER PLANT DEVELOPMENT

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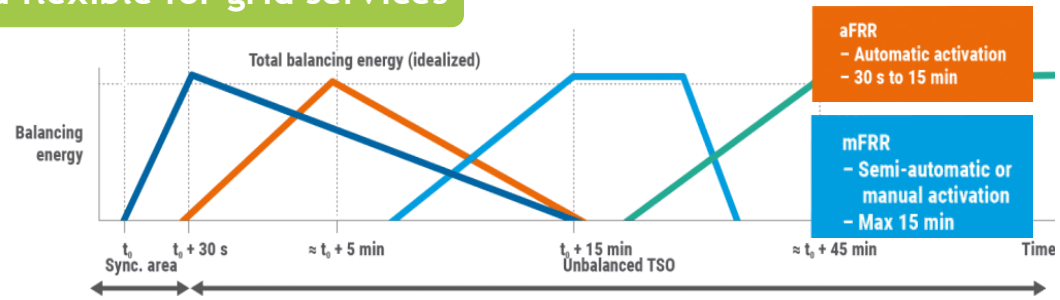
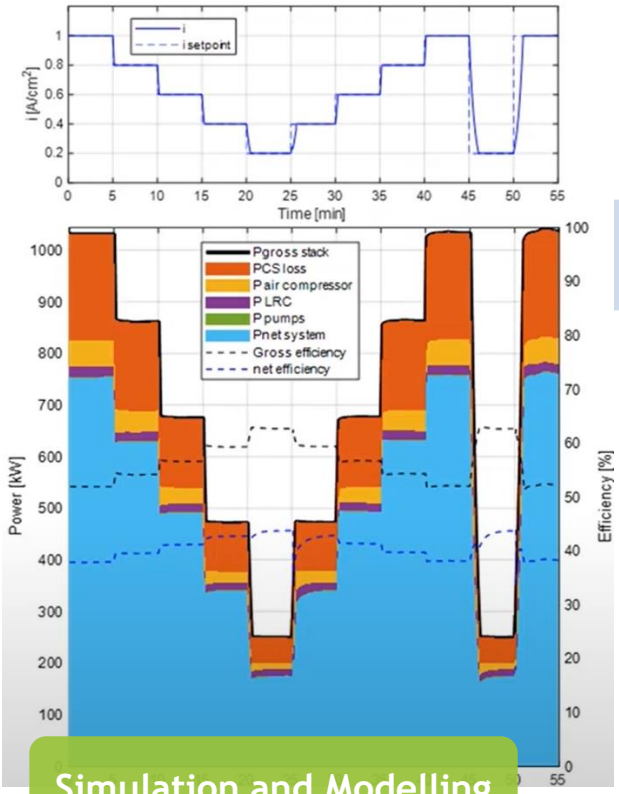
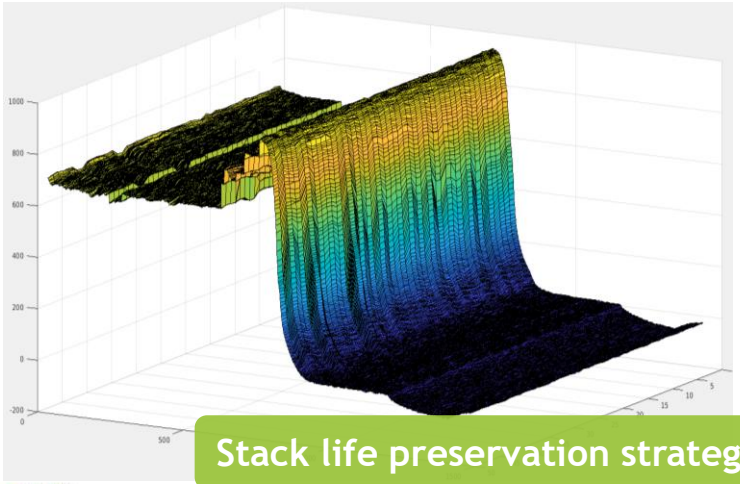
Fast and flexible for grid services



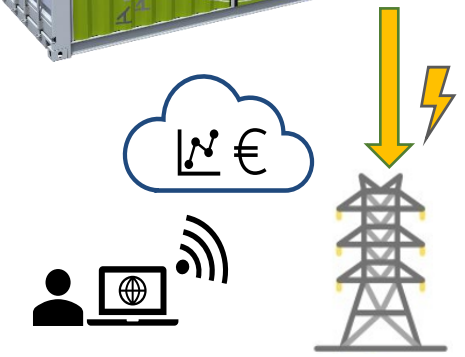


Simulation and Modelling



Stack life preservation strategies

IN VALIDATION



Remote & autonomous operation

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VALIDATION IN A REAL ENVIRONMENT

A 100 kW Pilot plant that:

- Is a development environment to continue research on systems, control strategies, and fuel cell stacks.

- Demonstrates viability in a real location
- Provides visibility and promotes the installation of other demonstration units for different applications

Commissioned & tested at Abengoa's test facilities in Seville (Spain)

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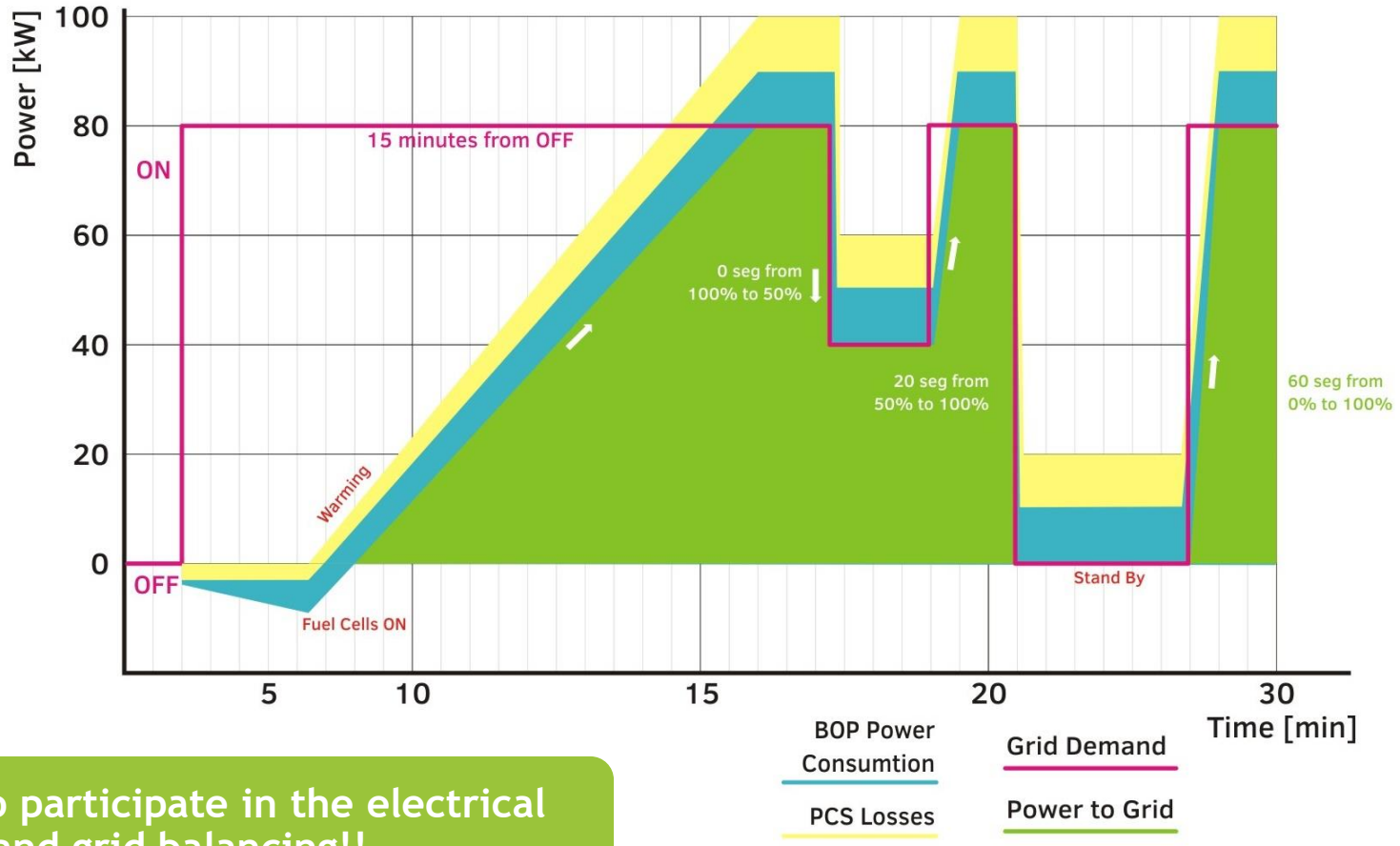
FCPP RESULTS SO FAR

- Flexible and fast dynamic response to load demands
- Sustained efficiency from 20% to 100% power output
- Hot standby capabilities
- Demand-driven operation
- Autonomous and remote operation



Great potential to participate in the electrical market and grid balancing!!

Results obtained through the operation of the pilot plant in Abengoa's testing facilities in Seville (+100 hours)

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FUTURE OF THE PILOT PLANT

- 12 months in Sevilla FAT + Additional Testing
- 6+ months in Arnhem for additional Testing
- 5 years of operation after the project end in Delfzjil

ABENGOA Nedstack PEM FUEL CELLS

Agreement to jointly operate the pilot plant and continue expanding the know-how obtained from it, beyond the project end

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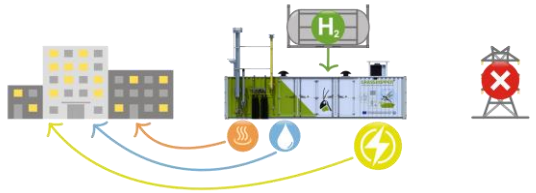
TOWARDS COMMERCIALISATION

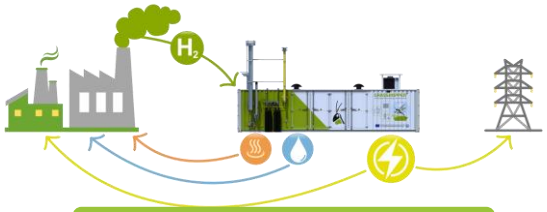
Multi-MW FCPP was designed based on the learnings of the pilot plant, and development will continue

Development for grid stabilisation is also applicable to a big number of other applications, and is currently being studied

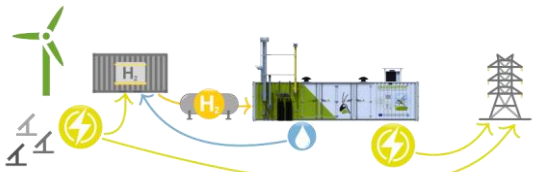


Microgrids

Mobile power units



Residual Hydrogen



Power-to-Power

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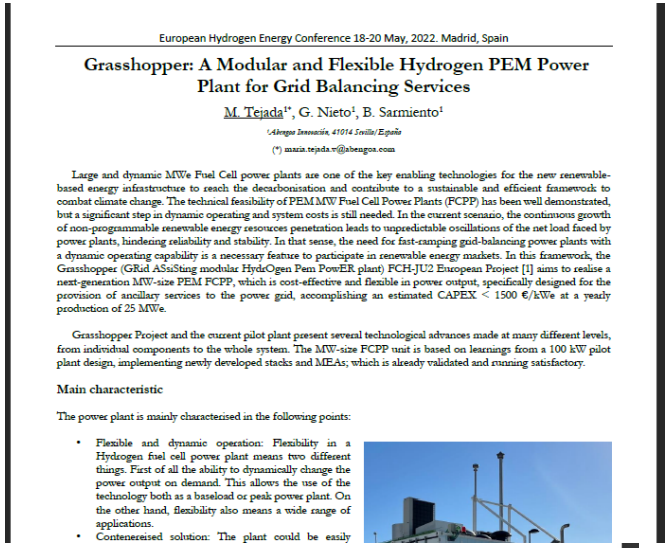
DISSEMINATION

Visits to the pilot plant: authorities, research and education centers, industrial companies, early adopters, TSOs & DSOs…

Conferences and Journals publications



European Hydrogen Energy Conference 18-20 May, 2022. Madrid, Spain

Grasshopper: A Modular and Flexible Hydrogen PEM Power Plant for Grid Balancing Services

M. Tejada[1*], G. Nieto[1], B. Sarmiento[1]

[1]Abengoa Innovación, 41014 Sevilla/España

(*) maria.tejada.rr@abengoa.com

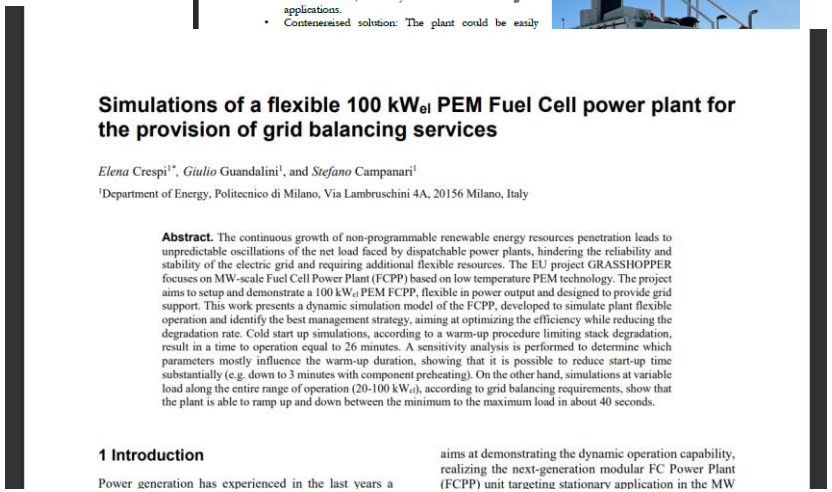
Large and dynamic MWe Fuel Cell power plants are one of the key enabling technologies for the new renewable-based energy infrastructure to reach the decarbonisation and contribute to a sustainable and efficient framework to combat climate change. The technical feasibility of PEM MW Fuel Cell Power Plants (FCPP) has been well demonstrated, but a significant step in dynamic operating and system costs is still needed. In the current scenario, the continuous growth of non-programmable renewable energy resources penetration leads to unpredictable oscillations of the net load faced by power plants, hindering reliability and stability. In that sense, the need for fast-ramping grid-balancing power plants with a dynamic operating capability is a necessary feature to participate in renewable energy markets. In this framework, the Grasshopper (GRid ASsiSting modular HydrOgen Pem PowER plant) FCH-JU2 European Project [1] aims to realise a next-generation MW-size PEM FCPP, which is cost-effective and flexible in power output, specifically designed for the provision of ancillary services to the power grid, accomplishing an estimated CAPEX < 1500 €/kWe at a yearly production of 25 MWe.

Grasshopper Project and the current pilot plant present several technological advances made at many different levels, from individual components to the whole system. The MW-size FCPP unit is based on learnings from a 100 kW pilot plant design, implementing newly developed stacks and MEAs; which is already validated and running satisfactory.

Main characteristic

The power plant is mainly characterised in the following points:

- Flexible and dynamic operation: Flexibility in a Hydrogen fuel cell power plant means two different things. First of all the ability to dynamically change the power output on demand. This allows the use of the technology both as a baseload or peak power plant. On the other hand, flexibility also means a wide range of applications.
- Contenereised solution: The plant could be easily



Simulations of a flexible 100 kW_{el} PEM Fuel Cell power plant for the provision of grid balancing services

Elena Crespi[1*], *Giulio* Guandalini[1], and *Stefano* Campanari[1]

[1]Department of Energy, Politecnico di Milano, Via Lambruschini 4A, 20156 Milano, Italy

Abstract. The continuous growth of non-programmable renewable energy resources penetration leads to unpredictable oscillations of the net load faced by dispatchable power plants, hindering the reliability and stability of the electric grid and requiring additional flexible resources. The EU project GRASSHOPPER focuses on MW-scale Fuel Cell Power Plant (FCPP) based on low temperature PEM technology. The project aims to setup and demonstrate a 100 kW_{el} PEM FCPP, flexible in power output and designed to provide grid support. This work presents a dynamic simulation model of the FCPP, developed to simulate plant flexible operation and identify the best management strategy, aiming at optimizing the efficiency while reducing the degradation rate. Cold start up simulations, according to a warm-up procedure limiting stack degradation, result in a time to operation equal to 26 minutes. A sensitivity analysis is performed to determine which parameters mostly influence the warm-up duration, showing that it is possible to reduce start-up time substantially (e.g. down to 3 minutes with component preheating). On the other hand, simulations at variable load along the entire range of operation (20-100 kW_{el}), according to grid balancing requirements, show that the plant is able to ramp up and down between the minimum to the maximum load in about 40 seconds.

1 Introduction

Power generation has experienced in the last years a

aims at demonstrating the dynamic operation capability, realizing the next-generation modular FC Power Plant (FCPP) unit targeting stationary application in the MW

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VALIDATION CONTINUES

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- ✓ Development and Testing of ST2F
- ✓ Increased power density
- ✓ Development of a new MEA
- ✓ Development of a new flow field
- ⚙ New generation of FC with an increased active area

TRL 5 ⟶ 7

- ✓ Flexible FCPP
- ✓ Dynamic performance at high efficiency
- ✓ Integrated into the Electric market
- ✓ CAPEX reduction
- ✓ Commissioning and FAT
- ⚙ Validation at a real environment
- ⚙ OPEX studies
- ⚙ Business Case Validation

MRL 5 ⟶ 7

START 01/2017

END 05/2022

NextStep

05/2027

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NextStep

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Product

Stack to the Future (II)

TRL 7 ⟶ 9

Program	ShipDrive
Grant Resources	Grant: € 3.069.052 (max)
Work Packages	1. Design Validation Current FC-Solution 2. Design & Prototype New Generation Stack 3. Design & Prototype New Generation System 4. Model Integration & Control Improvement Next Gen 5. Remote Monitoring & Diagnostics System Development
Duration	November 1st 2021 – October 31st 2025

Organiz. + PPE

FUEL CELL GIGA FACTORY

Fuel Cell Giga Factory (FCGF)

MRL 7 ⟶ 10

	IPCEI Hydrogen Hy2Tech
	Grant: € 21.736.099 (max)
	1. Assembly System Design and FCGF Plant layout 2. FCGF in-line Test System Bill of Process Design 3. Assy Cell Deployment & B-Sample built Power field live 4. FCGF Line Realization and C-Sample Built 5. Start of Production and FCGF Tuning 6. Supply Chain Planning & Development 7. Site Revit Project & PEM Power field @IPKW 8. Plant Quality Planning and Production Control
	September 1st 2022 – August 31st 2027

ENG: This Innovation / Project is being supported under the IPCEI administered by the Netherlands Enterprise Agency on behalf of the Dutch Ministry of Economic Affairs and Climate
NL: Deze innovatie/dit project is ondersteund vanuit de IPCEI die RVO in opdracht van het ministerie van Economische Zaken en Klimaat uitvoert

Netherlands Enterprise Agency

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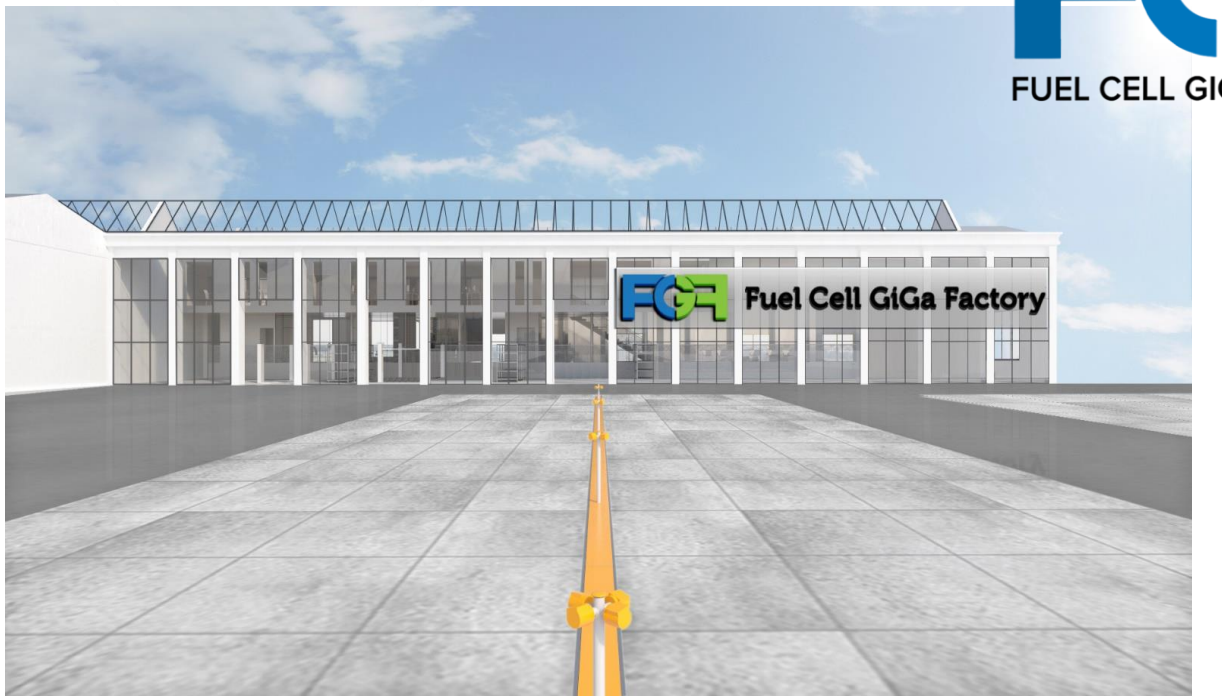
Nedstack Fuel Cell Giga Factory project

FUEL CELL GIGA FACTORY



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www.grasshopperproject.eu

Youtube.com/GrasshopperProject

linkedin.com/groups/12204671

GRASSH$_2$OPPER

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European Hydrogen Week

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Nedstack PEM FUEL CELLS

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 779430. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Co-funded by the European Union