PECSYS

Technology demonstration of large scale photo-electrochemical system for solar hydrogen production

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Programme Review Days 2019

Brussels, 19-20 November 2019

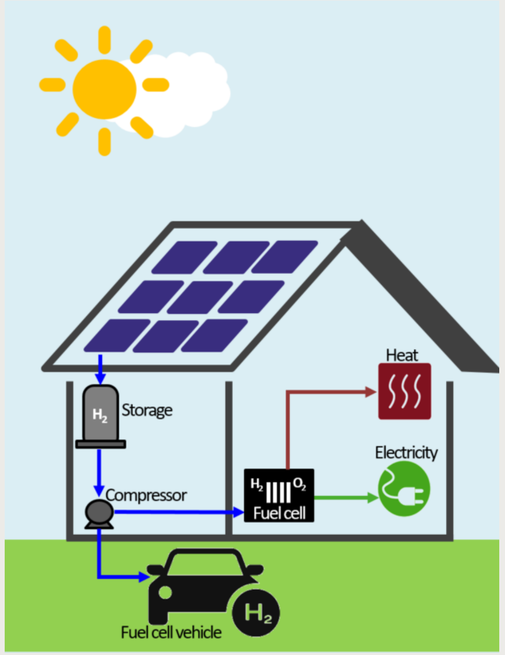
PROJECT OVERIVEW

- Call year: 2016
- Call topic: H2020-JTI-FCH-2016-1, FCH-02-3-2016: Development of processes for direct production of hydrogen from sunlight
- Project dates: 01/01/2017 - 31/12/2020
- % stage of implementation 01/11/2019: 75 %
- Total project budget: 2.5 M €
- FCH JU max. contribution: 2.5 M €
- Other financial contribution: 0 €
- Partners: [Helmholtz Zentrum Berlin (DE), Uppsala Universitet (SE), Consiglo Nazionale delle Ricerche, Catania (IT), Forschungszentrum Jülich (DE), Solibro Research AB (SE), Enel Green Power (IT)]

PROJECT SUMMARY & OBJECTIVES

PECSYS - Technology demonstration of large-scale photo-electrochemical system for solar hydrogen production

Application and market area



Decentralised solar energy supply for single residential or small commercial building

Objectives	*Context*	*Target*	*PECSYS Status*	*SoA*	*SoA Source, YEAR*
Solar collection area prototypes (cm^2)	Project's own	> 100	✓	64	FZ Jülich, 2017
Solar collection area, demonstrator array (m^2)	Call	≥ 10	⚠	1.6	KU Leuven, Belgium, 2019*
Cost of hydrogen production, demonstrator (€/kg)	Call	5	⚠	None yet	
Solar to hydrogen efficiency, demonstrator (%)	Call	> 6	⚠	15	KU Leuven, Belgium, 2019
Hydrogen production ($g\ H_2/h/m^2$)	Call (Project)	> 1.5 (≥ 1.6)	⚠	2.03	KU Leuven, Belgium, 2019
Degradation (%) after 6 months operation	Call	≤ 10	⚠	None yet	

*https://nieuws.kuleuven.be/en/content/2019/belgian-scientists-crack-the-code-for-affordable-eco-friendly-hydrogen-gas

PROJECT PROGRESS/ACTIONS – Solar to hydrogen conversion efficiency

Silicon 294 cm², 1.5 g/h/m², 6.5 %

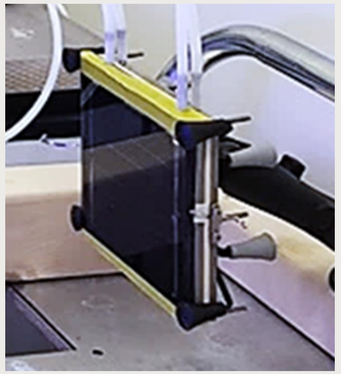
CIGS 0.9 cm²
?? g/h/m²
12.6 %

25% 50% 75%

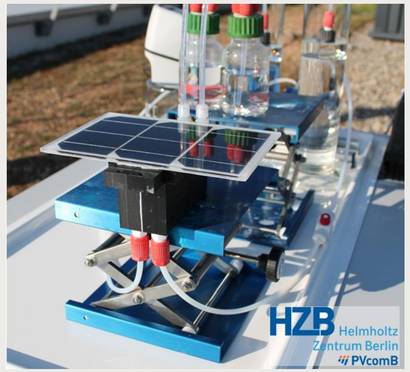
10 m²
≥ 1.6 g/h/m²
≥ 6%

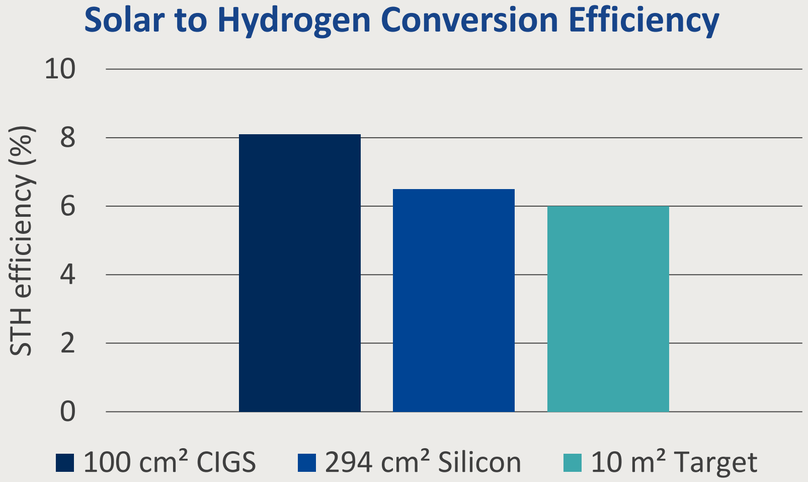
- Fully integrated photovoltaic electrolyser
- Alkaline electrolyte 1.0 M KOH
- Earth abundant catalysts

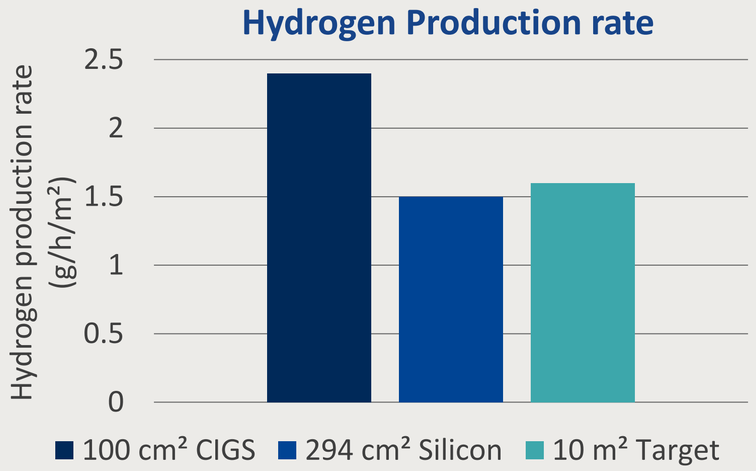
100 cm² CIGS



294 cm² Silicon







Hydrogen production rate and STH efficiency reduce as solar collection area increases

PROJECT PROGRESS/ACTIONS – Solar to hydrogen conversion efficiency

Silicon 294 cm², 1.5 g/h/m², 6.5 %

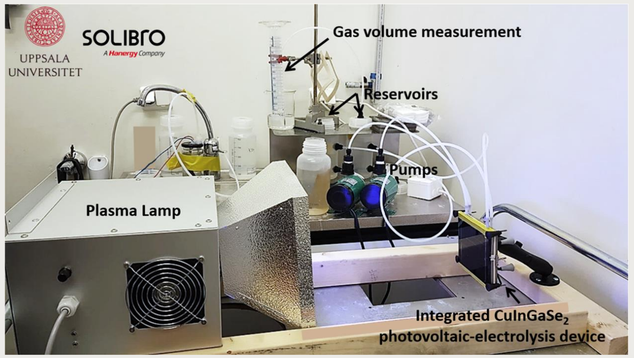
CIGS 0.9 cm²
?? g/h/m²
12.6 %

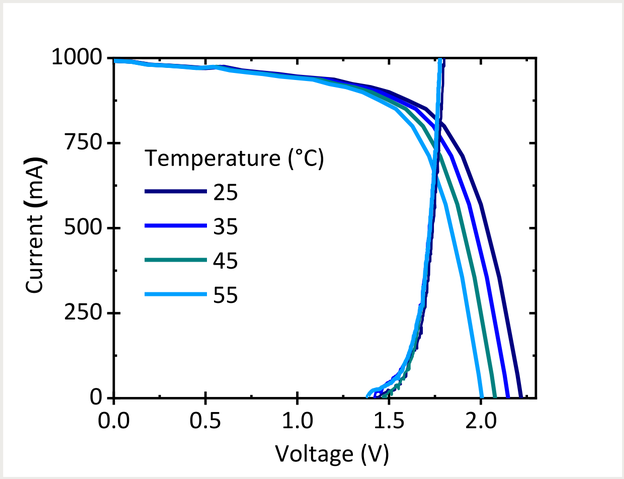
25% 50% 75%

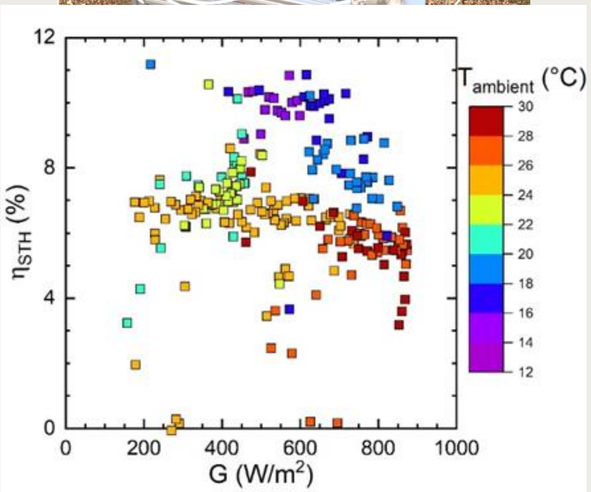
10 m²
≥ 1.6 g/h/m²
≥ 6%

Solar to hydrogen efficiency η_{STH}

- Value depends on temperature (*T*) and irradiance (*G*)
- Non-existent internationally recognised standard test procedures
- Samples larger than 100 cm² can only be tested outdoors







PROJECT PROGRESS/ACTIONS – Levelised cost of H_2 production

6.72 €/kg-H_2
294 cm²

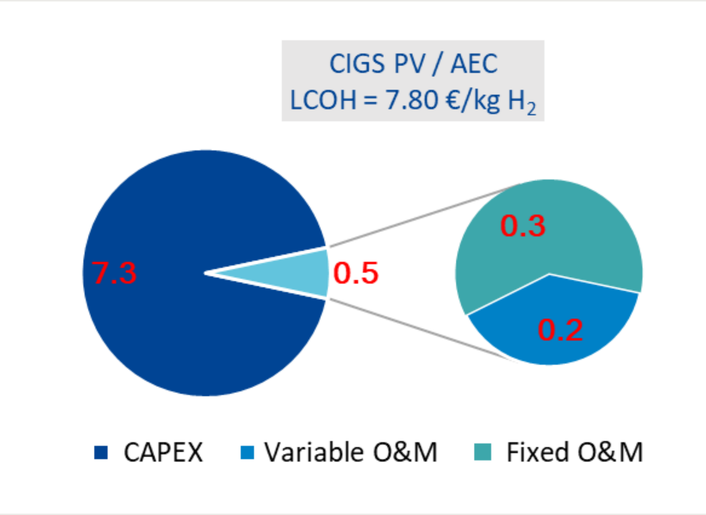
NO START VALUE

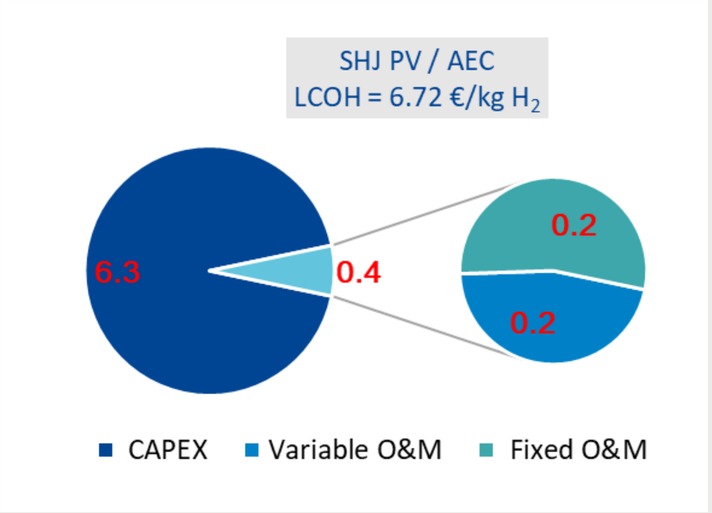
25% 50% 75%

< 5 €/kg-H_2
10 m²

100 cm² CuInGaSe (CIGS) prototype
- Producing 24 mg-H_2 /h
- NiFeO|NiFeO catalysts on nickel foam

294 cm² silicon (SHJ) prototype
- Producing 44 mg-H_2 /h
- NiFeO|NiMo catalysts on nickel foam





Cost drivers

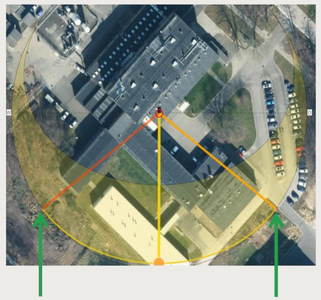
- Energy conversion efficiency
- Price of electrolyser casement material
  - Nickel frame for CIGS approach
  - 3-D printed polymer for silicon heterojunction (SHJ) approach

Cost calculation scaled for 16 g/h production located in Juelich, Germany

PROJECT PROGRESS/ACTIONS – Preparation for demonstrator

21 December

21 June



Sundown

Sunrise

No shadowing by experiment hall

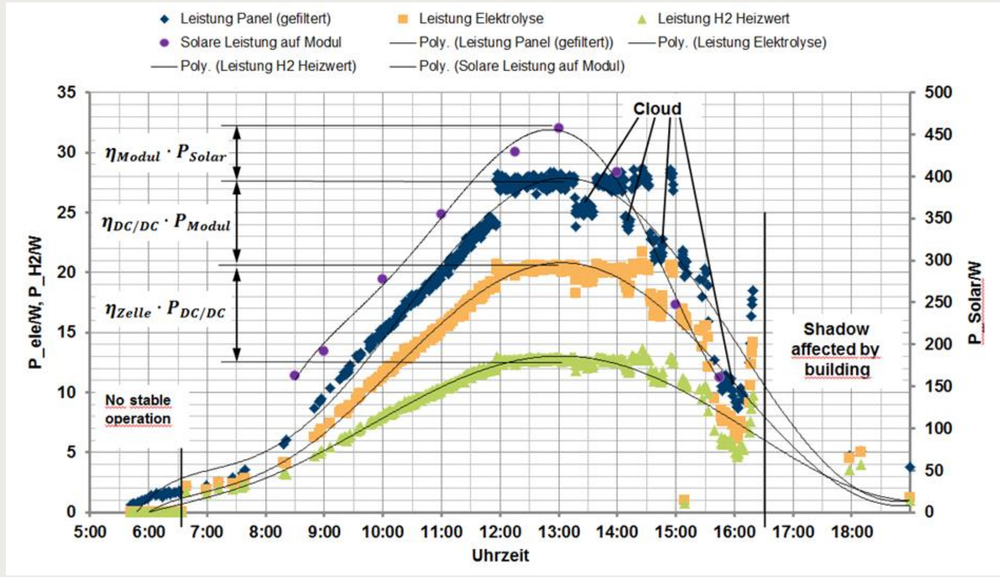
Sundown

Sunrise

Shadowing by experiment hall from ca.16:00

Progress of test field preparation

- PV modules connected to an PEM electrolyser used as a reference
- Pending installation of integrated photovoltaic electrolysers
- First monitoring tests using reference completed



Challenge

Scale- up losses in performance have delayed construction of integrated modules for demonstrator

PROJECT PROGRESS/ACTIONS – Preparation for demonstrator

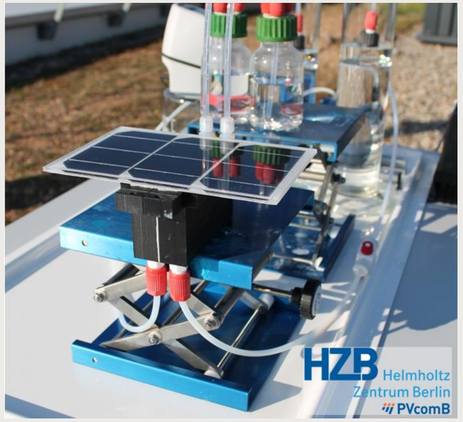
936 cm²

No start value

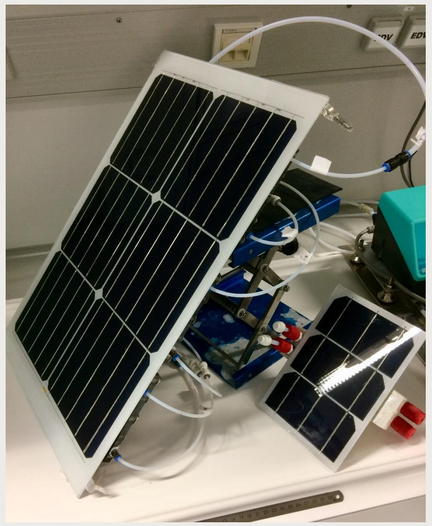
25% 50% 75%

10 m²

Mar 2019: 294 cm²



Oct 2019: 936 cm²



Feb 2020: > 1 m²

- ✓ Target at end of Project
- ✓ Demonstrator array of ~ 1 m² modules
- ✓ Total area = 10m²

- Scale-up leads to reduction in hydrogen production rate and STH efficiency
- Electrolyser part being re-designed to reduce resistance losses

Risks and Challenges

Risks

- Efficiency loss in both PV and EC part because of upscaling. 3-D computations introduced to aid design devices with low resistance losses.
- Unfavourable business environment conditions in the PV industry. Two industrial partners provide parallel route toward implementation of integrated demonstrator.

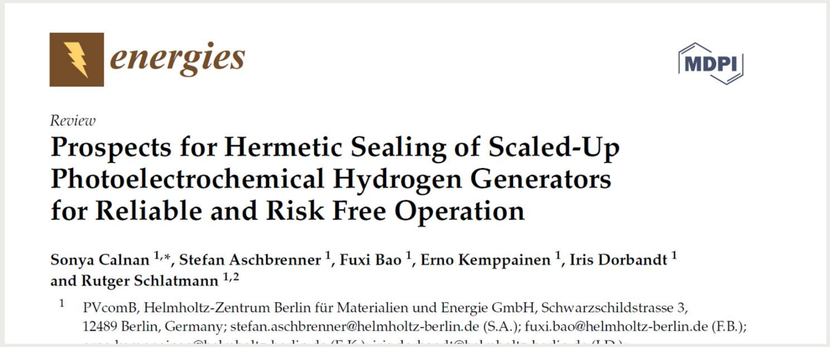
Challenges

- Lack of availability of low cost, lightweight materials that are resistant to alkaline electrolyte at temperatures above room temperature.
- Assembly of electrolyser part and integration of photovoltaics module to it, is not mechanized making construction of larger units difficult.

Communication and Dissemination Activities

- Demonstrations to general public: **4**
- Conferences and workshops attended: **23**
- Project Brochure: **1**
- Guest editors of Special issue of “Energies” journal on Materials and Devices for Solar to Hydrogen Energy Conversion **(CNR)**
- Peer reviewed publications: **8**

- Project organized workshop and video: **due in Spring 2020**
- Patents (and applications): **none as yet**
- Public deliverables of the project
  - D7.2 Field and balance of plant ready for use online


energies

MDPI

Review

Prospects for Hermetic Sealing of Scaled-Up Photoelectrochemical Hydrogen Generators for Reliable and Risk Free Operation

Sonya Calnan [1,*], Stefan Aschbrenner [1], Fuxi Bao [1], Erno Kemppainen [1], Iris Dorbandt [1] and Rutger Schlatmann [1,2]

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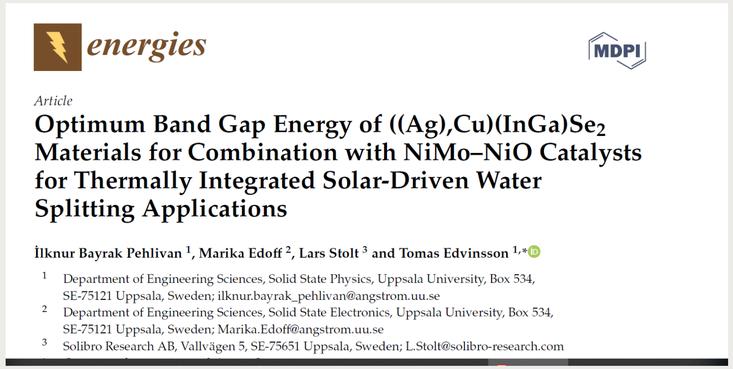
energies

MDPI

Article

Optimum Band Gap Energy of ((Ag),Cu)(InGa)Se_2 Materials for Combination with NiMo–NiO Catalysts for Thermally Integrated Solar-Driven Water Splitting Applications

İlknur Bayrak Pehlivan [1], Marika Edoff [2], Lars Stolt [3] and Tomas Edvinsson [1,*]

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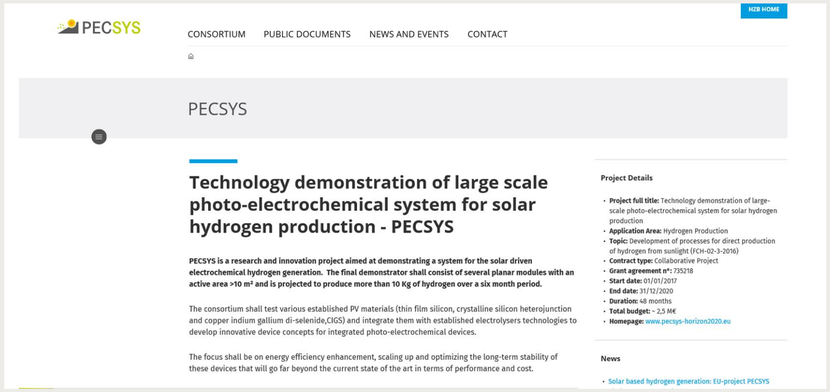

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EXPLOITATION PLAN/EXPECTED IMPACT

Exploitation

- Development of new catalyst materials and devices designs for solar hydrogen generation **(CNR, HZB, UU)**
- Provision of testing and performance measurement services for industry: **(FZJ, HZB)**
- Development of new materials for PV cells and catalysts for solar hydrogen generation: **(UU, HZB)**
- Patenting and licensing any intellectual property gained: **(all partners)**
- Process development for PV modules for solar hydrogen generation **(EPG, HZB)**
- Consortium started using **EU Support Service for Exploitation of Research Results** in November 2019

Impact

- Technical and economic feasibility of integrated PV-EC solar-hydrogen generation: value addition to photovoltaic module production
- Lessons learned and results: foundation for further research and possible commercialization of the next generation devices for solar fuel production such as the artificial leaf

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES

Interactions with projects funded under EU programmes

- **ARCIGS-M:** Advanced aRchitectures for ultra-thin high-efficiency CIGS solar cells with high Manufacturability

- **HPEM2GAS:** Attendance of workshop in EMDEN (DE) on 12th February 2019 in order to establish interaction with other H2020 Projects in the same field of PECSYS project

- "**CIGS-WO3 solar water splitting systems"** (UU-SRAB). A pre-study funding from European Regional Development Fund.

Interactions with national and international-level projects and initiatives

- **Energiesystem 2050**: A joint initiative of the research field energy of the Helmholtz Association aimed at improving the understanding of energy systems and at developing technological solutions for deployment. FZJ and HZB benefit from studies on deployment of renewable energies and hydrogen in the energy supply system of Germany

- The **Helmholtz Energy Materials Foundry** (HEMF): Indoor and outdoor measurement capabilities developed for photovoltaic driven electrolysers at HZB

Acknowledgements

Thank you for your attention

The project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735218. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme and Hydrogen Europe and N.ERGHY. The project started on the 1st of January 2017 with a duration of 48 months.

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