High efficiency hydrogen production to support industrial decarbonization

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Energies du futur

OUTLINE

1. Hydrogen: usages and production routes
2. Interest of Solid Oxide Electrolysis (SOEL)
3. SOEL technology description
4. R&D background at CEA
5. Genvia
6. Conclusion

Hydrogen usages

Usage in 2020

“Industrial” H_2

- World ≈ 90 Mt/yr
- France ≈ 1 Mt/yr

- Chemistry (ammonia)
- Refining
- Iron & steel

Usages in 2030 and beyond

“Industrial” and “energy” H_2

Achieving deep decarbonization of >80% of CO_2 emissions requires hydrogen

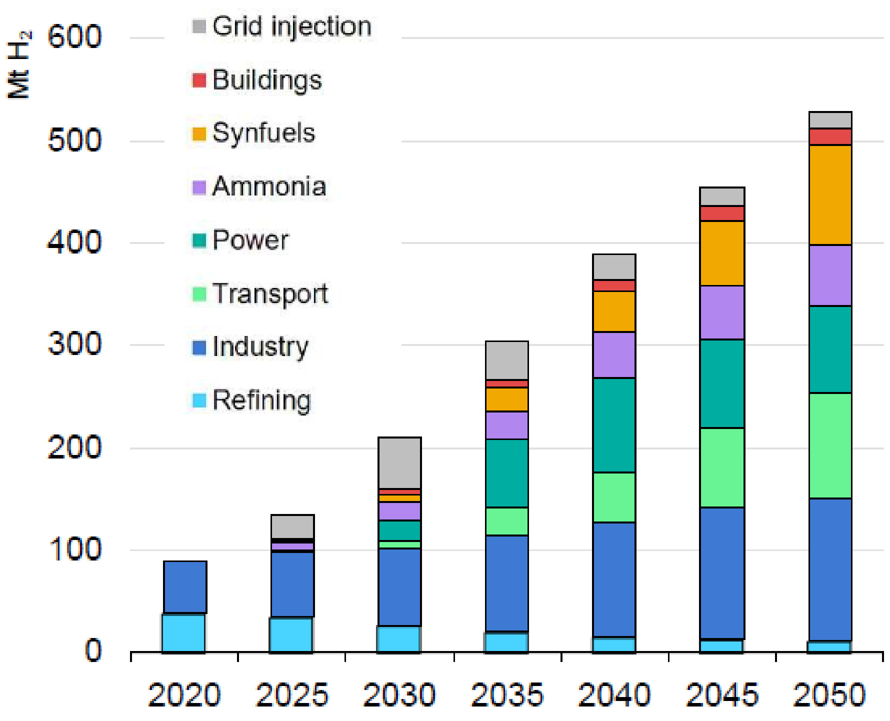
Ultra-low-carbon H_2 as feedstock, e.g, ammonia

High-grade heat for industry & in steel

H_2 to decarbonize the gas grid

Fuel cells/synfuels for heavy transport and long distances

Source:FCH-JU



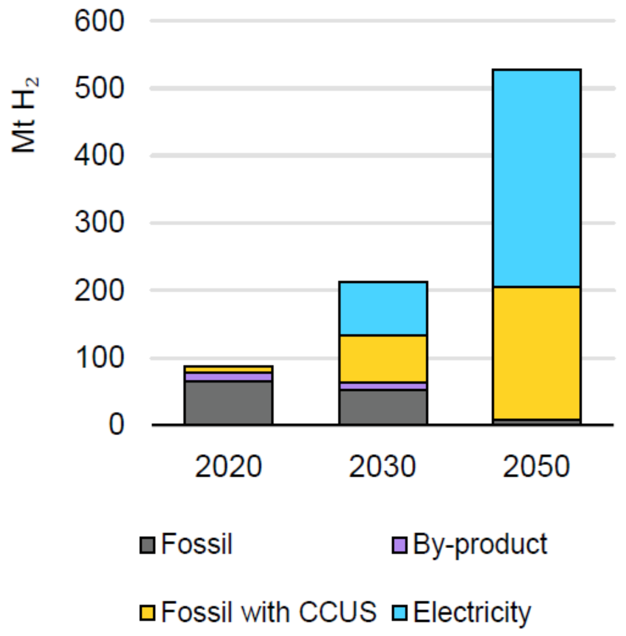
Source : Global Hydrogen Review 2021, IEA

H_2 Needs x6 until 2050

Hydrogen production routes

2020: Fossile H_2

≈ 11 kg of CO_2 per kg of H_2

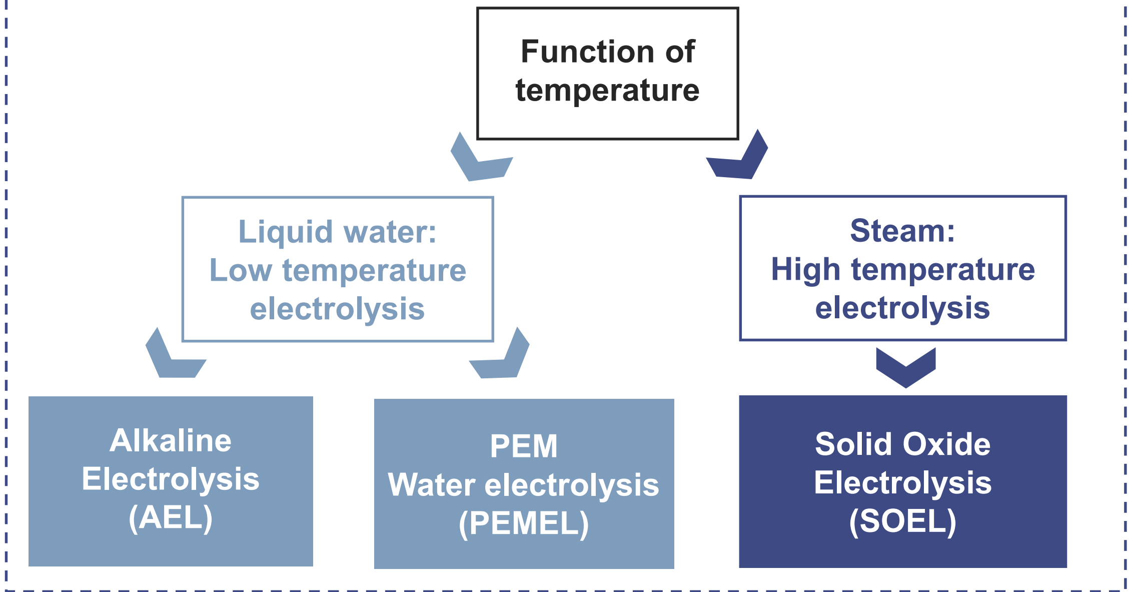


Source: Global Hydrogen Review 2021, IEA

Challenge for 2030 and beyond

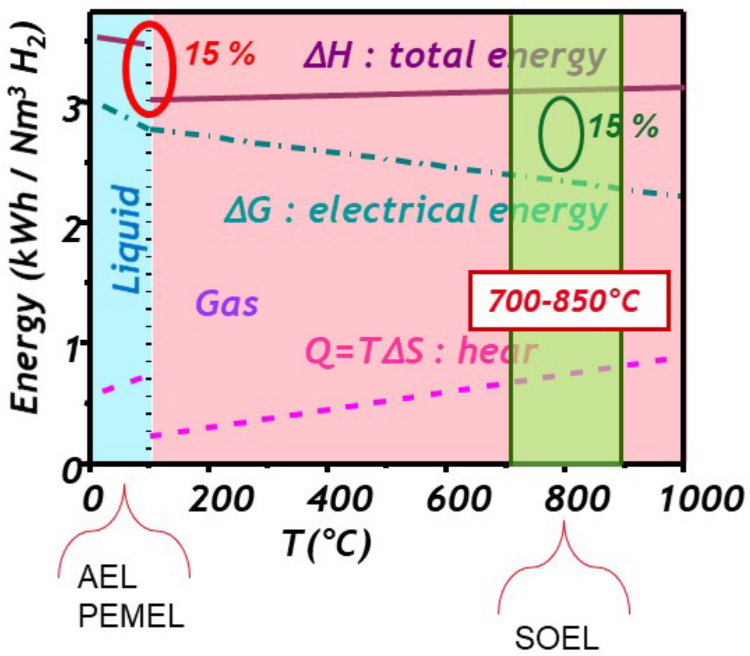
- Low carbon H_2 production route ➔ Electrolysis
- RePowerEU plan: 10 Mt of domestic production + 10 Mt imports (~ 100 GW electrolysis installed in EU and abroad for imports)

Different electrolysis technologies



Interest of Solid Oxide electrolysis

HIGH EFFICIENCY TECHNOLOGY



H_2O (g) → H_2 (g) + ½ O_2 (g)

ΔH = ΔG + TΔS ~ constant

ΔH Working in gas/liquid mode **saves 15% in Energy**

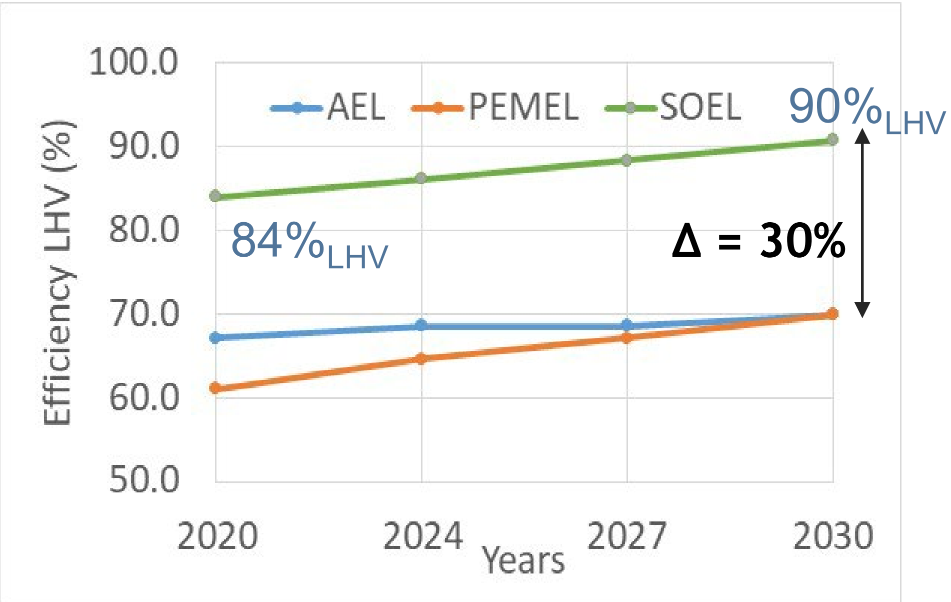
ΔG : Rising in T saves **15% additional electricity**

➡ **30% gain for high temperature steam electrolysis**

When coupled to a heat source (~ 150°C) to produce steam

➡ SOEL operating range = 700-850°C

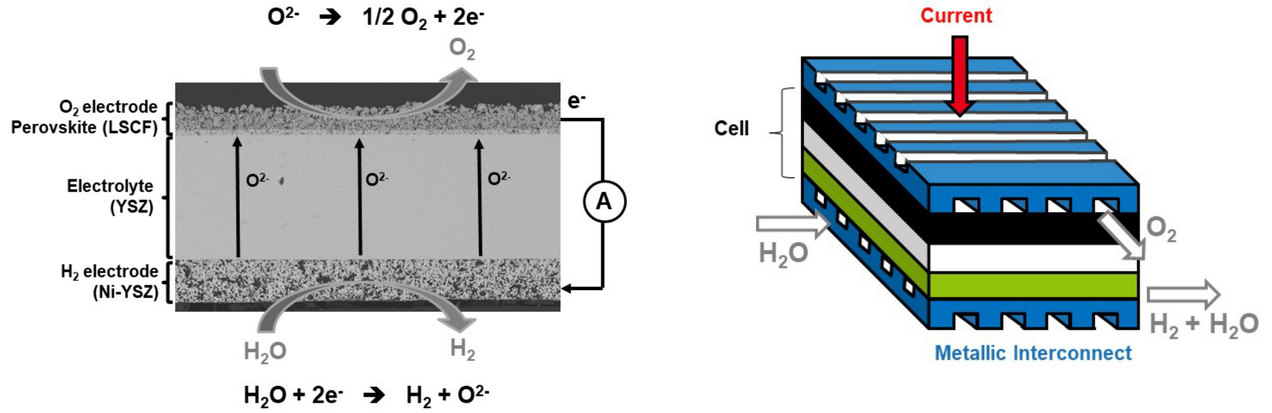
EFFICIENCIES



Source : Strategic Research and Innovation Agenda, Clean H2 partnership, Feb 2022

SOEL technology description

Technology with no expensive noble catalysts



Modular technology

Electrolysis cell composed of:

- 2 electrodes (anode and cathode)
- One electrolyte
- Need of electricity (and heat)

Stacking of several electrolysis cells to increase the power

Integration of stacks into a **module** including 1st level Balance of Plant components

Can/will include several stacks into a module

Integration of modules into an **electrolysis system/plant** including all Balance of Plant components **= electrolyser**

Can/will include several modules into the electrolysis system/plant

SOEL technology : flexibility of use

Same core technology for several applications





HYDROGEN PRODUCTION

Feedstock for industry, fuel for mobility, energy storage

H_2 Module (SOEL)

CO-ELECTROLYSIS CO_2/H_2O

Production of synthetic fuels

Power to X

Co-electrolysis Module

CORE TECHNOLOGY STACK

Fuel cell Module (SOFC)

ELECTRICITY PRODUCTION

Stationnary CHP

Heat and power

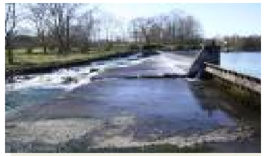
Reversible Module (rSOC)

SOEL/SOFC REVERSIBLE

Renewable energies storage







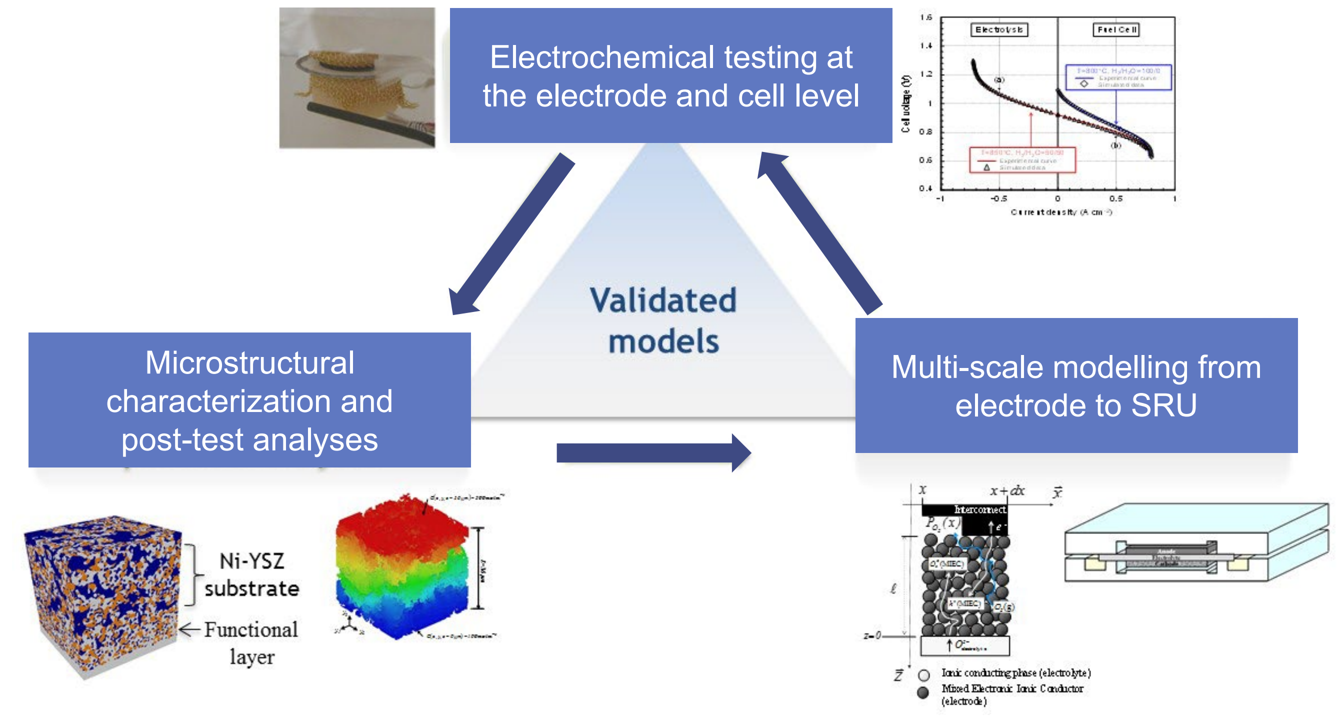

Some R&D results

1. CELL OPTIMIZATION WITH AN APPROACH COMBINING MULTI-SCALE/MULTI-PHYSICS MODELLING AND ADVANCED CHARACTERIZATION

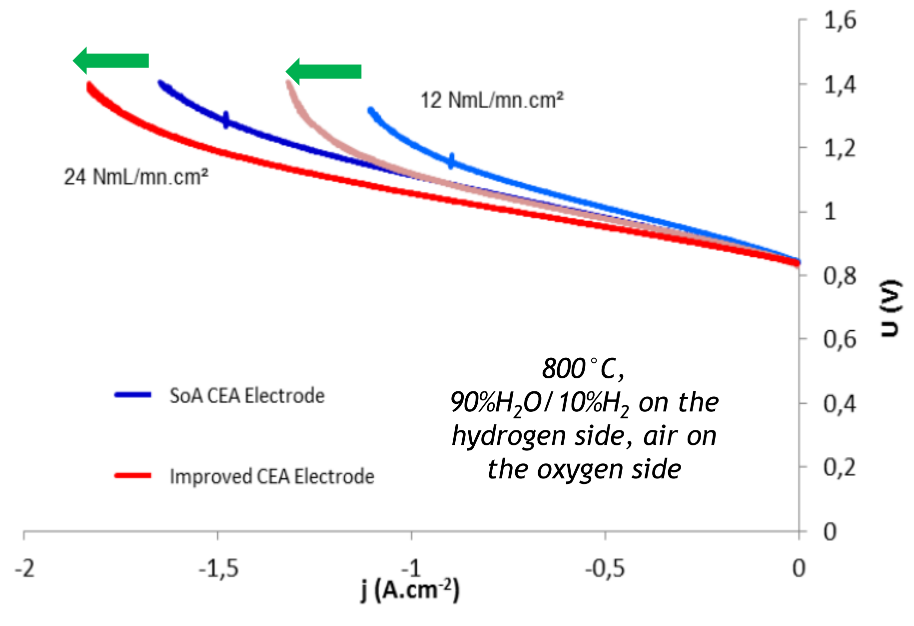
2. SYSTEM EFFICIENCY DEMONSTRATION

3. HIGH PRESSURE SOEL OPERATION

1 Cell optimization to reach the best combination of performance/durability with an approach combining



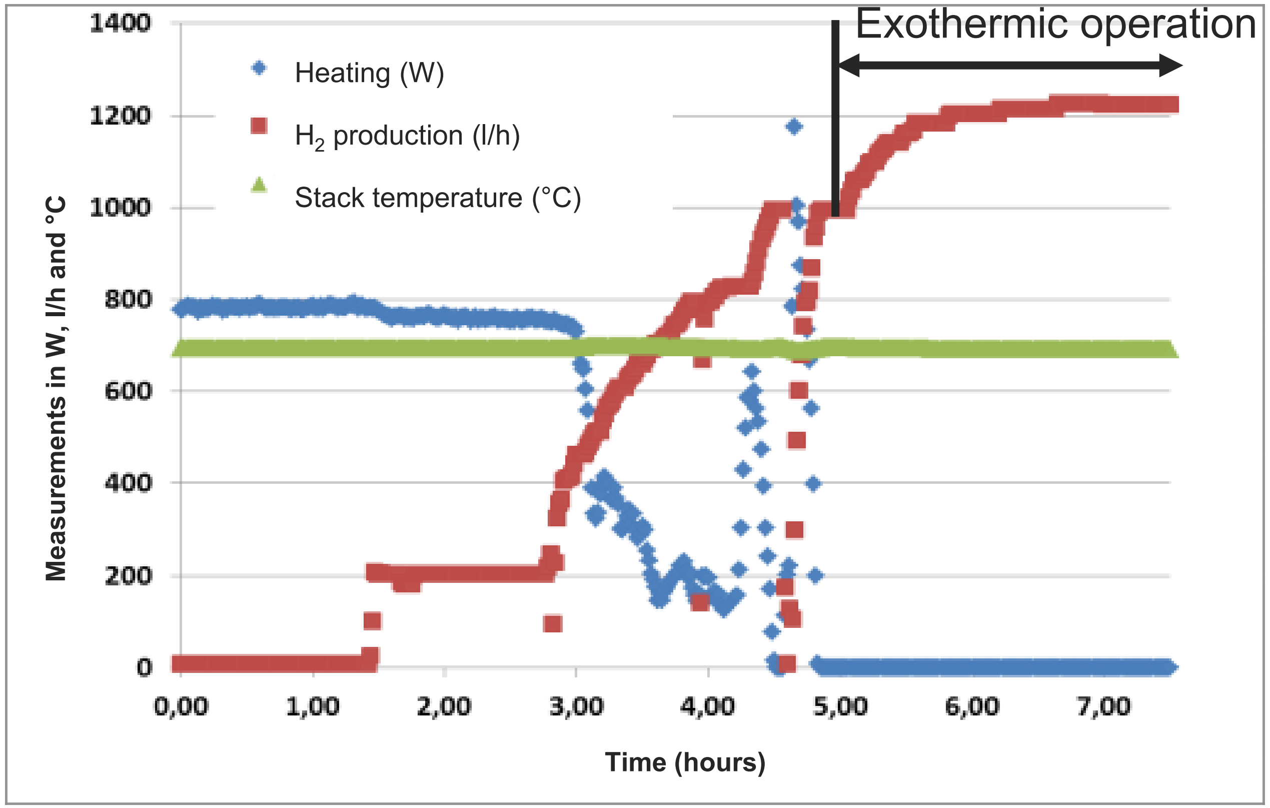
Source: Monaco et al., J. Electrochem. Soc. 166 (15), (2019) F1229-F1242



Large improvement of cell performance

- At 800°C: ~ + 15% of current density as compared to SoA cell
- Understanding of phenomena responsible of degradation

2 SOEL system efficiency demonstration



Source: A. Chatroux, et al., ECS Transactions, 68 (1) (2015) 3519-3526
J. Mougin, 12th European SOFC&SOE Forum 5-8 July 2016, Luzern, A0605 (2016)

- No need of high temperature heat source to reach high efficiency
  Heat source at 150°C is sufficient

- High efficiency measured in SOEC mode thanks to:
  - **Highly efficient heat exchangers**
  - **Operating point slightly exothermic**

Direct consequence on efficiency

Steam electrolysis

η_{LHV} = 84%

if steam not generated with electricity

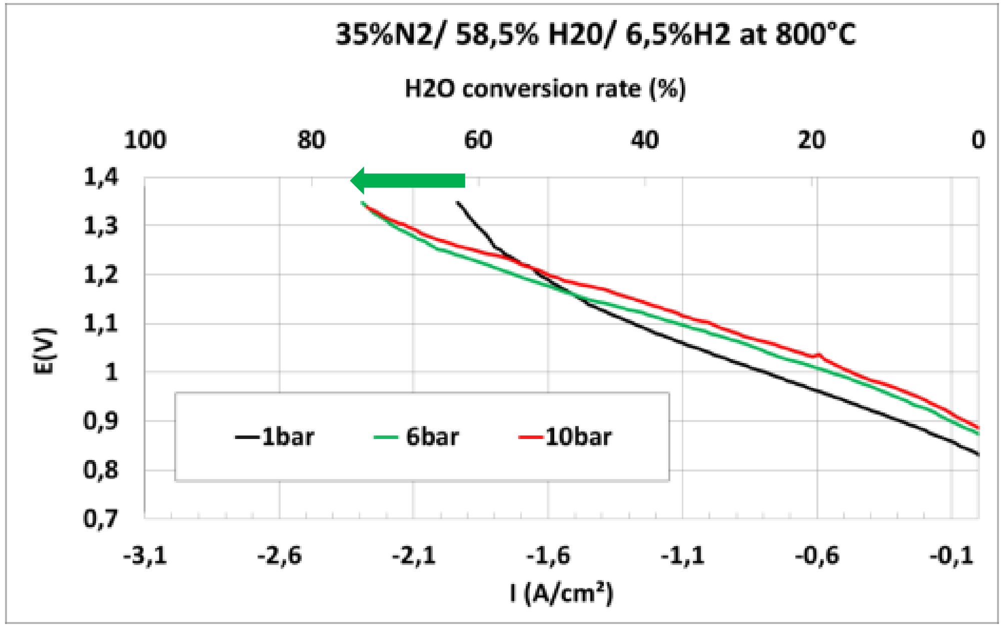
Water electrolysis

η_{LHV} = 60-70%

Nota: If steam generated electrically η_{LHV} ~ 76% LHV

3 High pressure SOEL operation

- **Up to 30 bar** in the lab at cell level
- Pressurized operation allows to:
  - reach higher current densities and steam conversion
  - Shift limiting current to higher current densities
- Most important impact between 1 and 6 bar



L. Bernadet, et al., Electrochimica Acta 253 (2017)

Direct consequence on efficiency

Double benefit

- Cell/stack level: performance
- System benefit:
  - One H2 compression step avoided
  - Higher steam conversion

20 years of R&D at CEA

From resourcing to valorization

From R&D to technology transfer

1999

Phase of exploratory research on ceramic cells

Launch of High T° Fuel Cell (SOFC) activity at CEA

2005-2010

Recognized expertise acquisition phase

Techno-economic relevance of **SOEL technology** for the **production** of **cost-competitive "low carbon" H2** by electrolysis

2010-2015

Consolidation phase of a leadership position

1st proof of concept at system scale: **84%LHV efficiency** measured experimentally

WHEC 2014 Award – Julie Mougin

2015-2020

Technological maturity rise phase

Confirmation of the status of **game changer** for the **SOEL technology CEA**

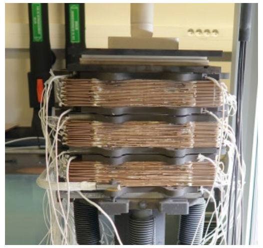
- **Stack design more robust**
- manufacturing process more reliable
- 1st works on **multistack modules**

2021-2024

Technological transfer phase

GENVIA

1st March 2021 Genvia creation



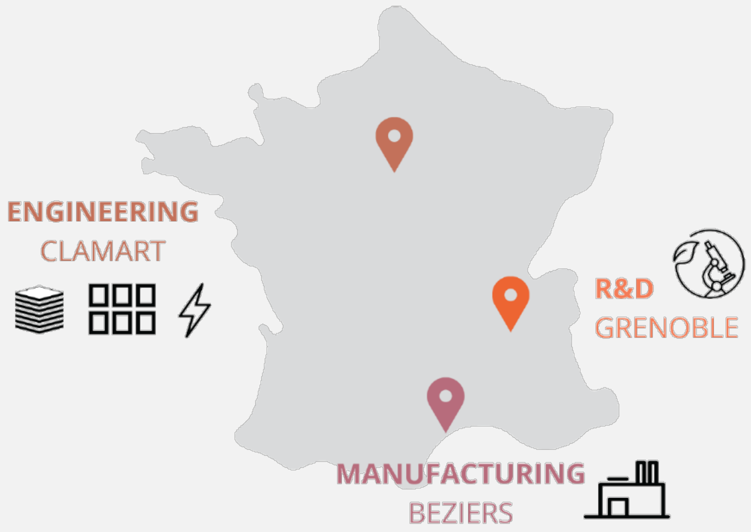
- 1st powerstack (x6)
- pilot workshop in Beziers for stack manufacturing
- Modules engineering

Industrial production phase

2024-2030

Genvia

- Established 1 March 2021, based on 40 patents and 15 years of R&D
- Today >100 employees
- Maturing, industrialising and developing industry solutions with Solid Oxide Technology



3 – mature sites

5 public / private partners

> Building electrolysers for industrial needs

kWh/Kg H2 ↓

Optimize reaction conditions

Chase every joule of loss

Swap electrical for heat energy

$ / Kg H2/hour ↓

Scale up manufacturing to reduce cost/stack

Increase stack power density

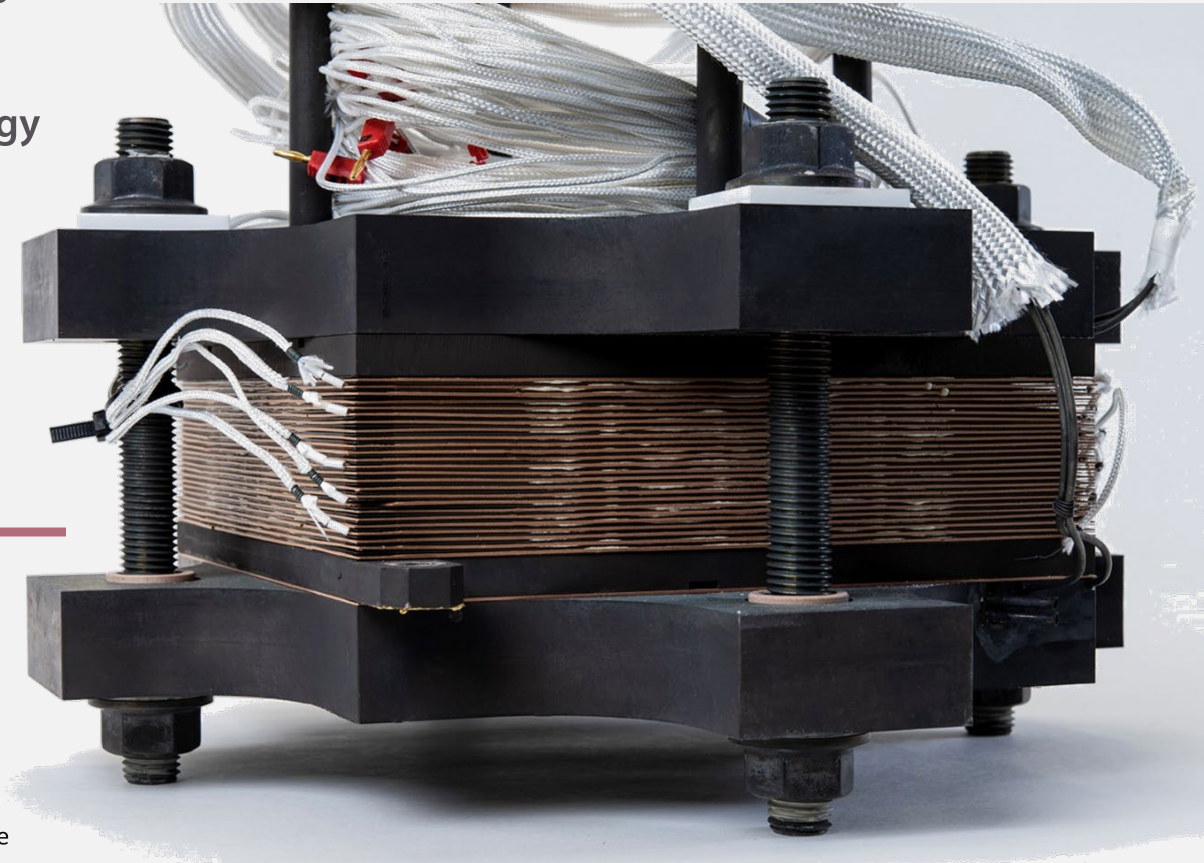
Scale projects to optimise BOP cost

Lifetime ↑

Zero-defect manufacturing

Reduced cell degradation

Fault-tolerant design



Genvia - Private

> Open the market through pilot projects

Major industrial partners in the three major emitting sectors, leading renewables and storage partners

200 Kg/day pilot projects

ArcelorMittal Plant Decarbonization

Renewable H_2 Hub

EDF / Hynamics / Vicat Testing at R&D site

600 Kg/day pilot projects

Vicat Cement Plant Decarbonization

Swiss Steel Foundry Decarbonization

Chemical plant Decarbonization

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Genvia - Private

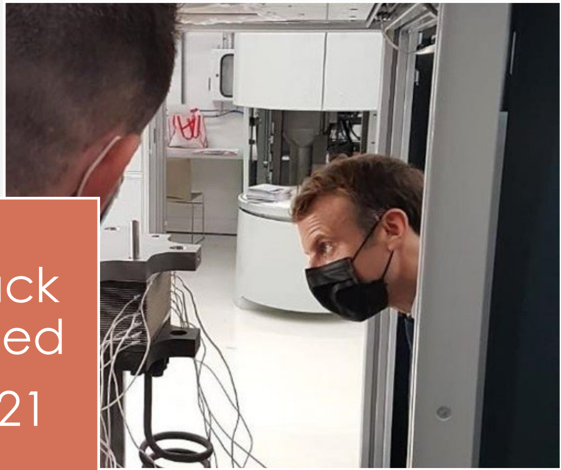
> Genvia's first steps

Genvia founded
Q1 2021

Electrolyser workshop delivered
Q3 2021

First Stack produced

Q4 2021



Genvia Beziers Team

Q1 2022

Genvia at Elysée

Q4 2022

GENVIA

HIGH TEMPERATURE ELECTROLYSIS (SOEL): TECHNOLOGY WITH MANY ASSETS

HIGH EFFICIENCY TECHNOLOGY
with potential for excellent level of performance

HIGH FLEXIBILITY TECHNOLOGY:
co-electrolysis, reversible operation
- which opens up additional applications to pure production of H_2 such as P2X and renewable energy storage

HIGH ADAPTABILITY TECHNOLOGY
with appropriate BOP & management strategies:
- No need for a high T heat source
- Ability to operate with intermittent energy sources, and under pressure 10-30 bar

Potential to be a "game changer" to produce low cost H_2

> The Genvia Ambition

2021-2024 → **2025-2030** → **Target 1GW**

- **2021-2024**: Maturation and industrialization
- **2025-2030**: Massive industrialization of power modules
- **Target 1GW**: Full capacity in 2030

cea liten

GENVIA

Thank you for your attention

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