MULTIPLHY

Multimegawatt high-temperature electrolyser to generate green hydrogen for production of high-quality biofuels

Workshop - Heat-to-Fuel interfaces to advanced Power-to-Gas and Power-to-Liquids Technologies (e-fuels)

Virtual

9 March 2021

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Start date: 01/01/2020
Duration: 60 months

Outline

- Introduction
  - Role of hydrogen
- Benefits of High Temperature Electrolysis
- MULTIPLHY goal and objectives
- Concept and methodology
- Consortium
- Main tasks
- Conclusion

Introduction

ACHIEVING DEEP DECARBONIZATION OF >80% OF CO_2 EMISSIONS REQUIRES HYDROGEN

Challenge

Hydrogen is the best or only choice for at-scale decarbonization of key segments, for example:

Achieving deep decarboni-zation

- H_2 TO DECARBONIZE THE GAS GRID
- FUEL CELLS/ SYNFUELS FOR HEAVY TRANSPORT AND LONG DISTANCES
- HIGH-GRADE HEAT FOR INDUSTRY & IN STEEL
- ULTRA-LOW-CARBON H_2 AS FEEDSTOCK, E.G., AMMONIA

Source: FCH JU

Introduction

MULTIPLHY

IN INDUSTRY, HYDROGEN PROVIDES LARGE-SCALE OPPORTUNITIES TO DECARBONIZE HIGH-GRADE HEAT OR REPLACE CARBON-INTENSIVE INPUTS AS A FEEDSTOCK

HIGH-GRADE HEAT FOR INDUSTRY AND AS FEEDSTOCK

1. **Only feasible route for decarbonization of steel**
   Replacement of blast furnace with direct reduction process using hydrogen

2. **At-scale decarbonization of high-grade heat industrial processes**
   Decarbonization route compatible with current processes

3. **Conversion of hydrogen production to ultra-low-carbon hydrogen**
   Decarbonization of hydrogen production where currently used – e.g., in ammonia production, refining and petrochemical industries

Source: FCH JU

Introduction

- Alongside electricity, **H2** will become the **main energy vector** that enables a **zero-emission Europe**.
- In an energy system dominated by the **use of renewable power** from wind and solar, using these green electrons to power whole sectors of the economy poses **insurmountable challenges if not complemented by hydrogen**.
- Hydrogen will play a necessary role in **integrating large amounts of renewable power** in the **transport, industrial processes and heating and cooling sectors**, which are today hard to decarbonise.
- H2 can:
  - serve as an ideal energy vector, **linking renewable energy** sources with **several final uses**
  - have a net zero or low **GHG footprint**, when produced from electrolysis
  - be **transported over long distances**, allowing distribution of energy between countries
  - **store energy** for **long periods** of time, serving as a needed system buffer and providing resilience, e.g. in underground storage
  - **decarbonize** a wide range of final uses, providing clean power and/or heat to **transport and stationary applications**

Source: SRIA, July 2020

Introduction

- H2 production by electrolysis
- Different technologies

Function of temperature

Liquid water:
Low temperature electrolysis

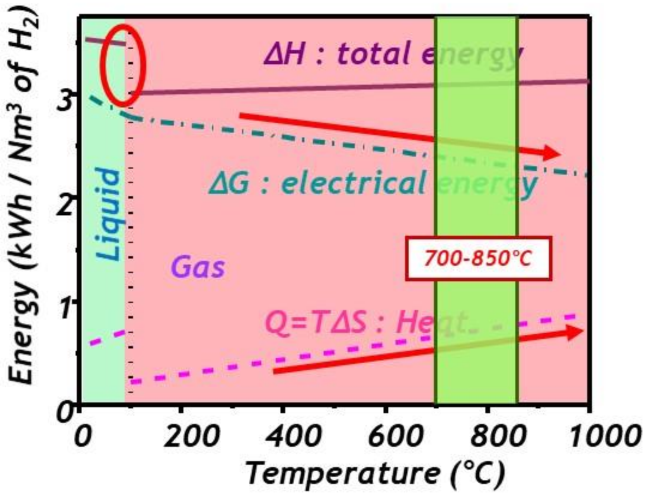
- Alkaline Electrolysis (AEL)
- PEM Water electrolysis (PEMWE)

Steam:
High temperature electrolysis

- High temperature steam electrolysis (HTSE or SOEC)

Benefits of HTE

- High efficient technology



$$H_2O\ (g) \rightarrow H_2\ (g) + \frac{1}{2}\ O_2\ (g)$$

$$\Delta H = \Delta G + T\Delta S \sim \text{constant}$$

To electrolyse a H2O molecule the reaction **overall energy ΔH** has to be provided **either as electric energy** or **as heat**

- **ΔG is the minimum part of electrical energy required for the electrolysis reaction,** the rest can be provided as heat

➡ The hotter the electrolysis operation, the lower the electricity demand:
- High T: energy = 70% electricity, 30% heat
- Low T: energy = 85% electricity / 15% heat

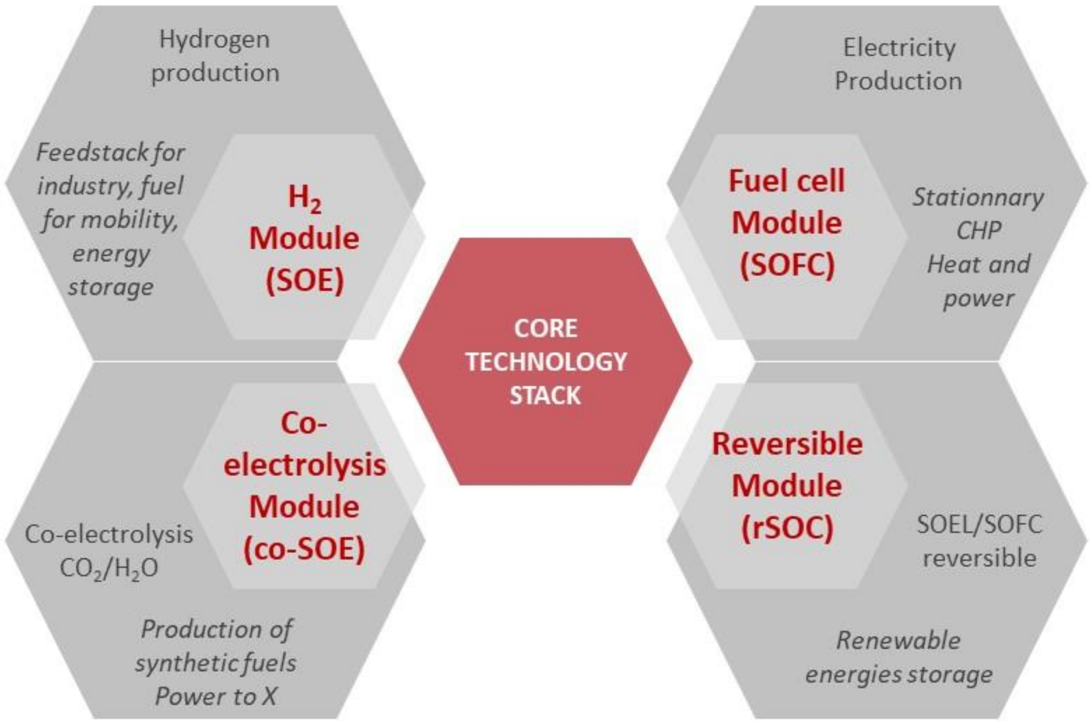
➡ **Main advantage of SOEL with T range = 700-850°C**

Benefits of HTE

- Flexibility of use
  - Same core technology for several applications





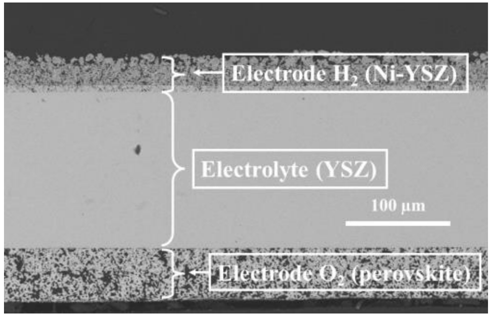




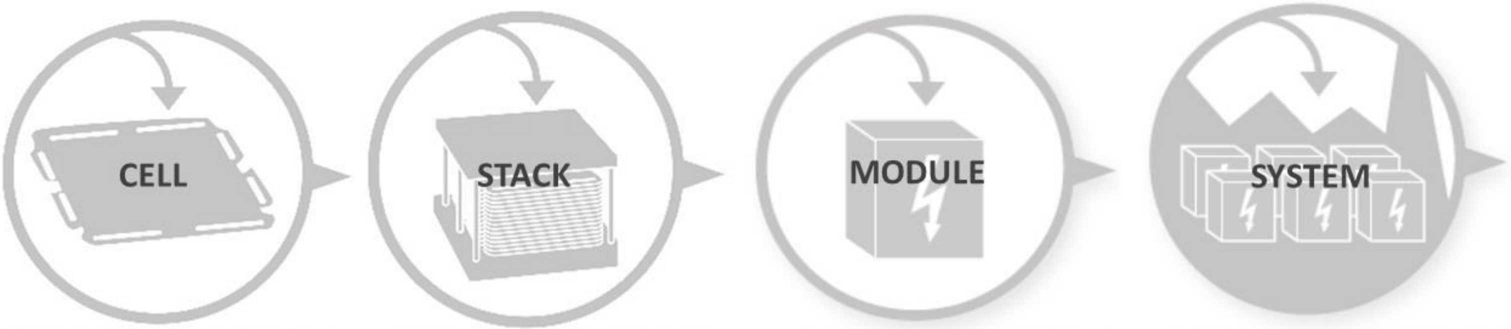



Benefits of HTE

- 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**

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

MULTIPLHY goal and objectives

- **Goal:**
  - manufacturing, installation and integration of the world's first high-temperature electrolyser (HTE) system in multi-megawatt-scale, TRL8
  - at a biorefinery located in Rotterdam / The Netherlands

- **Key figures:**
  - electrical rated connection power of ~ 3.5 $MW_{el,AC}$
  - electrical rated nominal power of ~ 2.6 $MW_{el,AC}$ (HTE and Hydrogen Processing Unit (HPU))
  - hydrogen production rate of ≥ 60 kg_{H2}/h (≥ 670 Nm^3/h), quality of at least 3.0
  - will cover around 1 % of the current hydrogen demand at the biorefinery in Rotterdam.
  - Operation period of 16,000 h
  - leading to substantial GHG emission reductions

MULTIPLHY goal and objectives

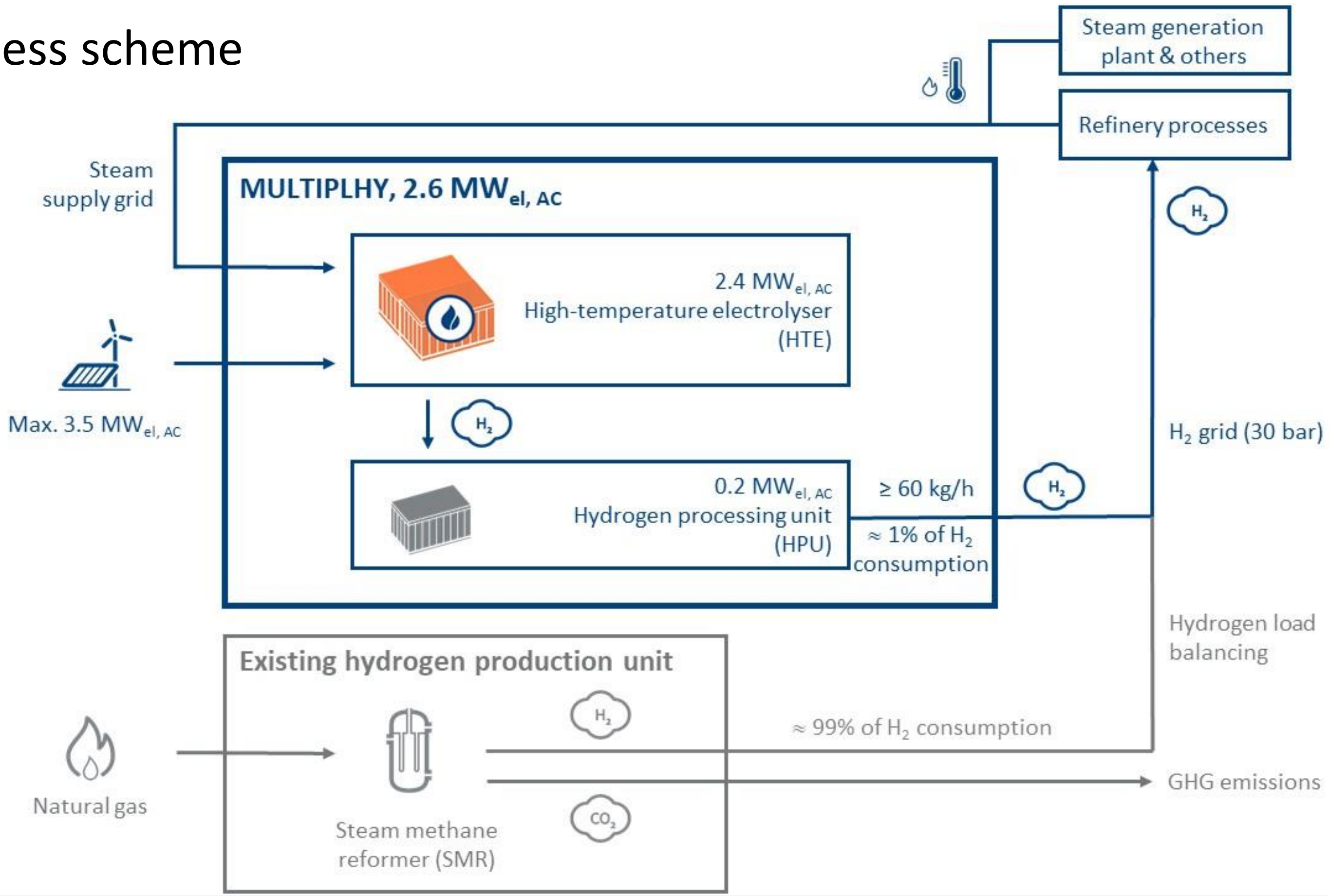
- **Technical objectives**
  - Scale-up of technology to multi-MW
  - Electrolyzer electrical efficiency of up to 85%$_{el,LHV}$
  - Electricity consumption @ nominal capacity: ≤ 39 kWh / kg$_{H2}$
  - Availability: ≥ 98 %
  - Operation for ≥ 16,000 h
  - Production loss rate: ≤ 1.2% / 1000 h

- **Economic objectives**
  - Capital Cost: ≤ 2,400 € / (kgH2/d)
  - Operations & Maintenance cost ≤ 120 €/(kgH2/d)/year
  - Techno-Economic analysis of HTE utilisation in refineries
  - Pave the way for a further upscaling step to a 100 MW scale

- **Societal objectives**
  - Increased awareness of HTE as viable solution within EII
  - Procurement strategy for renewable electricity
  - Certification of the green hydrogen according to CertifHy

Concept and methodology

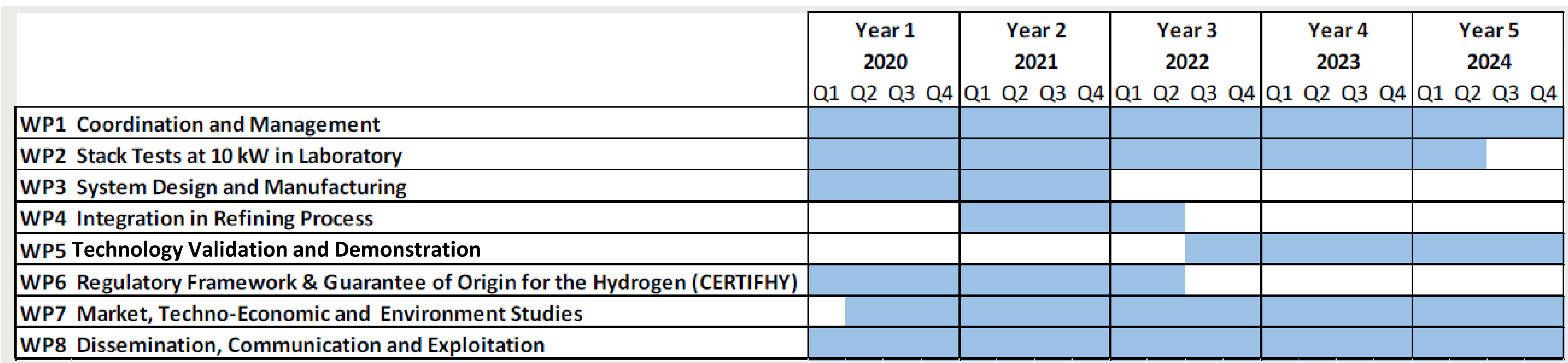
- Process scheme



Concept and methodology

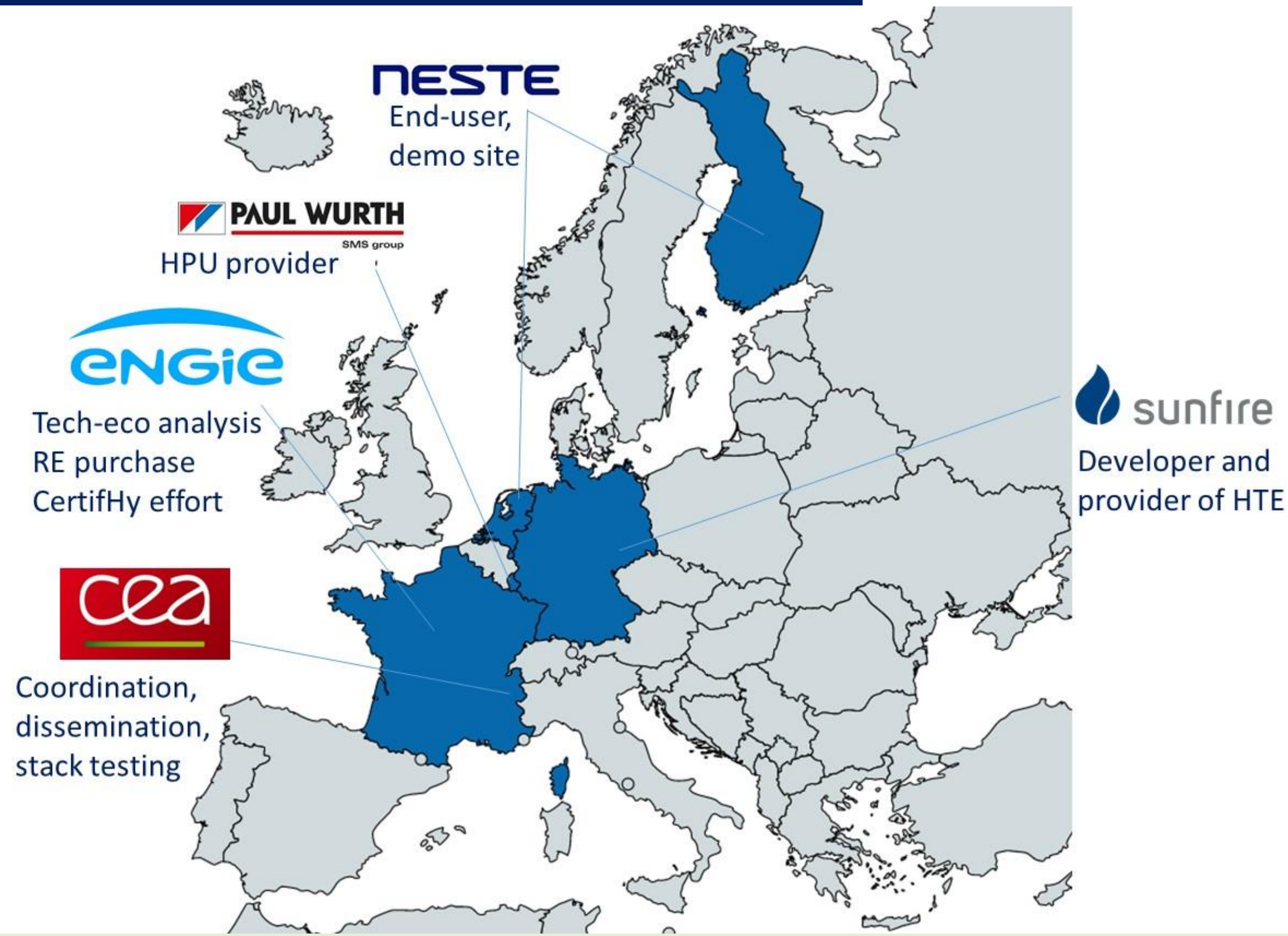
- **Timeline:**
  - Project started 01/01/2020
  - Duration 60 months
  - Installation of demo unit mid 2022

- **Project structure:**



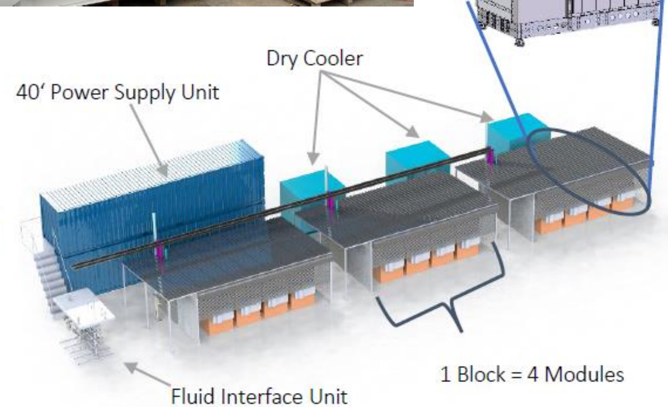
Consortium

- 5 partners
  - 4 industrials
  - 1 RTO



Main tasks

- **System design and manufacturing**
  - Increase the number of stacks per unit: 24 → 36 → 60
  - Improve electrical connection
  - Gen. 2 SOEC module: 220 kWAC
  - Increase of volumetric density: 30 kg/h in a 40 feet container
  - 2 HTE containers installed for MULTIPLHY + 1 HPU container



- **Strategy to increase availability**
  - Further improvement of auxiliary components
    - steam supply, hydrogen compression, purification
  - Redundant installation of failure-prone components
  - Realization of O&M work under operational conditions, which is feasible thanks to the modular design.

Main tasks

- **Integration in refining process**
  - Neste is responsible for integration and site preparation

Main tasks

- **Improvement of stack durability**
  - Benchmark of 3 stack technologies
    - Sunfire:
      - Electrolyte-supported based cells
      - Technology considered for the demonstration
    - CEA
      - Cathode-supported cell
    - Third-party stack - TBC
    - Fingerprint initial performance and short term durability characterization
    - Long term durability of two stacks in the range of 10 kWe
    - + 25 000 h durability on a 2.5 kWel Sunfire stack
  - On-field return on experiment: 16 000 h
  - Target:
    - ASR degradation rate < 17 mΩ.cm²/1000h
    - 1.2%/1000h of H2 production rate

Conclusion

- HTE: a 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 Power-to-X and renewable energy storage
  - Potential to be a "game changer" to produce low cost H_2:
    - ~ 2 € / kg or even less for large units ~ 100 MW
    - ~ 7 € / kg for small decentralized units ~ 100 kW
  - Less mature than low-T technologies, but demonstrators now out of the laboratory worldwide, and power growing exponentially

- MULTIPLHY will build and operate the world's largest high temperature electrolysis demonstration unit

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- Thank you for your attention !