Hydrogen Research & Innovation Days
24-25 November 2025

MULTIPLHY

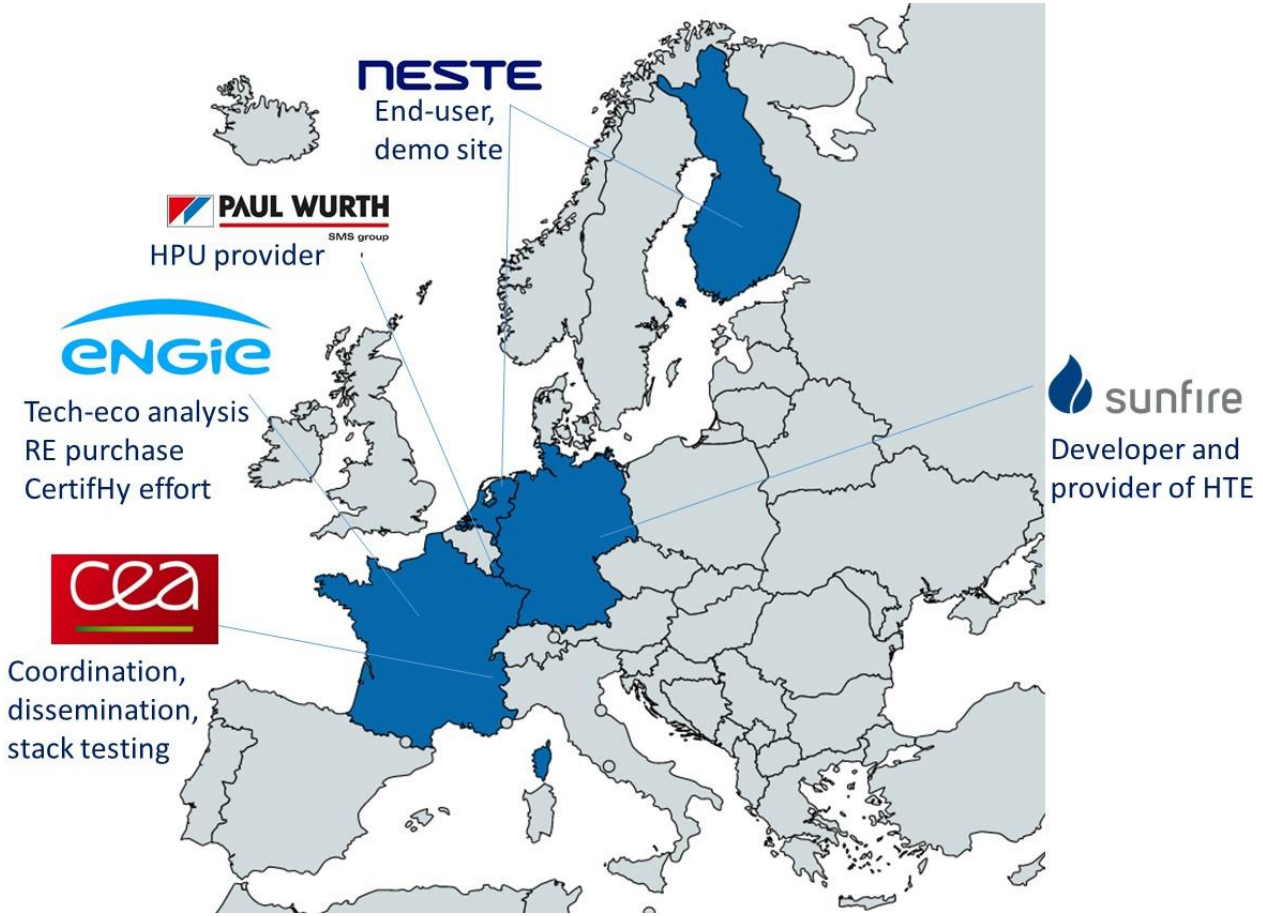
DESIGN, LABORATORY CHARACTERIZATION, ACCEPTANCE TESTS, COMMISSIONING AND START-UP OF A 2.6 MW HIGH TEMPERATURE STEAM ELECTROLYSIS SYSTEM IN A REFINERY

Clean Hydrogen Partnership

Co-funded by the European Union

MULTIPLHY project at a glance

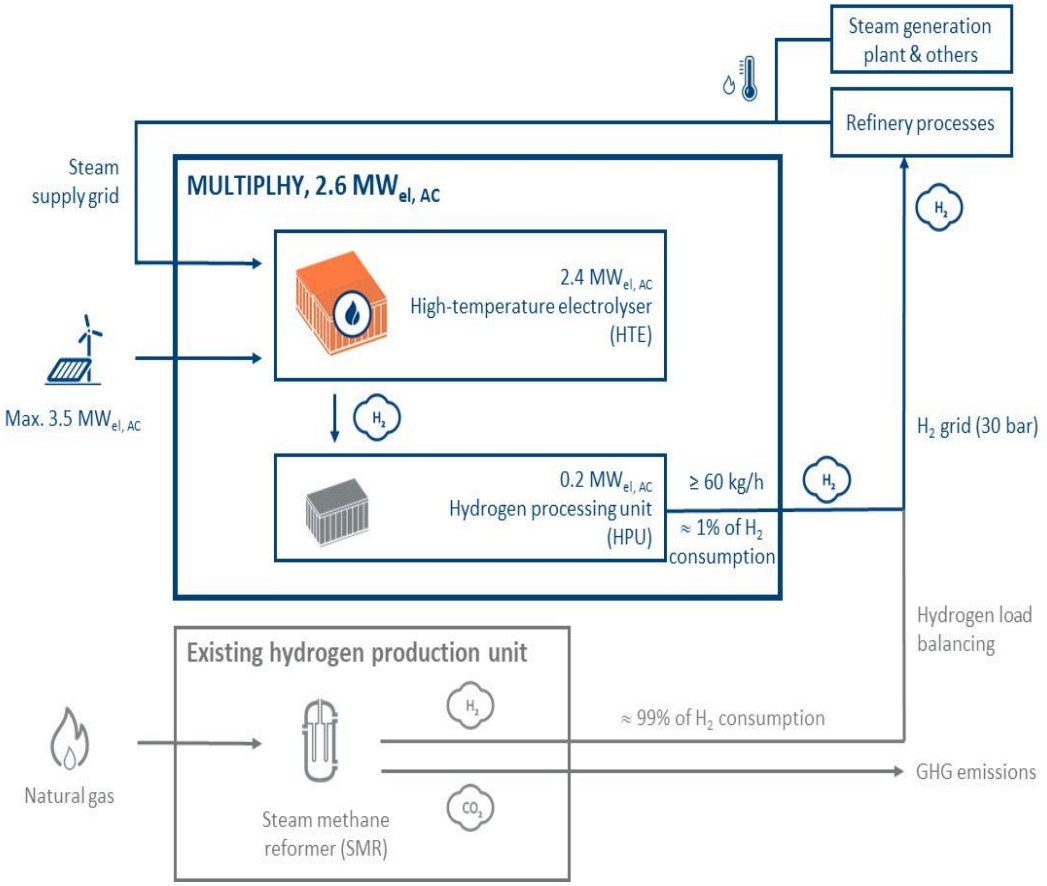
- EU funded project
  - Call FCH-02-2-2019: Multi megawatt high-temperature electrolyser for valorisation as energy vector in energy intensive industry
- Project start: 01/2020 ; duration: 72 months
- Partners:
  - CEA (F),
  - NESTE (FI, NL),
  - SUNFIRE (D),
  - PAUL WURTH (L),
  - ENGIE (F)



MULTIPLHY project main objectives

- **Goal:**
  - Manufacturing, installation and integration of the world's first multi-MW high-T electrolyser (HTE) system
  - At a renewable products refinery located in Rotterdam / The Netherlands

- **Key figures:**
  - Electrical rated nominal power of ~ 2.6 MWel,AC (HTE & Hydrogen Processing Unit (HPU))
  - Hydrogen production rate of ≥ 60 kgH2/h (≥ 670 Nm³/h)
- **Technical objectives:**
  - Electrolyser electrical efficiency of up to 85%$_{el,LHV}$
  - Nominal Electricity consumption: 39 kWh/kg$_{H2}$
  - H_2 Production loss rate: ≤ 1.2% / 1000 h



Benefits of High T Electrolysis

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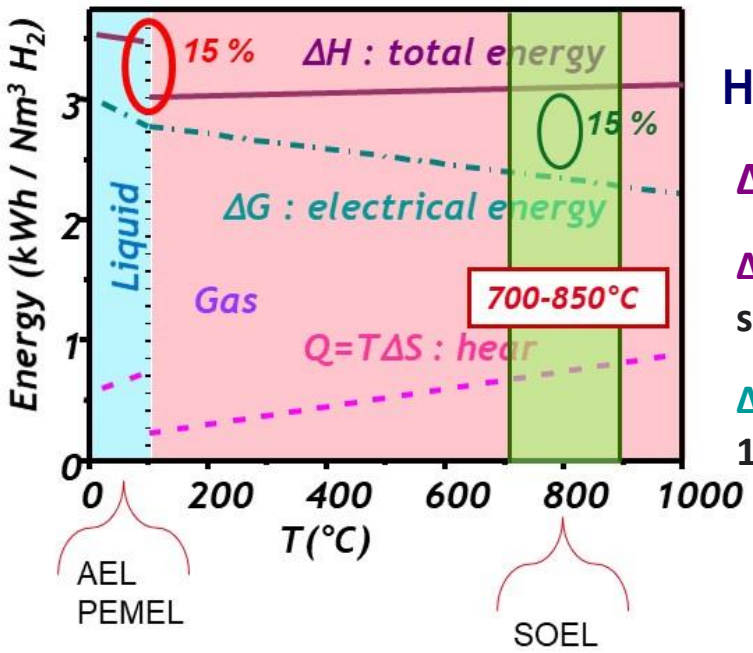
HIGH EFFICIENCY TECHNOLOGY



H_2O (g) → H_2 (g) + ½ O_2 (g)

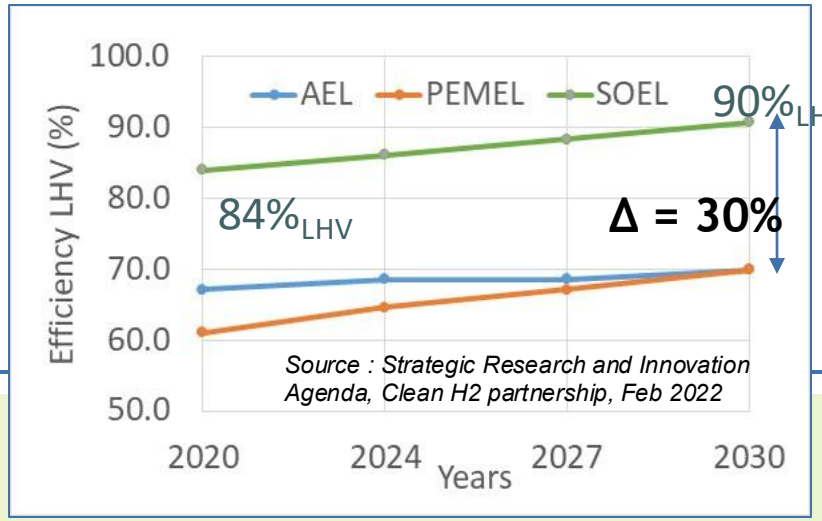
ΔH = **ΔG** + **TΔS** ~ constant

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

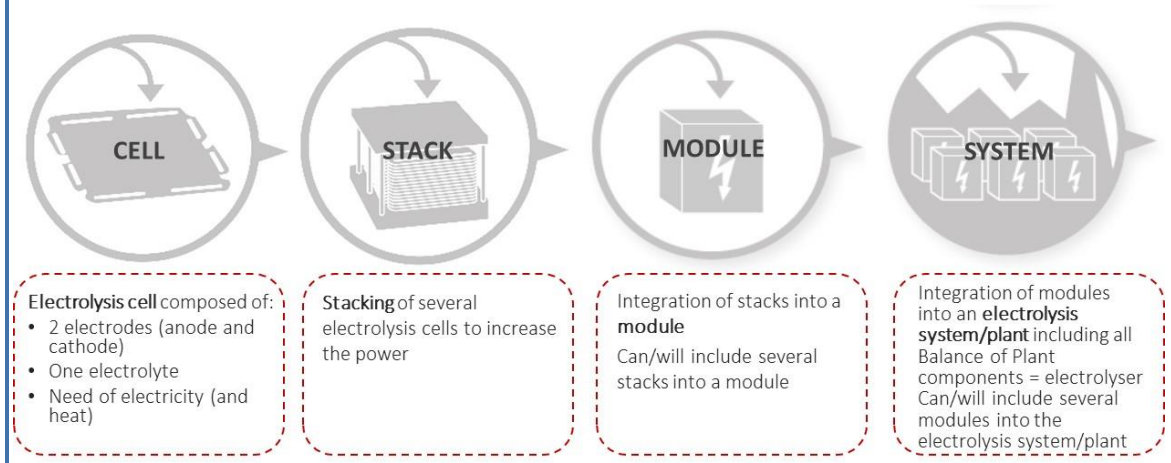
ΔG : Rising in T saves **15% additional electricity**

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

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

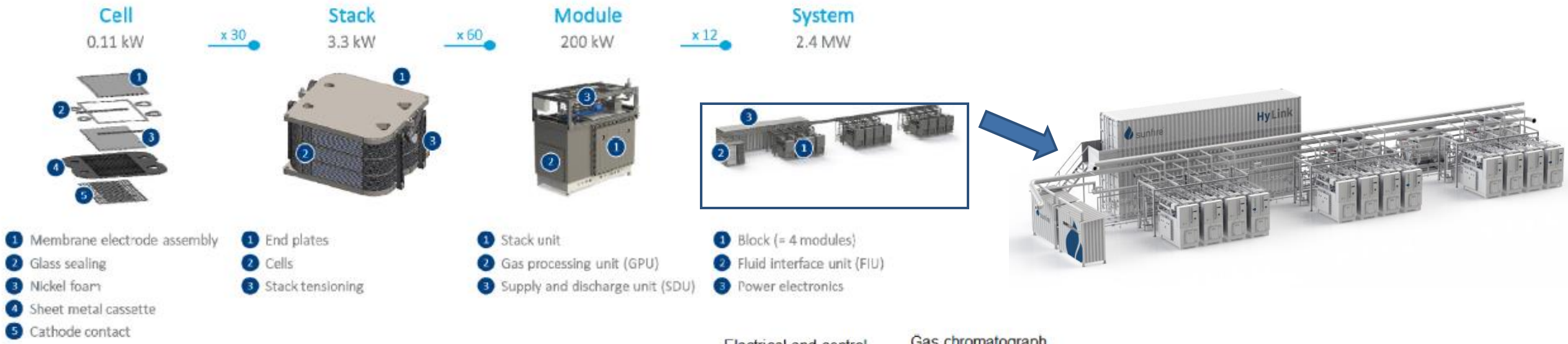


MODULAR TECHNOLOGY WITH NO NOBLE CATALYSTS

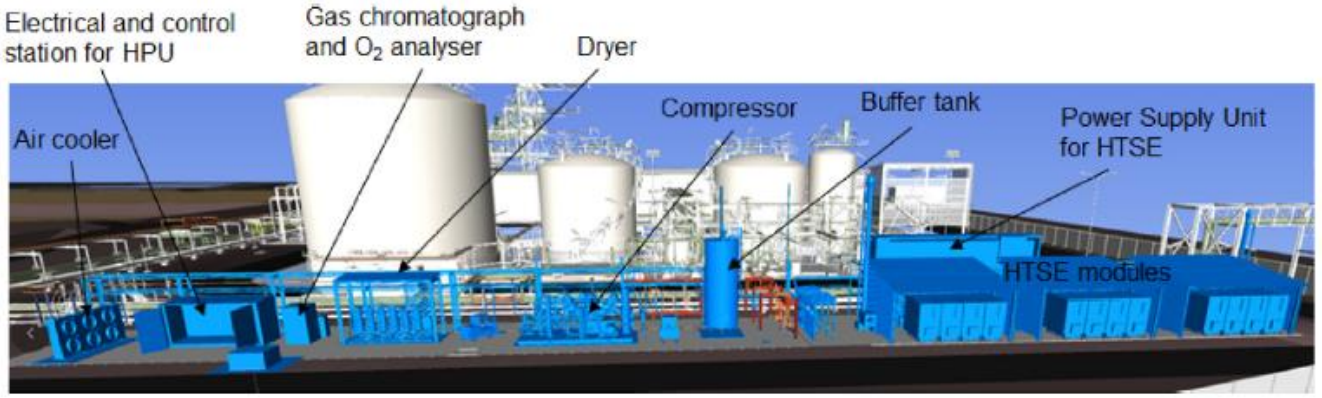


MULTIPLHY Demonstration unit

- **High temperature electrolyser (HTE):**
  - Large upscaling step compared to previous projects: X 17 vs GrinHy (150 kW), X 3.6 vs GrinHy 2.0 (720 kW), installed in Salzgitter steel plant
  - Modular design of the HTE part: 3 blocks of 4 modules each comprising 60 stacks of 30 cells



- **Hydrogen Processing Unit (HPU)**
  - to meet quality (at least 3.0) and pressure (30 bar) criteria of the refinery process
  - Comprises several components:



Factory acceptance test

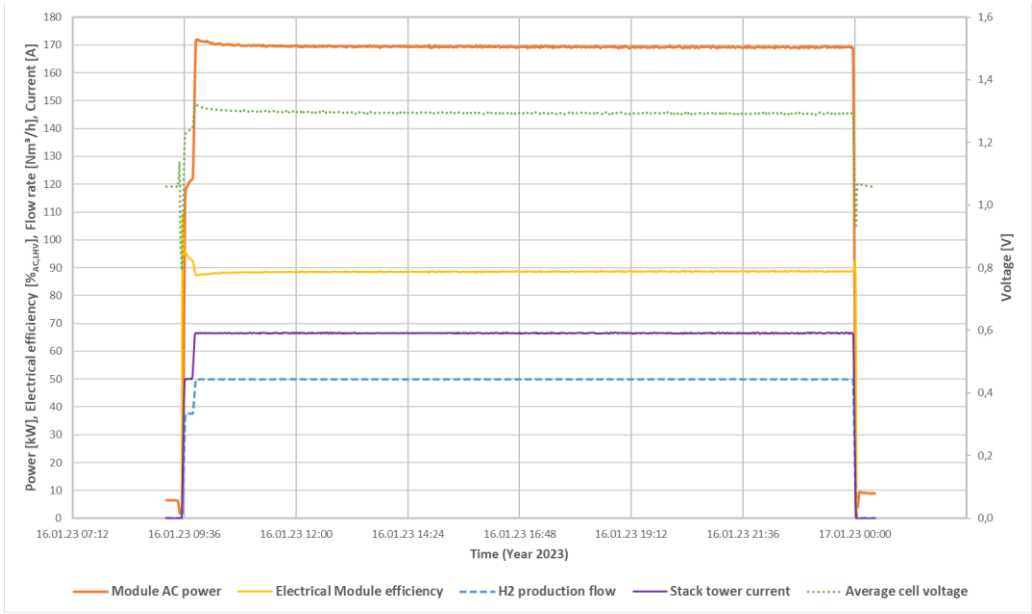
- **For each HTE module**
  - Cold commissioning + Leakage test+Operation test: rated and maximum load
  - All modules passed FAT at first time → Could be shipped on site
  - 65.7 Nm³/h H_2 production achieved per module
  - Very homogenous temperatures and voltages in stacks
  - Module efficiency :
    - above 86 % $_{el,LHV}$ at full load
    - up to 89 % $_{el,LHV}$ at part load

- **For HPU components**
  - Mechanical/pressure tests, leakage tests, visual inspection, coupling
  - Components passed → Could be shipped on site

sunfire	FAT-Protocol	Document No.: F-D&P-036-00
	HyLink Modul Gen2.1.1	Module no.: Module #01

Location	Dresden, Germany	Verifier	*Anonymized*
Variation	HyLink Modul	Type of test	Factory Acceptance Test
Generation	Gen2.1.1	Test according to	EN 60204:06-2019
Article no.	ASW-103732	Date	24.05. – 30.05.22
Revision status no.	A00	Test equipment	FAT-TS C011
Serial number	SYS-100357	Test procedure	PS-PRO-056-00

Test result	PASS



Site preparation

- Civil and structural works
- Piping
- Electrical substation
- Instrumentation, automation and contr
- Safety approval
- Installation of the different elements
- Interface connections


HTE unit


Compressor


HTE module

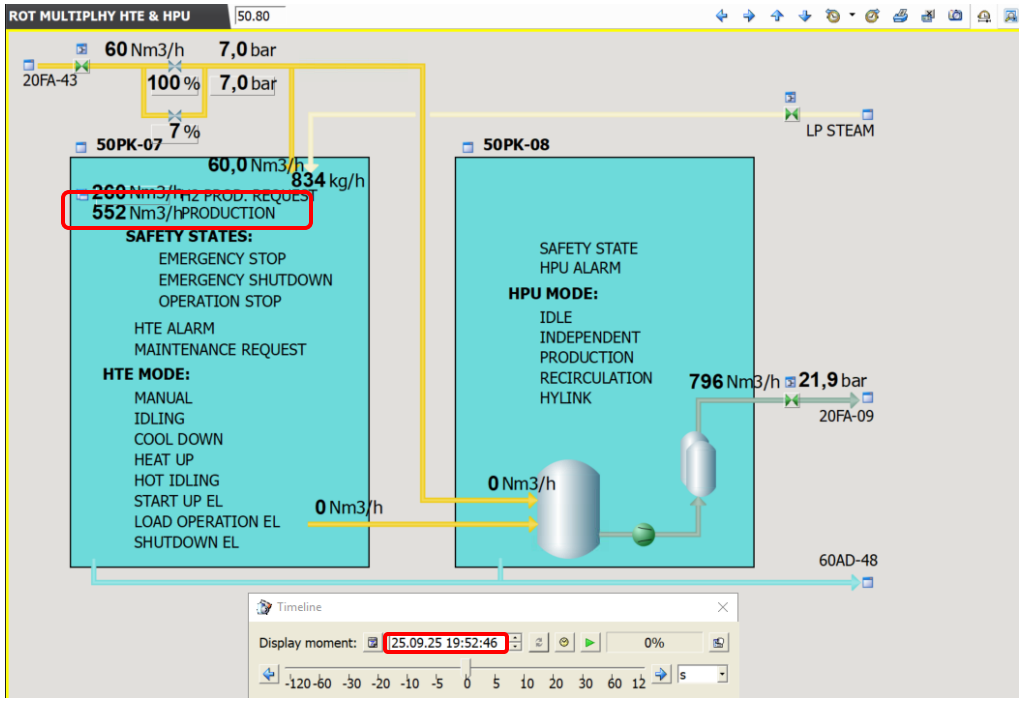

HPU unit

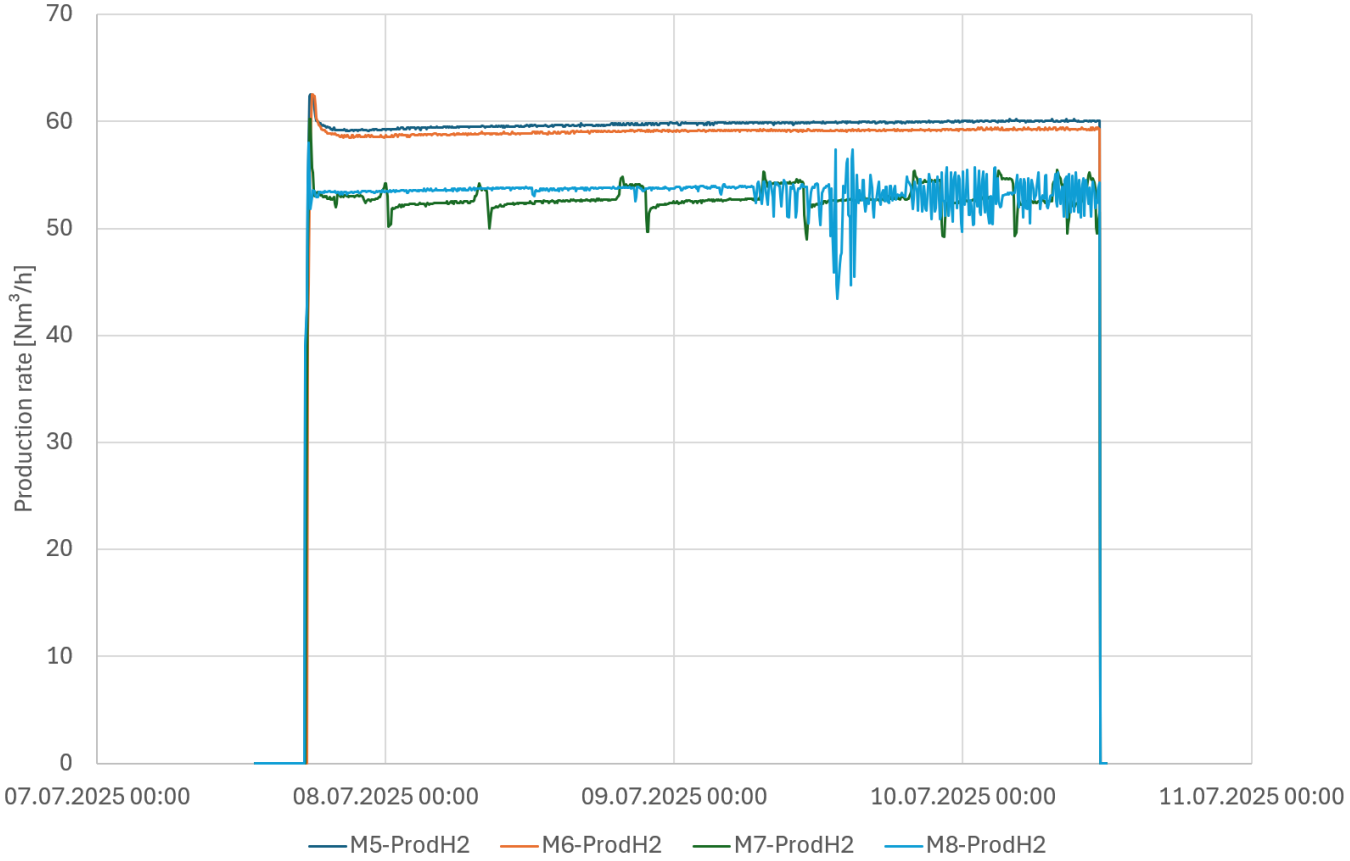
Validation steps before startup

- **HTE unit:**
  - Cold commissioning (N_2 and instrument air as media)
    - I/O checks; Purging and flushing of lines; Calibration of sensors and gas detectors
    - Equipment and group functional testing
  - Start-up (H_2 and steam as media)
    - Leakage tests
    - Bringing power supply unit online
    - Heat up -> All modules taken from cold state to hot idling mode
    - SOEC operation -> First production of Hydrogen by modules in singular and blockwise manner
- **HPU unit:**
  - Cold commissioning (N_2 as media)
    - I/O check; Equipment function tests; Group function tests
  - Start-up (H2 as media)
    - Leakage test
    - Running HPU in Independent mode – compressing up to 30 barg
- **Coupling of Hydrogen from modules to HPU system**

Start-up

- HTE system capable of operation since mid 2024
- Delays due to repairs on auxiliary equipments with long lead times
- Example of 4 days of operation of block 2 in July 2025



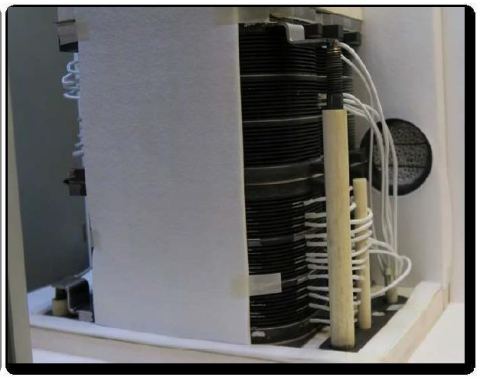


- Injection of H2 in the refinery process performed on 25 September 2025

Long term stack tests

- **2 types of stacks**
  - Sunfire: Electrolyte supported cells (ESC)
  - CEA: Cathode supported cells (CSC)
- **2 power ranges:**
  - ~ 3-6 kW
  - ~ 8-19 kW

CEA stack
25 x 100 cm² CSCs
2.2-2.7 kW

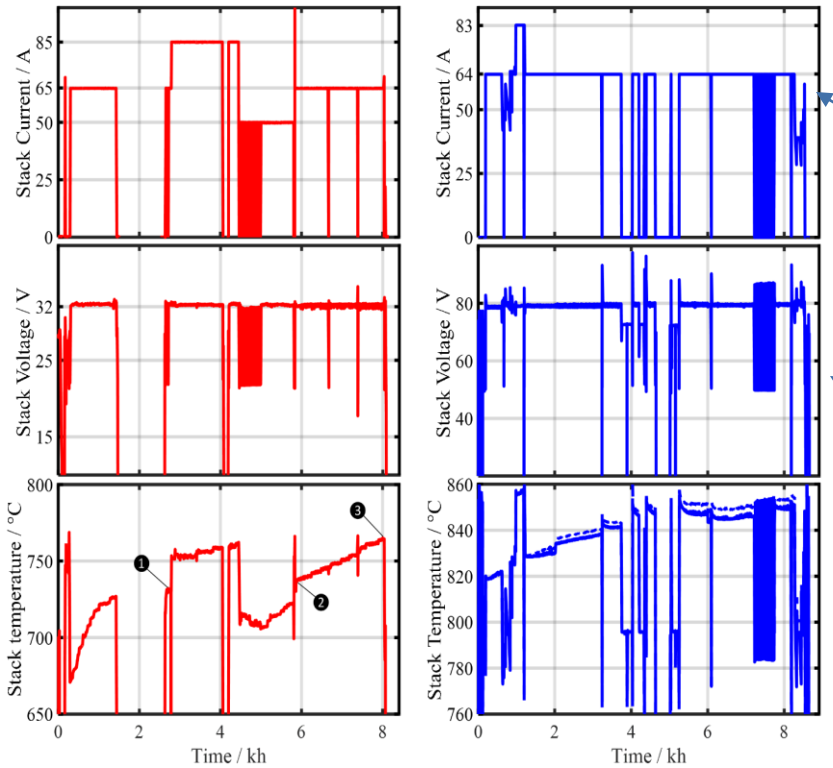


Sunfire pile of 2 stacks
2 x 30 x 128 cm² ECSs
2x2.5 kW

- **Harmonized test protocol:**
  - Performance maps at BoL and EoL
  - Several steps at constant current in thermoneutral conditions
  - Load point and thermal cycles
  - For long term operation:
    - Fixed current density for fixed H_2 production: - 0.65 A/cm² as ref., up to 0.9 A/cm² on latest/large stacks
    - Constant steam conversion (SC): ≥ 60%
    - Stack voltage maintained at 1.3V to reduce thermal gradients in the stack and maximize efficiency.
    - Stack T increased to compensate for the degradation and maintain the cells in (near) thermoneutral voltage

Long term stack tests

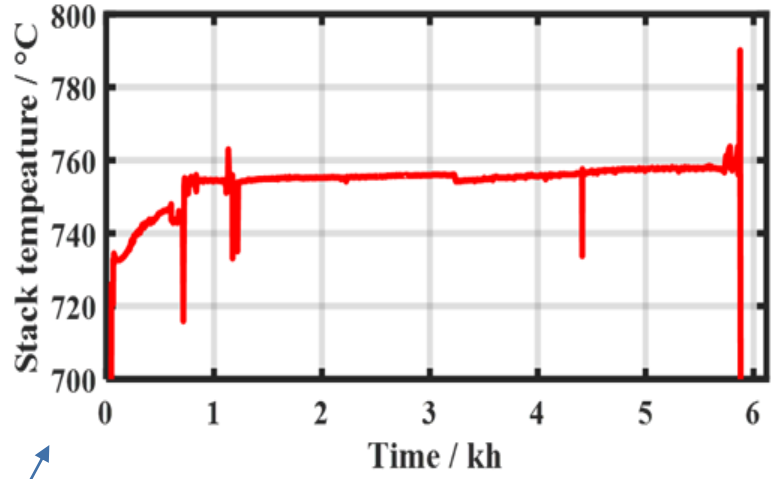
- **Successful operation of all stacks: > 42,000 h of test data**
  - Tests ranging between 7 and 8 kh for 3-6 kW stacks
  - Tests ranging between 6 and 8 kh for 8-19 kW stacks



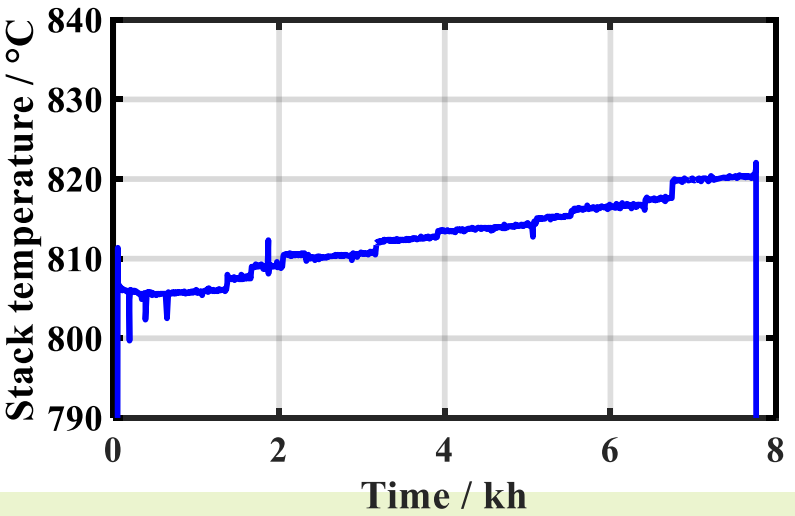
CSC stack | ESC stack

- **Constant I → No H2 production loss over the whole duration thanks to the smart strategy adopted**
- **Constant U (thermoneutral voltage)→ maximum efficiency and minimum thermal gradient**
- **> 3 tons of H_2 generated by one single stack over the test duration**

CSC stack, - 0.9 A/cm²



ESC stack, - 0.79 A/cm²



Conclusion

- **Largest HTE electrolyser installed in an industrial environement**
  - Key figures:
    - 2.6 $MW_{el,AC}$ (HTE and HPU)
    - Hydrogen production rate of ≥ 60 kg_{H2}/h (≥ 670 Nm^3/h)
    - electrolyser electrical efficiency of up to 86%$_{el,LHV}$
    - Smart operating strategy for the stacks to avoid hydrogen production loss over the time of operation
  - Successful FAT of HTE and HPU
  - Site preparation
  - Commisionning
  - Startup completed
- **Long term stack testing**
  - Extensive study on 2 types of stacks of 2 power ranges
  - Durability evaluated over periods of up to 8000h
  - Total accumulated testing time > 42000 h
  - Operation at zero hydrogen production loss validated

Acknowledgements

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Design, laboratory characterization, factory acceptance tests and installation of a 2.6 MW High temperature steam electrolyser in a refinery

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Thank you for your attention

- Please visit MULTIPLHY website for latest results and publications: https://multiplhy-project.eu/
- Read: https://doi.org/10.1016/j.ijhydene.2025.02.070