MULTIPLHY

High temperature electrolysis latest developments in the frame of the MULTIPLHY project

Julie Mougin, Jérome Aicart, CEA, France

Arthur Gajewski, Sunfire GmbH, Germany

Anand Kumar Agrawal, Paul Wurth S.A, Luxembourg

Heidi Bergman, NESTE, Finland

Pierre Olivier, ENGIE Lab CRIGEN, France

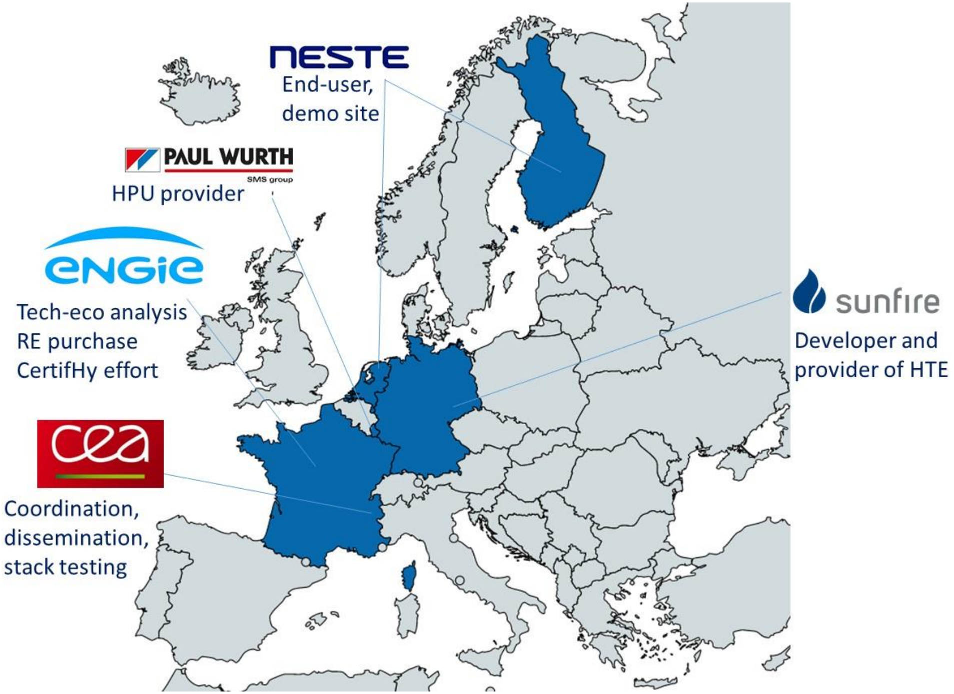
WHEC 2024, Cancun, Mexico, 24-27 June

Outline

- **Context: the MULTIPLHY project**
- **Presentation of the High Temperature Electrolysis (HTE) technology**
- **MULTIPLHY Demonstration unit**
- **Long term stack testing results**
- **Conclusion**

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: 60 months
- Partners:
  - CEA (F),
  - NESTE (FI, NL),
  - SUNFIRE (D),
  - PAUL WURTH (L),
  - ENGIE (F)



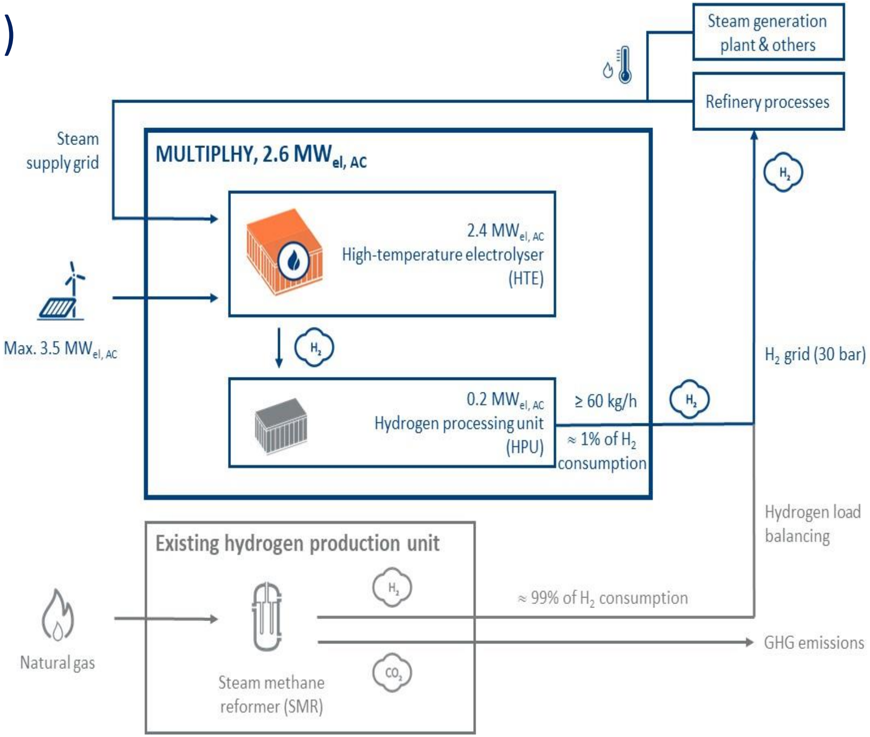
MULTIPLHY project main objectives

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

MULTIPLHY project main objectives

- **Key figures:**
  - Electrical rated connection power of ~ 3.5 MWel,AC
  - Electrical rated nominal power of ~ 2.6 $MW_{el,AC}$ (HTE & Hydrogen Processing Unit (HPU))
  - Hydrogen production rate of ≥ 60 kg_{H2}/h (≥ 670 Nm^3/h)
  - Operation period as long as possible
  - Leading to substantial GHG emission reductions

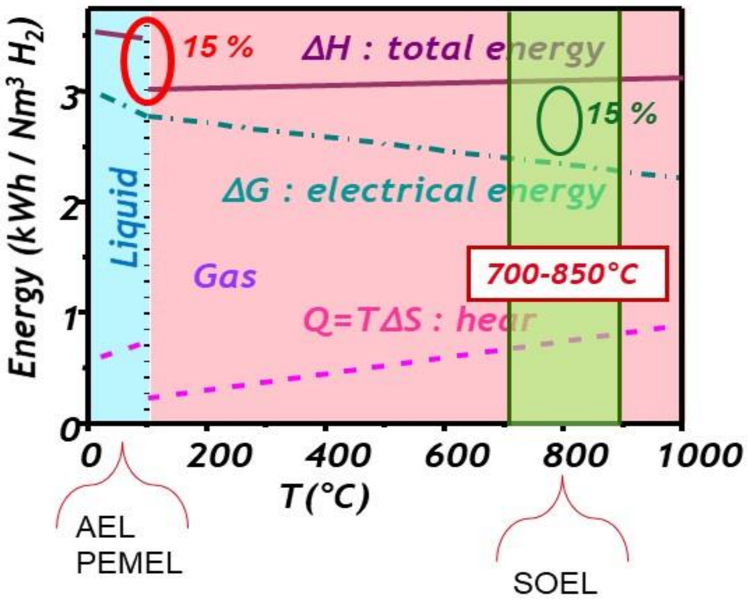
- **Technical objectives:**
  - Electrolyzer electrical efficiency of up to $85\%_{el,LHV}$
  - Nominal Electricity consumption: 39 kWh/kg_{H2}
  - Availability: ≥ 98 %
  - H_2 Production loss rate: ≤ 1.2% / 1000 h



Presentation of the HTE technology

MULTIPLHY

HIGH EFFICIENCY TECHNOLOGY EXPECTATION



H_2O (g) → H_2 (g) + ½ O_2 (g)

ΔH = ΔG + TΔS ~ constant

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

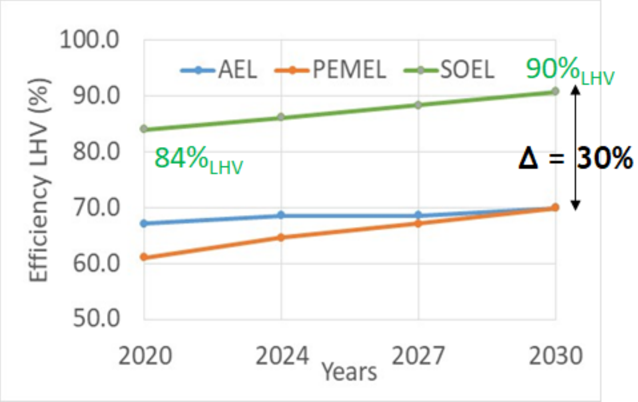
ΔG : Rising in T saves **15% additional electricity**

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

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

➡ SOEL operating range = 700-850°C

EFFECTIVE EFFICIENCIES

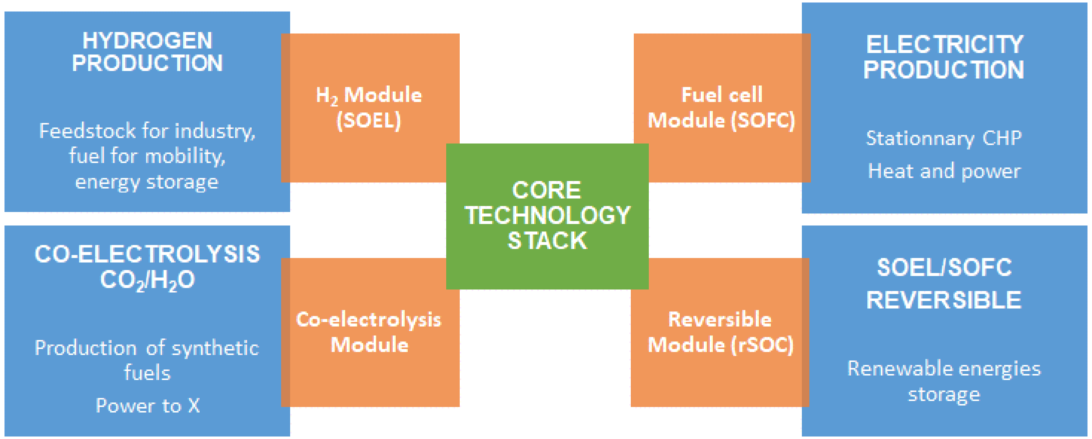


Source : Strategic Research and Innovation Agenda, Clean H2 partnership, Feb 2022

Presentation of the HTE technology

VERSATILE and FLEXIBLE TECHNOLOGY

- Versatile:
  - Same core technology for several applications
- Flexible:
  - Different fuels can be used

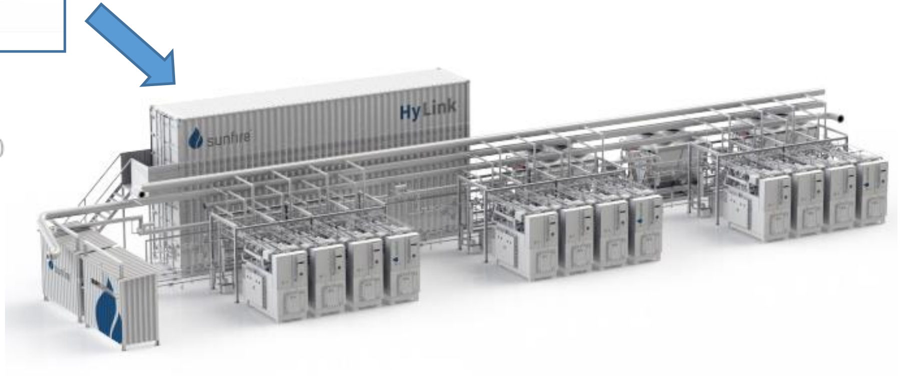


MODULAR TECHNOLOGY

- No noble catalysts

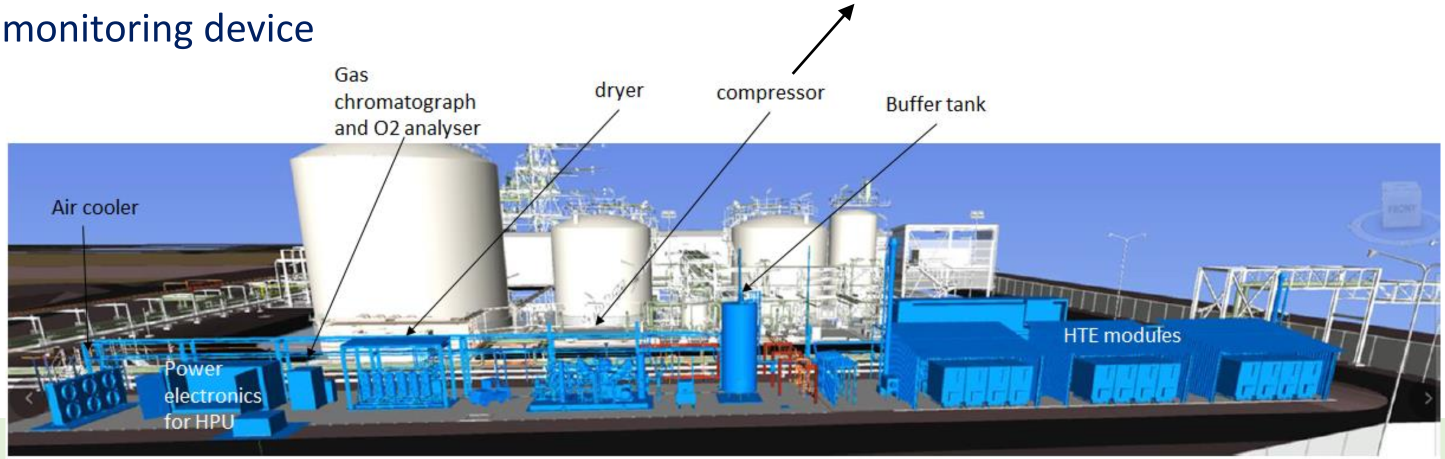
MULTIPLHY Demonstration unit

- **Description:**
  - **High temperature electrolyser (HTE):**
    - Hydrogen production rate of ≥ 60 kgH2/h (≥ 670 Nm³/h),
    - Large upscaling step: X 17 vs GrinHy, X 3.6 vs GrinHy 2.0 previous projects
    - Modular design of the HTE part: 3 blocks of 4 modules each comprising 60 stacks of 30 cells



MULTIPLHY Demonstration unit

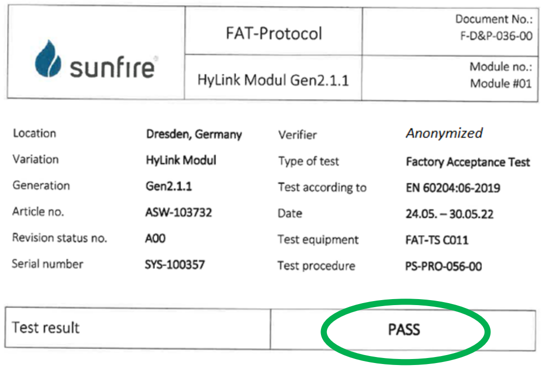
- **Description:**
  - **Hydrogen Processing Unit (HPU)**
    - to meet quality (at least 3.0) and pressure (30 bar) criteria of the refinery process
    - Comprises several components:
      - Hydrogen buffer tank
      - Hydrogen Compressor
      - Hydrogen Dryer
      - Air cooler and chiller
      - Gas quality online monitoring device



MULTIPLHY Demonstration unit

MULTIPLHY

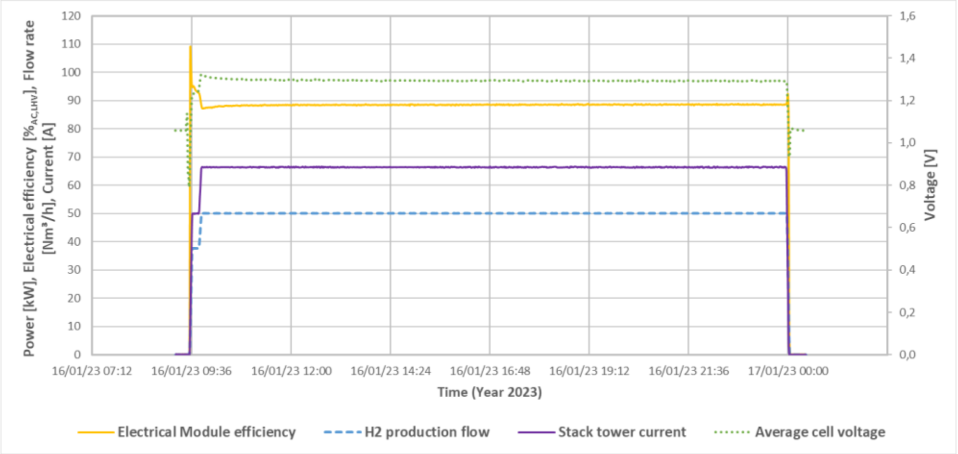
- **Validation steps before startup:**
  - Factory acceptance test for each HTE module
    - Cold commissioning
    - Leakage test
    - Operation test: rated and maximum load
  - All modules passed FAT at first time → Could be shipped on site
    - 65.7 Nm³/h H_2 production achieved per module
    - Very homogenous temperatures and voltages in stacks
    - Module efficiency more than 84 % $_{el,LHV}$



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

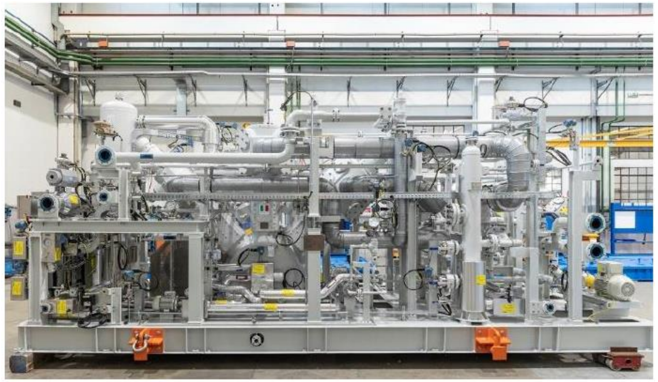
Test result	PASS



MULTIPLHY Demonstration unit

- **Validation steps before startup:**
  - Factory acceptance test for HPU components
    - Compressor: Mechanical running test with control of P&T of key elements, noise, speed of vibration, leakage + visual inspection
    - Dryer and Chiller: run of dryer with chiller connected : check of absence of leakage and of remote signals
    - H2 tank: Visual inspection, NDT (non destructive testing) and pressure test of tank
    - Analyzers: Visual inspection of analyzers and valves panel
  - Components passed → Could be shipped on site

Compressor



Air cooler

MULTIPLHY Demonstration unit

- **Validation steps before startup:**
  - Site preparation
    - Civil and structural works
    - Piping
    - Electrical substation
    - Instrumentation, automation and control
    - Safety approval
  - Installation of the different elements
  - Interface connections

HTE unit

Compressor

HTE module

HPU unit

MULTIPLHY Demonstration 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
  - Pre-Startup Safety Review meeting held (PSSR3) and documentation signed
  - 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
    - Coupling of Hydrogen from modules to HPU system
  - Site Acceptance Test (SAT)
    - To be completed

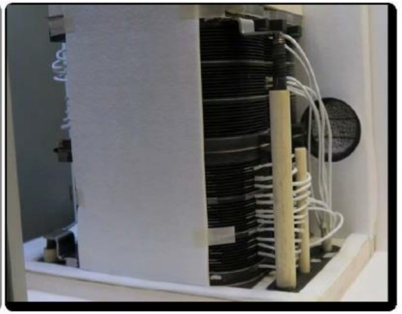
MULTIPLHY Demonstration unit

- **Validation steps before startup – HPU unit:**
  - Cold commissioning (N_2 as media)
    - I/O check
    - Equipment function tests
    - Group function tests
  - Pre-Startup Safety Review meeting (PSSR3) is signed
  - Start-up (H_2 as media)
    - Leakage test
    - Running HPU in Independent mode – compressing up to 30 barg
    - Coupling with HTE up to 6 modules
  - Site Acceptance Test (SAT)
    - To be completed

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
- **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

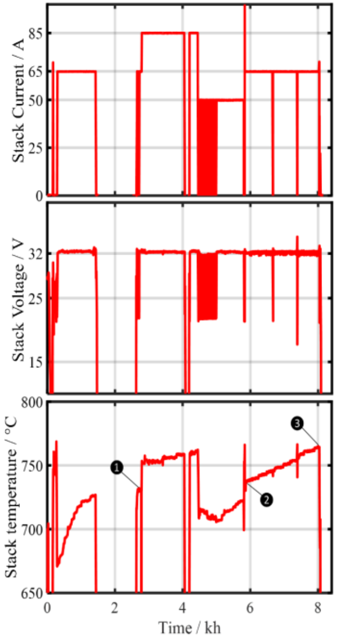
CEA stack
25 x 100 cm² CSCs



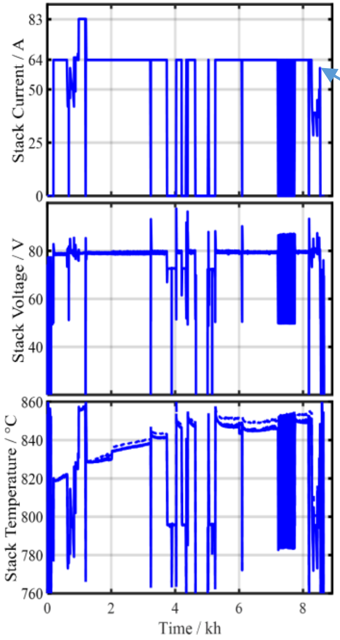
Sunfire pile of 2 stacks
2 x 30 x 128 cm² ECSs

Long term stack tests

- **Successful operation of all stacks**
  - Tests ranging between 7 and 8 kh for 3-6 kW stacks
  - Tests ranging between 3 and 6 kh for 8-19 kW stacks



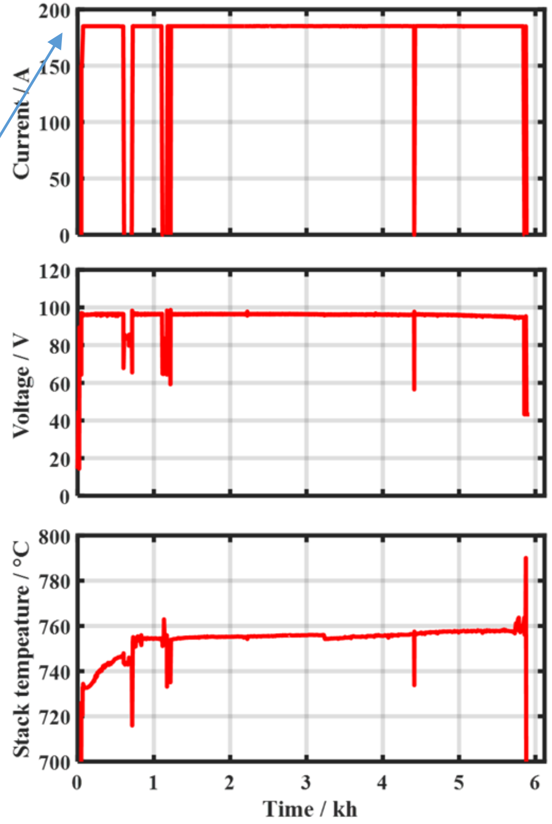
CSC stack



ESC stack

- **Constant I → No H2 production loss over the whole duration thanks to the smart strategy adopted**

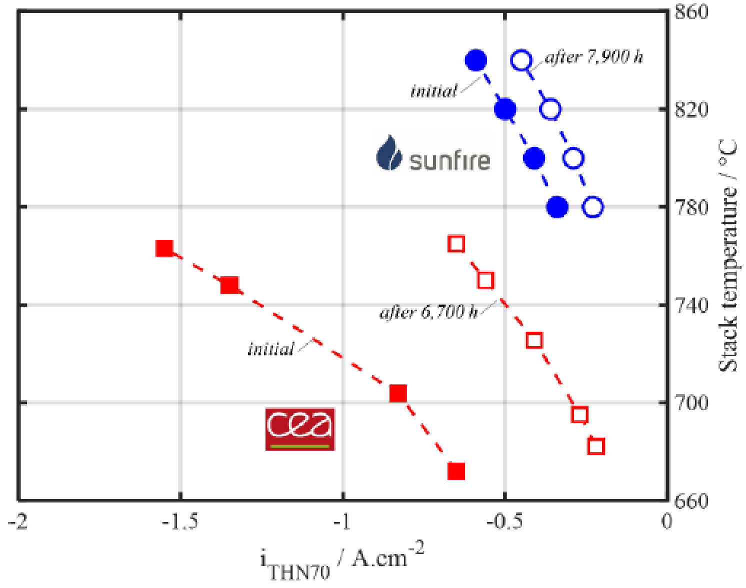
- **> 3 tons of H_2 generated by one single stack over the test duration**



Long term stack tests

- **Successful operation of all stacks**
  - Performance maps before and after durability tests
  - Significant gap in performances between CSC and ESC stacks:
    - Initial: about 200°C
    - Final: about 100°C
  - Drop of performances over time:
    - ~ 60% for CSC stack, ~ 25-30% for ESC stack
    - Apparent degradation decreases with higher T
  - ➔ Importance of T when evaluating degradation
  - ➔ Degradation rate ≠ Lifetime at iso-performances due to T_{BoL}
  - Extrapolated lifetime of up to 15000 h at iso-performance expected with this operation strategy until T_{EoL} is reached
  - After T_{EoL} is reached, operation still possible with decreased hydrogen production

For 3-6 kW stacks



(Thermoneutral voltage & 70%SC)

Conclusion

- **Largest HTE electrolyser installed in an industrial environement**
  - Key figures:
    - 2.6 $MW_{el,AC}$ (HTE and Hydrogen Processing Unit (HPU))
    - Hydrogen production rate of ≥ 60 kg_{H2}/h (≥ 670 Nm^3/h)
    - Electrolyzer electrical efficiency of up to $85\%_{el,LHV}$
    - 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 to be 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 > 25000 h
  - Operation at zero hydrogen production loss validated

Acknowledgements

- This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 875123. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Thank you for your attention

- Please visit MULTIPLHY website for latest results: https://multiplhy-project.eu/

Disclaimer

- The presentation was created with the utmost care. However, the MULTIPLHY partners do not assume any liability for the accuracy, completeness and timeliness of the contents.
- The information in this presentation is for general informational purposes and is not an offer or part of an offer.
- This presentation and the texts, images, and diagrams included in this presentation are subject to copyright protection. Unauthorized use or distribution is prohibited unless otherwise explicitly agreed to by the respective MULTIPLHY partners to hold such copyright.
- The brands and trademarks mentioned on this presentation are subject to applicable trademark law and property rights of their respective owner without restriction. The words "Sunfire“, “HyLink” and the "Flame" logo are registered trademarks of Sunfire GmbH, Germany. The mere mention of a trademark does not imply that it is not protected by intellectual property rights.