SOEC ELECTROLYSIS

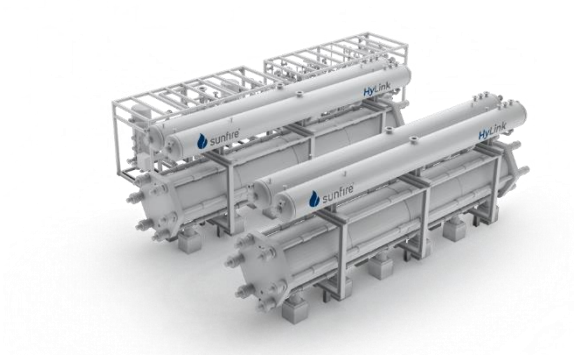
The game changer for industrial applications

05/04/23 Christian von Olshausen (CTO)

EXECUTIVE SUMMARY

Sunfire is a leading industrial electrolysis company

Solutions & Markets

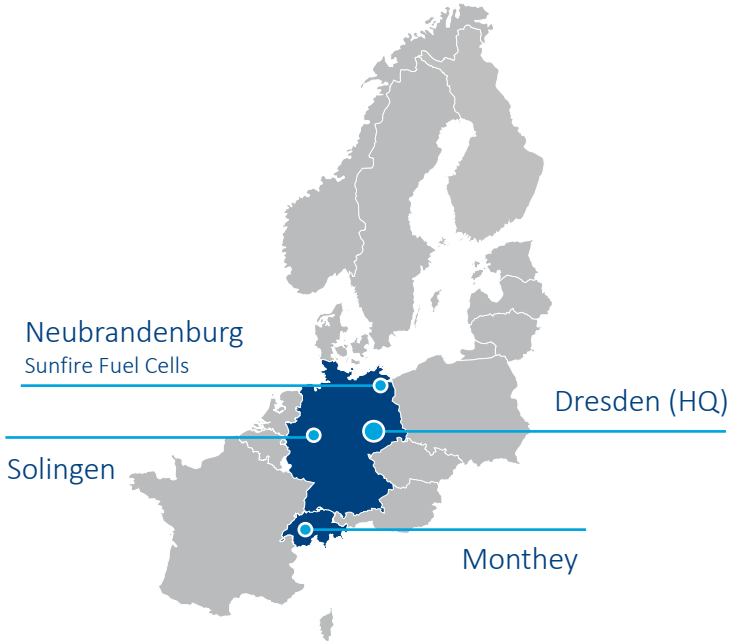


Pressurized Alkaline Electrolyzers

Solid Oxide (SOEC) Electrolyzers

Steel | Refineries | Utilities | Chemicals | Mobility

Company Sites

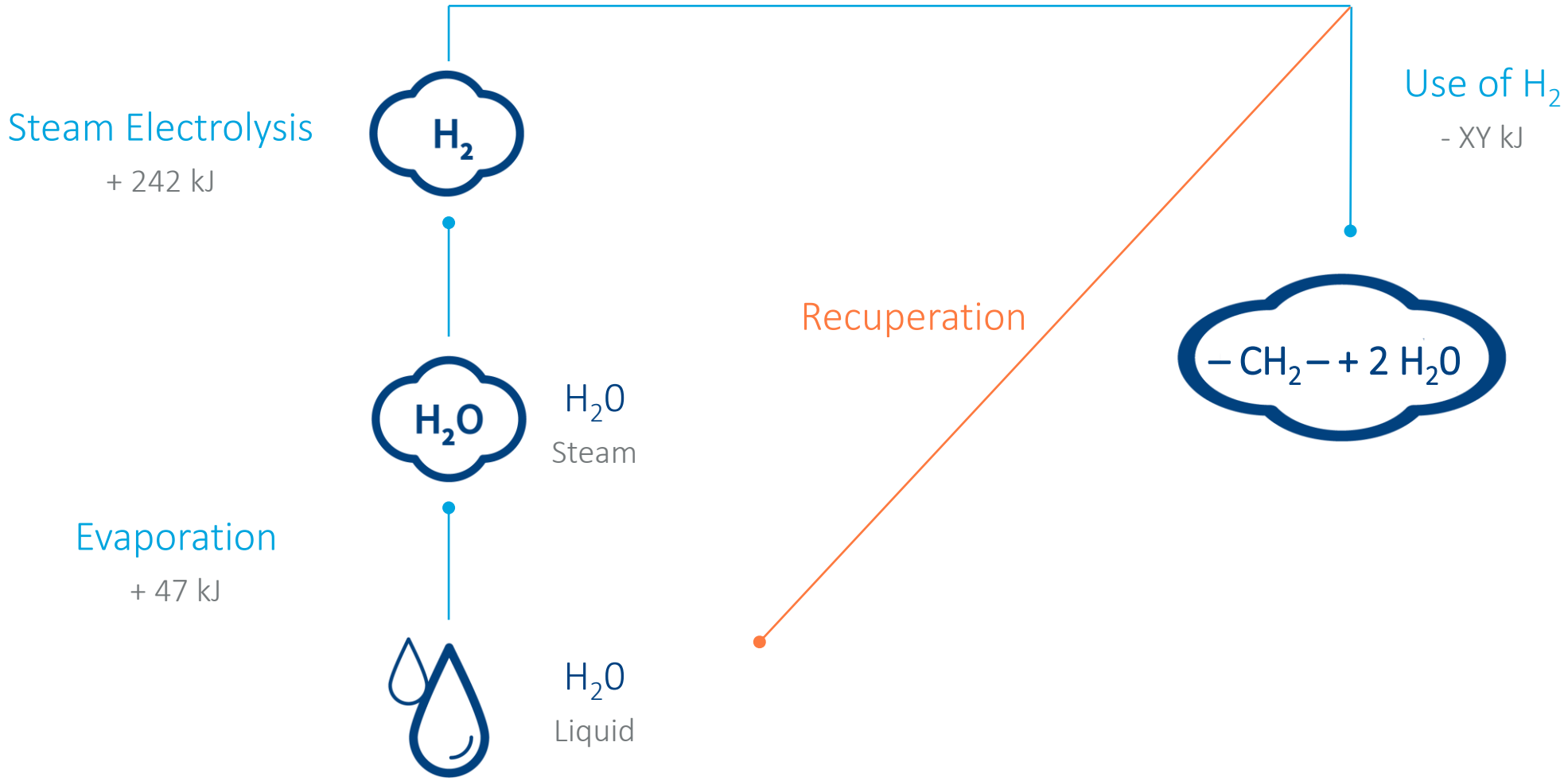


> 70	> 250 MW	100 MW	500 MW/year	> 500	> EUR 500 m
Electrolysis projects[1)]	Installed capacity[1)]	Largest electrolyzer installation	Production capacity as of 2023	Talented employees	Private and public funding

1) Including projects from predecessor alkaline company “IHT SA” prior to the acquisition by Sunfire

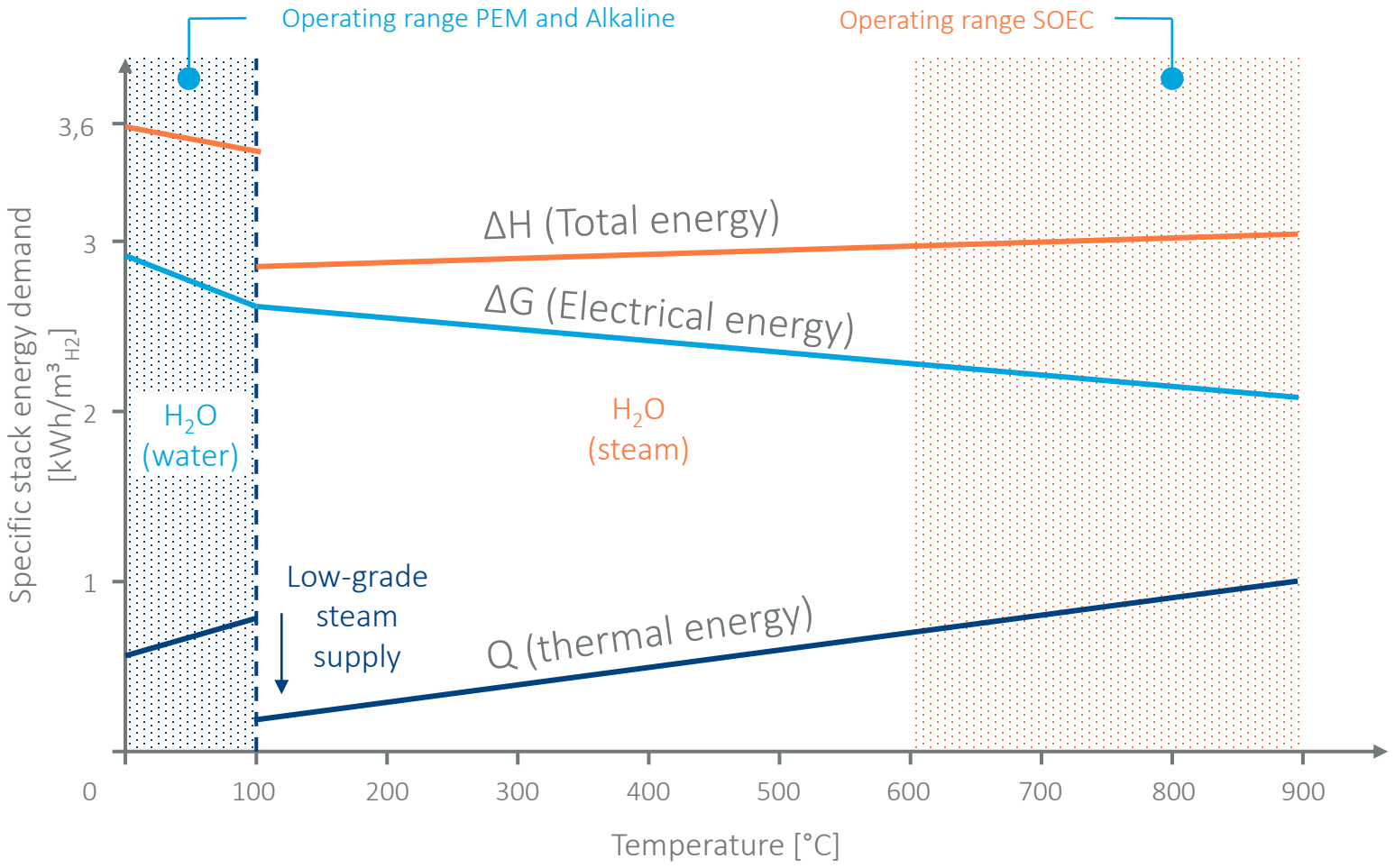
OPERATING PRINCIPLE

SOEC electrolysis uses heat as additional energy feed to electricity



SOEC CONVERSION EFFICIENCY

SOEC's efficiency outperforms low-temperature electrolysis technologies



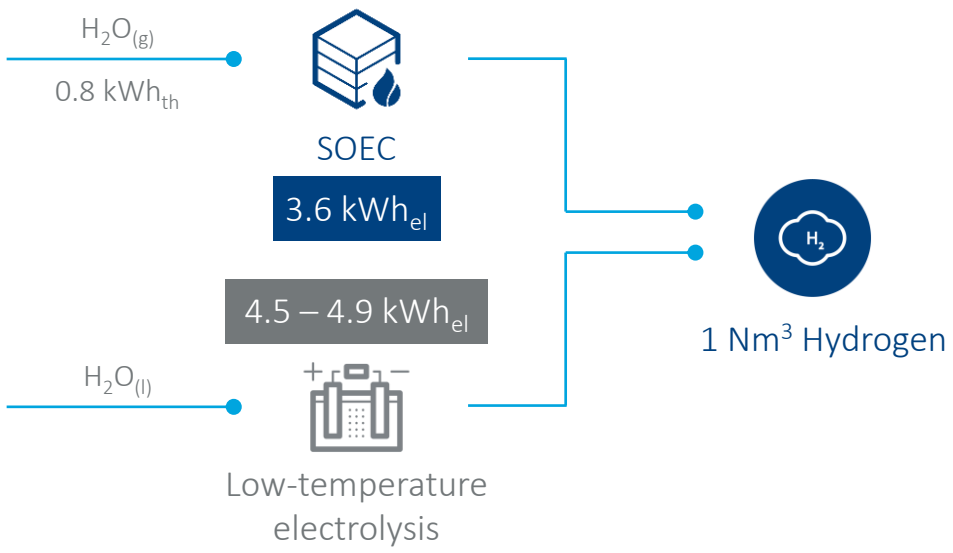
- Due to the dissociation of steam, SOECs require less energy compared to liquid water.
- SOEC has a theoretical minimum stack efficiency advantage of 16 % assuming optimal low-temperature conversion.
- As roughly one-fifth of the total required energy comes from heat, SOECs require less renewable electricity.
- Today, compared to state-of-the-art low temperature electrolysis, SOECs achieve a 30 % higher conversion efficiency on a system level.

CORE ADVANTAGES

SOEC achieves superior electrical efficiency and produces syngas in one step

Electrical Efficiency

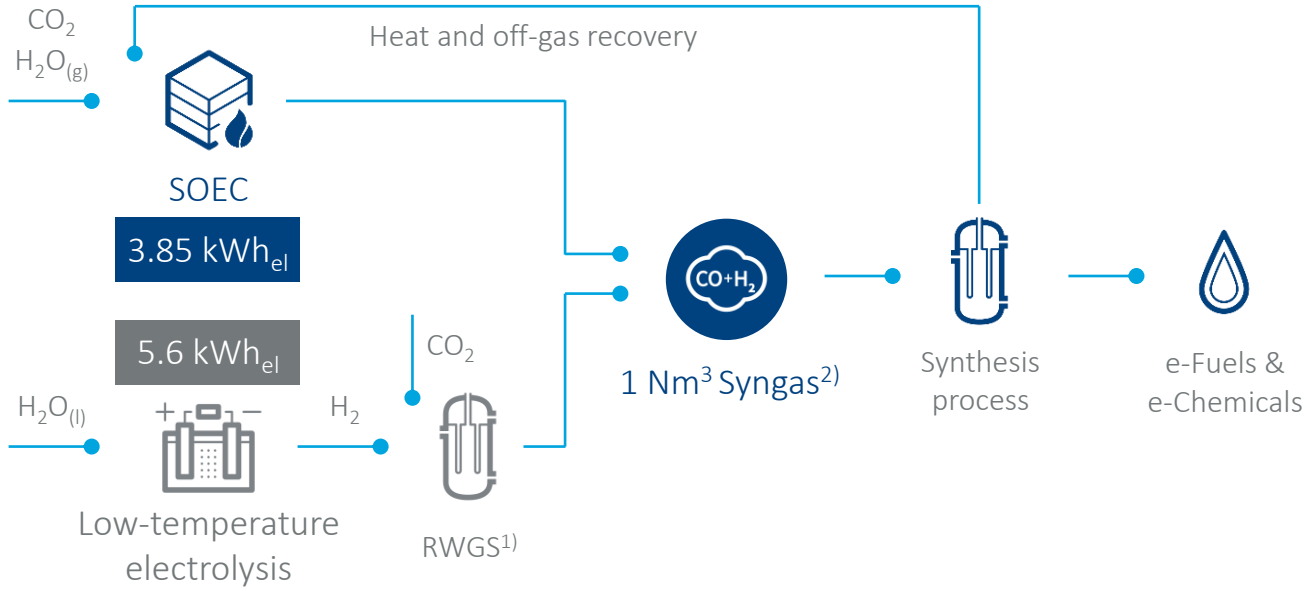
3.6 kWh_{el}/Nm^3



- SOEC uses heat (provided as steam) as additional energy feed to electricity, thus lowering electricity demand
- The efficiency advantage translates into electricity savings of up to 25 %

CO_2 utilization capability

One-step syngas production



- With a one-step SOEC co-electrolysis of CO_2 and H_2O to syngas, significant CAPEX and OPEX savings can be realized
- Production of syngas for Fuels and Chemicals requires a more CAPEX and energy intensive 2-step process using low-temperature electrolysis

1) Reverse-Water-Gas-Shift reaction is required in order to generate Carbon monoxide (CO) 2) 3.17 kWh/Nm^3 lower heating value of syngas (H_2:CO = 2)

GRINHY

First industrial demonstration of SOEC electrolyzers

Salzgitter
Germany

SALZGITTER FLACHSTAHL
Ein Unternehmen der Salzgitter Gruppe

1 MW
-150 / +30 kWAC RSOC prototype system

- Reversible SOC system with 3 operation modes
  - Hydrogen production (40 Nm³/h)
  - Power production from natural gas
  - Power production from hydrogen
- Integrated into an iron-and-steel works using existing infrastructures
- System tested for load management and grid balancing
- Decommissioned after 13,000 hours
- 90,000 Nm³ H2 produced and injected

Note: This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826350. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Germany, Luxembourg, Italy, France.

GRINHY2.0

In the follow-up project, SOEC electrolysis has reached megawatt scale

Salzgitter
Germany

SALZGITTER FLACHSTAHL
Ein Unternehmen der Salzgitter Gruppe

PAUL WURTH
SMS group

1 MW
SOEC

Steel
Application

2020
Commissioned

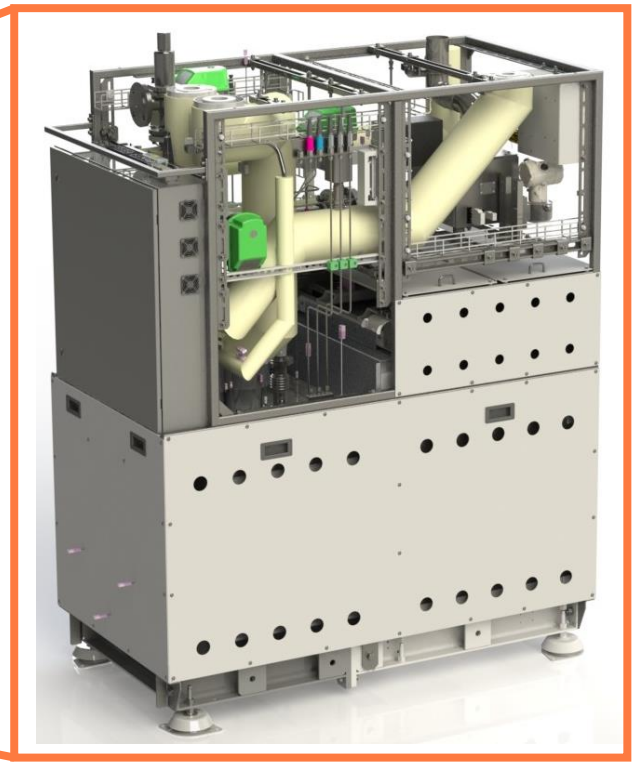
GrInHy2.0
Green Industrial Hydrogen

Showcasing renewable hydrogen production via SOEC's steam electrolysis at megawatt-scale, utilizing waste-heat from the iron- and steel works of Salzgitter Flachstal GmbH.

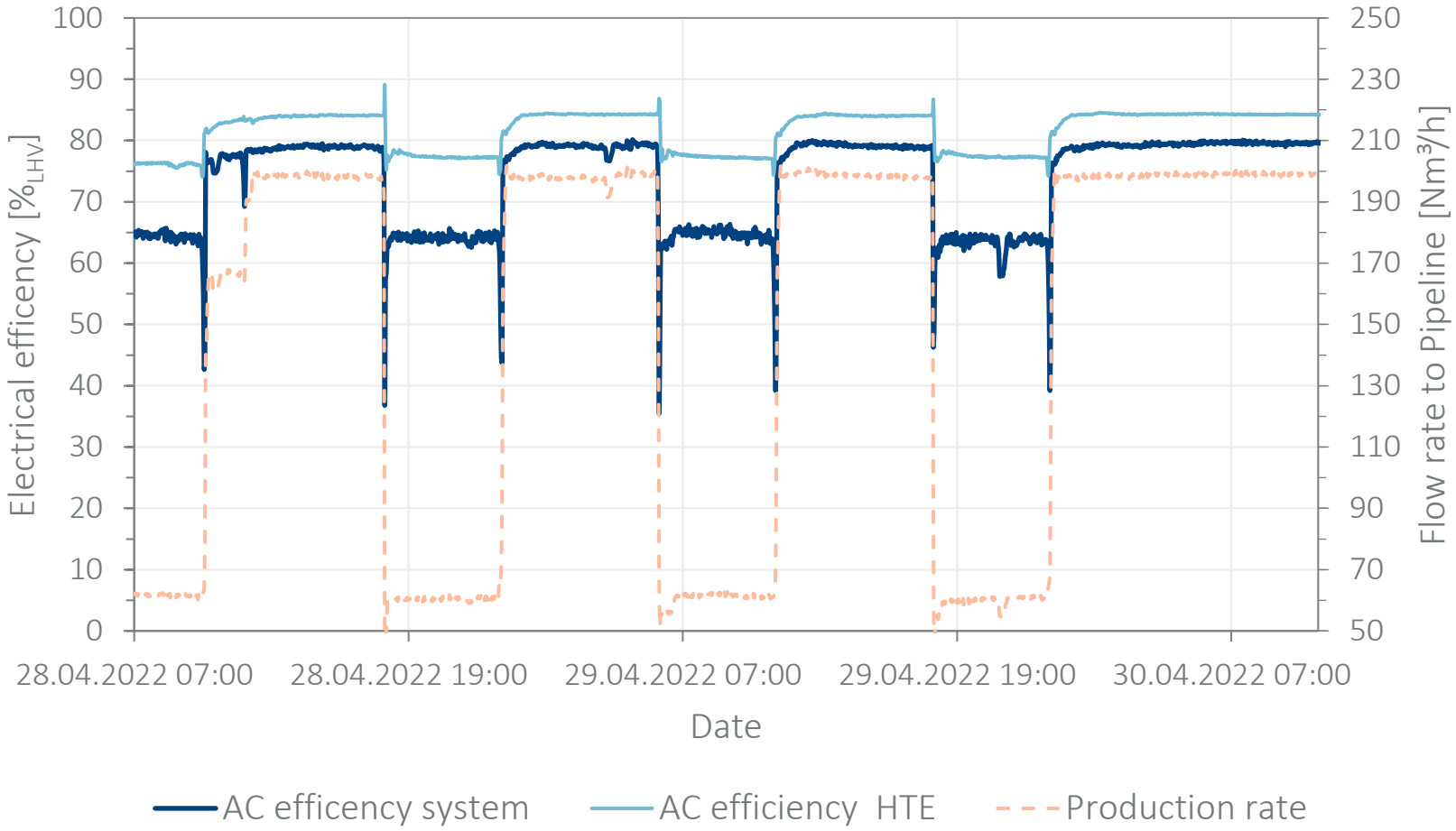
Note: This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826350. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Germany, Luxembourg, Italy, France.

Salzgitter Flachstahl operates the world's largest high-temperature electrolyzer

- Up to 8 modules of generation 1 in a containerized system
  - Up to 1 MW electrolysis power
  - Easy transport and implementation
  - Modular approach enables rapid exchange and low downtime



The SOEC electrolyzer has achieved record efficiency

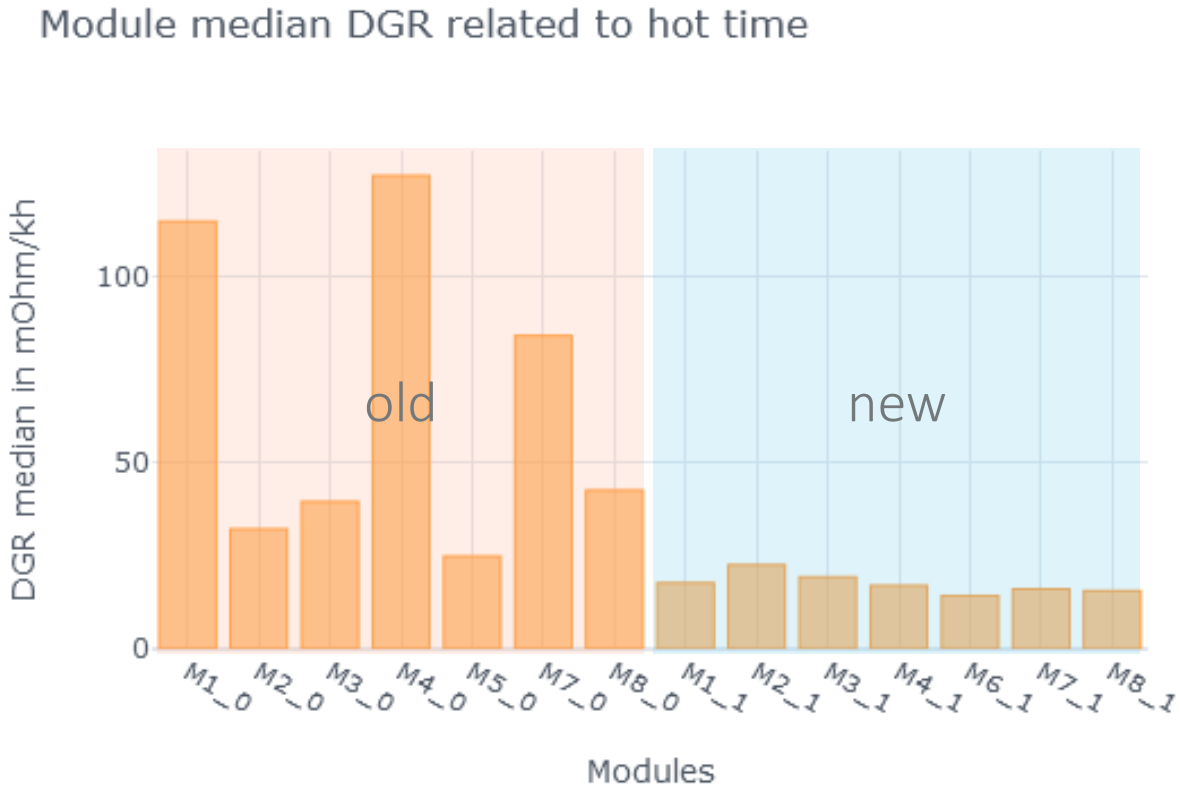


→ 84 $\%_{LHV}$ (39.7 kWh/kg) at full load, 79 $\%_{LHV}$ (42.2 kWh/kg) including compression

In the course of the GrInHy-projects, degradation could be reduced significantly

- „Old" modules operating hours: 600…9000 hours
  - high degradation rates, early stack failures
  - all modules replaced by now
- New modules operating hours: 5000…11000 hours
  - Very low average degradation: 7.5…19.0 mOhmcm²/kh (average 14 mOhmcm²/kh)

  → 0,35 % Production Rate Loss



ONGOING PROJECTS

SOEC has reached multi-megawatt scale

> 5 MW
Installed SOEC electrolysis capacity

> 10 industrial projects
with global companies

World's longest
SOEC operating experience

NL 1)

MultiPLHY

3 MW

HyLink SOEC

Refineries

Commissioning 2022

DE

e-CO_2Met

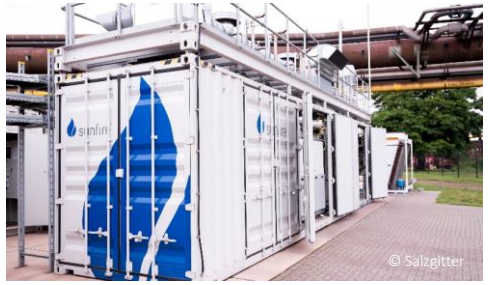
1 MW

HyLink SOEC

Chemicals

Commissioning 2022

DE 1)



GrInHy2.0

1 MW

HyLink SOEC

Steel industry

Commissioned 2020

DE

Kopernikus P2X

0.2 MW

SynLink SOEC

Power-to-X

Commissioned 2022

1) Disclaimer: Please find the funding acknowledgement information at the end of the presentation

PRODUCT ROADMAP

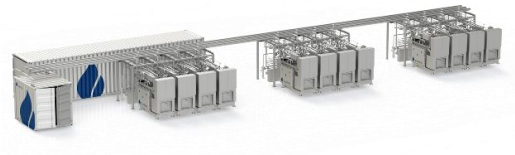
We are further developing SOEC electrolysis

2022 | 2023 | 2024 | Outlook

Pre-commercial demonstration

SynLink Module Test

Start-up
2.7 MW HyLink and 0.2 MW SynLink



Next Gen Development

Radically improved stack design

Test module operation

Next Gen Roll-out

Start-up commercial modules

Startup-up
10+ MW Prototypes

Next Gen mass commercialization

Scale-up to GW

THANK YOU!

Christian von Olshausen, CTO
christian.olshausen@sunfire.de

Sunfire GmbH · Gasanstaltstrasse 2
01237 Dresden · Germany
www.sunfire.de