# GrInHy

**Green Industrial Hydrogen via reversible high-temperature electrolysis**

GrInHy
Green Industrial Hydrogen

**Programme Review Days 2018**

Brussels, 14-15 November 2018


**Oliver Posdziech**

**Sunfire GmbH**

**www.green-industrial-hydrogen.com**

**info@green-industrial-hydrogen.com**

# PROJECT OVERIVEW

- **Call year:** 2015
- **Call topic:** FCH-02.4-2015: Proof-of-concept of HT electrolysers at a scale > 70 kW
- **Project dates:** 03/2016 – 02/2019
- **% stage of implementation 01/11/2018:** 95 %
- **Total project budget:** 4,498,150 €
- **FCH JU max. contribution:** 4,498,150 €
- **Other financial contribution:** 0 €
- **Partners:** Salzgitter Mannesmann Forschung GmbH, Salzgitter Flachstahl GmbH, Sunfire GmbH, Boeing Research & Technology Europe, Technical Research Centre of Finland Ltd (VTT), European Institute for Energy Research, Institute of Physics of Materials, Politecnico di Torino

# PROJECT SUMMARY

## GrInHy – Green Industrial Hydrogen via reversible high-temperature electrolysis

- Objectives

| *Objectives* | *Context* | *Status* |
|---|---|---|
| *SOEC electrical efficiency, 80 $\%_{LHV}$* | AWP 2015 | (✓) |
| Electrolyser capacity, 150 $kW_{el,AC}$ | AWP 2015 | ✓ |
| *Lifetime system test, 7,000 h* | AWP 2015 | ✓ |
| *Stack durability, > 10,000 h, < 1 % /kh* | additional | (✓) |
| *Proof of reversible operation* | additional | ✓ |
| *Dependable data on system costs* | MAWP | ✓ |
| *Preparation of exploitation roadmap* | MAWP | ⚠ |

- Global positioning vs international state-of the art

| *State of the Art* | *Source* |
|---|---|
| *SOEC electrical efficiency (systems)* | N/A |
| Electrolyser capacity, 75 $kW_{el,AC}$ | Boeing/Sunfire |
| *Lifetime system* | N/A |
| *Stack durability, 1,800 h, < 2 % /kh* | Sunfire 2015 |
| *Reversible operation (H2-FC only)* | Boeing/Sunfire |
| *Dependable data on system costs* | N/A |
| *Preparation of exploitation roadmap* | N/A |

- Application and market area
  - **Steel Industry – Hydrogen (3.8) for annealing processes**
  - *Other industrial, mobility or energy sector related hydrogen applications in combination with waste heat*

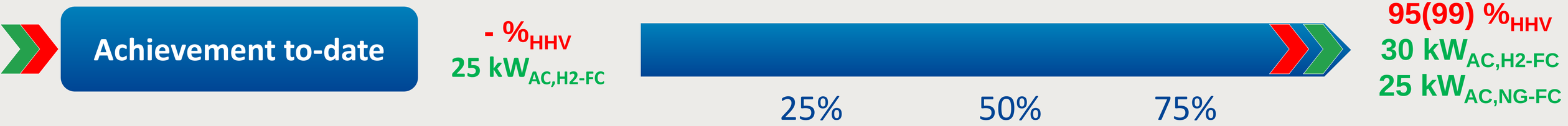
# PROJECT PROGRESS/ACTIONS – Electrolyser capacity

**Achievement to-date** **75 $kW_{el}$** **150 $kW_{el}$**

25% 50% 75%

- **AWP 2015:** Minimum (electrolyser) capacity of 70 $kW_{el}$
- **SoA:** Sunfire and Boeing developed a rSOC system (2x75 $kW_{el}$), start of operation in 2016
- **GrInHy:** Manufacturing of a reversible SOC unit with a capacity of 150 $kW_{el,AC}$ (BoP included) coupled to a hydrogen processing unit to compress, dry and inject $H_2$ into the pipeline at 8 $bar_{(g)}$
- **Start of manufacturing:** 10/2016
- **Start of commissioning:** 06/2017

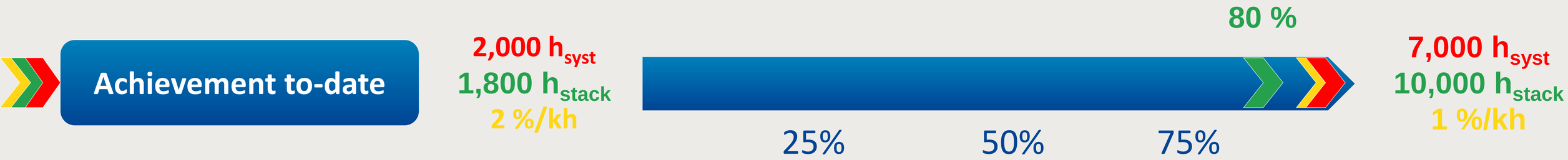
# PROJECT PROGRESS/ACTIONS – Electrical efficiency & reversibility




- **SoA:** Electrolyser efficiency - no relevant data available for 2016
- **GrInHy:** Achieved today 92 $\%_{HHV}$ (78 $\%_{LHV}$) by using steam from waste heat at thermo-neutral operation
  → Limited by low efficiency power electronics efficiency in electrolysis mode
  → Recalculation showed that the system as it is build could reach 99 $\%_{HHV}$ (84 $\%_{LHV}$)

- **Additional target:** Reversibility – Sunfire/Boeing $H_2$-rSOC Prototype from 2015
- **GrInHy:** "Full" reversibility, i.e. FC operation with hydrogen (30 $kW_{AC}$ at 47 $\%_{LHV}$) and natural gas (25 $kW_{AC}$ at 50 $\%_{LHV}$)

# PROJECT PROGRESS/ACTIONS – Lifetime, degradation




- **AWP 2015:** Minimum electrolyser system lifetime 2,000 hours
- **GrInHy:** Achieved today 7,000 hours system lifetime, steady state FC and EC acc. 50 % load operation
  → More challenging operation will be continued after exchange of early worn stacks in 11/2018

- **Additional target:** Stack durability in SOEC mode for > 10,000 h and less than 1 % /kh degradation
- **SoA: internal tests 2015:** Stack tested in electrolysis operation of max. 1,800 h
- **GrInHy:**
  - Long-term stack test operation was aborted after 8,000 h (stack damages by test bench failures)
  - Operation time limited because of BoP-components → improvement of components and test benches results in stable steady-state operation of more than 3,000 h without any failures (ongoing)
  - Degradation <0.8 %/kh on system level(!), 0.5 %/kh on stack level over 3,000 h

# PROJECT PROGRESS/ACTIONS – Cost analysis, exploitation roadmap

**Achievement to-date**

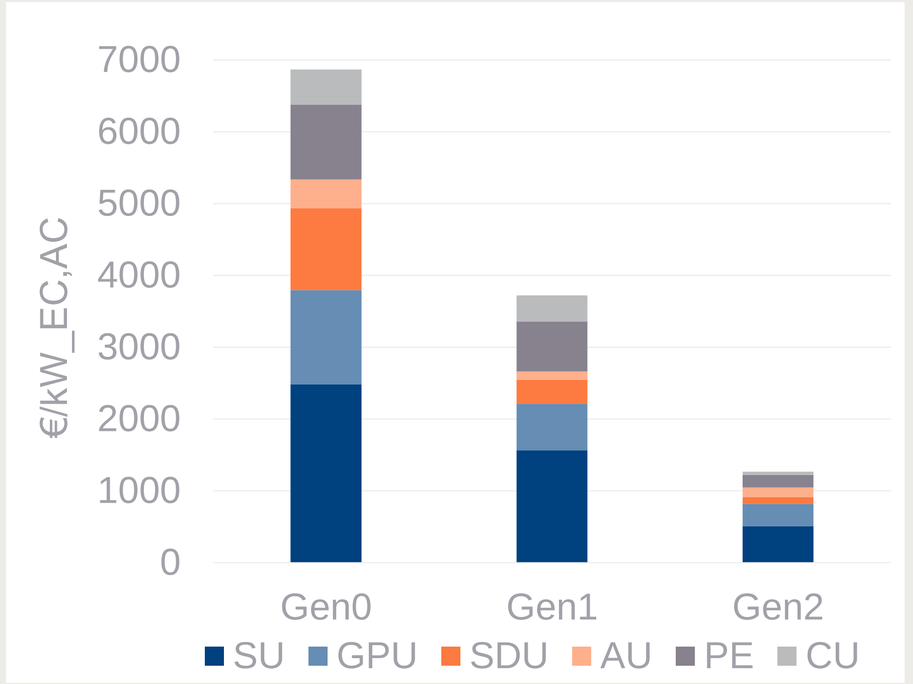
50 %

- completed
- completed

25% 50% 75%

- **MAWP 2014-2020:** Development of dependable system cost data
- **GrInHy:** Analyzed cost of the prototype system in detail and provides cost targets for next generations

- **MAWP 2014-2020:** Elaboration of Exploitation Roadmap
- **GrInHy:** Draft version was elaborated, will be updated before project end



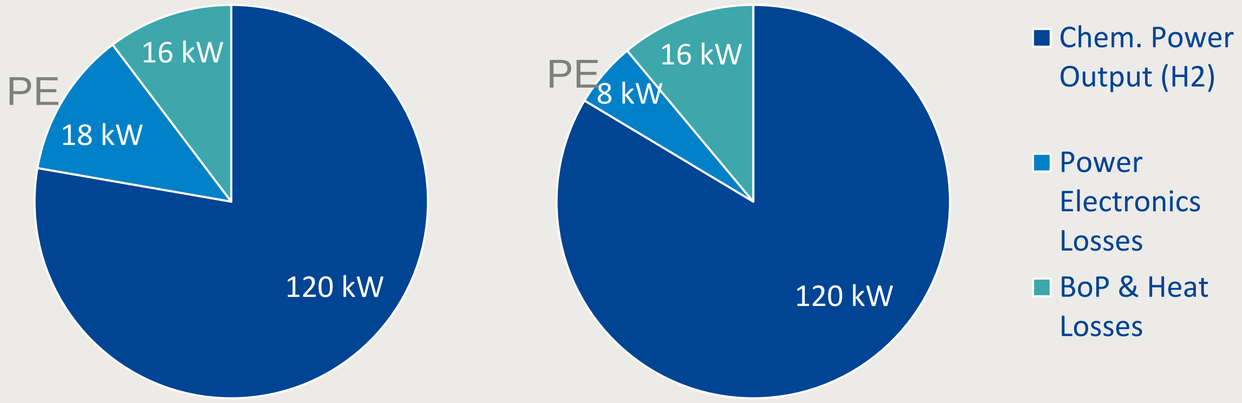
# Risks, Challenges & Bottlenecks

- Risk: Electrolyser efficiency not reached
  - Mitigation measures: Exchange of BoP components to minimize parasitic losses
  - Risk materialization: Power electronics efficiency lower then expected

    → Recalculation shows potential of the prototype

154 kWAC at 40 Nm³/h Production Rate → 78 %LHV

143 kWAC at 40 Nm³/h Production Rate → 84 %LHV

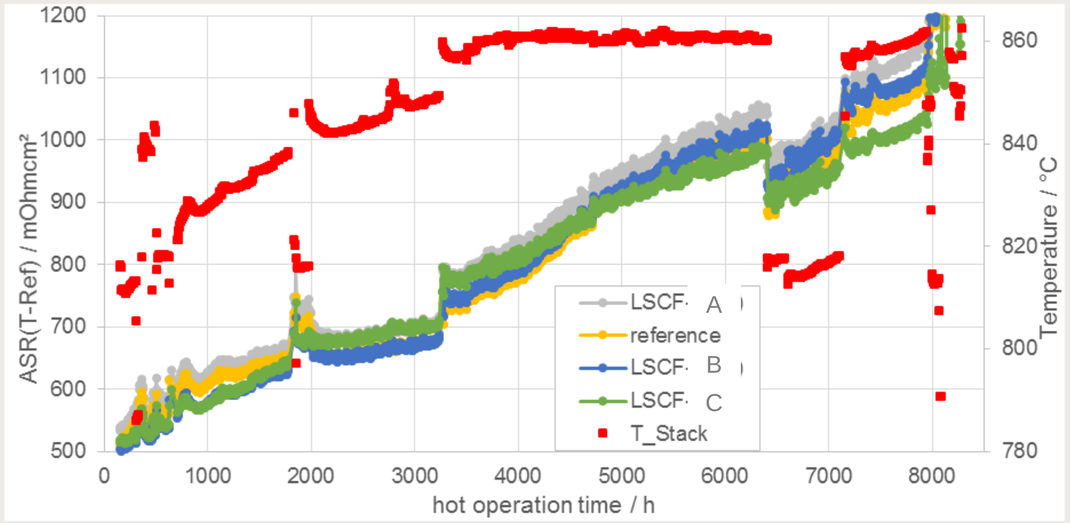


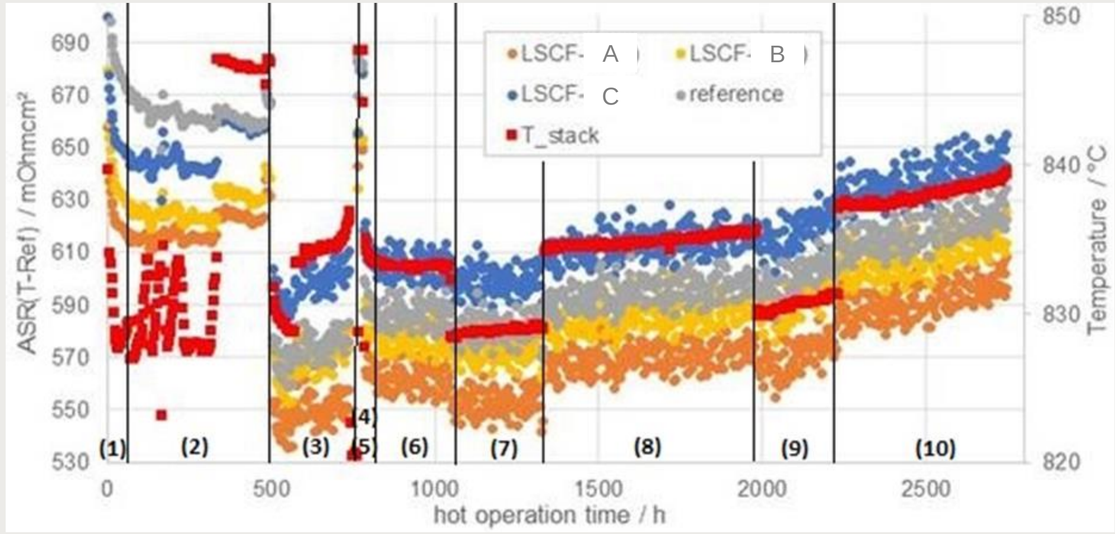

Power share at nominal load as recorded during field tests

Power share at nominal load recalculated with increased power electronics efficiency (94 %)

# Risks, Challenges & Bottlenecks

- Risk: Stack lifetime and degradation targets not fully reached due to test bench limitations
  - Mitigation measure 1: Test of several stacks at Eifer and Sunfire
  - Mitigation measure 2: Test of different cell technologies
  - Risk materialization: Long-term stack test was aborted after 8,000 hours due to test bench failures (e.g. breakdown of water supply) that led to stack damages
  - Low Degradation of ~0.5%/kh could be shown over 3,000 h of stack operation



# Dissemination Activities

## Joint Workshop – 03/09/2018, Salzgitter
## “Route to Industrialisation of High-Temperature Electrolysis”

- Workshop organized with ECo project (FCH2 JU, 699892)
- 40 experts from 8 EU countries (industry, research organisations)
- Focus: System design, Stack/cell maturity, economics, applications, LCA

## Statistics

- Number of conferences/workshops
  1 organized / 44 attended
- Number of publications: 5
- Number of patents: (2)
- Public deliverables of the project

# Communications Activities

- Main communication instruments: Website, conferences and fairs


www.green-industrial-hydrogen.com

**Statistics** (06/2016 – 09/2018)

- Website visitors: **ca. 8,000**
- Recorded downloads: **> 2,100**

**Conference “Hydrogen and fuel cell applications in Lower Saxony” (7th June ‘17)**

- a.o. excursion to GrInHy system
- Ca. 160 participants (politics, industry, media)


**Hannover Messe 2017 and 2018**

- Prominent project representation at the booth of Salzgitter AG

# EXPLOITATION PLAN/EXPECTED IMPACT

## Exploitation

- Development of a multi-step research and scale-up plan to exploit products and generated knowledge (Exploitation Road Map)
- GrInHy2.0 (project start 01/2019) will show the 1st MW-scale SOEC system with improved robustness and enhanced lifetime
- Gaps and hurdles for a commercial product launch have been analyzed and are subject of communication activities


MW-scale HT electrolyser system: GrInHy2.0

## Impact

- Successful integration of a rSOC system at industrial relevant scale in Salzgitter's iron and steel work producing high quality hydrogen
- Proof that HT electrolysers achieve superior electrical conversion efficiencies of 40 kWh/$kg_{H2}$ by using steam from waste heat
- Dynamic and flexible operation as electrolyser and fuel cell (with $H_2$ and natural gas) show potential in coupling with fluctuating renewable electricity
- Significant cost reduction
- Paving the path for succeeding large-scale projects

# GrInHy: We say “Thank you!”

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