OxiGEN
Next-generation Solid Oxide Fuel Cell stack and hot box solution for small stationary applications

OxiGEN
Next generation SOFC solutions

European Hydrogen Week

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FCH

European Commission

Project Overview

- Call year: 2017
- Call topic: H2020-JTI-FCH-2017-1

  Development of fuel cell system technologies
- Project dates: Jan 2018- Sept 2021
- % stage of implementation 01/11/2021: 100%
- Total project budget: 2,996,873.75 €
- FCH JU max. contribution: 2,996,873.75 €
- Other financial contribution: 0

OxiGEN

Next-generation Solid Oxide Fuel Cell stack and hot box solution for small stationary applications

Consortium members

Lead = Saint-Gobain

European Hydrogen Week

Project Summary

OxiGEN
Next generation SOFC solutions

Seven European partners focused on sizing and improving a stack while developing an appropriately sized and durable hotbox

Objectives

Define specifications for µCHP

- For European individual houses
- For small commercial markets

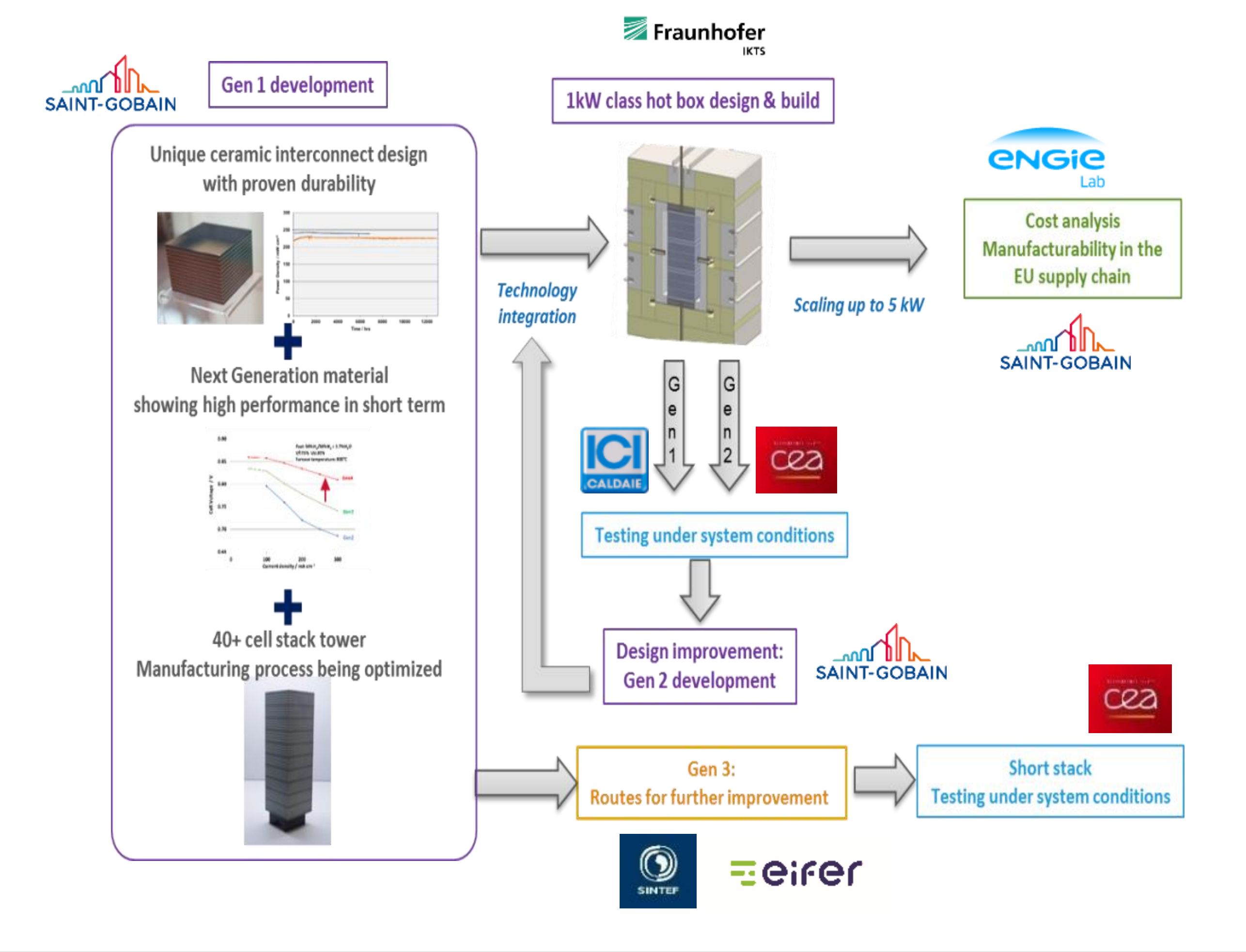
Develop technical platform

- Definition of suitable stack
- Modular hotbox concept
- Assessment of performance of prototype and its costs

Directions for further improvement

- Proposition of stack improvement
- Assessment of economic impact
- Integration into European supply chain
- Dissemination of results

Illustrative approach



Hotbox: optimal size determined

Achievement to-date

25% 50% 75% 100%

Input

Buildings

Building use: *single & multi-family, non-residential*
Market: *UK, FR, DE, NL, IT*
Building characteristics: *u-value, …*

Systems

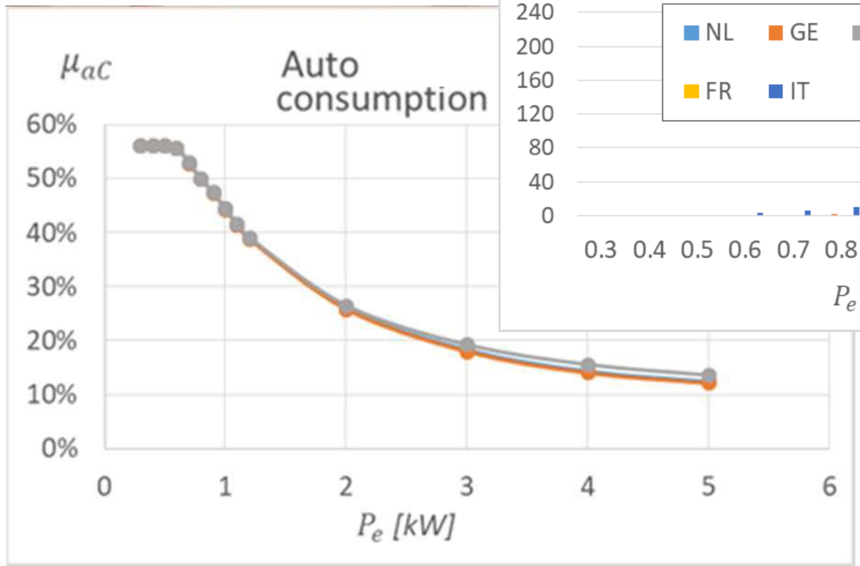
Characteristic: *Power, efficiency*
Management scheme: *Hot water temp, tank size,…*

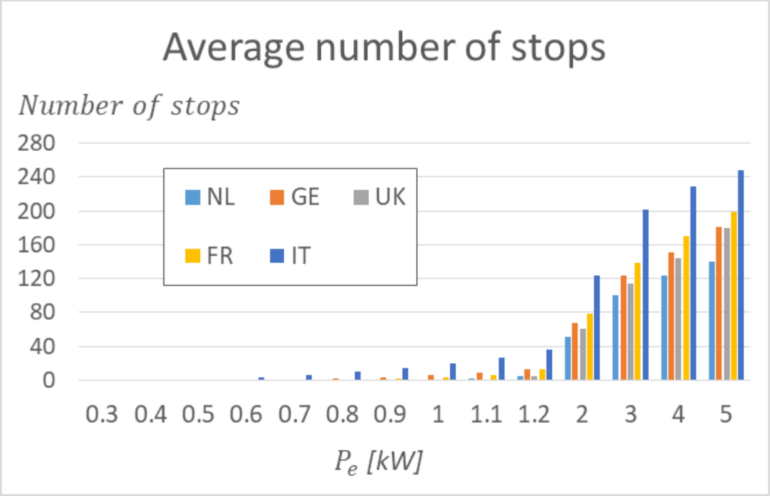
Output

Economics

Energy bill (Electricity + NG)
Total cost of ownership

Major insight - payback is limited by ***number of system stops*** throughout the year and the ***auto-consumption ratio***





Hotbox: definition

Achievement to-date

100%

25% 50% 75%

Hotbox Simulation Results

Single Family Houses

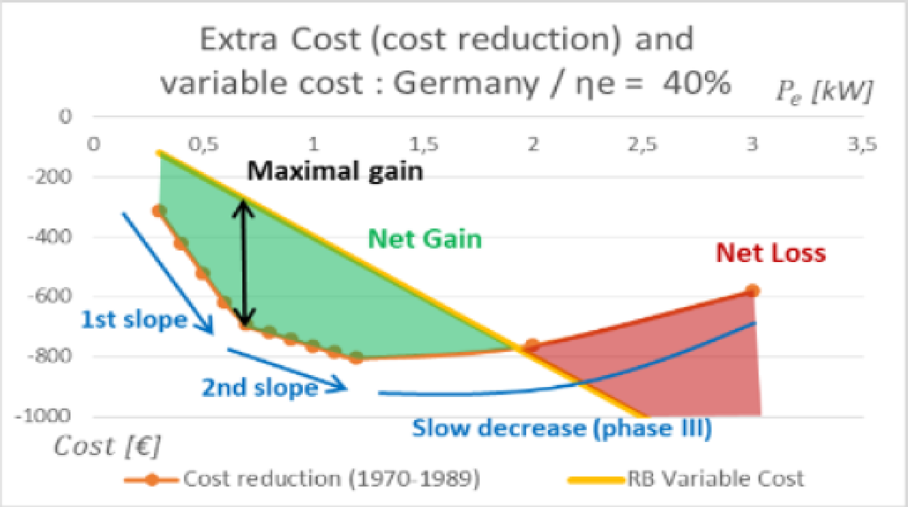
- Power output of 0.6 kW can fit all countries (0.5 for Italy)
- High power efficiency minimizes on/off cycles
- For most countries, a maximum of stack related CAPEX of 4000€/kW is compulsory, assuming 10 years lifespan

Multi Family Houses

- SOFC can be operated all year long
- Power output of 2 kW can fit all countries
- This market seems easier to address, from a cost point of view.

Commercial sector

- Retail, offices and education are tricky regarding on/off cycles limitations of SOFC
- Health and Hotels sectors appears attractive with 5 kW and 50% eff.



Hotbox: designed & tested

Fraunhofer IKTS | ICI CALDAIE | SAINT-GOBAIN

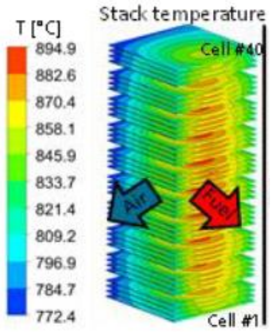
Achievement to-date

25% 50% 75% 90%

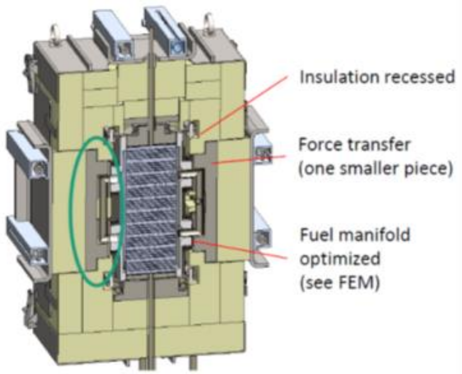
Hotbox design and testing results

- Critical parameters for stack operation/safety identified
- Operation at 50% current matched output power simulation (310W vs 306W)
- Simulation showed 600W achievable with output at 300 mA/cm2
- System gas feed demonstrated temperature and gas composition control
- Scalable design for multiple stacks

40 cell stack design and construction

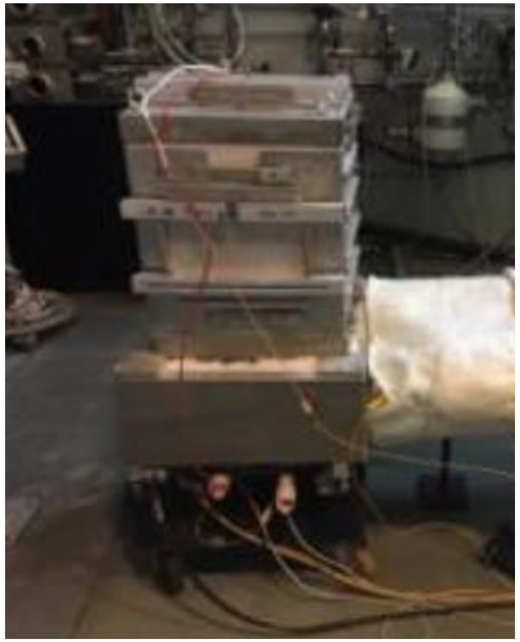


Modelling to optimize design and operation



18% weight reduction in 2nd gen design

Design successfully build and tested on benchtop



System integration shown with operational temperature & gas conditions

Material Development: button cell

Conditivity Targets

Achievement to-date

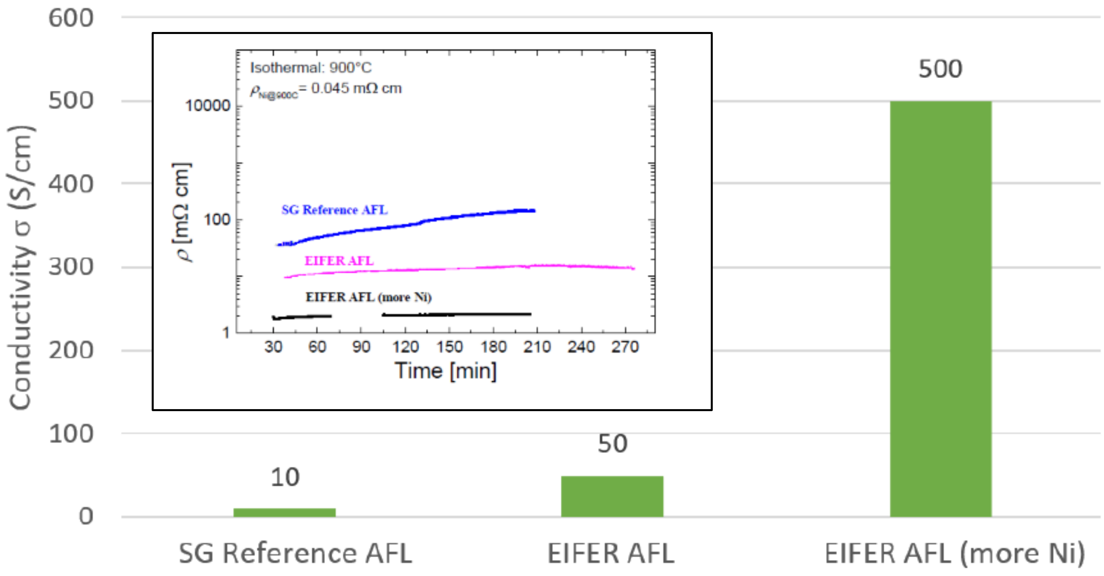
10 S/cm
33 mS/cm

25% 50% 75%

1000 S/cm
100 mS/cm

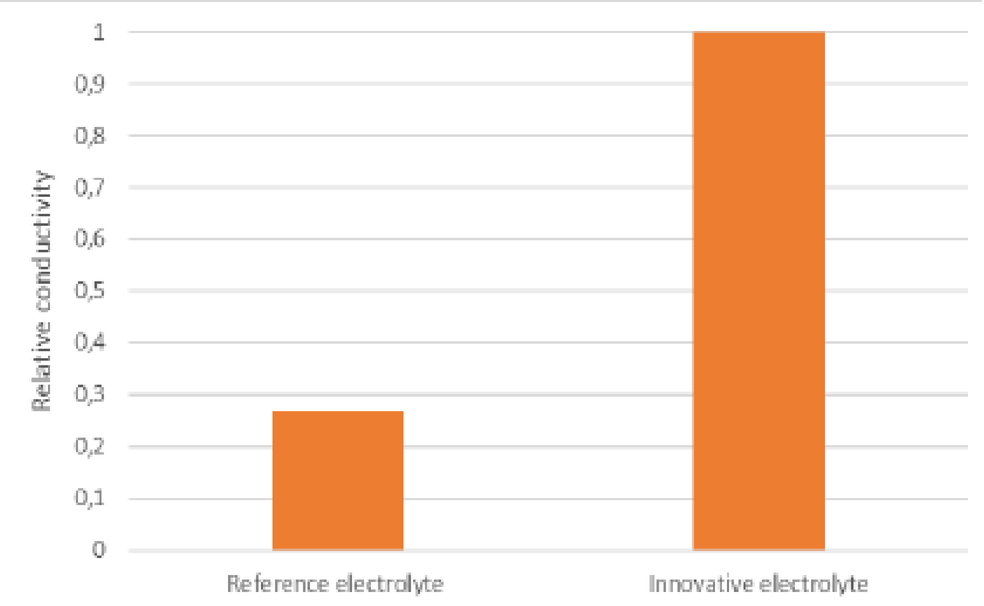
Anode Conductivity and Redox Stability

- Conductivity stabilized & increased by 50x
- Deep oxidation protocol developed – simulate emergency
- Ni coarsening reduced, redox stability marginally improved



Oxygen Ion Conduction

- Increased conductivity beyond target level
- Matched co-sintering characteristics



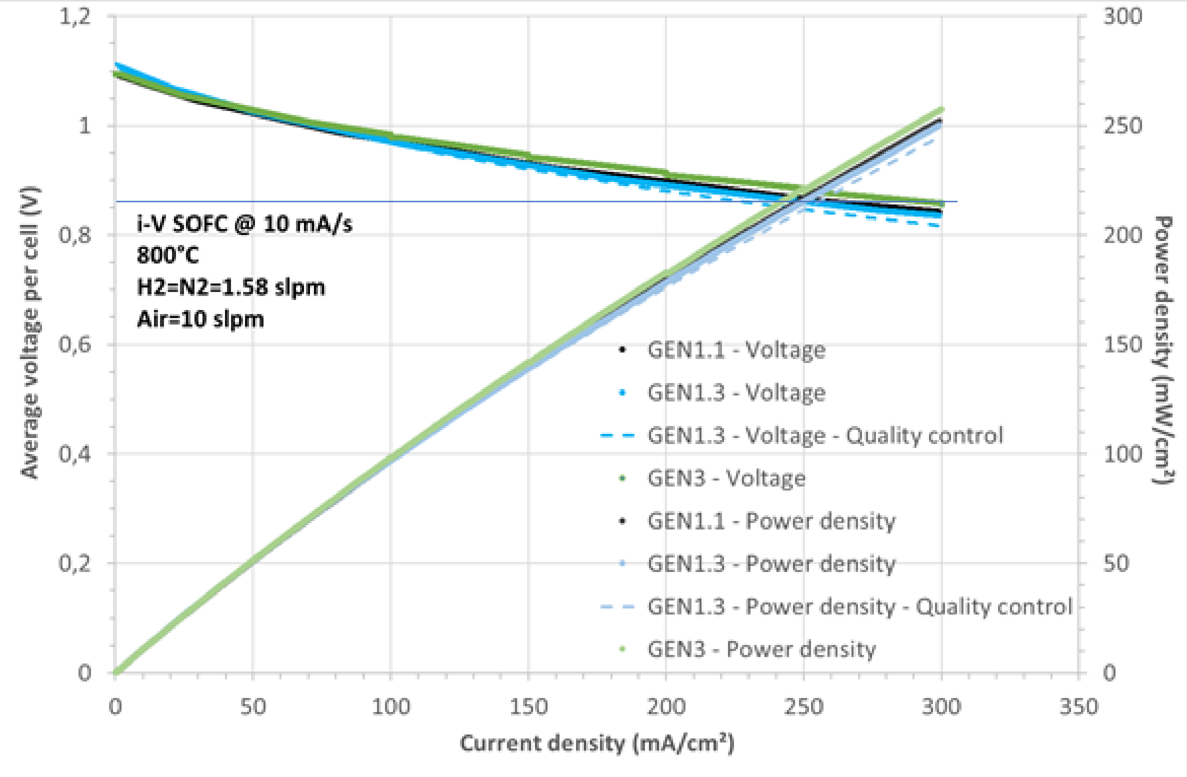
Material Development: integration into short stacks

Short Stack Testing

- **OCV:** Innovative materials are compatible with scaling the co-sintering process to full stack cross section
- **Efficiency:** 50% in simulated reformate, 65% Fuel Utilization @300 mA/cm²
- **Output:** verifies 650W achievable for full stack

- **Resistance, Ohmic** – shows expected reduction
- **Resistance, Polarization** – potential for further performance increase, did not have time to optimize the microstructure in this project

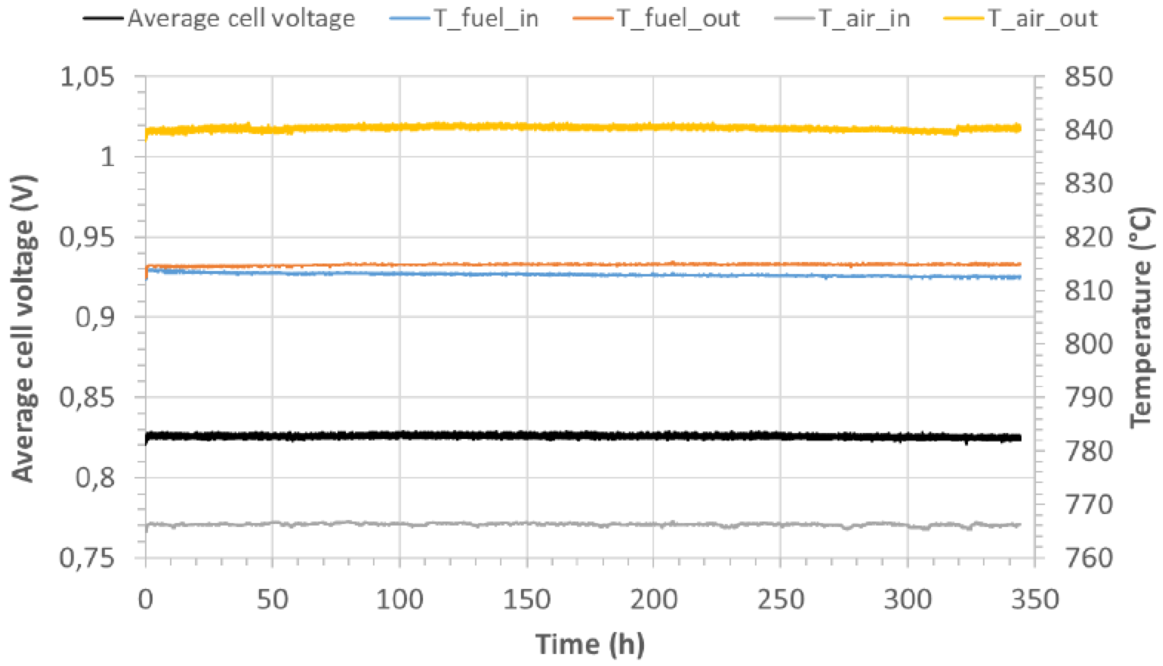
Average per cell	Rs (Ω.cm²)	Rp (Ω.cm²)
GEN1.1 – Wet H_2/N_2 - CEA	0.22	1.77
GEN1.3 – Wet H_2/N_2 - CEA	0.36	2.52
GEN3 – Dry H_2/N_2 - CEA	0.06-0.08*	2.07-2.09



Material Development: short stack testing

Durability

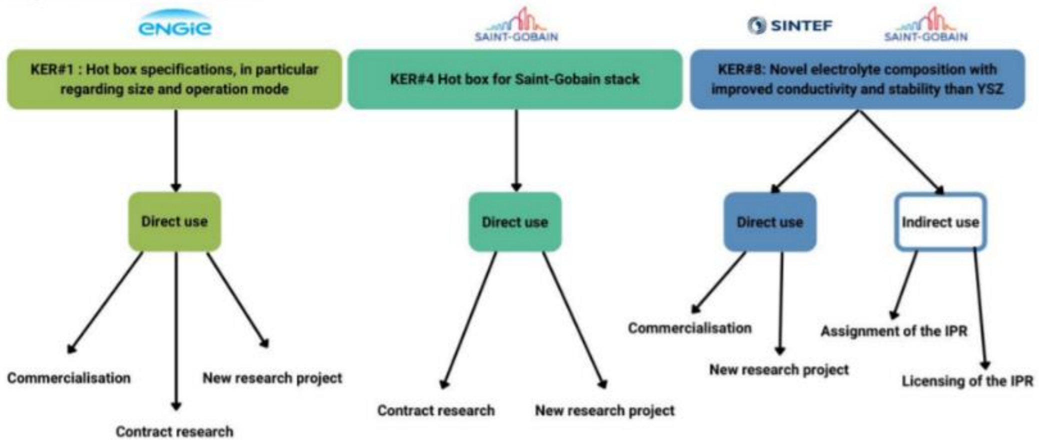
- 2900 hrs tested in steady state operation
- Multiple gas and current conditions probed
- Using simulated reformate and 30% Uf, degradation measured as -0.36 %/1000 hrs per cell



Exploitation Plan/Expected Impact

Exploitation

	Planned results in the initial proposal	Partner owner
1	Hot box specifications, in particular regarding size and operation mode	Engie
2	New stack design for improved interface with hot box allowing extended lifetime	Saint-Gobain
3	Scale-up of new materials (anode functional layer and electrolyte) into short stack	Saint-Gobain, Eifer, SINTEF
4	Hot box for Saint-Gobain stack	IKTS
5	Testing results of stack/hot box combination under application specific conditions	CEA, IKTS, ICI
6	SOFC system setup & operation strategy	ICI
7	Methodology to determine total cost of ownership	Saint-Gobain
8	Novel electrolyte composition with improved conductivity and stability than YSZ	SINTEF, Saint-Gobain
9	New anode functional layer composition, resistant to power loss after emergency shutdown (redox)	Saint-Gobain, Eifer



Impact

Stack performance in commercially relevant assembly (note : not individual cell performance): DC efficiency of at least 55%, for example by achieving voltage 0.83 V/cell at current density 0.30 A/cm2 under reformed natural gas and air. Operating conditions : air utilization >35% and fuel utilization >65%

Lifetime > 90 000 hours (defined as accumulated performance loss reaching 20%):

- Steady state degradation rate <0.1% per thousand hours, proven over a test duration of at least 5000 hours
- Resistance to normal cycling : <0.01% per cycle (controlled shut-down with stack brought to T<125°C) proven over at least 50 cycles
- Resistance to emergency shut-down : <0.25% per cycle (redox cycle such as fuel loss at operational temperature, specific to the system outlay) proven over at least 10 cycles

Stack Cost: below 1000 €/kWe ultimately, as manufactured in a production plant with a capacity of > 50 MWe/y. This stack cost includes not only the cells but also the gas manifold, current collectors, compression systems, and potentially insulations and heat exchangers depending on the design

Risks, Challenges and Lessons Learned

<u>Non-technical learnings</u>

- Project segmentation allowed quick progress along many fronts
- Open communication with a high frequency was critical to move the project forward and solve issues
- Full team ‘on-site’ meetings kept work packages aligned, virtual meetings not as successful
- Stability (in testing infrastructure, personnel, and production) is an important factor to success

<u>Technical learnings</u>

- The optimal hotbox size is strongly correlated to required system shut downs.
- A unique hotbox was designed to optimize thermal, gas, and electrical controls
- Innovative material sets were incorporated into button cells and then demonstrated at the short stack scale

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