OxiGEN

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

Grant Agreement n° 779537
Research and Innovation Project

Deliverable D8.5 Final Event

Start date of the project: 1st January 2018
Duration: 42 months
Project Coordinator: Robert GERMAR – SG SEPR

Contact: Robert GERMAR – Robert.Germar@saint-gobain.com

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Document Classification

Title	Final Event
Deliverable	8.5
Reporting Period:	2
Date of Delivery foreseen	M42 30 June 2021
Draft delivery date	30 June 2021
Validation date	30 June 2021

Authors	R. Germar – P01 – SG SEPR
Work package	WP 8
Dissemination	PU = Public
Nature	Other
Version	*V1*
Doc ID Code	D8.5_OxiGEN_P01_SGSEPR_300621
Keywords	Final event, communication, webinar

Document History

Name	Remark	Version	Date
Rober Germar – P01 – SG SEPR	**Final version**	**1**	**30 June 2021**

Document Validation

Partner	Approval (Signature or e-mail reference)
P1 – SG SEPR	author
P2 – ICI	
P3 – FRAUNHOFER	
P4 – EIFER	
P5 – CEA	
P6 – SINTEF	
P7 - ENGIE	

Document Abstract

This deliverable is part of the task 8.4 “Dissemination” within the WP8 “Communication, Dissemination and Exploitation of project results”. It was expected at M42.
Due to the pandemic crisis, it has been decided with the consortium and the EC to convert the initially scheduled face-to-face event into a remote event (i.e. webinar).
The work reports the content of webinar delivered on the 25th of June 2021, illustrating the aim of the event, the organization strategy and the analytics of people who had participated.

Table of Contents

1. Introduction

As part of the attempt to reach stakeholders and public organization at local level, the consortium scheduled in the Grant Agreement to organize one European workshop at the end of the project.
The scope of the workshop was planned to inform specific stakeholder groups (including the Advisory Panel) of the achievements and opportunities that might derive from the project results specifically focusing on the innovation, cost-effectiveness and replication of the developed SOFC platform.

In this event, the different technological solutions that OxiGEN offers were presented, along with discussions on these solutions.
This webinar can be hugely beneficial for reaching stakeholders and public bodies and the same time important for the evaluation of the proposed solution in the framework of the exploitation strategy of the project. Furthermore, this activity is in line with the FCH 2JU mission, which aims to accelerate the market introduction of these technologies, realizing their potential as an instrument in achieving a carbon-clean energy system.
Therefore, the organization of is webinar is a practice that can be followed by the partners that will exploit OxiGEN's solutions after the project end.
Due to pandemic crisis and to the difficulties in organizing a face-to-face local event, the consortium decided to replace the workshop event by an online webinar.

2. Objective: Reaching stakeholders and public bodies

For the success and the sustainability of OxiGEN it is crucial to reach stakeholders interested to use the solutions developed within the project. For this reason, dissemination and communication tasks work in close collaboration to the exploitation and evaluation of the project with the aim to reach the target audience of OxiGEN as final products.
The consortium has presented project results, which will be used also by any organization or company interested, including small and medium-sized enterprises (SMEs) or bigger enterprises. By using OxiGEN solutions, any company or organization is able to extrapolate the results for their own specific requirements and deploy applications and services, e.g. for hydrogen transportation or other applications (transport …).
This webinar is an important part of the activities done during the last year of the project. These activities, as reported in the communication, dissemination and exploitation plan, include the participation to conferences, exhibition events, work groups, face-to-face interaction during targeted thematic events, networking …
The main purpose is to advertise the benefits and advantages offered by OxiGEN to stakeholders, business partners and public bodies, and also to conclude on the project.

3. Webinar description

OxiGEN's webinar is organized by Absiskey with the support of the FCH JU. The webinar took place on June, 25th 2021 from 3pm to 5pm. Details of the webinar are reported in the table below.

Event Name*	How to build, step by step, an innovative Solid Oxide Fuel Cell platform for small stationary applications in a collaborative way?
Date*	25th June 2021 (3pm-5pm)
Place	Remote Event
Website link with more information*	https://oxigen-fch-project.eu/
Registration link	https://event.webinarjam.com/register/16/39lrnb8
Agenda link	https://event.webinarjam.com/register/16/39lrnb8
Description	The OxiGEN project aims at promoting the development of an innovative SOFC platform with an all ceramic stack integrated into a modular hotbox, for small stationary applications. Thanks to its higher durability and simpler design, this novel stack can fulfill the customers' needs for long lifetime, high efficiency and low cost, in micro-CHP and other segments. As the OxiGEN project draws to a close, Saint-Gobain and its partners are proud to present lessons learned and advances that this project has enabled for the hydrogen industry.

The tool: Webinar Jam

Organizers decided to adopt WebinarJam tool. Among different options existent in the market, we converged to use a stable, intuitive, easy to use and ergonomic tool both for presenters and the public, with the possibility to customize the platform with the graphical visual identity of the OxiGEN project. Moreover, WebinarJam allows to stream videos and content beforehand uploaded on different platforms (e.g. YouTube channel), to animate a live session and to propose polls to the participants.
To avoid technical difficulties that a "live" event can encounter and that can introduce consistent delays respect to a scheduled programme, organizers decided to pre-record all the speaker's contribution and then to stream the content using the private Absiskey YouTube channel. Only the question/answer sessions were diffused in "live" in order to interact with the participants. The plan was to collect all the questions during the event through the WebinarJam chatbox.

The figure below illustrates a printscreen of the interface of the WebinarJam tool as an example.

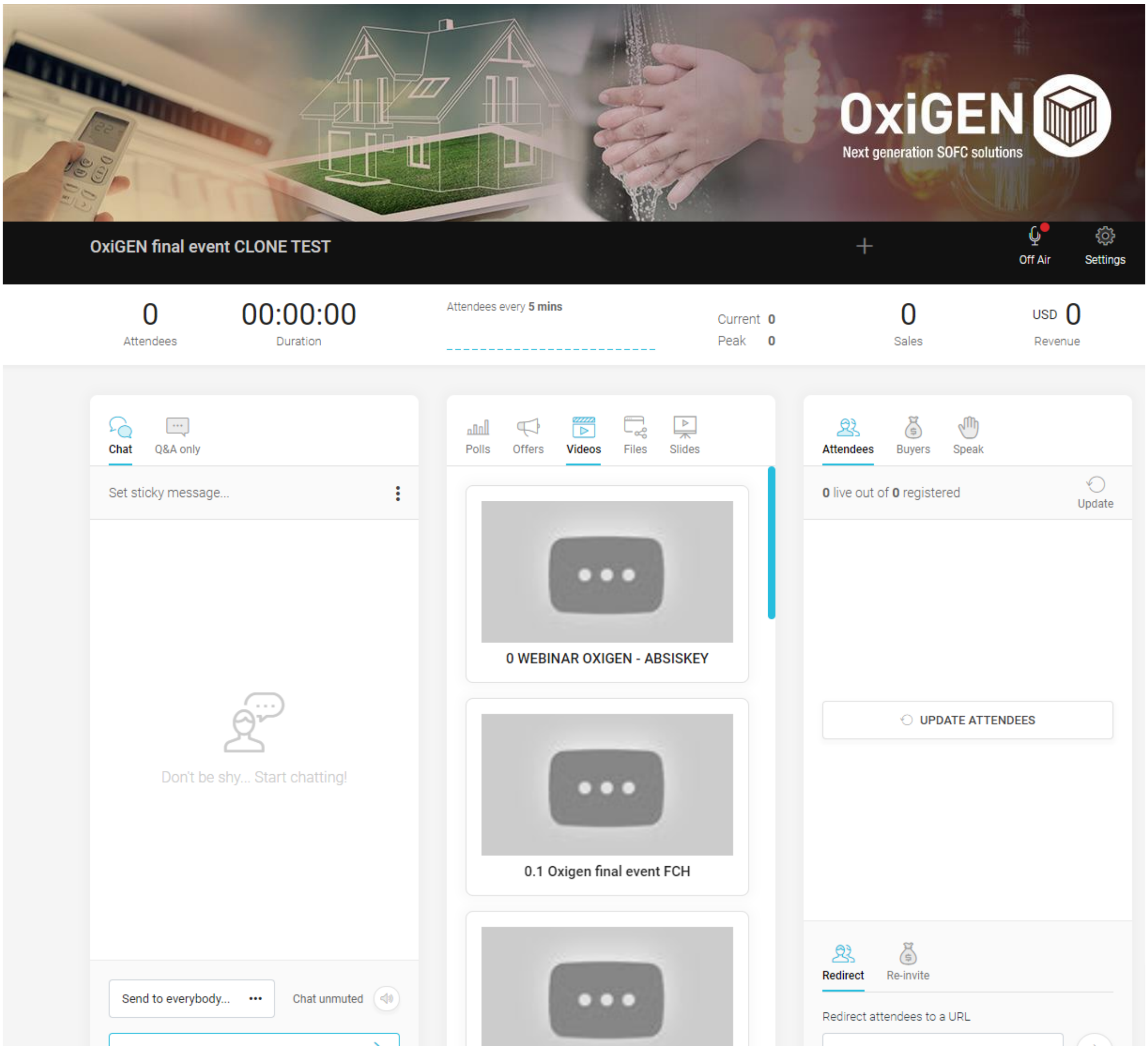


Figure 1: an example of Webinar Jam Dashboard

In parallel, the event was streamed in a dedicated LinkedIn page :
https://www.linkedin.com/events/freewebinar-oxigenh2020project-6803259344440832000/

The webinar can be followed in replay mode : https://youtu.be/1XHLEz2uF5k

4. Advertising campaign

The webinar was announced through various channels, especially using:

- Partner's contact lists (emailing),
- Absiskey's contact list in hydrogen field,
- Through LinkedIn accounts of people involved in the project and LinkedIn dedicated page,
- The project website (https://oxigen-fch-project.eu/).

The advertising campaign started one month before the event and was reiterated each week feeding social medias. Figures below illustrates some examples of this campaign.

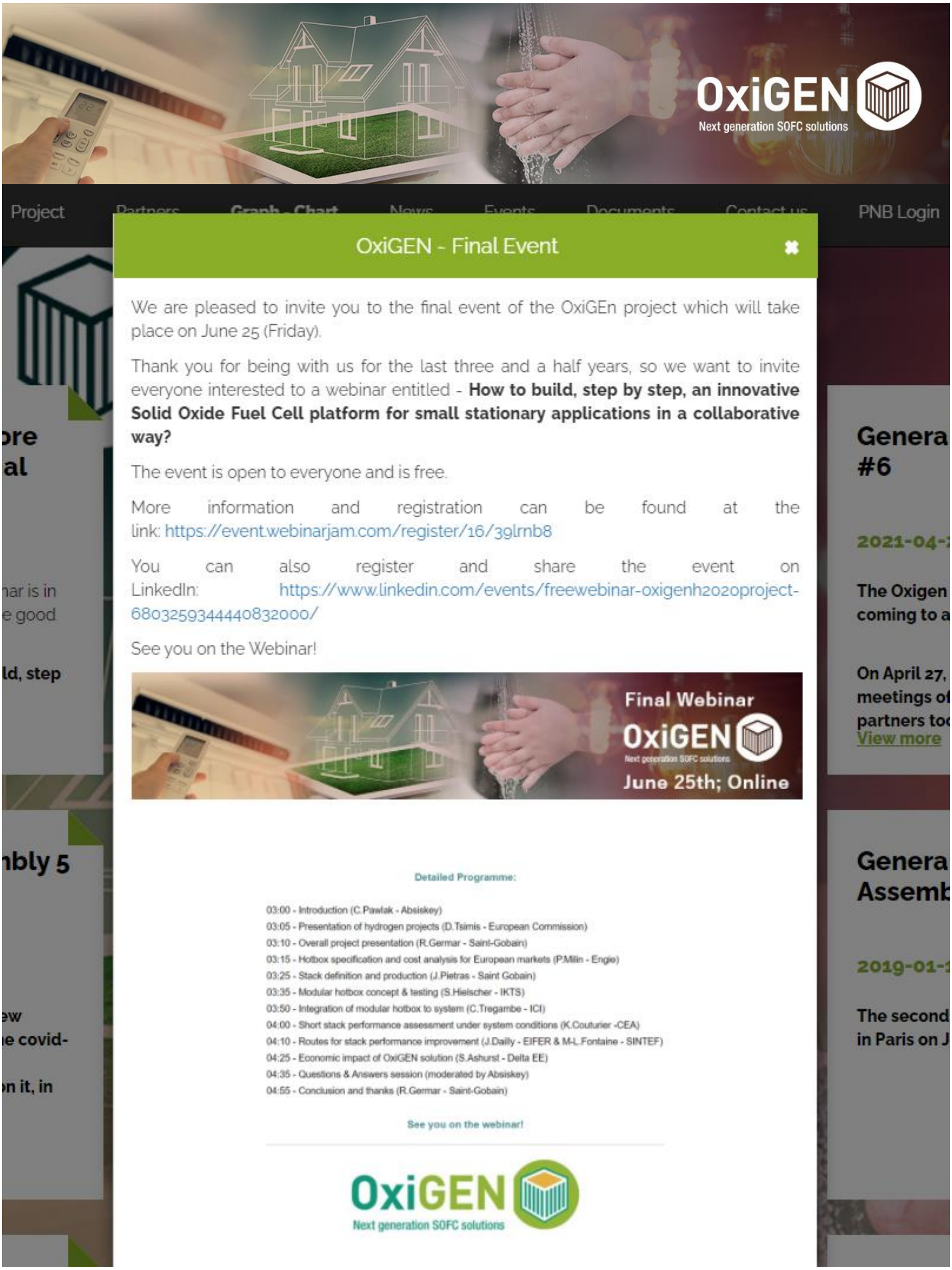


Figure 2: a promotional news on the project website

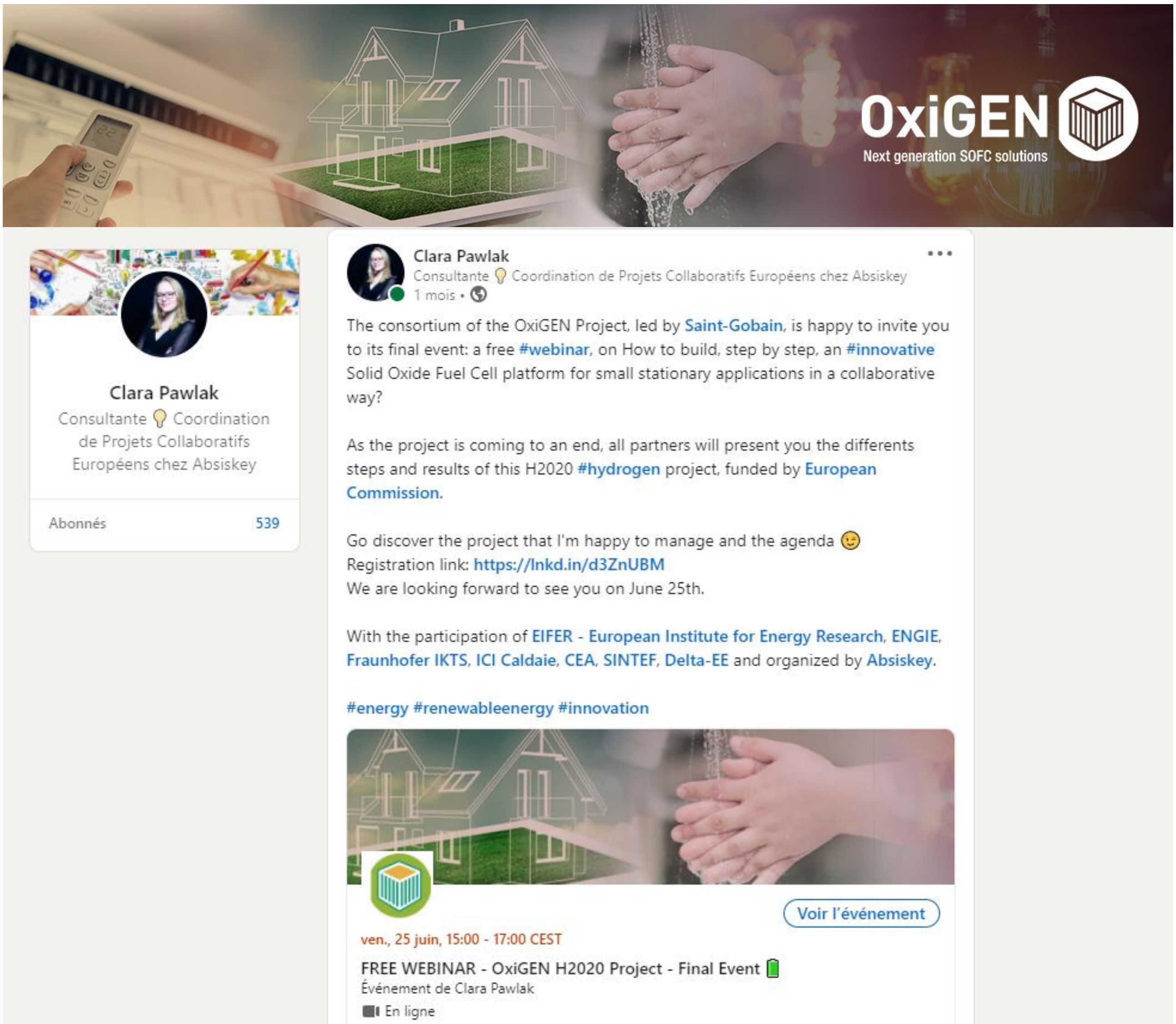


Figure 3: a LinkedIn post

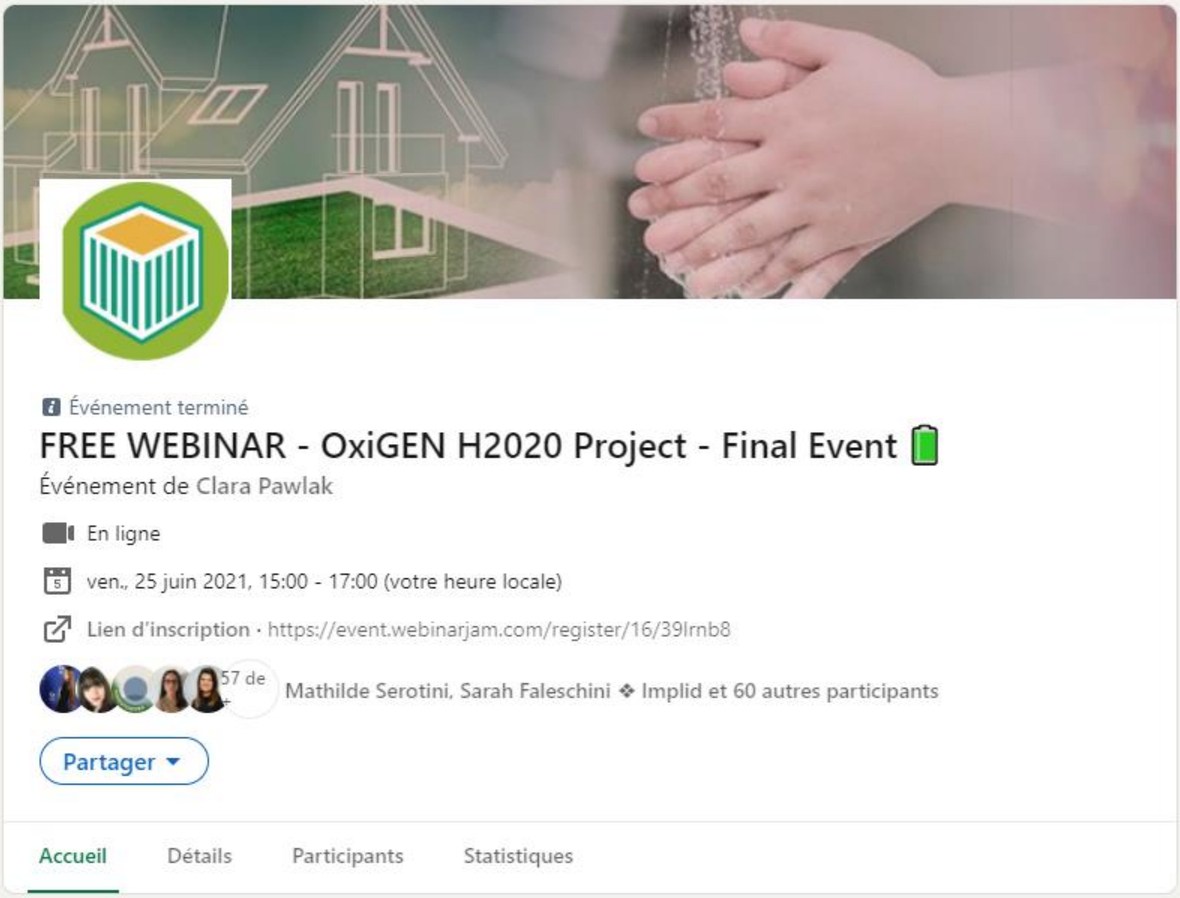


Figure 4: LinkedIn Event Page

Figure 5: Promotional newsletter

5. Programme

The webinar involved the participation of all the partners involved in the OxiGEN project and of the FCH JU, EC department supporting research, technological development and demonstration activities in fuel cell and hydrogen energy technologies in Europe.

The full program is here below reported:

Detailed Programme:

03:00 - Introduction (C.Pawlak - Absiskey)
03:05 - Presentation of hydrogen projects (D.Tsimis - European Commission)
03:10 - Overall project presentation (R.Germar - Saint-Gobain)
03:15 - Hotbox specification and cost analysis for European markets (P.Milin - Engie)
03:25 - Stack definition and production (J.Pietras - Saint Gobain)
03:35 - Modular hotbox concept & testing (S.Hielscher - IKTS)
03:50 - Integration of modular hotbox to system (C.Tregambe - ICI)
04:00 - Short stack performance assessment under system conditions (K.Couturier -CEA)
04:10 - Routes for stack performance improvement (J.Dailly - EIFER & M-L.Fontaine - SINTEF)
04:25 - Economic impact of OxiGEN solution (S.Ashurst - Delta EE)
04:35 - Questions & Answers session (moderated by Absiskey)
04:55 - Conclusion and thanks (R.Germar - Saint-Gobain)

See you on the webinar!

OxiGEN
Next generation SOFC solutions

Figure 6: Webinar agenda

6. Webinar analytics

Online polls were submitted during the webinar and discussed at the end of the webinar. The aim was to "take the temperature" of the audience, and evaluate our communication strategy. Polls and questions per each proposed options are reported below.
As main takeaways of the polls, the following conclusions can be drawn:

- The social media campaign has not reached a lot of registrants, but it can be explained by sereval reasons:
    - there was no dedicated page to the OxiGEN project ;
    - most of the communication was made by Absiskey, which is not specialized in the hydrogen field ;
    - globally, there was a lack of communication during the last years of the project, so the interest of the audience was lower than expected.
- The audience was split in two sections : hydrogen workers, and totally beginners in this topic. It explains why 50% of the audience was gone at the end of the webinar, as the most general information was shared at the beginning, and more technical information at the end.
- 1/3 of the registrants was/has been already involved in an European collaborative project.

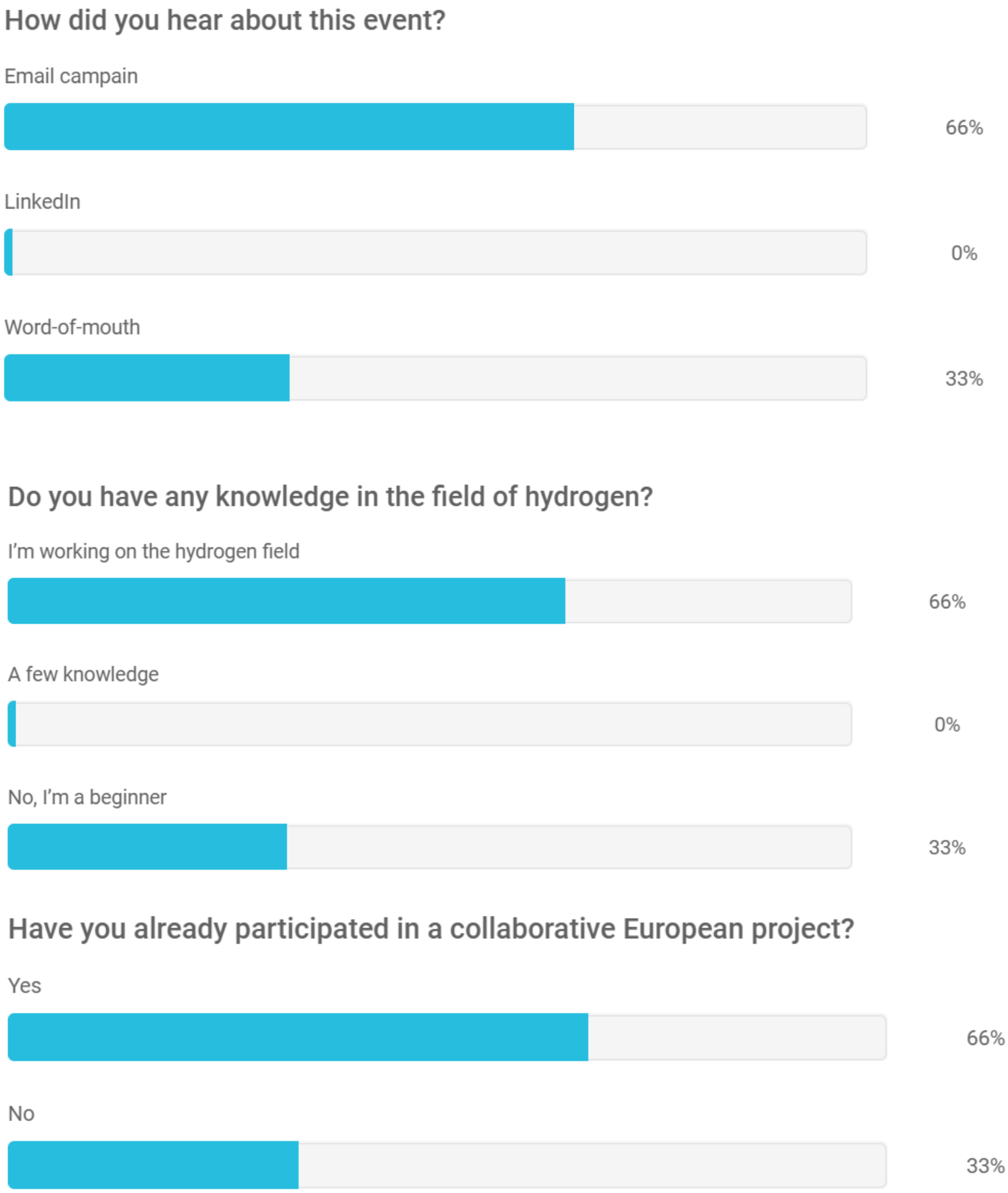


Figure 7: Polls results

The platform allow us to check the webinar data about audience:

- 152 visitors came to the registration link, but only 31,58% of them has registered. It can be explained by the regular checking of the page when we were building it or sharing it.
- 48 persons have registered, and 64.58% came to the webinar.

- 31 persons have watched the webinar, but, like said above, 50% of them has left by the end of the event.

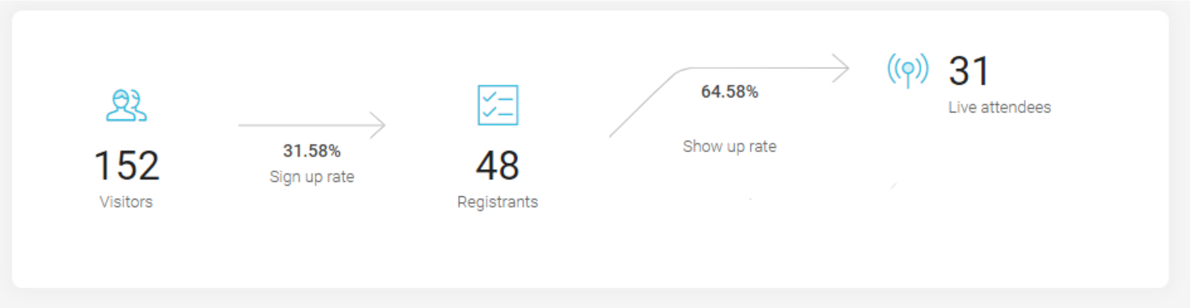
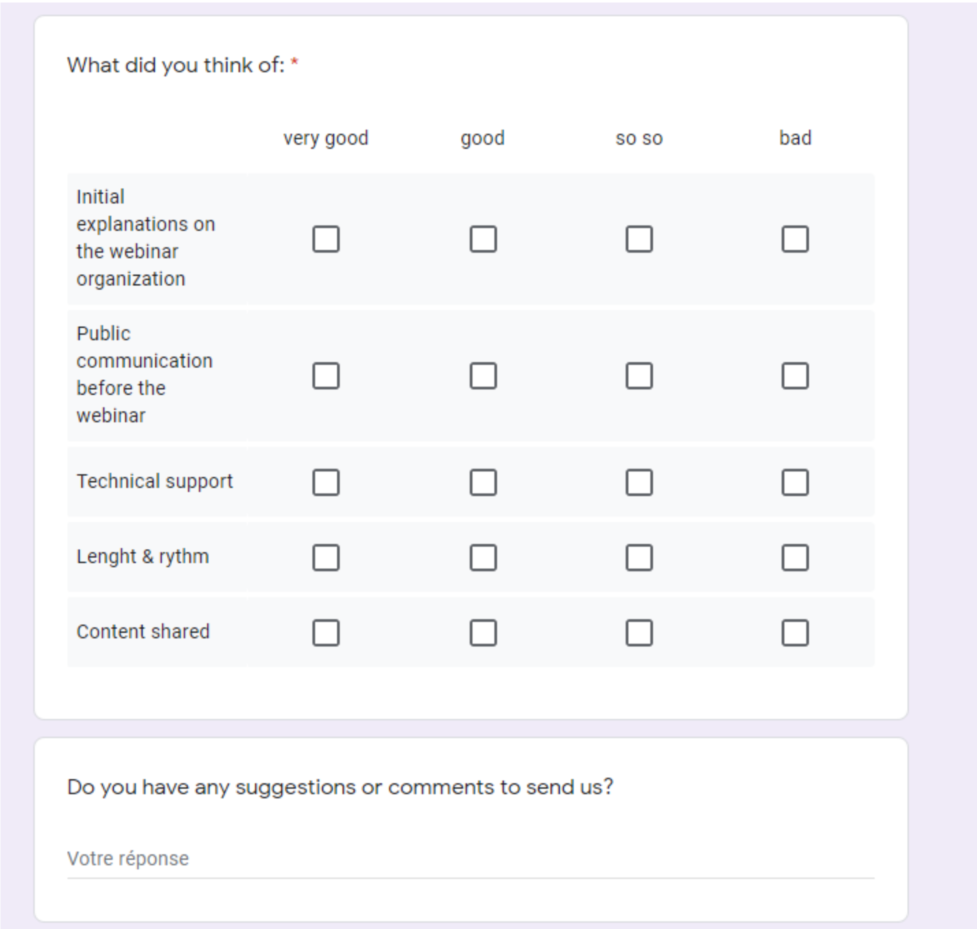


Figure 8: Webinar analytics

7. Satisfaction questionnaire

Participant to the webinar were contacted the week after the event by email. In this message we provided the link to access to the “replay” of the webinar and to propose a short questionnaire of satisfaction. 2 questions have been submitted: answers will be collected and analyzed in the future.



What did you think of: *

	very good	good	so so	bad
Initial explanations on the webinar organization	☐	☐	☐	☐
Public communication before the webinar	☐	☐	☐	☐
Technical support	☐	☐	☐	☐
Lenght & rythm	☐	☐	☐	☐
Content shared	☐	☐	☐	☐

Do you have any suggestions or comments to send us?

Votre réponse

Figure 9: Satisfaction questionnaire

8. Conclusion

This deliverable presented the content of the final OxiGEN webinar within the framework of the dissemination, communication and exploitation activities (WP8).
These activities aim at attracting potential supporters and users of the OxiGEN results, and for this reason dissemination is executed in close partnership with project partners and funding institution. This represents the first step for further market activities, after the end of the project.
In order to achieve this, all members of the consortium gave a presentation during the webinar with the aim to spread their knowledge and expertise in the targeted domains. The non-confidential project's results were disseminated to help on the exploitation of the technical solutions developed in OxiGEN.
Other dissemination activities will continue after the project's end, like the project website, the use of promotional material such as brochures, leaflets, posters, newsletters and social media, in order to increase the dissemination and pre-marketing effectiveness of OxiGEN.

9. Annex I: Partners presentations

OxiGEN
Next generation SOFC solutions

FINAL WEBINAR

How to build, step by step, an innovative Solid Oxide Fuel Cell platform for small stationary applications in a collaborative way?

June 25th 2021

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Next generation SOFC solutions

SHORT INTRODUCTION TO THE WEBINAR

Clara PAWLAK, Project Manager

INNOVATION SPIRIT

5’

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

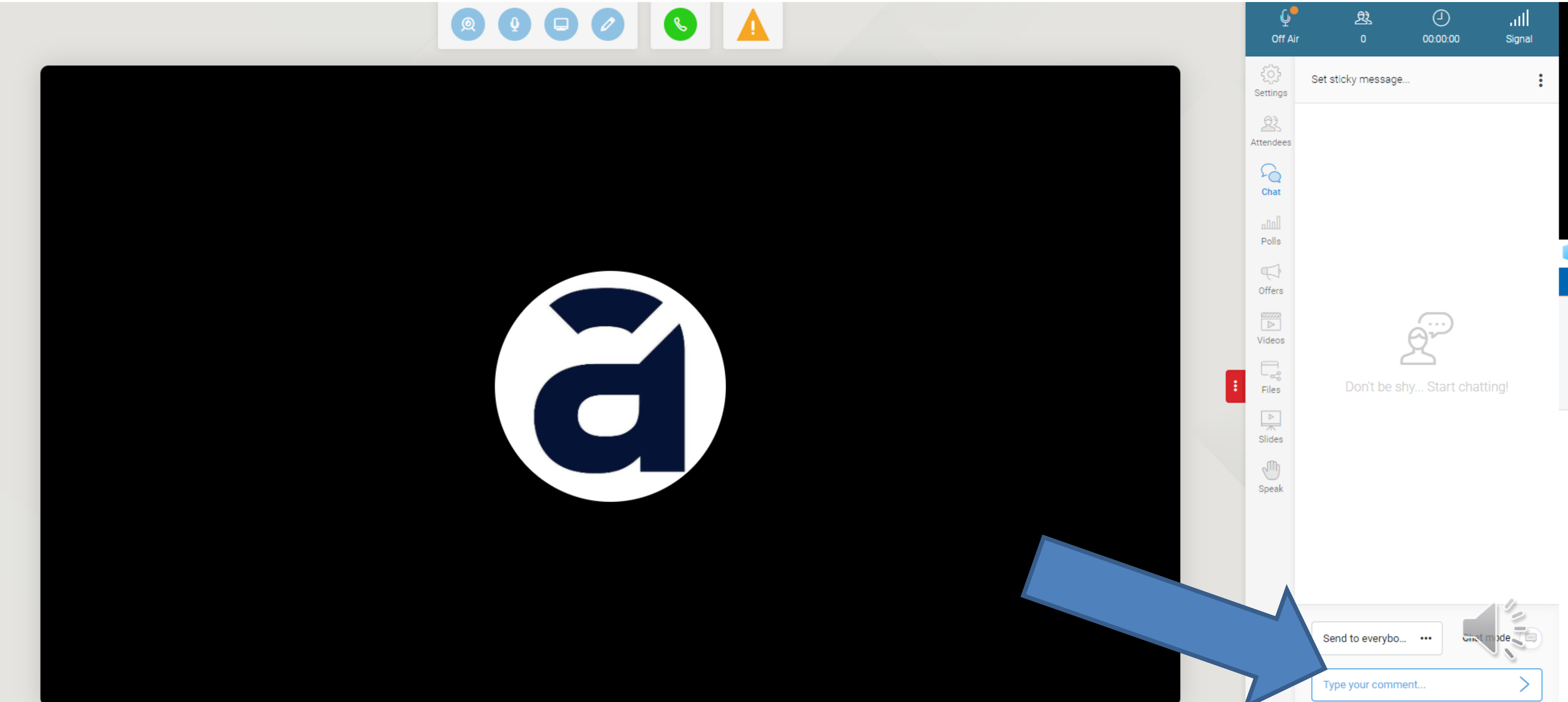
Agenda

OxiGEN
Next generation SOFC solutions

Time	Subject	Speaker	Time
03:05 – 03:10	**Presentation of European Commission & FCH** • Overview of similar projects • Introduction of the next partnership	**Dionisis Tsimis** – European Commission	5’
03:10 – 03:15	**Overall Project Presentation** • Global presentation of Saint-Gobain, and Robert Germar, the Coordinator (personal background) • Project background • Project Overview • Objectives of the Project/Planned results • Purpose of the Webinar/Results chosen to build the agenda	**Robert Germar** – Saint-Gobain	5’
03:15 – 03:25	**Hot box specification and cost analysis for European markets**	**Patrick Millin** - ENGIE	10’
03:25 – 03:35	**Stack definition and production**	**John Pietras** – Saint-Gobain	10’
03:35 – 03:50	**Modular hot box concept & testing**	**Sebastian Hielscher** - IKTS	15’
03:50 – 04:00	**Integration of modular hotbox to system**	**Carlo Tregambe** - ICI	10’
04:00 – 04:10	**Short stack performance assessment under system conditions**	**Karine Couturier** - CEA	10’
04:10 – 04:25	**Routes for stack performance improvement**	**Julian Dailly** - EIFER **Marie-Laure Fontaine** - SINTEF	15’
04:25 – 04:35	**Economic impact of OxiGEN solution**	**Steven Arshurst** – Delta EE	10’
04:35 – 04:55	**Questions & Answers**	**John Pietras** – Saint-Gobain **Robert Germar** – Saint-Gobain Assisted by Clara Pawlak – Absiskey	10’
04:55 – 05:00	**Conclusion**	**Robert Germar** – Saint-Gobain	5’

Features – Chat, Q&A

OxiGEN
Next generation SOFC solutions



NEXT

Dionisis Tsimis

European Commission and FCH-JU

OxiGEN
Next generation SOFC solutions

OVERALL PROJECT PRESENTATION

Robert Germar, Coordinator of the Project
Saint-Gobain

SAINT-GOBAIN

5'

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Saint-Gobain

- French based company with worldwide activities
- Turnover round 40 b€, 170.000 employees
- Construction Materials: Building glass, glass & stone wool, gypsum, mortar 80%
- High Performance Solutions: Mobility, Life Science and Ceramic Materials 20%
- Eight Transversal R&D Centres, in France Saint-Gobain Research Paris and SGR Provence
- The company's purpose is “Making the World a Better Home”
- Saint-Gobain is engaged to get to carbon neutrality in 2050

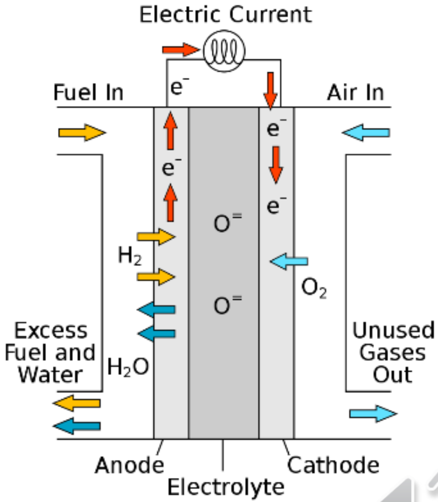
  => Research in alternative technologies for industrial applications & housing

  => Decrease of energy consumption and carbon dioxide emissions

Project background

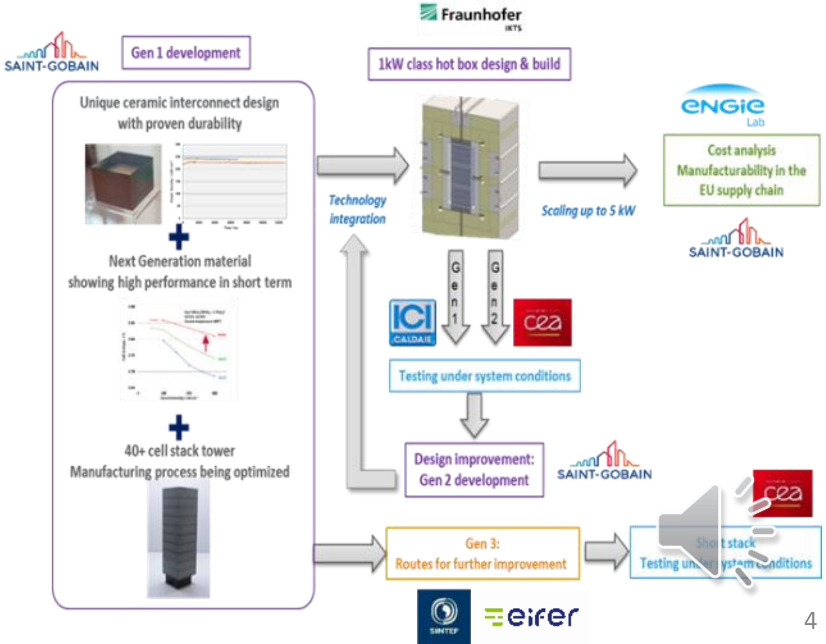
- Solid Oxide Fuel cells
- Electrochemical reaction producing electric current & heat
- Without CO_2 emissions
- Small size allowing local individual implementation
- Made from Ceramic materials

- µCHP
- Micro Cogeneration of Heat & Power



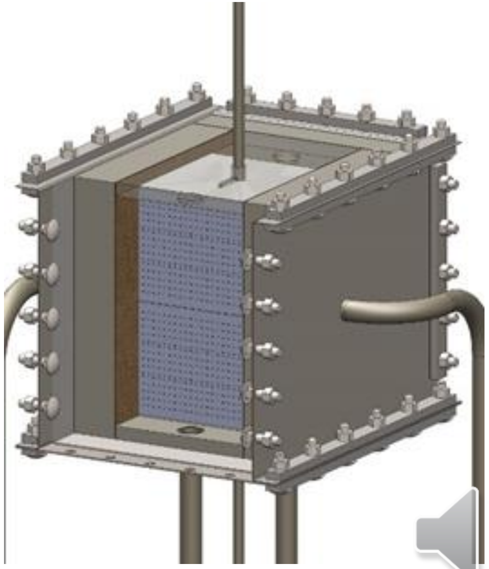
Project overview

- Seven European Partners
- Generation 1 Development
  - Stacks: **Saint-Gobain**
  - Hot box design & build'up: **Fraunhofer**
  - Cost, munufacturabilty & supply chain: **Engie**, SG (Delta EE)
  - Testing under system conditions: **ICI** and **CEA**
  - Eventually leading to a Generation 2 design: SG
- Improvements leading to Generation 3
  - Routes of further improvement: **Sintef**, **Eifer**
  - Short stack testing: CEA



Objectives of the project

- Define Specifications for µCHP
  - for European individual houses
  - & small commercial markets
- Develop Technical Platform
  - Definition of suitable stack
  - Modular hot box concept
  - Assessment of performance of prototype & its costs
- Direction for Further Improvement
  - Proposition of stack improvement
  - Assessment of economic impact
  - Integration into European supply chain
  - Dissemination of results



OxiGEN
Next generation SOFC solutions

NEXT

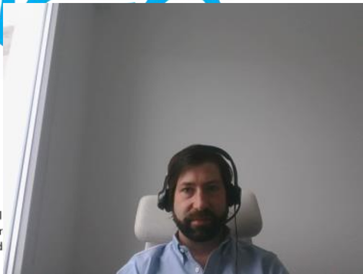
Patrick Milin

Hot box specification and cost analysis for European Market

OxiGEN
Next generation SOFC solutions

HOT BOX SPECIFICATION AND COST ANALYSIS FOR EUROPEAN MARKET

Patrick Milin, ENGIE



This project has received funding from the Fuel
agreement No 779537. This Joint Undertaking r
2020 research and innovation programme, Hyd

Objectives: To define the best sizing of SOFC mCHP

Residential

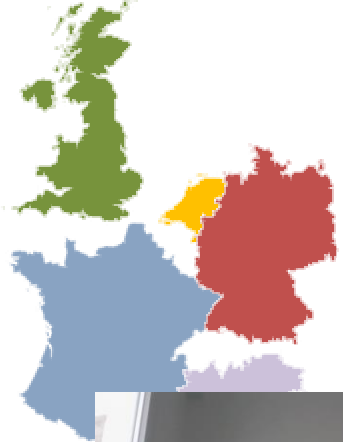
- ✓ Individual
- ✓ collective

Commercial

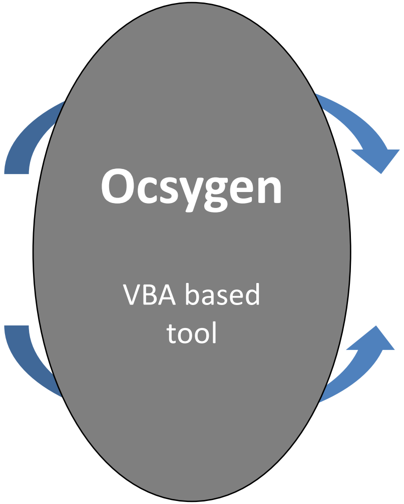
- ✓ Offices
- ✓ Education
- ✓ Retail
- ✓ Health
- ✓ Hotels

5 countries

- ✓ France
- ✓ Germany
- ✓ UK
- ✓ Italy
- ✓ The Netherlands



Ocsygen Tool to support OxiGEN project



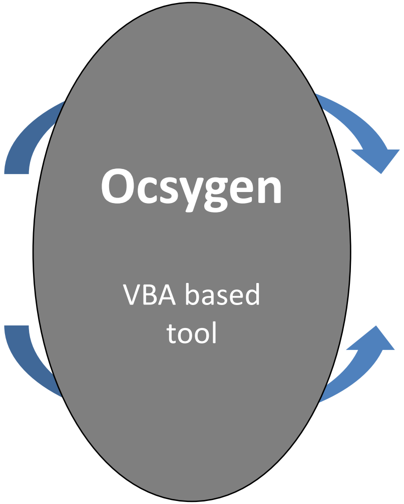
Match the Buildings and the Systems to optimize the **outputs**

Ocsygen Tool to support OxiGEN project

Inputs :

Buildings

- Type of Market :
  - Residential (individual and collective)
  - Non-residential (Education, Retail,…)
- 5 countries : UK, FR, GE, NL, IT
- Different Building characteristics (U-value,…)



Match the Buildings and the Systems to optimize the **outputs**

Ocsygen Tool to support OxiGEN project

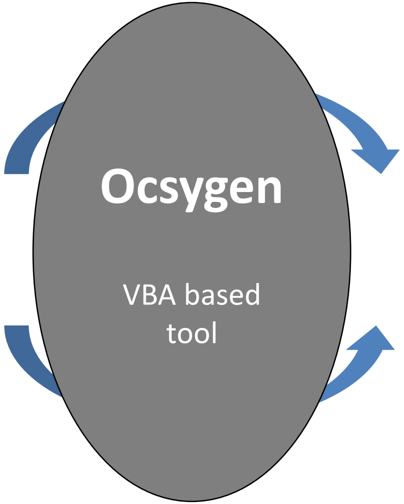
Inputs :

Buildings

- Type of Market :
  - Residential (individual and collective)
  - Non-residential (Education, Retail,…)
- 5 countries : UK, FR, GE, NL, IT
- Different Building characteristics (U-value,…)

Systems

- Different system characteristics : Power, efficiency
- Different system management



Match the Buildings and the Systems to optimize the **outputs**

Ocsygen Tool to support OxiGEN project

Inputs :

Buildings

- Type of Market :
  - Residential (individual and collective)
  - Non-residential (Education, Retail,…)
- 5 countries : UK, FR, GE, NL, IT
- Different Building characteristics (U-value,…)

Systems

- Different system characteristics : Power, efficiency
- Different system management

Ocsygen

VBA based tool

Outputs :

Monetary

- Energy bill (Electricity + NG)
- Total Cost of Ownership

- Environment consumption

Match the Buildings and the Systems to optimize the **outputs**

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Focus on the model used for simulation

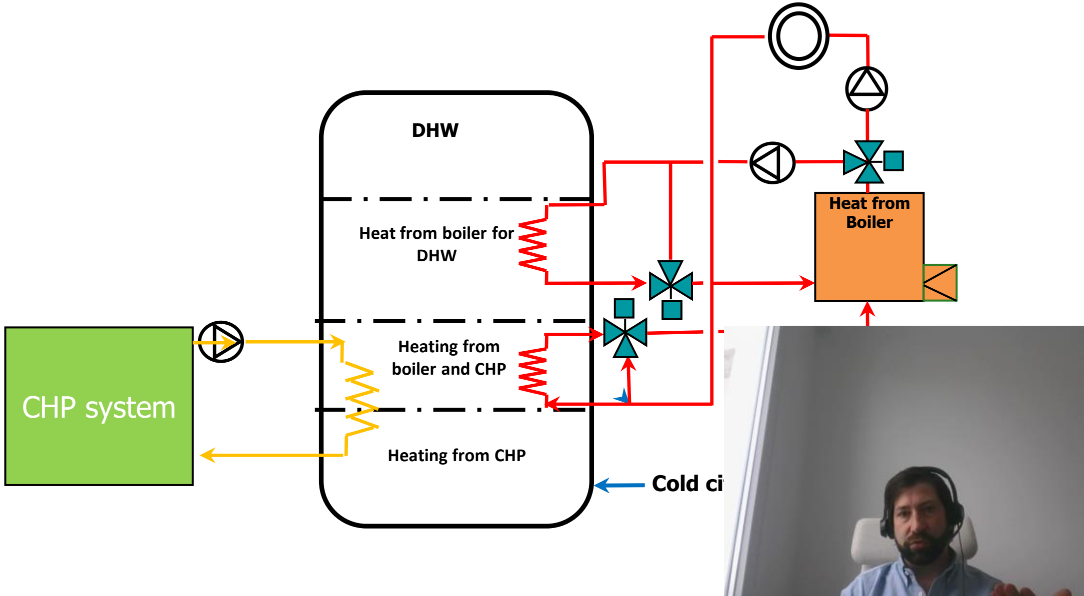
A CHP system with its own monitoring rules (temperature, cycling)

CHP system

Focus on the model used for simulation

A CHP system with its own monitoring rules (temperature, cycling)

Connected to a complex energy system

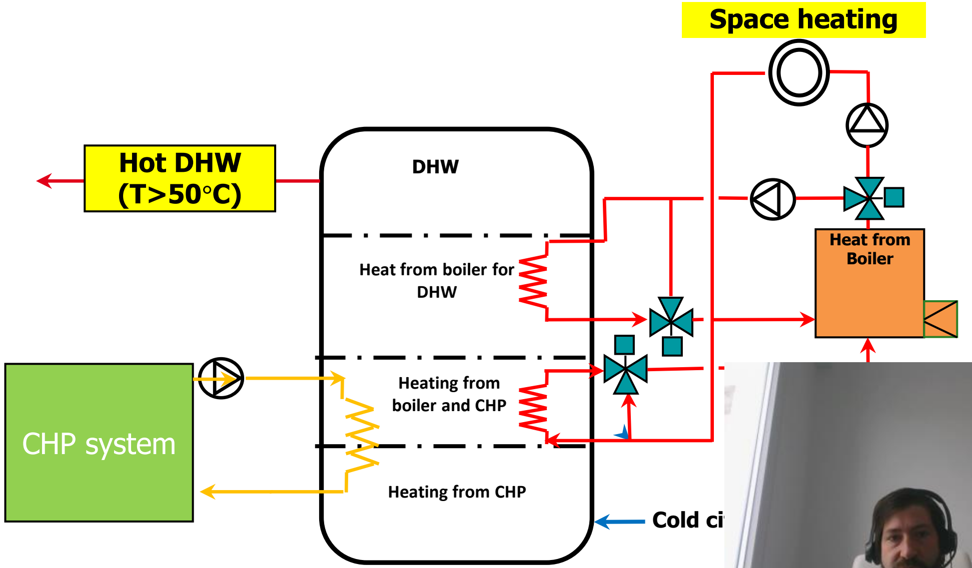


Focus on the model used for simulation

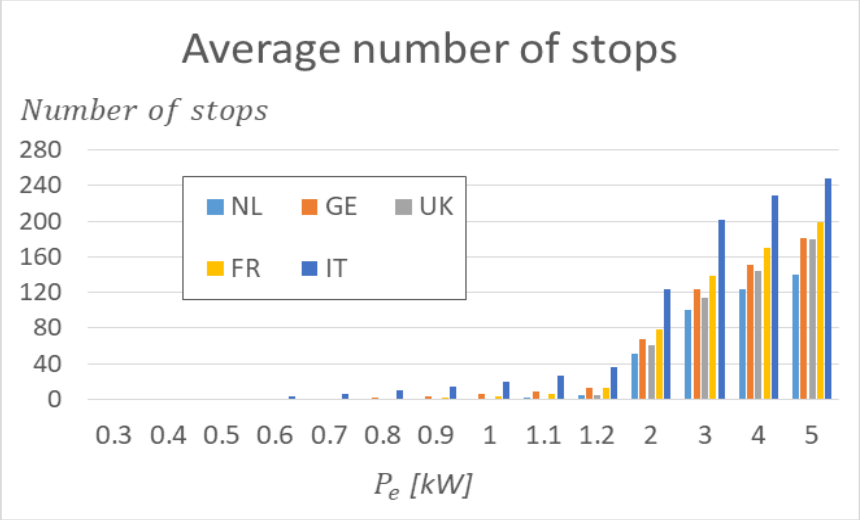
A CHP system with its own monitoring rules (temperature, cycling)

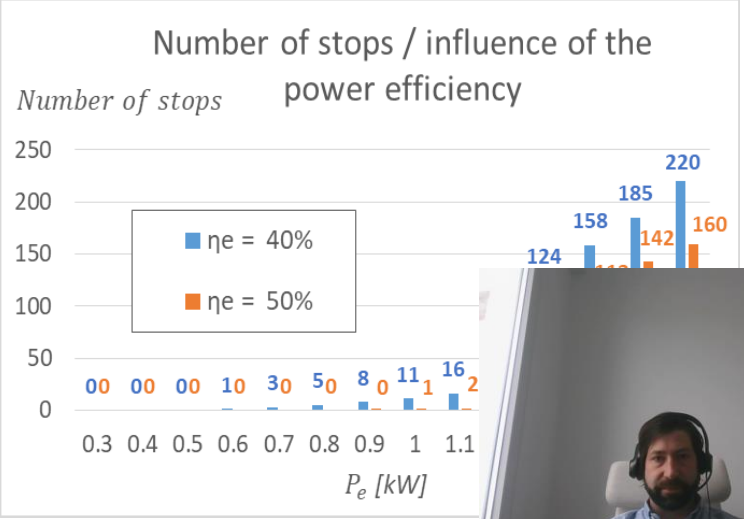
Connected to a complex energy system

To produce for space heating and domestic hot water production



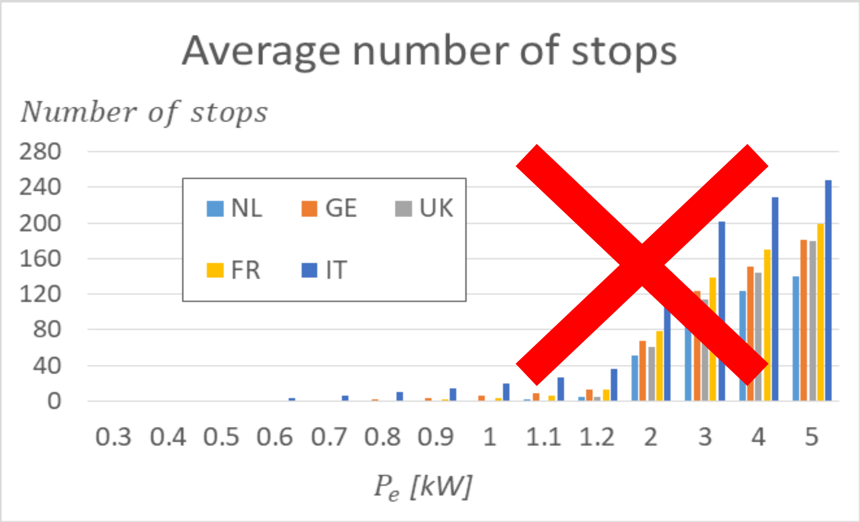
Methodology: technical specifications

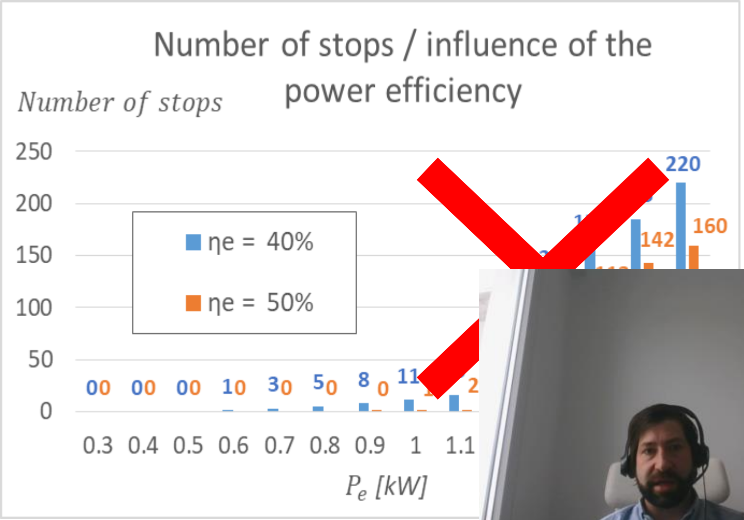




Methodology: technical specifications

- The priority is to limit cycling of the SOFC system

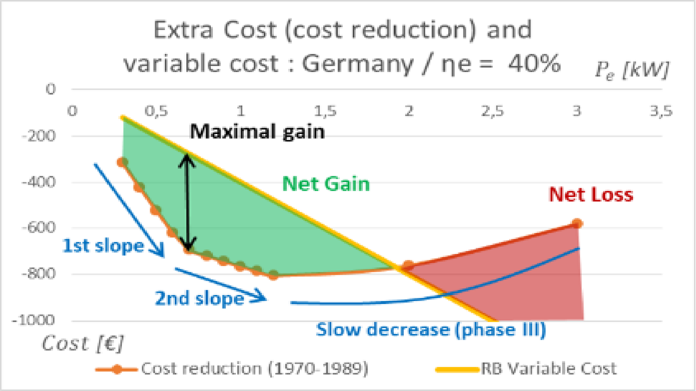




Methodology: economic aspects

- A CAPEX of FC mCHP can be described as CAPEX = Fix cost + Cost of SOFC(kW)
- The study analyzed the equilibrium CAPEX/OPEX to reach profitability compared to boiler

Slopes are linked to self-consumption of electricity



	NL	D	UK	FR	IT
Maximum Power output [kWe]	0,9	0,7	1,1	0,6	0,5
variable cost [€/kWe]	4000€	4000 €	4000 €	4000 €	3000 €
Maximum cost (€)	1210 €	4110 €	14 1		

M
profi
situ

Summary of results (1/2)

- Single Family Houses :
  - ✓ **Stopping the SOFC in summer seems to be compulsory**
  - ✓ **Power output of 0.6 kW** can fit all countries (0.5 for Italy)
  - ✓ Efficiency has a limited impact on cost savings, but **high power efficiency minimizes on/off cycles**
  - ✓ Regarding costs, for most countries, **a maximum of stack related CAPEX of 4000€/kW is compulsory**, assuming 10 years lifespan.
  - ✓ With this stack cost, total CAPEX objective (boiler, inverter, and other BOP) appears to be hard to reach, except **UK and maybe Germany**. These two countries appear to be the most promising, and generation tariffs (other incentives have not been considered).

Summary of results (2/2)

- Multi Family Houses
  - ✓ **SOFC can be operated all year long**
  - ✓ **Power output of 2 kW can fit all countries**
  - ✓ Higher positive impact of power efficiency on on/off cycles than for SFH
  - ✓ This market seems easier to address, from a cost point of view. **Germany and UK are the most attractive**.

- 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. mCHP**

Conclusions: the conditions of success are now defined

OxiGEN
Next generation SOFC solutions

NEXT

John Pietras

Stack definition and production

OxiGEN
Next generation SOFC solutions

STACK DEFINITION AND PRODUCTION

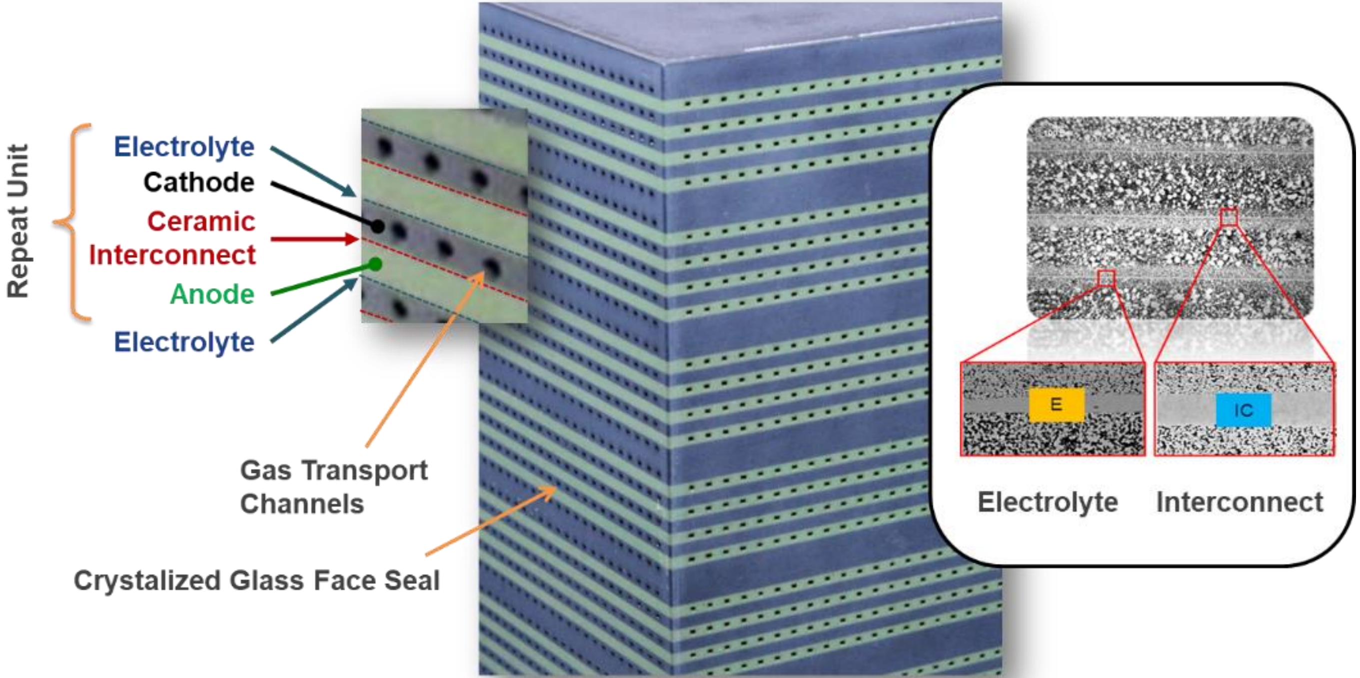
John PIETRAS, Saint-Gobain

SAINT-GOBAIN

10’

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Novel monolithic stack design achieved by ceramic co-firing and a surface glass seal



Monolithic design provides high durability, efficiency and manufacturability

Durability & Reliability

- Novel ceramic interconnects (Cr free)
- Reliable glass seal
- Designed for thermal cycling stability

Low Cost

- Multi-cell processing & co-firing
- Vertically integrated company
- Modular design

High Electrochemical Performance

- High operational voltage in reformate gas
- Design allowing multi-pass fuel processing
- Extendable to electrolysis operation

FCH
SAINT-GOBAIN

WP2 designed to prepare co-sintered cells/stacks for the development work packages

Powder Sourcing

- Order materials for all layers within the stack (functional layers, electrolyte, interconnect)
- Produce in-house powders (bulk electrodes, functional layers)
- Qualify sintering kinetics/performance of all powders

Cell/Stack Production

- Finalize stack design based on WP1 results, targeting a 600W stack (40 cells)
- Green forming
- Co-sintering
- Finishing / sealing

Powder Sourcing | Stack Production

Powders *SG produced*

Powders *Externally sourced*

Qualification *Sintering kinetics*

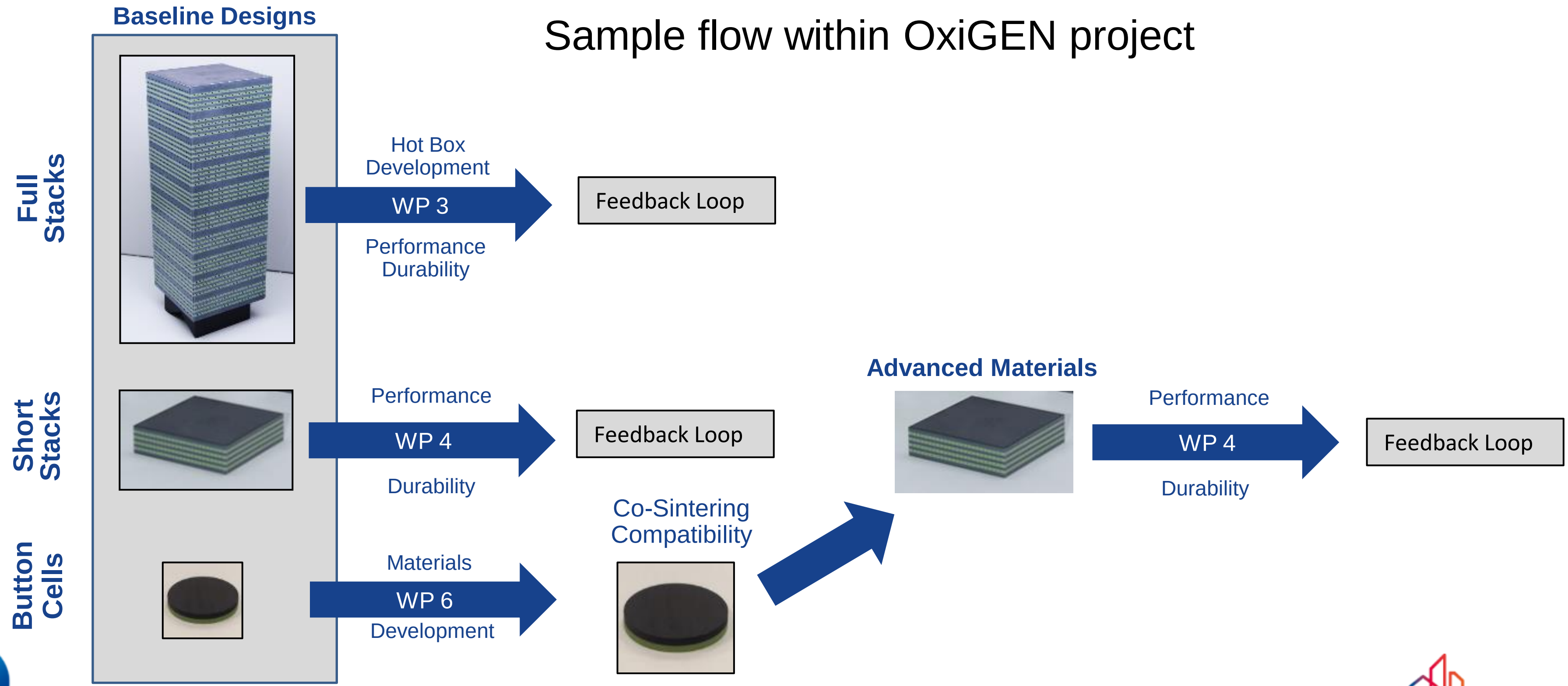
Green Forming *Casting, lamination…*

Co-Sintering *Button cells, stack*

Sealing *Glass application*

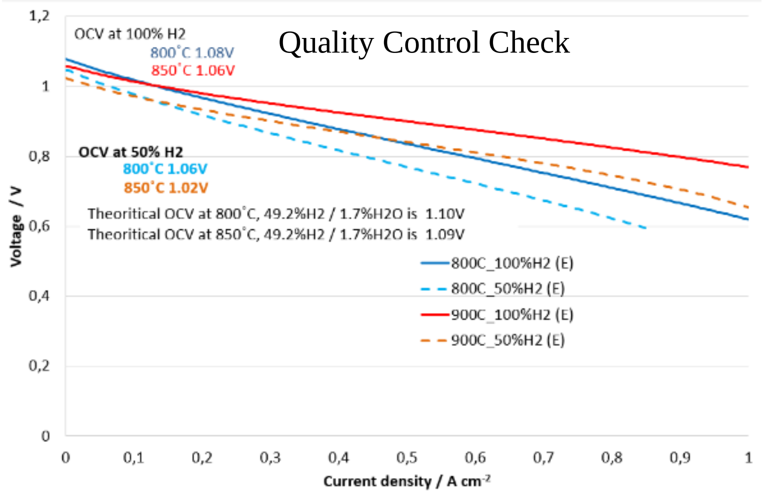
SAINT-GOBAIN

Sample flow within OxiGEN project

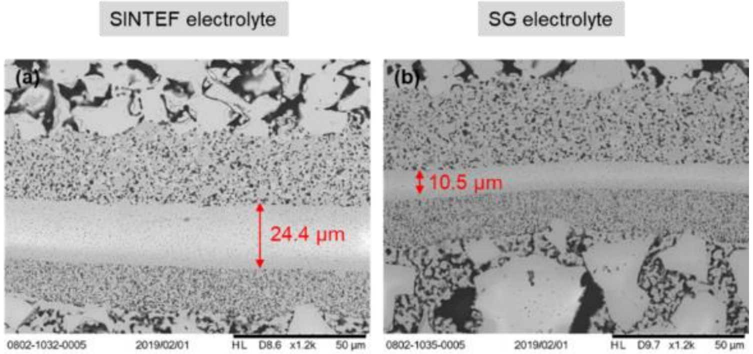


Summary of button cell manufacturing

- Ten button cells were prepared for use in WP6 as baseline cells
- Quality check performed at SG before shipping
- Button cell platform used to guide development of Advanced Materials



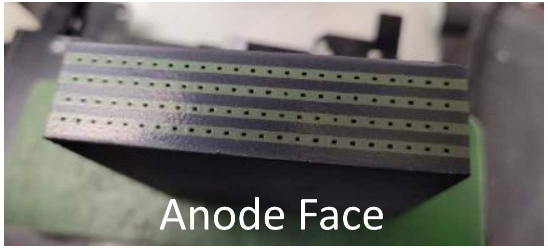
Example of Advanced Materials
to be presented in WP6



Cell ID	T (C)	OCV (V)	Current @0.8 V (A/cm^2)
0802-1035 (SG)	800	1.096	0.688
0802-1032 (SINTEF)	800	1.101	0.803

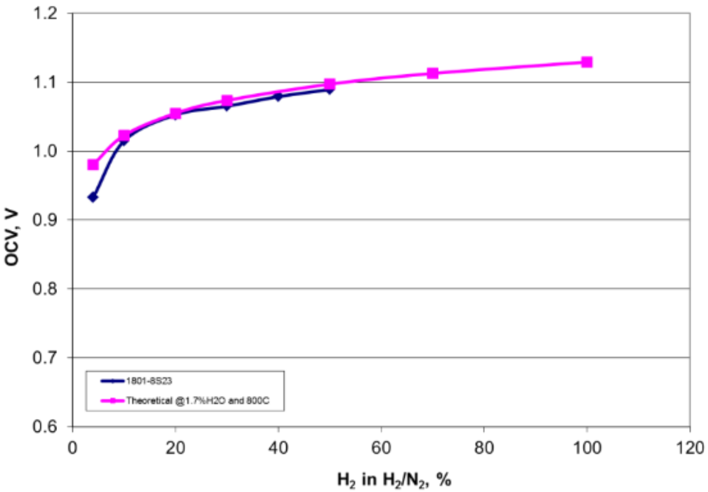
Short stack production and quality control

Glass Sealed Faces



Test manifold and cross leak testing

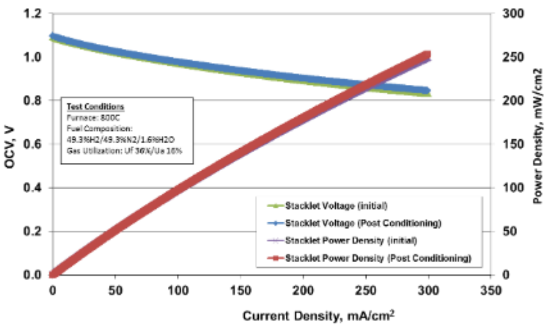
Leak Check - Passed



Short stack testing prior to shipping

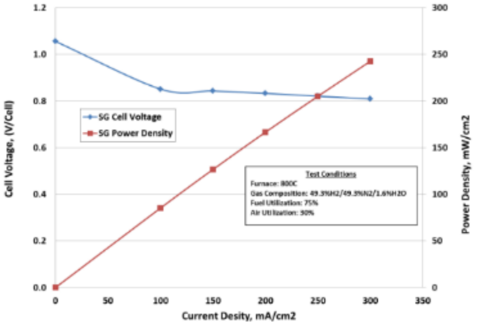
Low Utilization Performance

(Uf = 36%, Ua 16%)

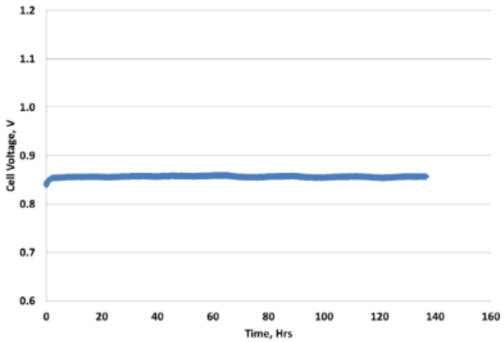


High Utilization Performance

(Uf = 75%, Ua = 30%)



Performance Conditioning



Full stack design & production

Production process:

- Subcomponents for stack (40 cells) prepared
- Subcomponents undergo quality checks

Component	1	2	3	4	5	6	7	8	9	10
Status	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

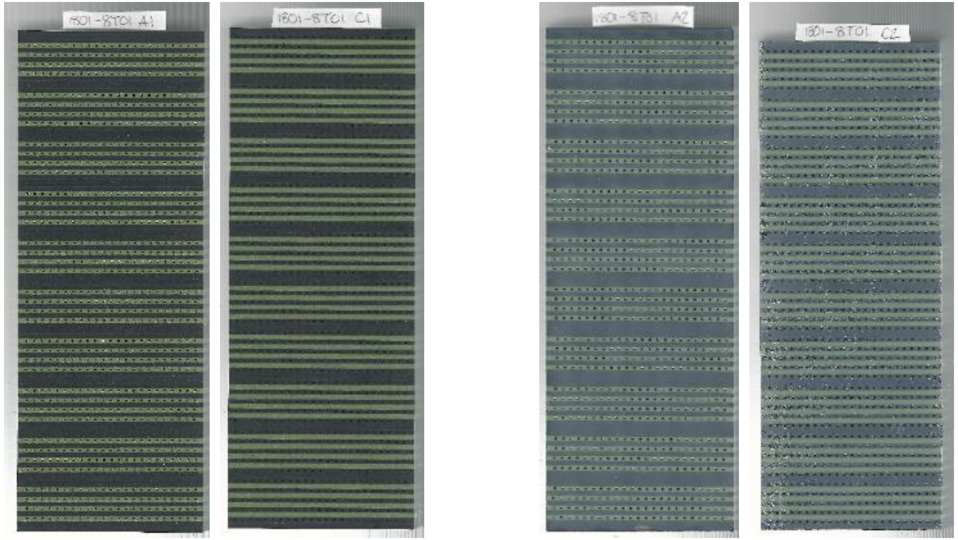
- Stack is completed

Problems encountered:

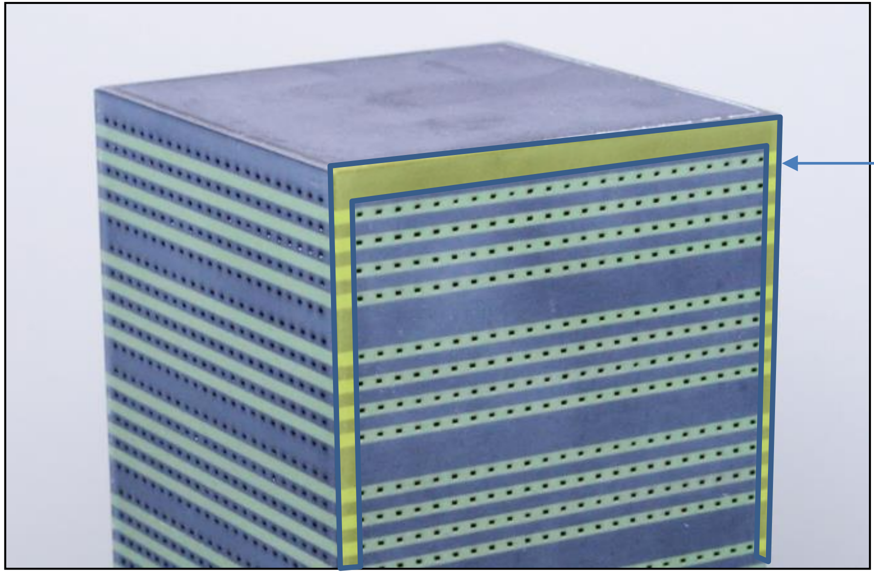
- Sealing glass defects
- Maintaining alignment of subcomponents
- Reduction based quality control, manifold concurrently developed in WP3

As-Prepared

Glass-Sealed



Face sealed stack requires unique hotbox design discussed in WP3



Gasket region

Challenges encountered:

- Although sintering rate for the electrolyte was matched, and the AFL particle sizes were similar – this does not ensure proper co-sintering behaviour
- Transition from individual material development to fully sized stack requires much development work.
- Glass sealing quality – batch to batch variations could lead to point defects
- Start-up conditions, especially critical with the hot box

Achievements and Lessons Learned:

- Parameters developed to incorporate advanced electrolyte and AFL into button cells
- 4-cell short stack with advanced electrolyte and AFL produced
- Glass seal application improvements increased yield
- Improved stack production process minimizing chance for misalignment of cells
- Short stack operation during WP4 identified ‘risky’ H_2 concentration conditions for stack identified during transients
- Initial hot box start-up and performance testing completed, ‘risky’ conditions for stack identified during transients

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

SAINT-GOBAIN

NEXT

Sebastian Hielscher

Modular hot box concept & testing

MODULAR HOT BOX CONCEPT & TESTING

Sebastian Hielscher, IKTS

OxiGEN
Next generation SOFC solutions

Fraunhofer
IKTS

10'

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

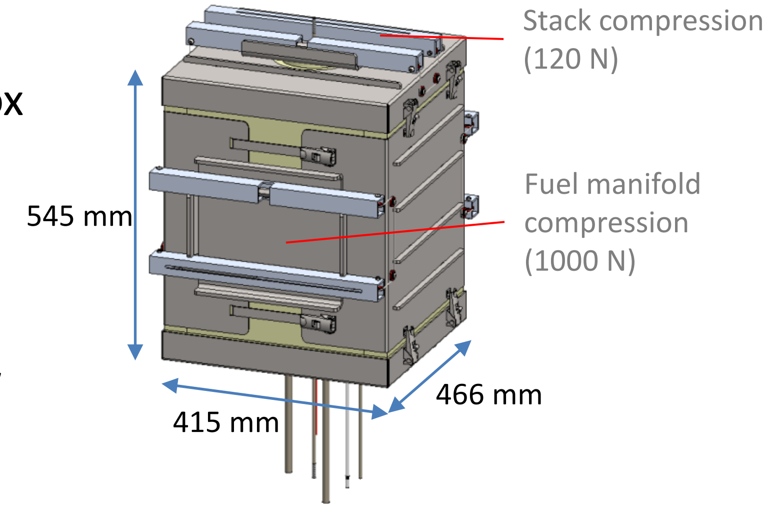
Design and development of a modular hot box

Fraunhofer
IKTS

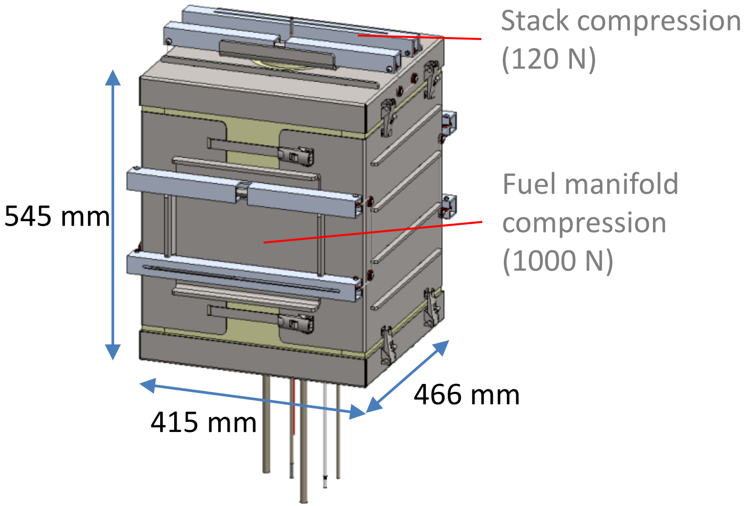
Hotbox version HB1.1

Generation HB1.1
- Saint-Gobain 40 cell tower within air-tight box
- Insulated with microporous material
- Outer compression
- Media feed from below

→ Basis for modular concept 600 W and 2.5 kW

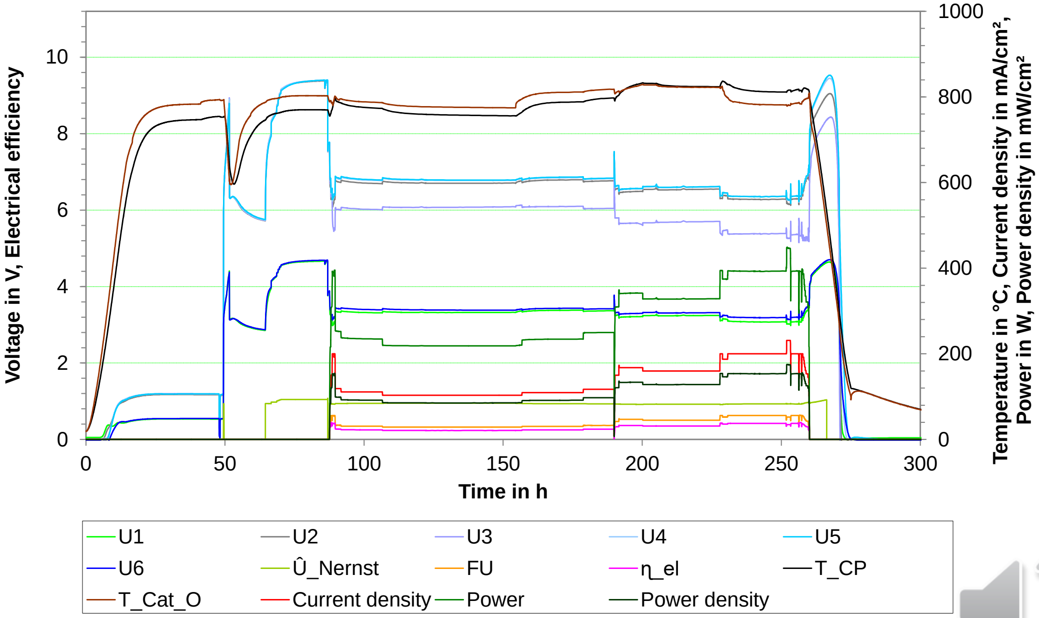


Hotbox version HB1.1



Hotbox operation

Commissioning test:
- Heating up
- Reduction phase
- Operation phase:
  393 W @200 mA/cm²



OxiGEN Next generation SOFC solutions

FCH Fuel Cells and Hydrogen Joint Undertaking

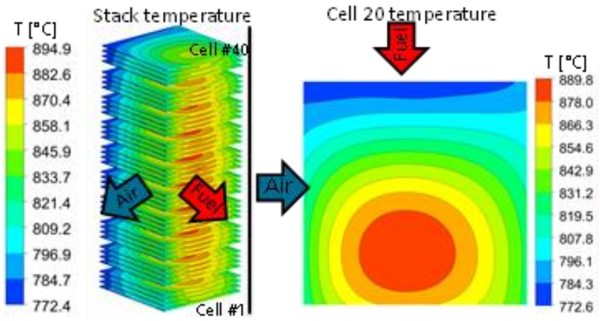
Fraunhofer IKTS

Hotbox operation

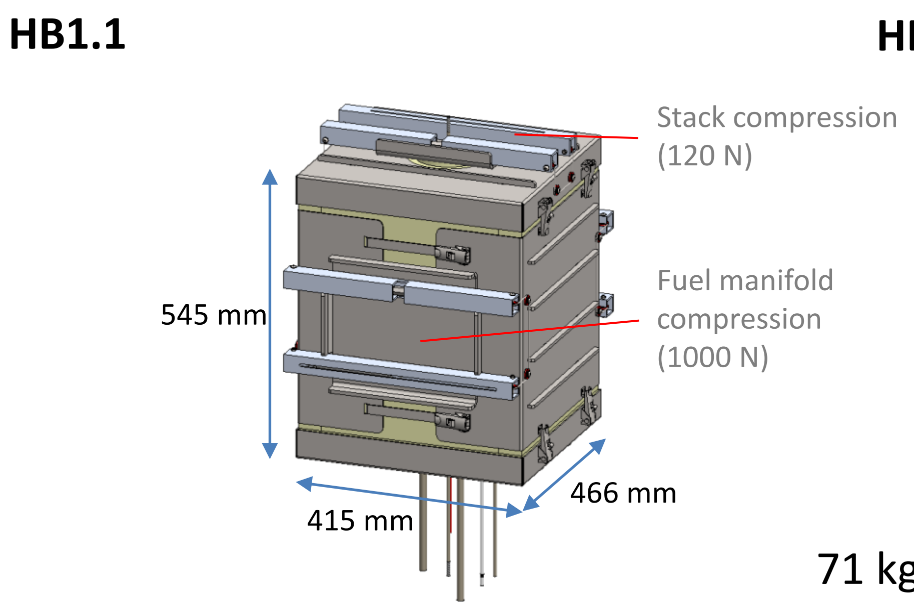
Operation phase:

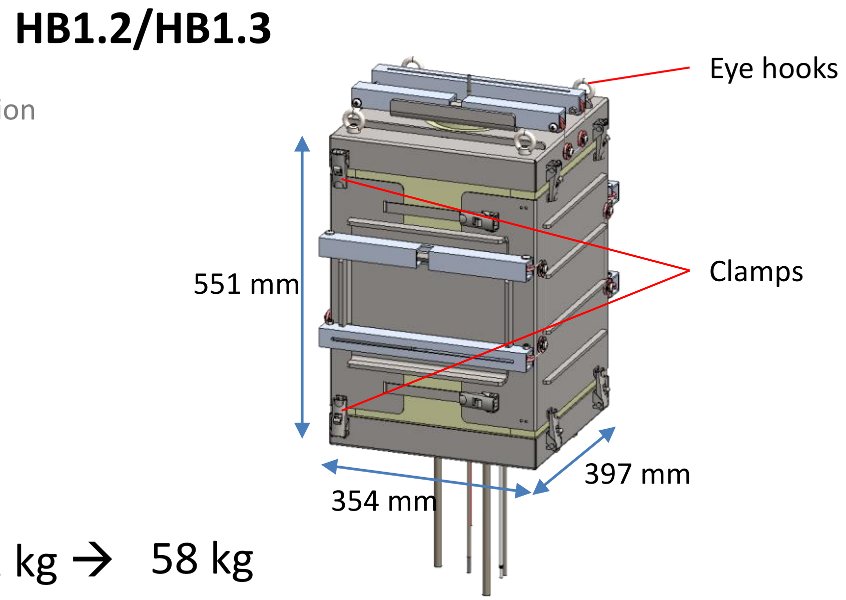
- 9.6 A reached with 310 W
  → comparable to simulation (306 W)
- 12.8 A (200 mA/cm²) stationary at 393 W for 20 h

→ 600 W at 300 mA/cm² with Gen2 stack is possible



Hotbox version HB1.2/1.3

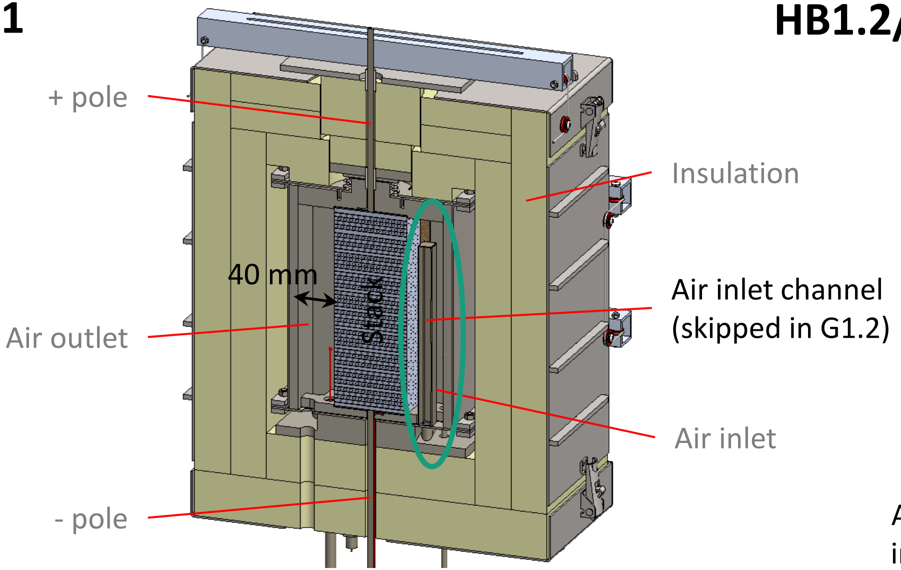




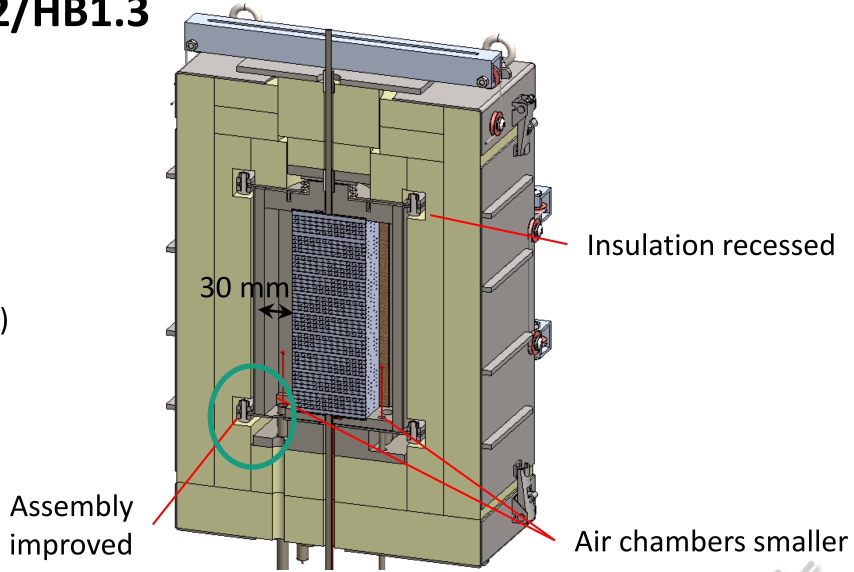
71 kg → 58 kg

Hotbox version HB1.2/1.3

HB1.1

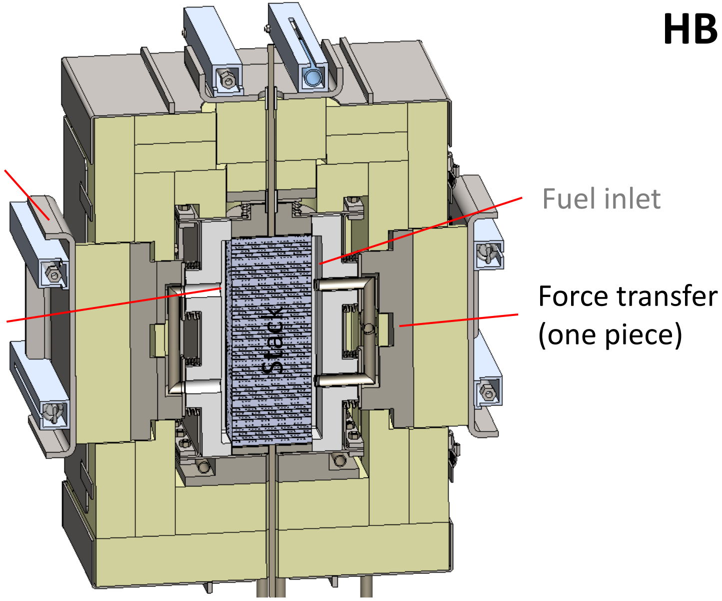


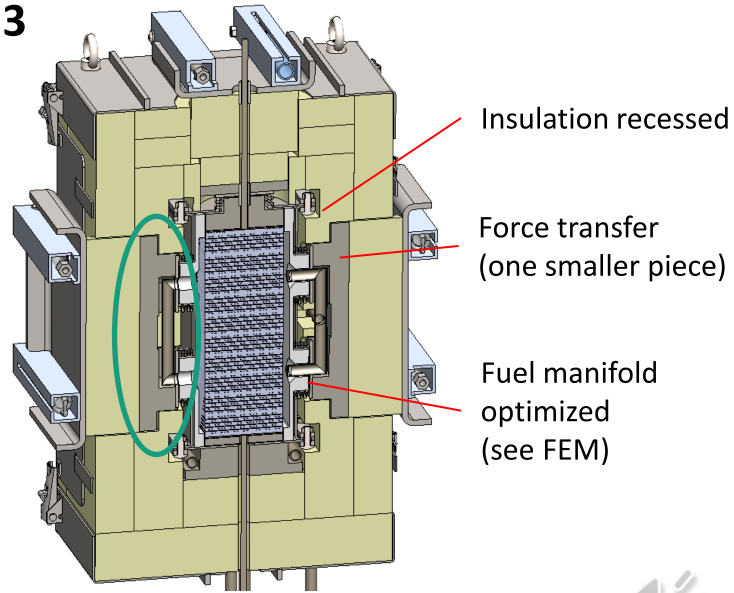
HB1.2/HB1.3



Sectional view air side

Hotbox version HB1.2/1.3

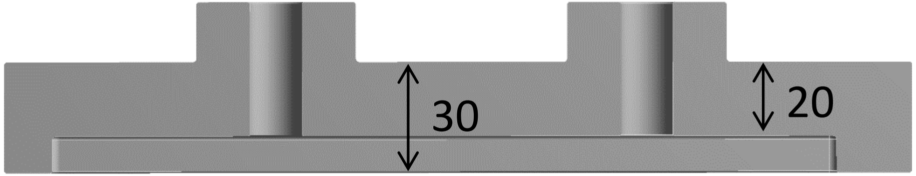


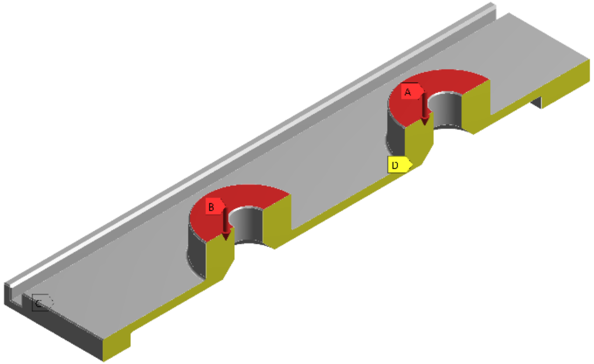


Sectional view fuel side

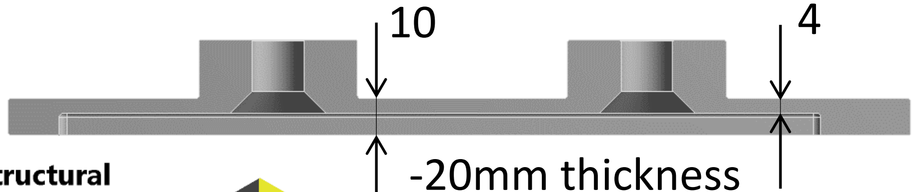
FEM simulation manifold

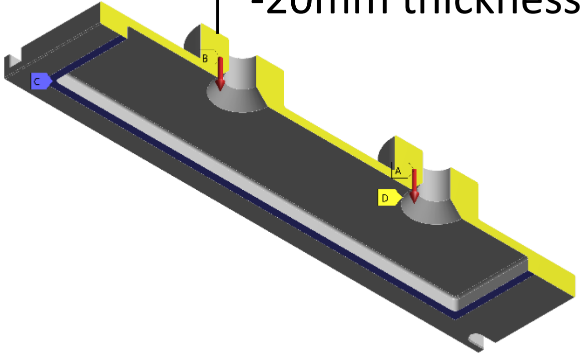
Thick manifold





Thin manifold





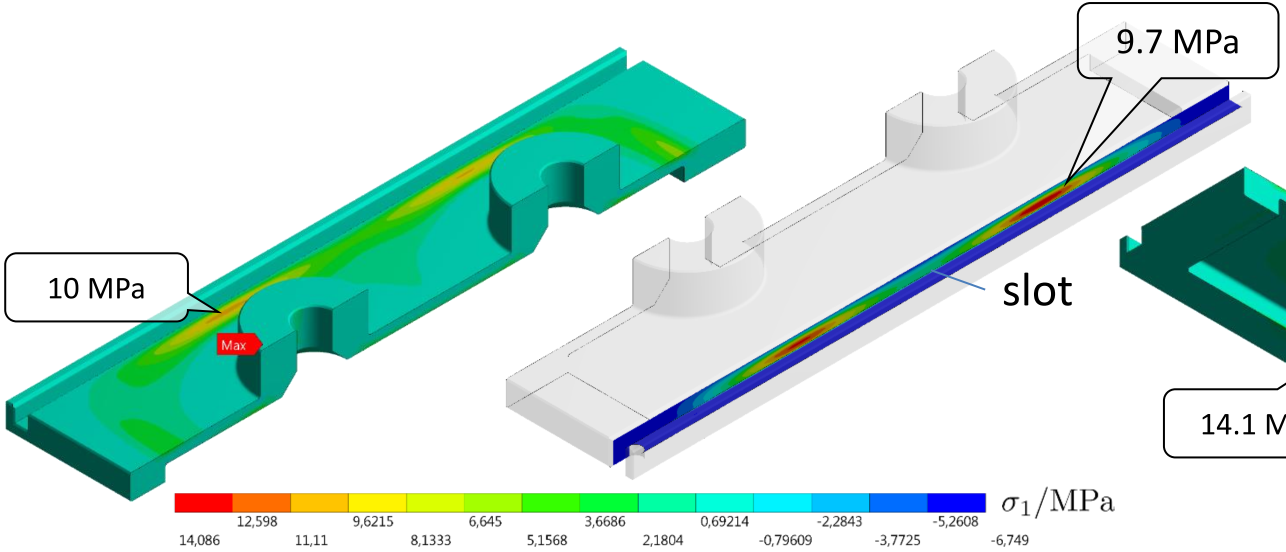
A: Static Structural
Static Structural
Time: 1, s

- **A** Force: 250, N
- **B** Force 2: 250, N
- **C** Fixed Support
- **D** Displacement

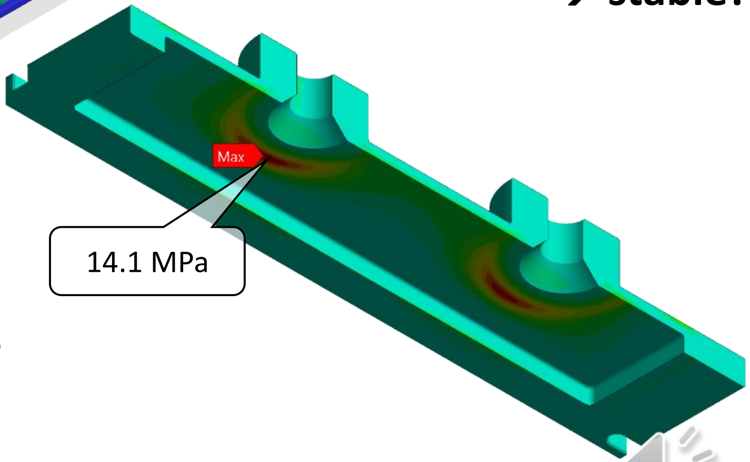
FCH Fuel Cells and Hydrogen Joint Undertaking

Fraunhofer IKTS

FEM simulation manifold



Max. allowable strength:
14.1 MPa < 300 MPa
→ stable!

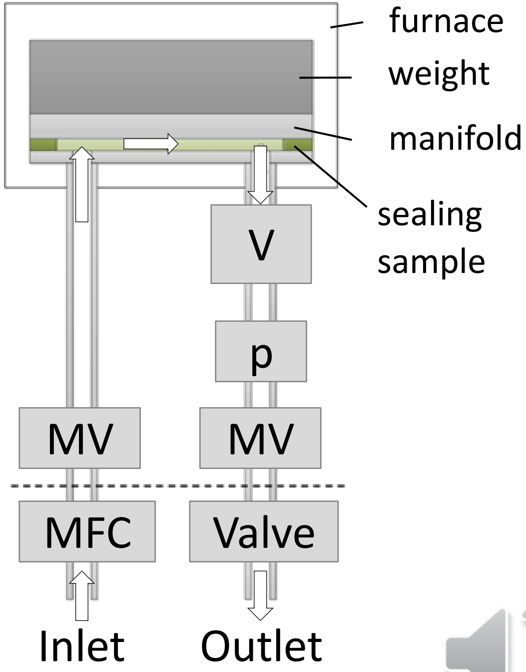


FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Fraunhofer IKTS

Fuel manifold – tightness test

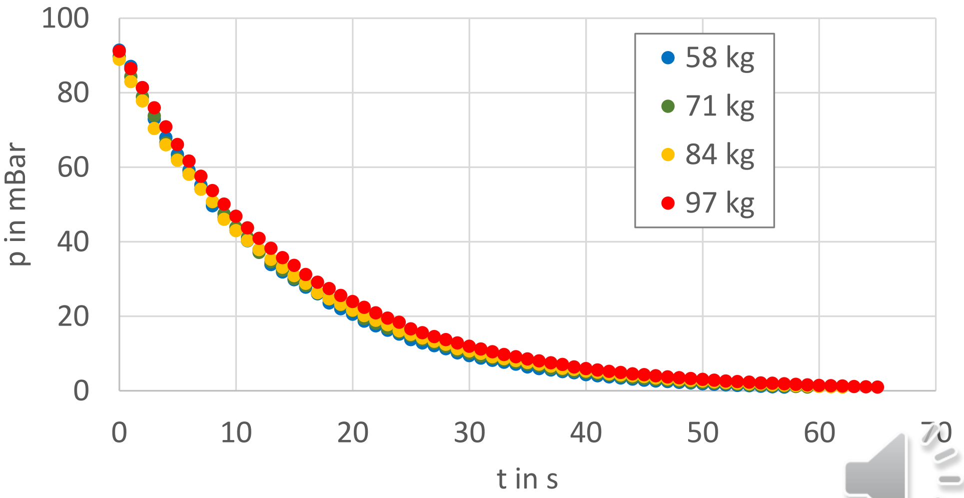
- Standardized pressure drop tests with Cogebi mica and manifold sets
- Test rig for pressure drop tests → verified with silicone dummy



Fuel manifold – tightness test

- Standardized pressure drop tests with Cogebi mica and manifold sets
- Test rig for pressure drop tests → verified with silicone dummy

- Manifolds resist 97 kg (950 N) pressure
- Pressure drop 90 to 1 mbar >30 s
- Pressure drop from 40 to 20 mbar in 9-10 s
- No influence of compression (→ 500 N for Gen 2)
- Cyclability 5 time with improved tightness

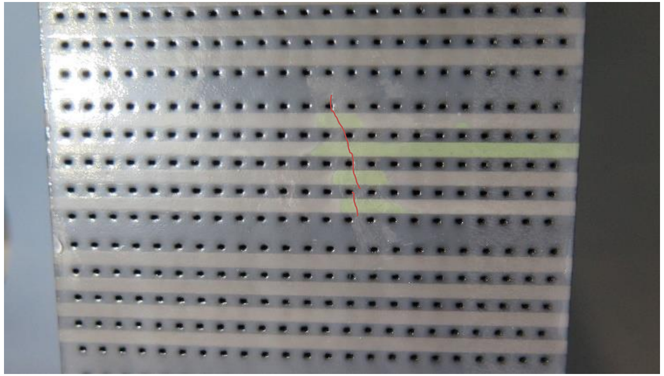


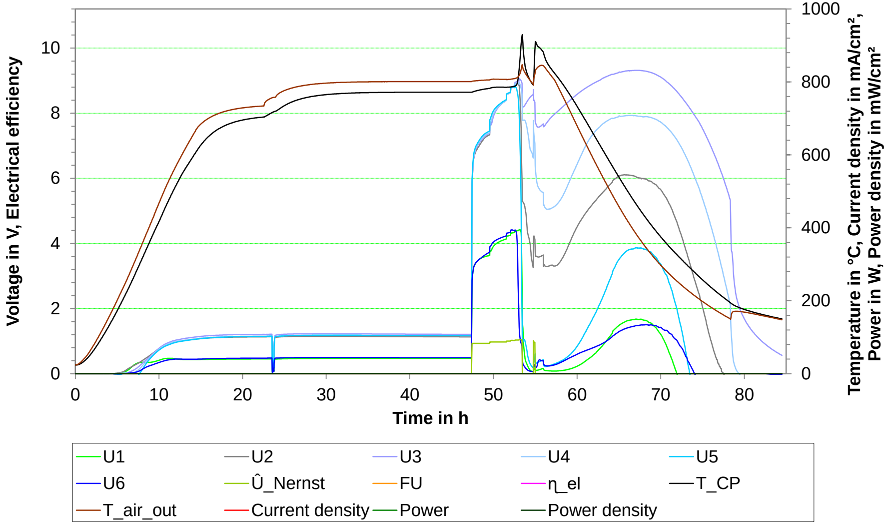
Fraunhofer IKTS

Hotbox version HB1.2/1.3

Operation

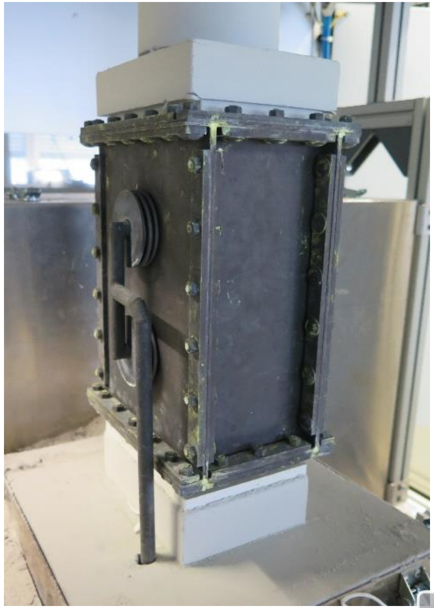
- Sudden stack damage
  → Leckage detected in time
- Cooled down with no further damage





Hotbox stack integration

- Hotbox assembled 5 times
- No burning marks or damages on insulation

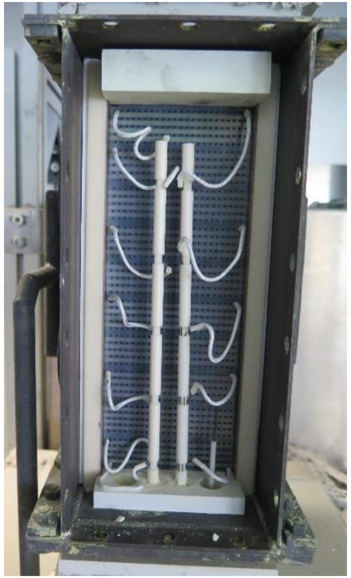


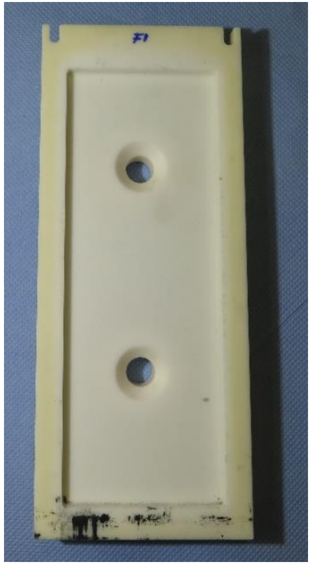
Hotbox stack integration

- Hotbox assembled 5 times
- No burning marks or damages on insulation

- No damage on alumina manifold
- Strong mica imprint
  → good tightness

- Design ready for further tests

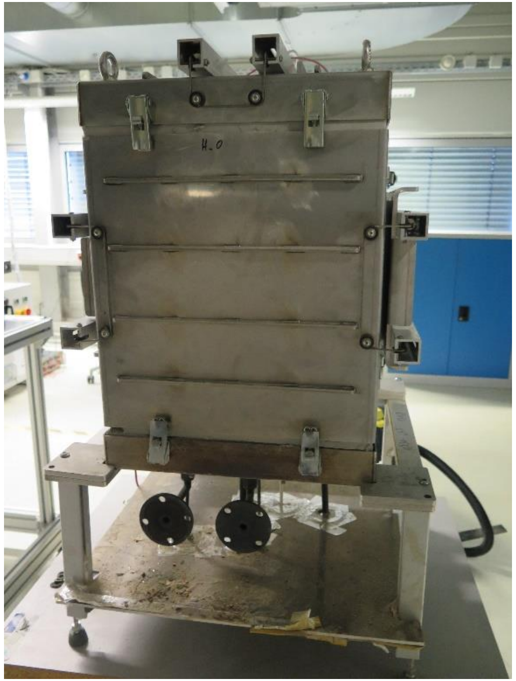




Conclusion and outlook

- Successful development of compact hotbox
- P_{el}=393 W reached

- Operation proof with next 40 cell tower
- 600W with Gen2 stack possible
- Scalable to >2 kW



OxiGEN
Next generation SOFC solutions

NEXT

Carlo Tregambe

Integration of modular hotbox to system

OxiGEN
Next generation SOFC solutions

INTEGRATION OF MODULAR HOTBOX TO SYSTEM

Carlo Tregambe, ICI Caldaie

ICI CALDAIE

10’

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

SYSTEM MANAGEMENT REQUIREMENTS

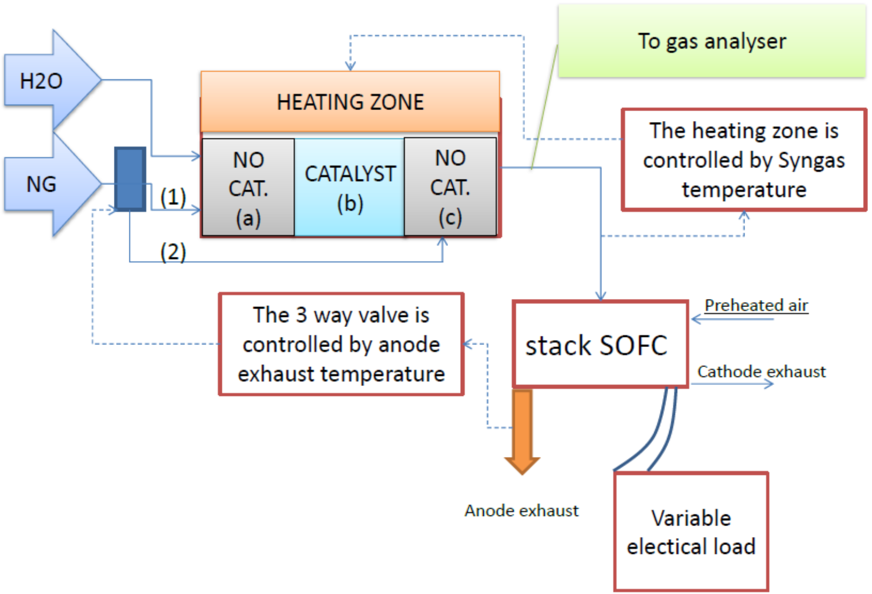
- Fast response to load variation (ranging from 20% to 100% in few seconds)
- Possibility of working at different fuel utilization
- Idle conditions at correct operation temperature for fast restart

- Stack temperature profile is a function of
  - Syngas and Air inlet temperature
  - Electrical load and fuel utilisation
  - Syngas composition (internal reforming)

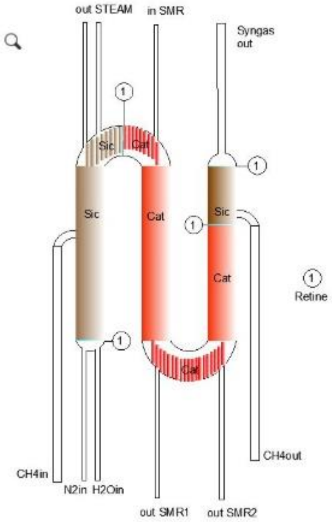
- Goal: mantein correct stack temperature profile in all operation condition

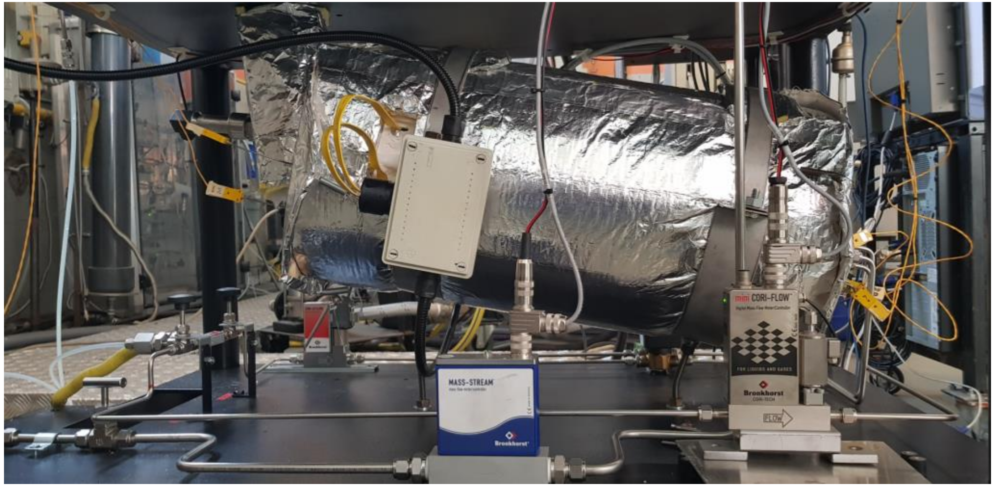
SYNGAS COMPOSITION CONTROL

- Internal reforming can be used as an independent temperature control lever for the stack
- It is possible to modify the syngas composition, and consequentially the internal reforming, acting on a bypass (a 3 way valve placed on NG line).
- Anode exhaust gas show a more reactive temperature variation than the STACK (higher thermal inertia)



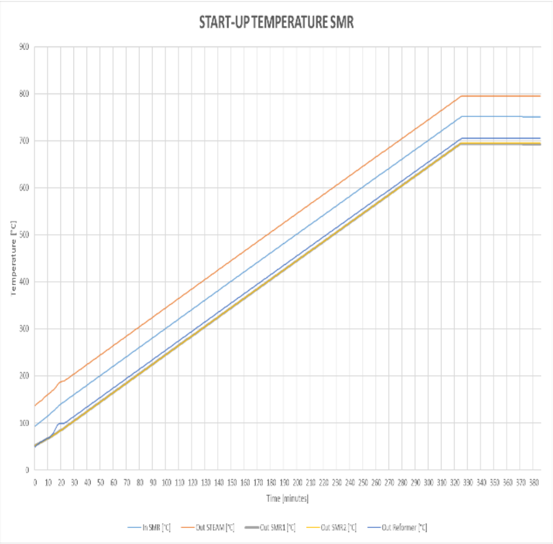
SYNGAS COMPOSITION CONTROL

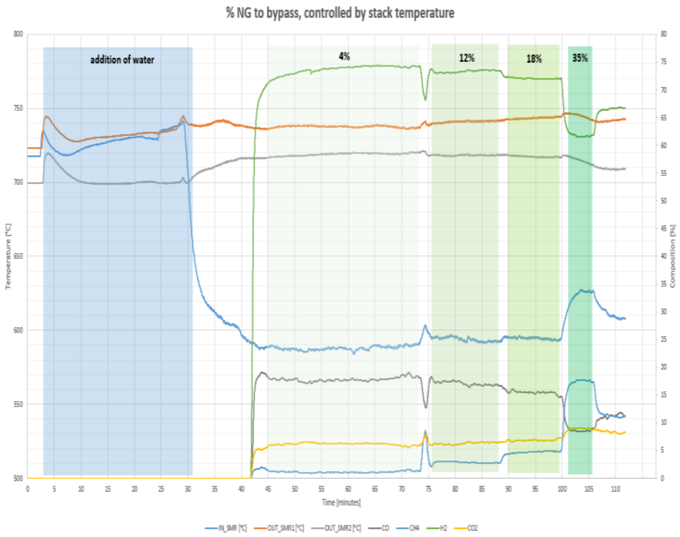




REACTOR CONTROL

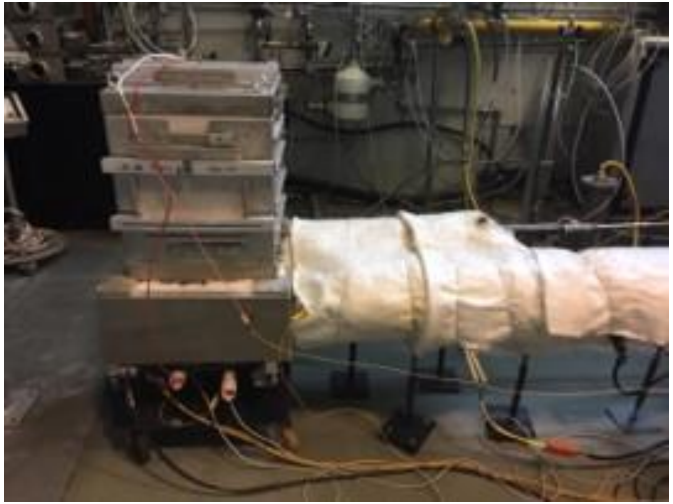
- Temperature ramp of the reformer as well as syngas temperature is fine controlled
- Syngas composition at different by-pass is indipendent from reformer temperature and could be reactively changed



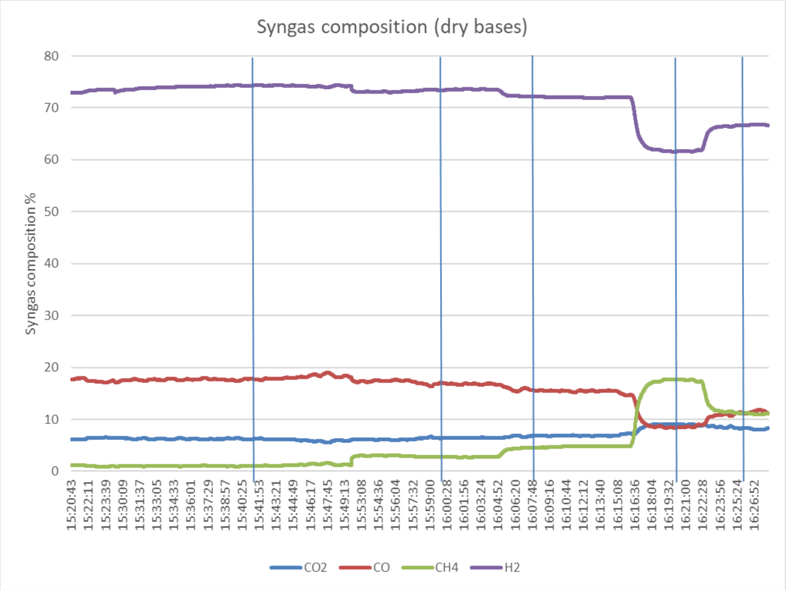


HOTBOX TEMPERATURE CONTROL

- For testing pourpouse syngas at T>850°C is required (not present in final integrated system)
- Reformer temperature > 850°C cause catalyst deactivation (syntering)
- Heating elements placed on fuel and air line before the hot-box



EFFECT OF BYPASS ON SYNGAS COMPOSTION



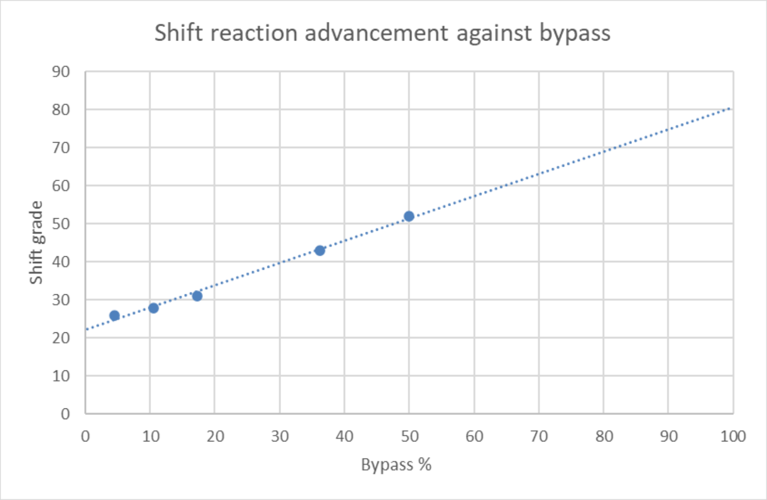
	measured value %, dry basis		
CH4	CO	H2	CO2
1,09	17,86	74,33	6,20
2,69	16,63	73,54	6,50
4,60	15,45	72,05	6,80
11,24	11,15	66,64	8,40
17,68	8,47	61,61	9,00

	real value % considering steam			
CH4	CO	H2	H2O	CO2
0,83	13,06	57,55	23,96	4,59
2,00	12,18	55,46	25,63	4,73
3,34	11,08	53,15	27,46	4,98
7,58	7,61	45,82	33,24	5,74
11,11	5,33	39,12	38,66	5,78

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

SAINT-GOBAIN

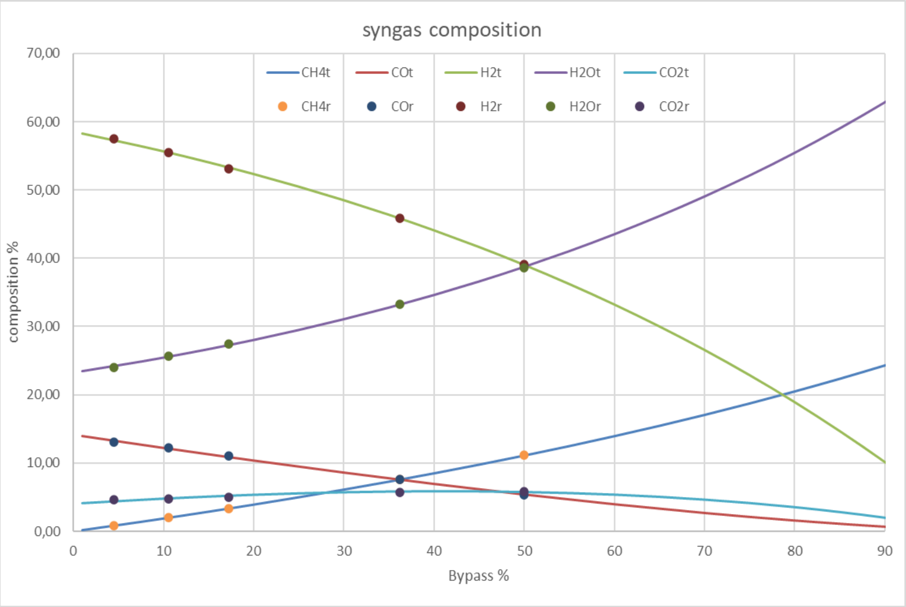
EFFECT OF BYPASS ON SHIFT REACTION



S/C ratio into the reformer depends on bypass grade

Bypass % calcolated	Shift advancement
4,48	26
10,57	28
17,22	31
36,2	43
49,99	52

EFFECT OF BYPASS ON SYNGAS COMPOSTION



CONCLUSION

- It is possible to control the stack temperature profile changing the syngas composition (internal reforming)
- Fast, controlled and dynamc syngas composition variation it is possible thanks to a bypass placed on NG line
- No need of syngas composition measurement for system control
- Only anode exaust temperature measurement is need for acting on NG bypass and regulate stack temperature profile

NEXT

Karine Couturier

Short stack performance assessment under system conditions

OxiGEN
Next generation SOFC solutions

SHORT STACK PERFORMANCE ASSESSMENT UNDER SYSTEM CONDITIONS

Karine Couturier, CEA

10'

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Testing protocols at hot box and short stack levels

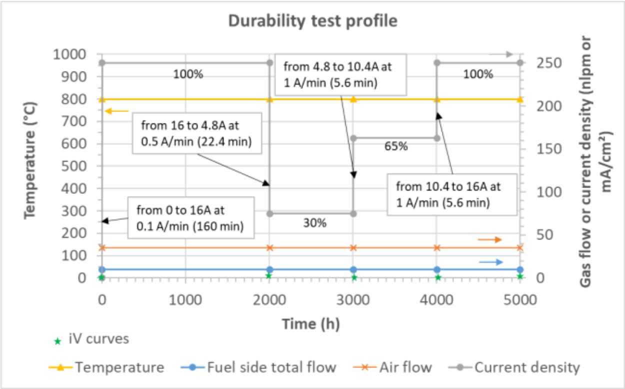
Defined in close collaboration with market needs and stack/hot box manufacturing for a good application-relevance ENGIE and good coherence between the different scales from single cell (eifer, European Institute for Energy Research by EDF and KIT) SINTEF to short stack SAINT-GOBAIN to hot box Fraunhofer IKTS and system ICI CALDAIE

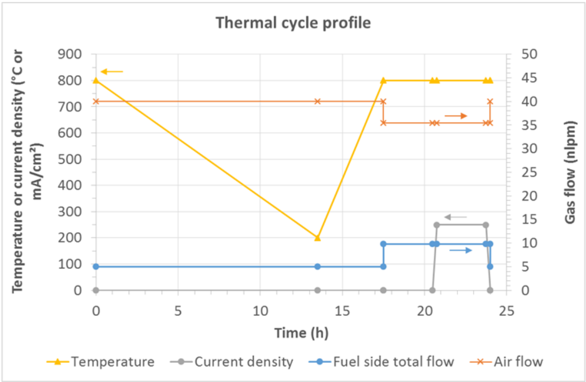
- Definition of conditions (temperature, gas composition and flow rate, electrical current density, fuel and air utilization FU/AU, step duration, power output, electrical power efficiency) and ways for:
  - 1^{st} start at production sites at IKTS / SG
  - Start-up and conditioning at system and lab testing sites at ICI / CEA
  - Performance measurements (standard iV curves, constant FU/AU, Electrochemical Impedance Spectroscopy)
  - Steady-state operation, thermal cycling and emergency shutdown
  - Final shut-down

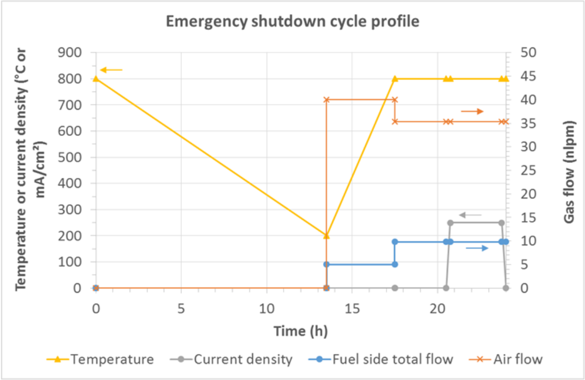
FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Testing protocols at hot box and short stack levels

At hot box level:







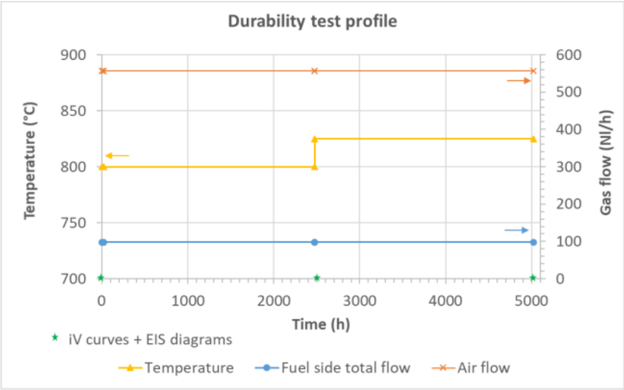
3 load steps, 3000h at 100% load
Different current ramp speeds
Constant gas composition
Performance evaluation in between

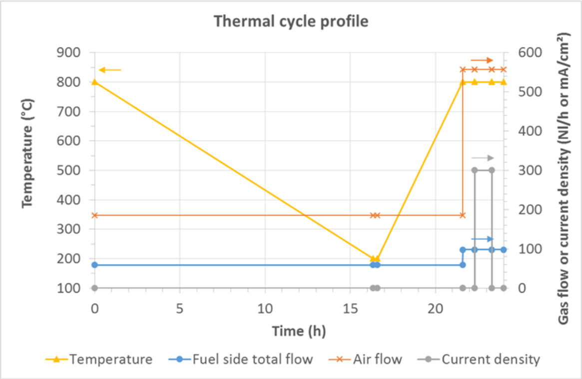
Daily thermal cycles from 800 to 200°C
2.5°C/min max. under 96vol.%N_2/4vol.%H_2
Performance evaluation after each cycle

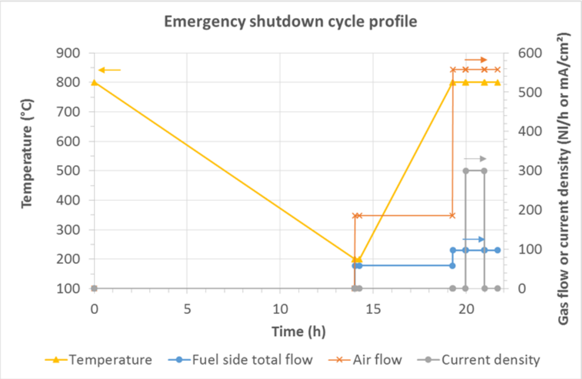
Gas preheaters / MFCs switched OFF at 800°C
Heating-up from 200°C in 96vol.%N_2/4vol.%H_2
Performance evaluation after each cycle

Testing protocols at short stack and hot box levels

At short stack level:







2 temperature steps, 2500h each
Constant gas composition
Performance evaluation in between

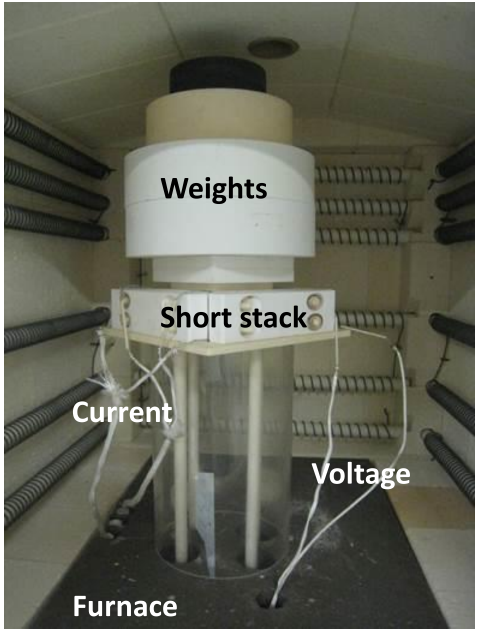
Daily thermal cycles from 800 to 200°C
2°C/min max. under 96vol.%N_2/4vol.%H_2
Performance evaluation after each cycle

Furnace / MFCs switched OFF at 800°C
Heating-up from 200°C in 96vol.%N_2/4vol.%H_2
Performance evaluation after each cycle

Short stack testing: Upgrade of the CEA test bench

For a proper characterization in accordance with the testing protocol

- Connection to carbonated gases
- MFCs calibration
- Installation and calibration of a new steam supply
- Programming work on the automaton …



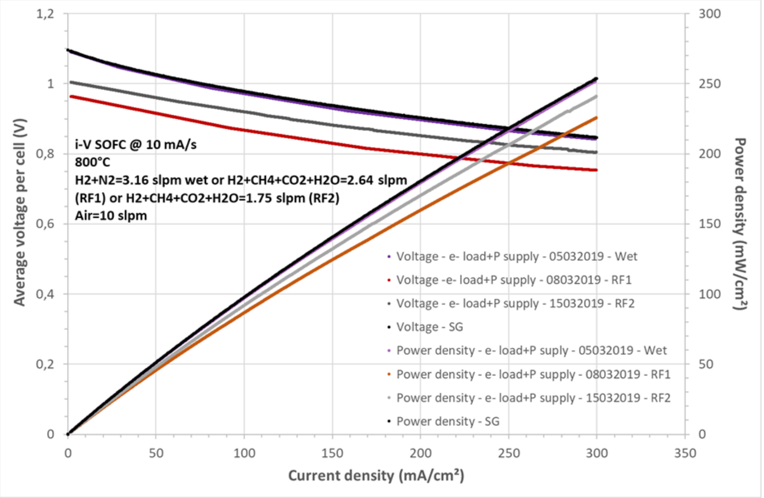
Short stack testing: Initial performances

➢ Gen1.1 stack: good initial performances achieved for each fuel gas condition, even after an uncontrolled thermal cycle to RT due to a short-circuit in the furnace

Reference condition → no degradation due to transport, good electrical contact, good tightness, good stack integration (iV curves and EIS)

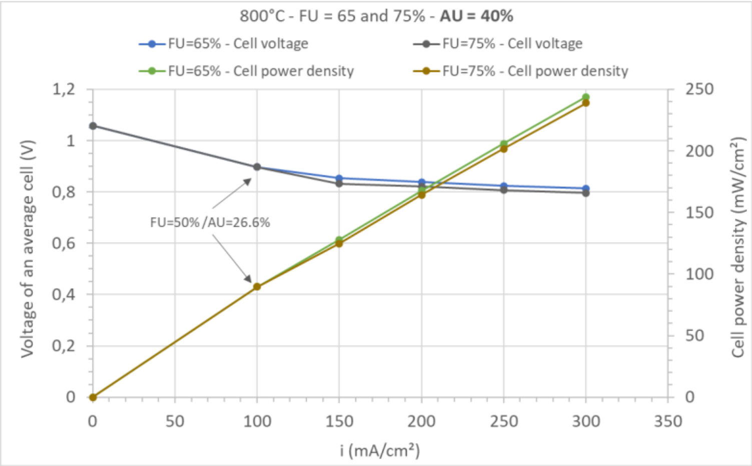
Average per cell	OCV (V)	U at 0.3 A/cm² (V)	P at 0.3 A/cm² (mW/cm²)	FU at 0.3 A/cm² (%)	AU at 0.3 A/cm² (%)	ASR at 0.3 A/cm² (Ω.cm²)
Wet H_2/N_2 - SG	1.097	0.846	254	36.5	14.4	0.44
Wet H_2/N_2 - CEA	1.093	0.840	252	36.5	14.4	0.45
RF1 - CEA	0.963	0.753	226	≈ 36.5	≈ 14.4	0.35
RF2 - CEA	1.004	0.805	241	≈ 36.5	≈ 14.4	0.35

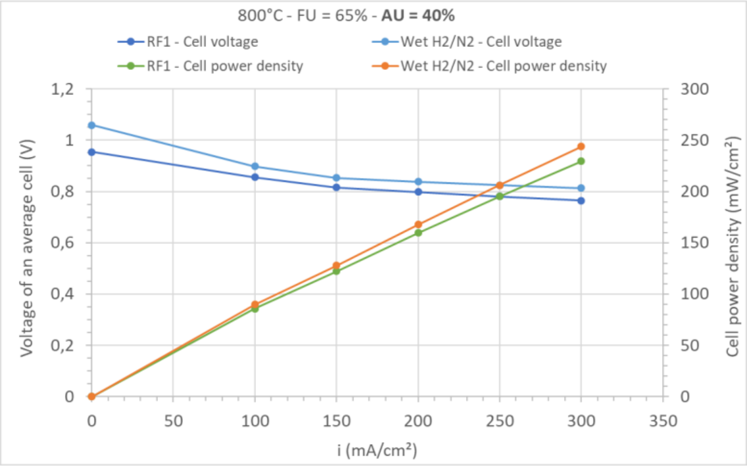
Initial iV curves at 800°C obtained in 49.15vol.%H_2/49.15vol.%N_2/1.7vol.%H_2O, 33vol.%H_2/9vol.%CH_4/30vol.%CO_2/28vol.%H_2O and 66vol.%H_2/8vol.%CH_4/16vol.%CO_2/10vol.%H_2O on fuel side and air on O_2 side at CEA compared to the quality control at SG



Short stack testing: Initial performances

➢ <u>Gen1.1 stack</u>: good results at constant FU/AU in 49.15vol.%H_2/49.15vol.%N_2/1.7vol.%H_2O and 33vol.%H_2/9vol.%CH_4/30vol.%CO_2/28vol.%H_2O at 800°C

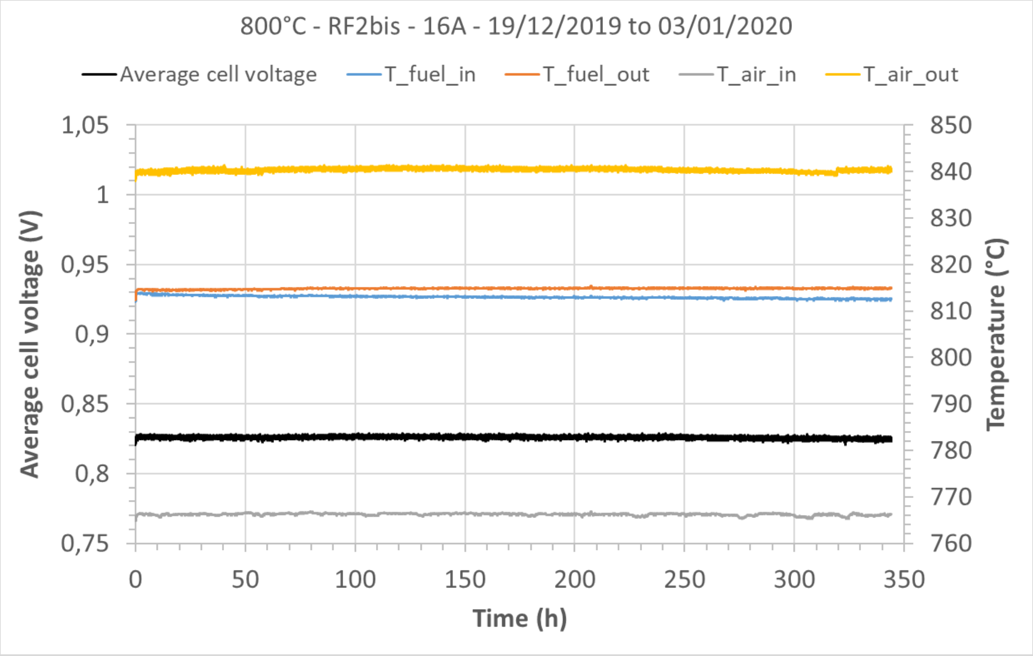




Electrical efficiencies around **50%** (LHV) at 300 mA/cm² and high FU

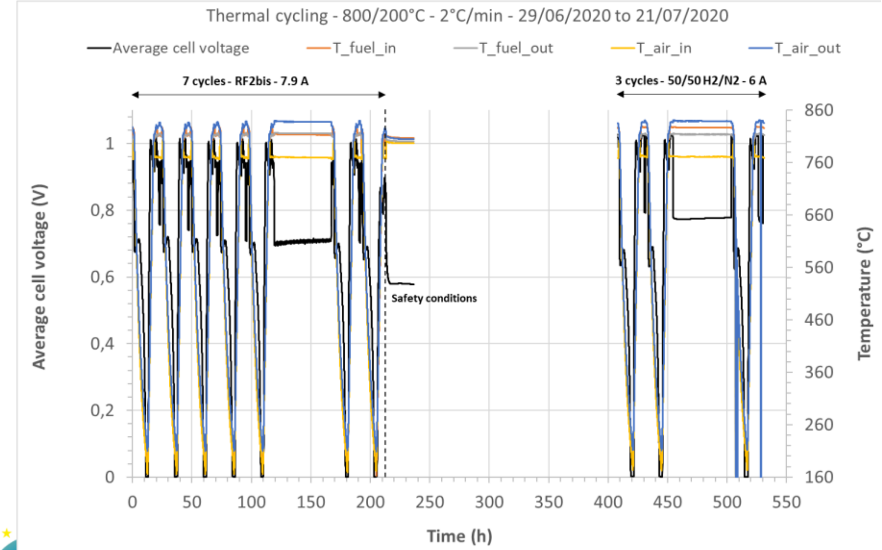
Short stack testing: Steady-state operation

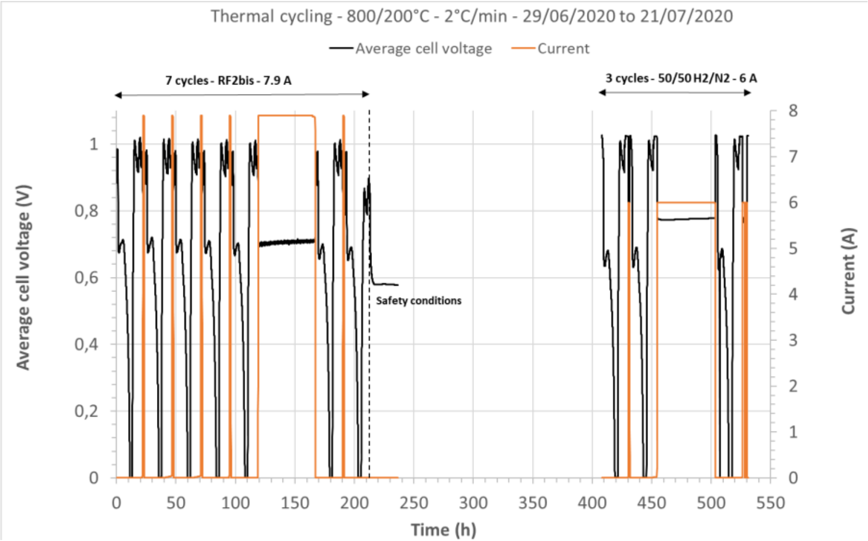
- Gen1.3 stack: 2910 h in steady-state operation at 800°C and different gas/current conditions
- In particular, 344 h at 0.25 A/cm² and FU=30.4% with -3 mV/kh or -0.36%/kh per cell in 52.3vol.%H_2/8vol.%CH_4/13.1vol.%CO_2/26.6vol.%H_2O



Short stack testing: Thermal cycling

- Gen1.3 stack: 10 thermal cycles from 800 to 200°C, decrease of OCV and voltage under current at 800°C at each cycle





Short stack testing: Outcomes

- Gen1.1 and 1.3 stacks:
    - About 0.80 V/cell and 0.35 Ω cm² at 0.3 A/cm², FU=36%, AU=14% and 800°C in reformate composition
    - About 0.77 V/cell at 0.3 A/cm², FU=75%, AU=40% and 800°C in reformate gas composition

    → around 50% LHV electrical efficiency
    - 2910 h in steady-state operation at 800°C and different gas/current conditions among which -3 mV/kh or -0.36%/kh per cell measured for 344 h at 0.25 A/cm² and FU=30.4% in reformate gas composition
    - 10 thermal cycles from 800 to 200°C, decrease of OCV and voltage under current at 800°C at each cycle

- Challenges encountered:
    - Uncontrolled thermal cycle to RT due to a short-circuit in a light on the front of the furnace during initial performance measurements, hopefully without any detrimental effect on the stack performance (Gen1.1)
    - Loss of the program in the automaton associated with temperature decrease and gas stop but under current observed very detrimental to the stack as expected (Gen1.3)
    - “Risky” H_2 concentration identified for gas change periods, leading to micro-cracks (Gen1.1)

OxiGEN
Next generation SOFC solutions

NEXT

Julian Dailly &
Marie-Laure Fontaine

Routes for stack performance improvement

OxiGEN
Next generation SOFC solutions

ROUTES FOR STACK PERFORMANCE IMPROVEMENT

Julian Dailly, EIFER
Marie-Laure Fontaine, SINTEF

SINTEF

eifer
European Institute for Energy Research by EDF and KIT

SAINT-GOBAIN

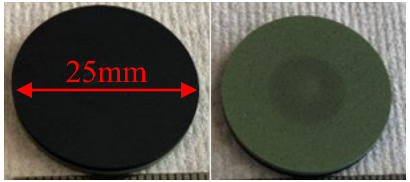
15’

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Context of the work package: Investigation on the possibility for improving cell's performances

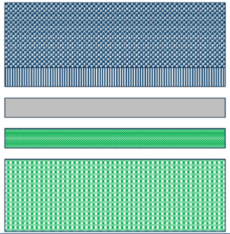
- First step: establishing the reference microstructure and performances = *where are we?*
  - ➔SG supplied 10 reference cells (Ø=25mm)

Reference cell manufactured by SG



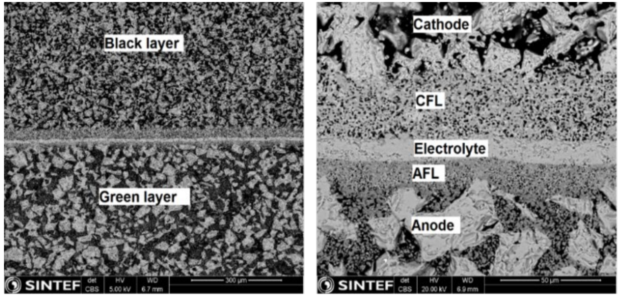
Configuration of the reference cells manufactured by SG

SAINT-GOBAIN



Investigation on the microstructure of the reference cells

SINTEF



Definition of the main parameters: Porosity, thickness, composition etc.

Electrochemical characterisations

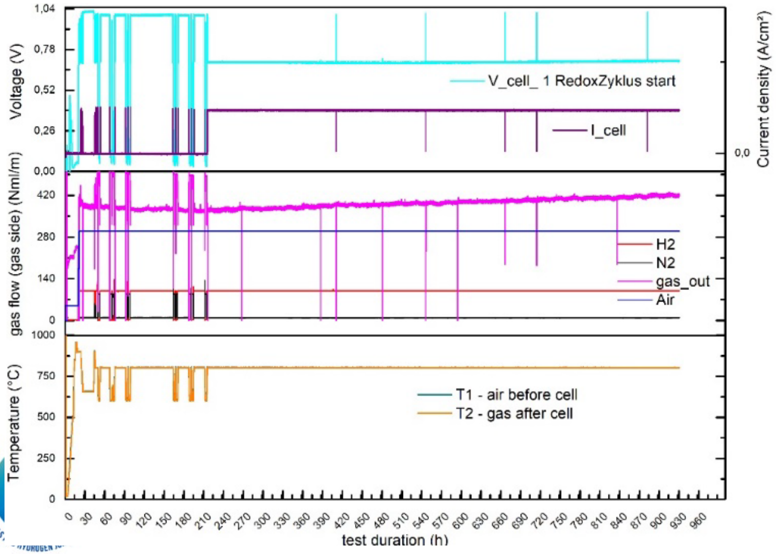
FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

eifer

Electrochemical Characterizations of reference samples

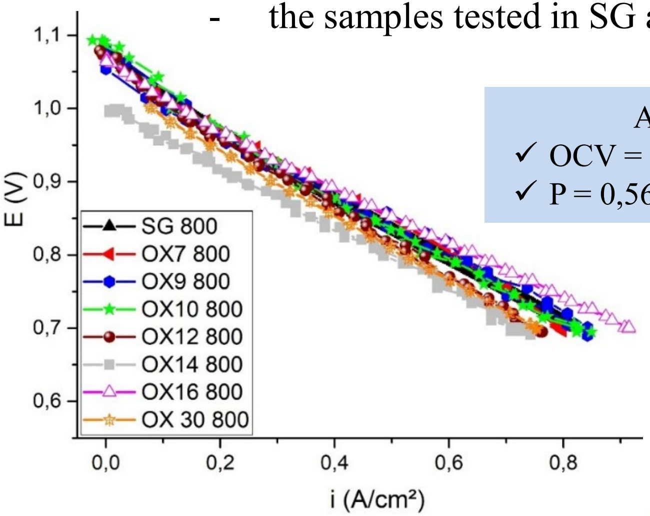
Protocols developed during the project
➔Public Deliverable 6.1: « Cell testing protocols »

iV curves / redox cycling / long-term testing



iV measurements: evaluation of the performances of the cells

Good reproducibility between:
- the reference samples at 800°C
- the samples tested in SG and in EIFER

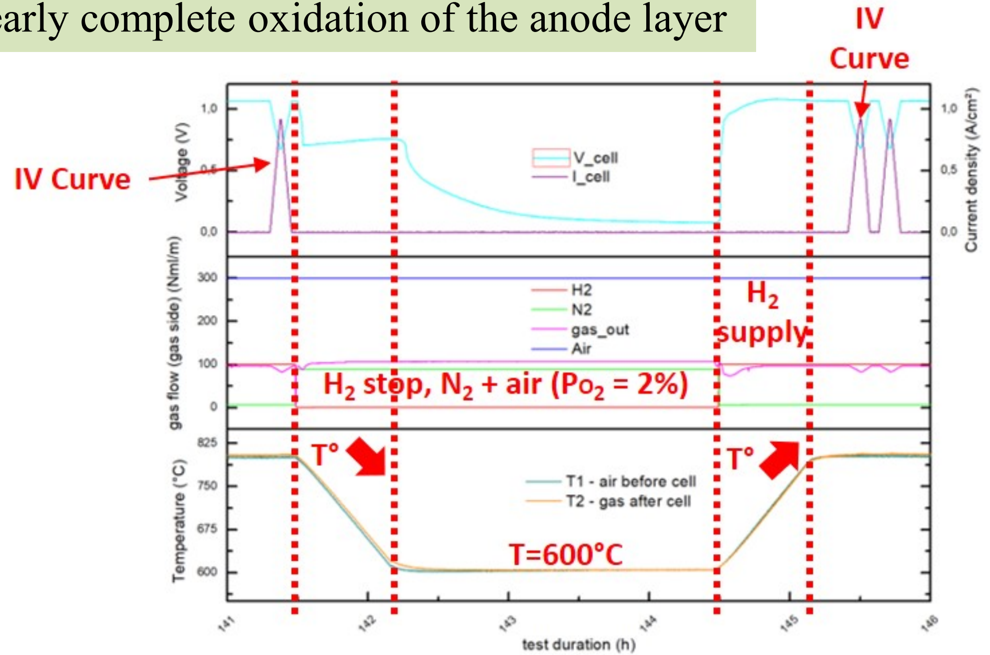


At 800°C:
- ✓ OCV = 1,07 V
- ✓ P = 0,56 $W.cm^{-2}$ @E=0,7V

Electrochemical Characterizations of reference samples

Redox cycling: optimized protocol to ensure a nearly complete oxidation of the anode layer

- Initial iV Curve
- Oxidation step
  - Decrease of the T°, stop H_2
  - @600°C: purge with N_2, input of air
  - Plateau until E ~ 0V
- Re-reduction step
  - Stop air, Purge with N_2, input of H_2 and increase of T°
- Stabilisation at 800°C
- Final iV curve

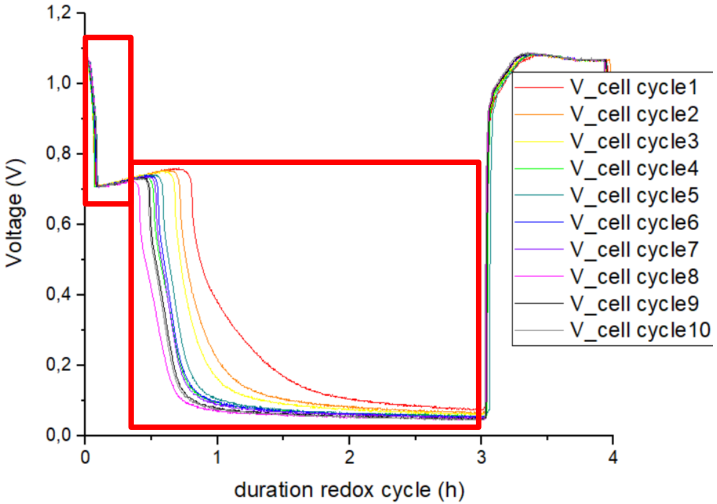


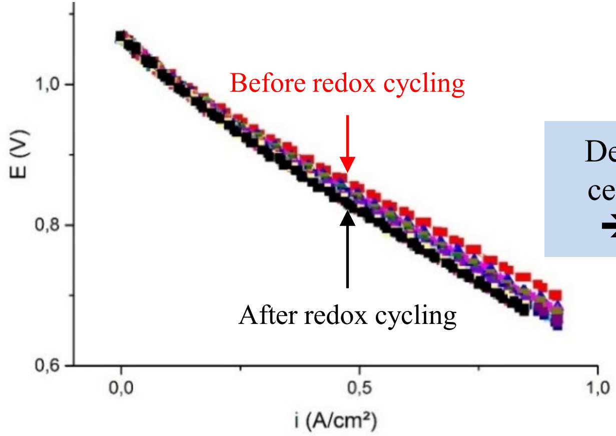
Electrochemical Characterizations of reference samples

Evolution of the cell voltage during the redox cycling experiment

2 oxidation stages:

- Decrease of P_{H_2} in the anode chamber: reproducible loss, whatever the number of cycles
- Introduction of P_{O_2} inside the chamber, mimicking a leakage on the fuel side



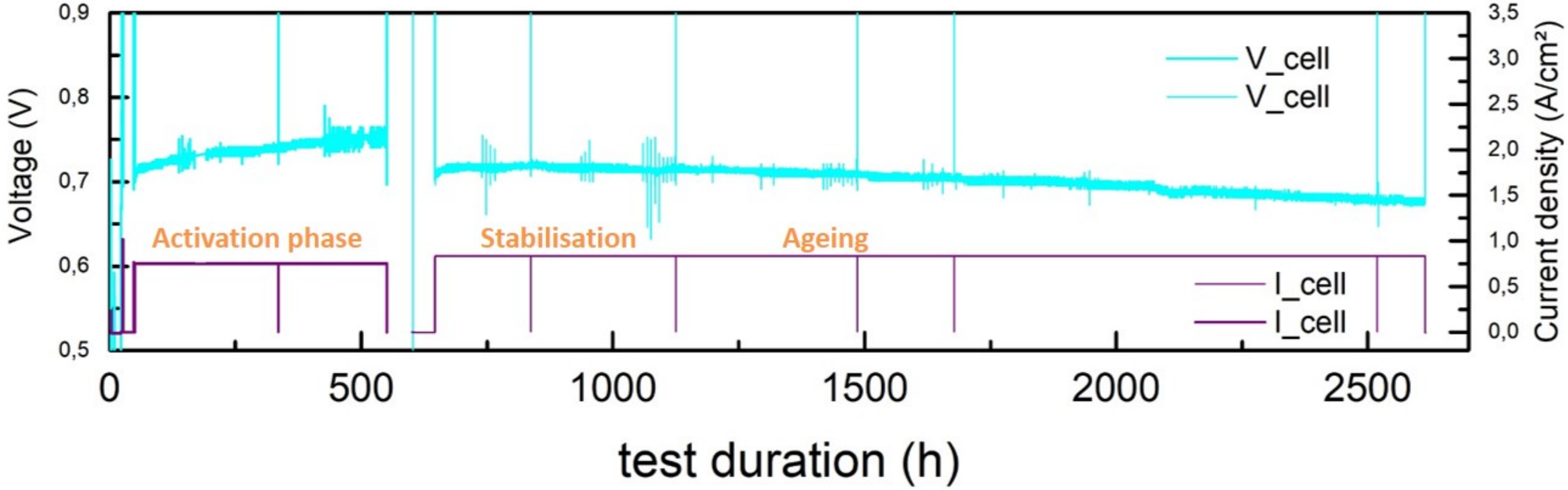


Degradation of the cell power density ➔ -0,67%/cycle

Electrochemical Characterizations of reference samples

Evolution of the cell voltage during long-term measurement

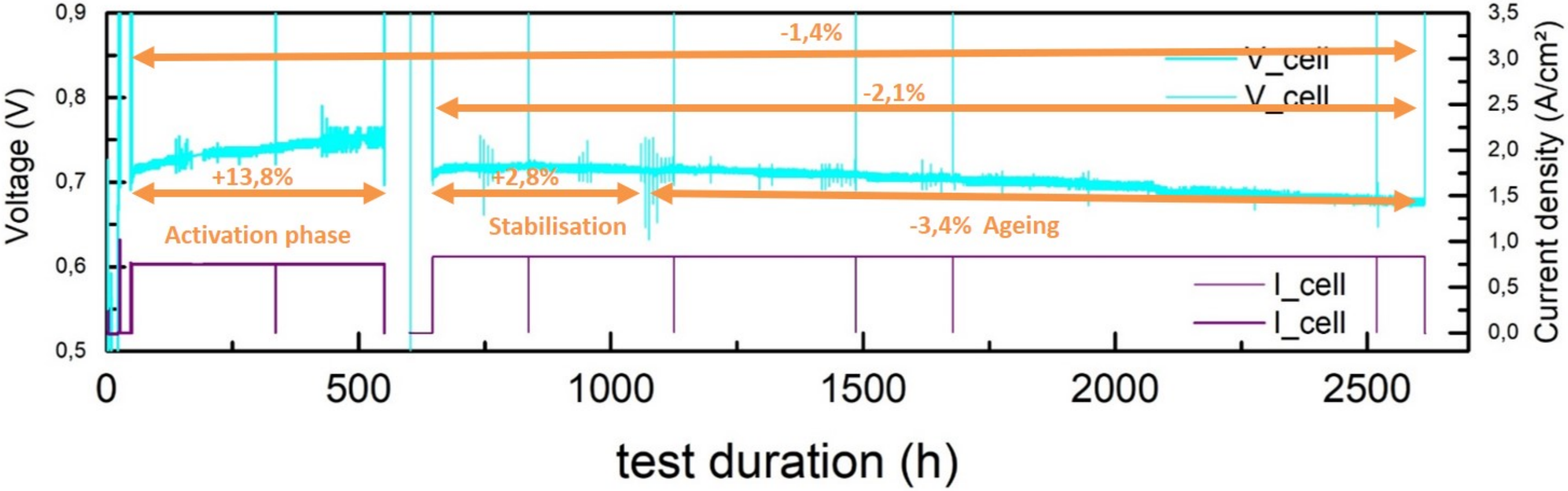
Three main parts can be identified:



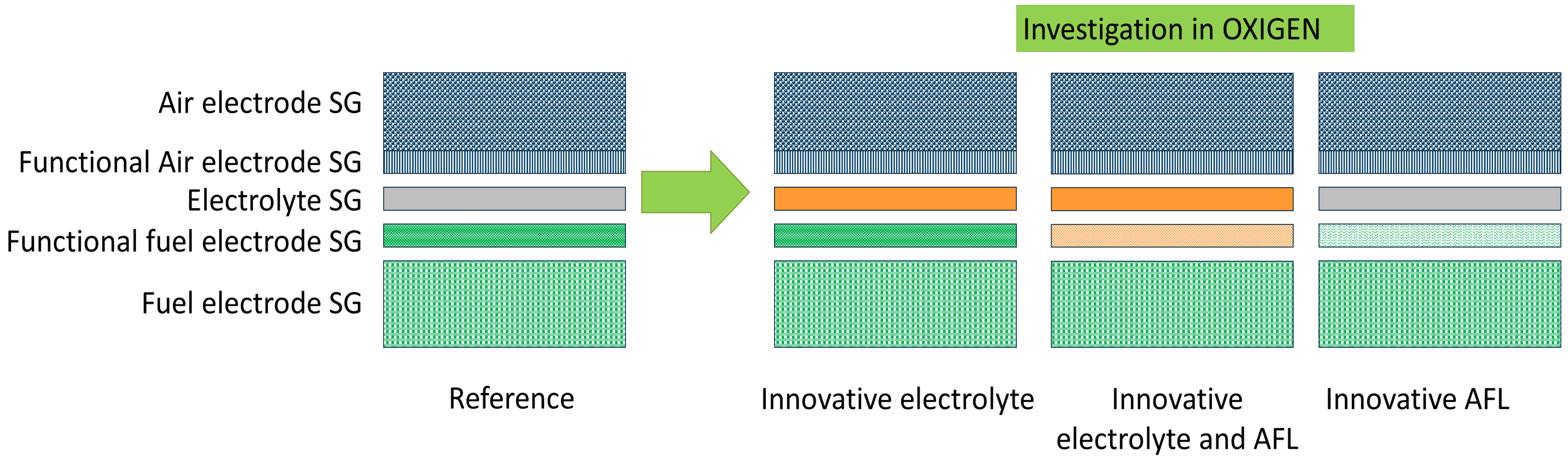
Electrochemical Characterizations of reference samples

Evolution of the cell voltage during long-term measurement

Average ageing rate of -1,4%/kh calculated over 2000 hours of test



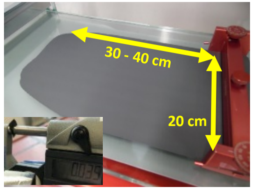
Objective of the WP6: Improvement of the reference cell

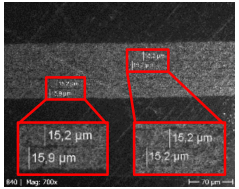


Objective: Improvement of the Anode Functional Layer

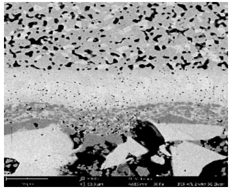
Reference: SG cells → Improvement of the redox stability

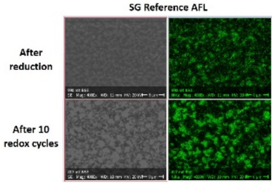
Manufacture of AFL → Reproduction of the microstructure of the reference AFL → Modification of the NiO/YSZ ratio → Preliminary integration in complete cells → Evaluation of the REDOX stability → Conductivity measurement

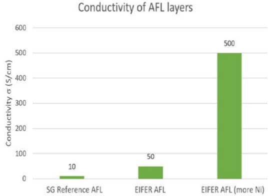




Selection of the best tape compositions



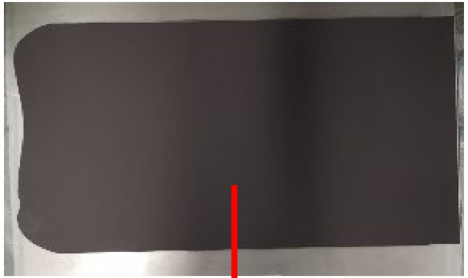




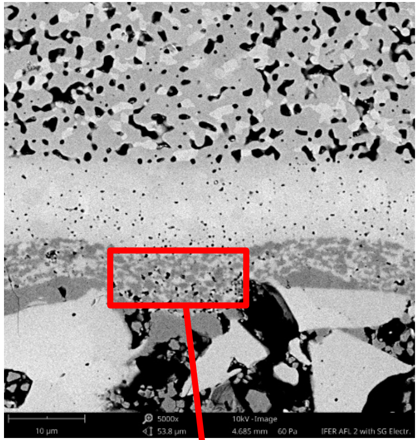
eifer

Integration of innovative Anode Functional Layer in complete cells

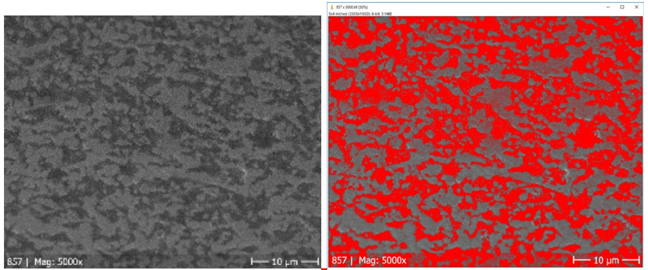
Tapes of AFL produced at EIFER → Production of cells at SG → Comparison of the microstructure with the layer not integrated inside the cell



800 cm² tape sent to SG
35 ± 5 µm before sintering
15 ± 1 µm after sintering



Porosity much lower than the KPI (<50%)

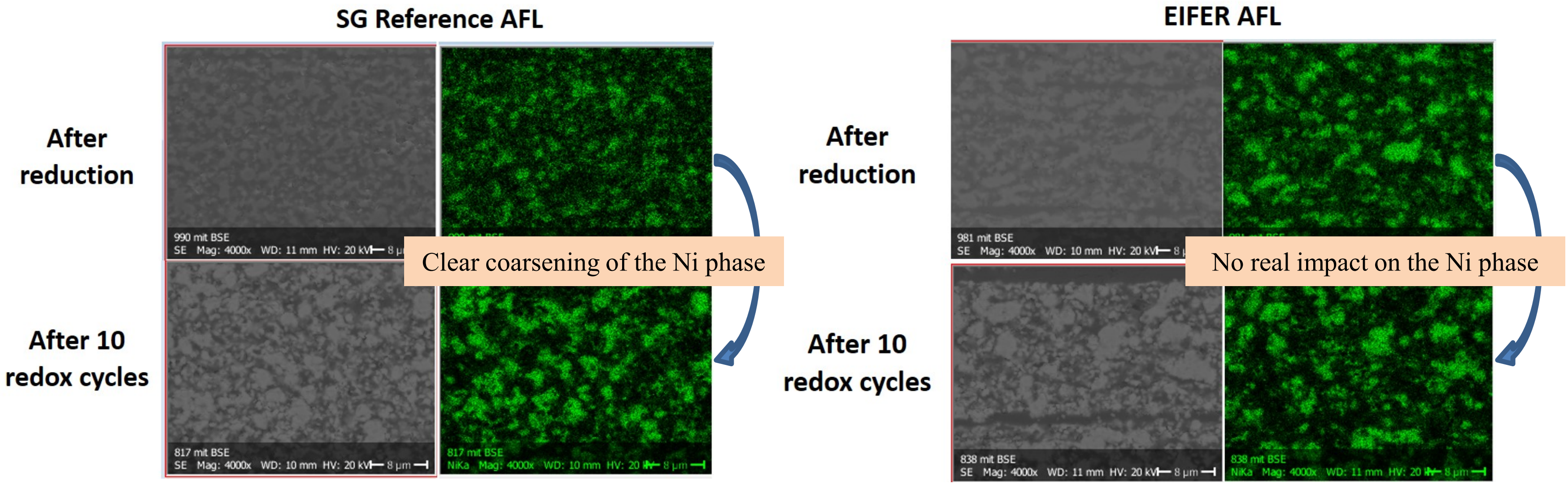


Porosity closed to the KPI (~50%)

Modification of the microstructure comes from the cell shaping process: optimization of the process/tape composition required.

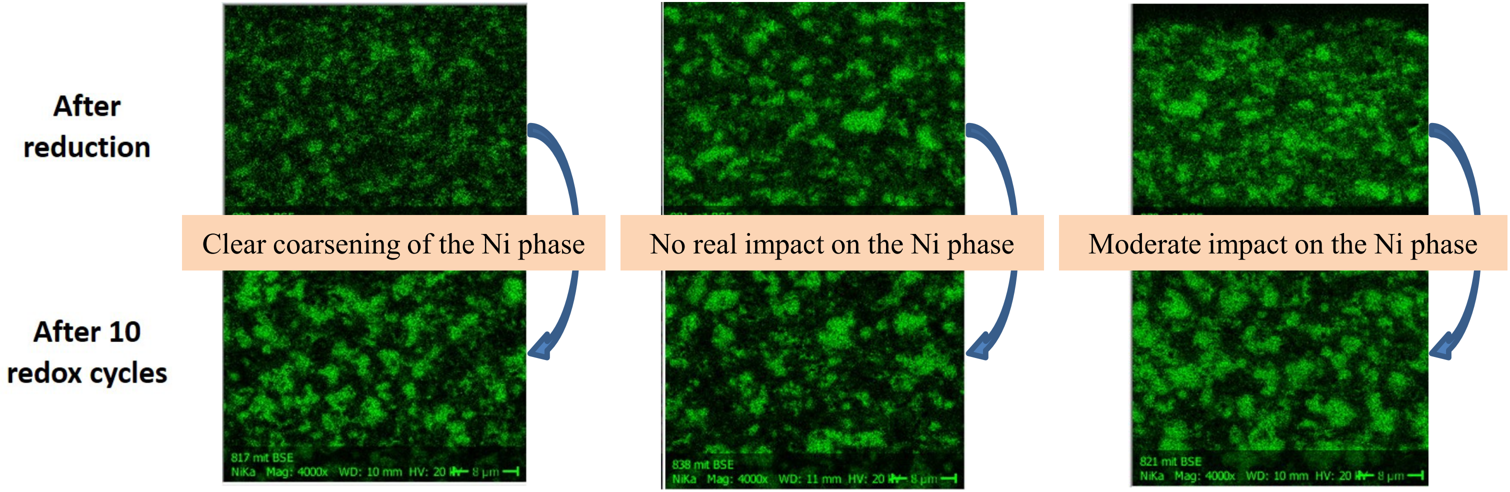
Improvement of the Redox stability of Anode Functional Layer

- Reduction protocol and Redox protocol applied to single layers to simulate various oxidation state (0 and 10 oxidations)
- EDX analysis to locate of the metallic nickel phase after reduction and after 10 redox cycles



Improvement of the Redox stability of Anode Functional Layer

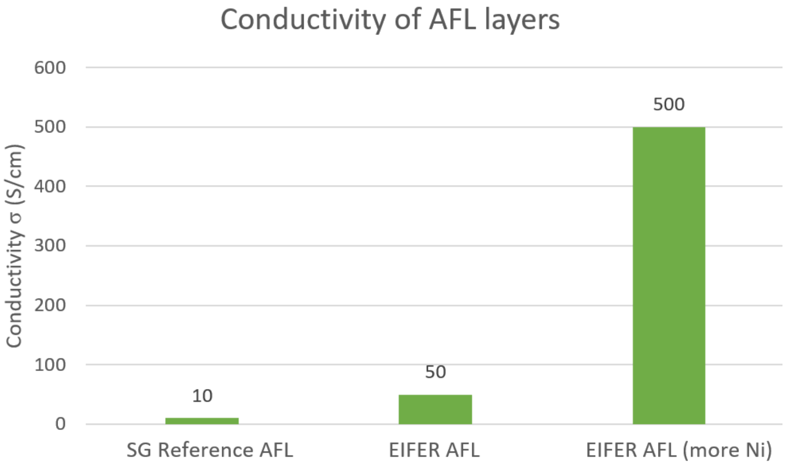
- ➢ Reduction protocol and Redox protocol applied to single layers to simulate various oxidation state (0 and 10 oxidations)
- ➢ EDX analysis to locate of the metallic nickel phase after reduction and after 10 redox cycles

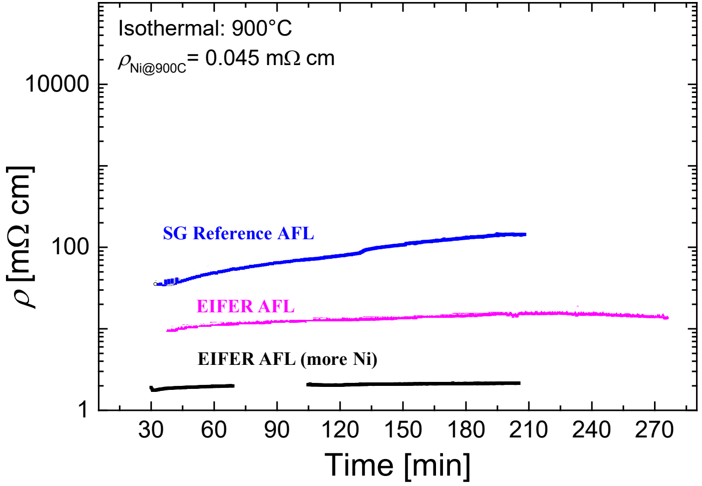


Positive effect of the innovative Anode Functional Layer on the microstructural stability versus redox cycling.

Conductivity measurements on the Anode Functional Layer

Measurements on single layers at SINTEF





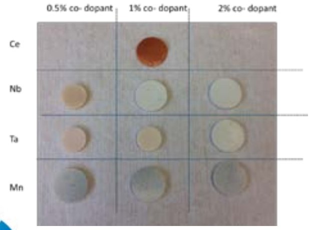
- **Conductivity increased by 50 and 500**
- **Stability of the layer slightly improved**

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING SINTEF eifer

Objectives: Investigation of alternative electrolyte compositions

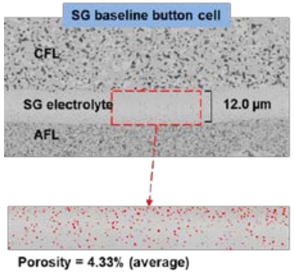
Reference: SG cells → Innovation: A_xO_y-Sc_2O_3-ZrO_2 with A = Ce, Nb, Ta, Mn

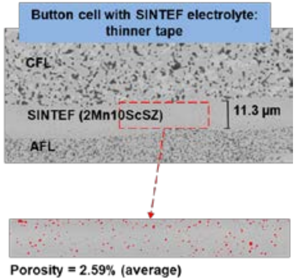
Screening: Structure & conductivity → Selection of one composition vs KPIs → Compatibility with electrode materials verified → Production of electrolyte → Integration in complete cells → Testing



- Conductivity
- Degradation rate
- Sintering profile
- TEC

- Diffusion couple experiments
- Ageing





SINTEF

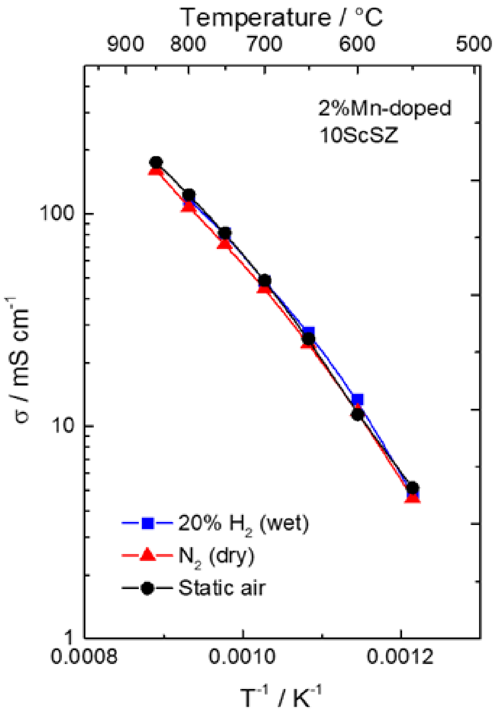
2Mn10ScSz pellets

- Pellets: Solid state reaction

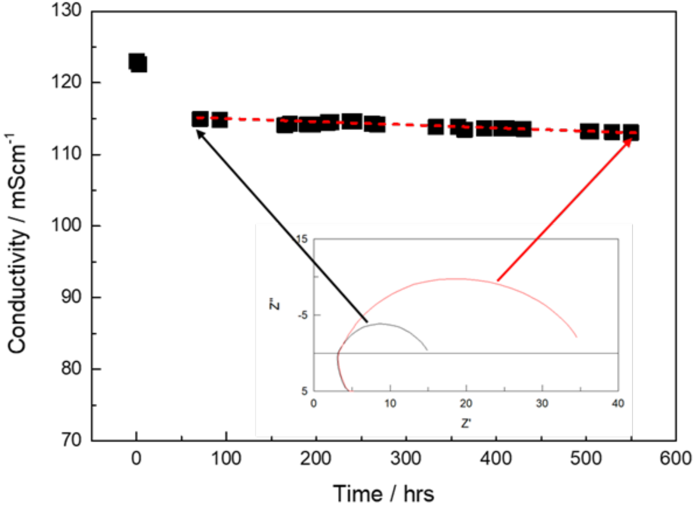
KPIs:

- Relative density > 95%
- Peak sintering temperature matches SG manufacturing
- Increased conductivity by 350% vs ref. electrolyte
- Degradation rate in FC mode: - 2% khr (large variation of electrode)

- Single atm. measurements



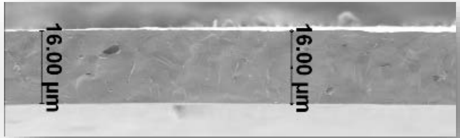
- Stability test in fuel cell mode
- Pt-10ScSZ electrodes

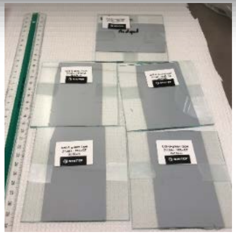


SINTEF

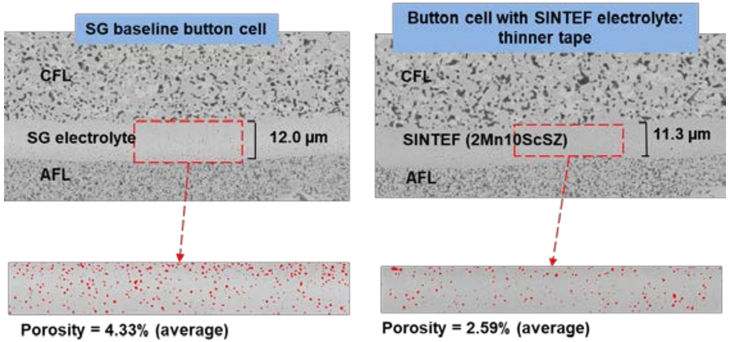
Complete cells with 2Mn10ScSz

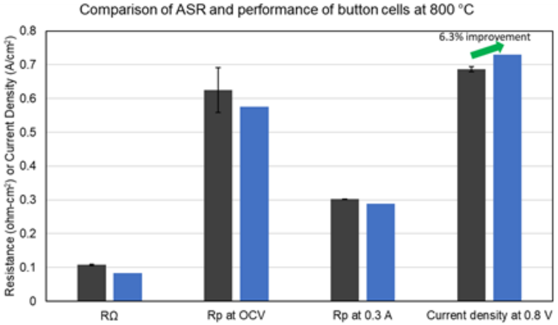
Tapes of electrolyte produced at SINTEF → Production of cells at SG → Testing of cells at SG





10 cm x 10 cm tapes sent to SG



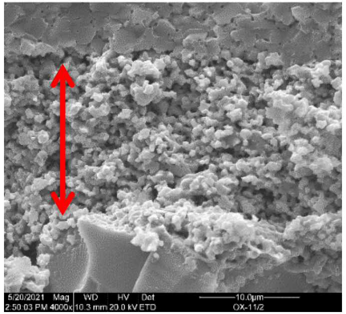


Reference SG
With new electrolyte

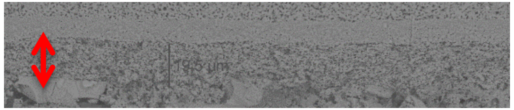
Complete cells with 2Mn10ScSZ and Ni-2Mn10ScSZ

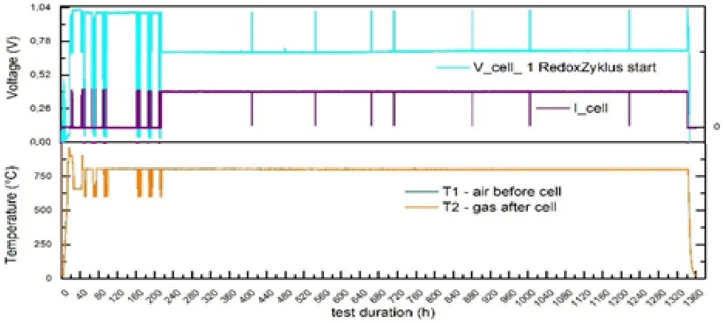
Tapes of electrolyte and AFL produced at SINTEF → Production of cells at SG → Testing of 1 cell at EIFER: redox cycling; stability

10 cm x 10 cm green tapes sent to SG



AFL Ca. 20 microns

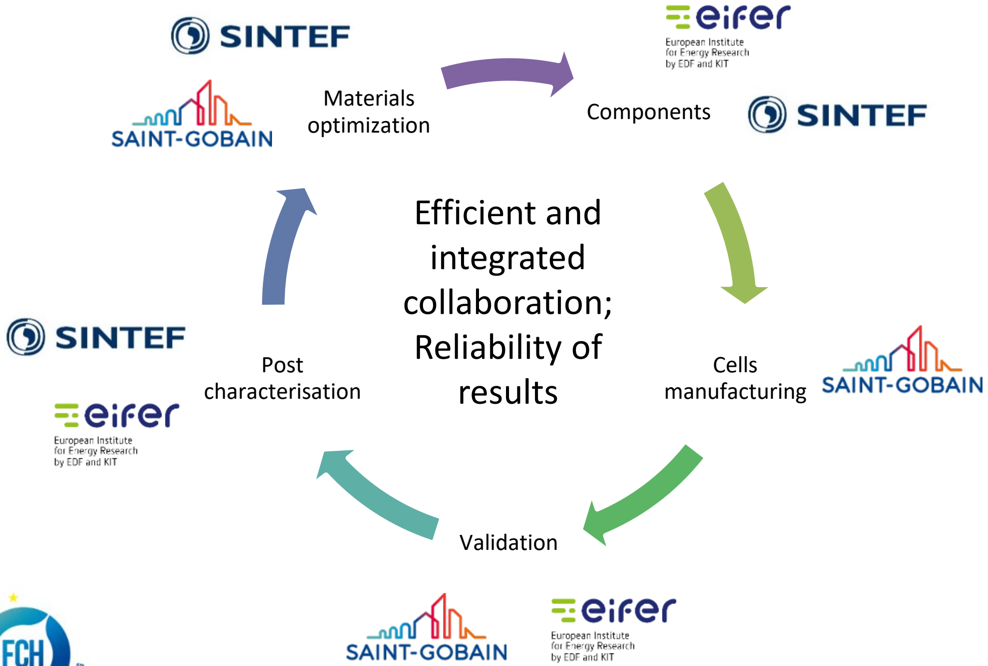




Results so far:

- Cell power density too low, and << ref cell
- Degradation rate per redox cycle 8% < ref cell
- Degradation rate: +1.39% khr over 1125 hr

Lessons learned and outcomes …



Key outcomes:

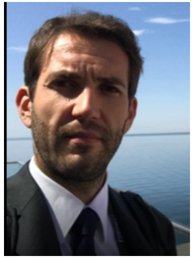
- Reliable assessment of reference cells
- Materials and components developed by RTD partners successfully incorporated in industrial production line @ SG
- KPIs:
  - Individual components: validated
  - Cells with innovative components:
    - Stability test
    - Redox cycling stability improved vs reference cell

Perspectives:
Possibility to benefit from the integration of *all innovative components in one cell*

Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

John Pietras
Saint-Gobain



Julian Dailly
EIFER

Catherine Notar
EIFER

Christelle Denonville
SINTEF

Einar Vøllestad
SINTEF

Vegar Øygarden
SINTEF

Marie-Laure Fontaine
SINTEF

OxiGEN
Next generation SOFC solutions

NEXT

Steven Arshurt

Economic impact of OxiGEN solution

OxiGEN

Next generation SOFC solutions

ECONOMIC IMPACT OF THE OXIGEN SOLUTION

Steven Ashurst, Delta-EE

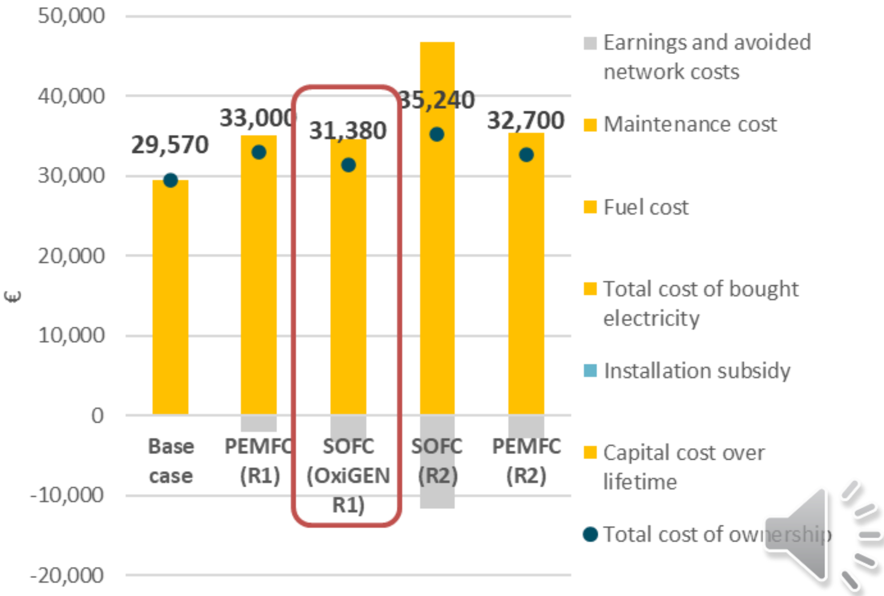
DELTA-EE

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779537. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Total Cost of Ownership (TCO) introduction

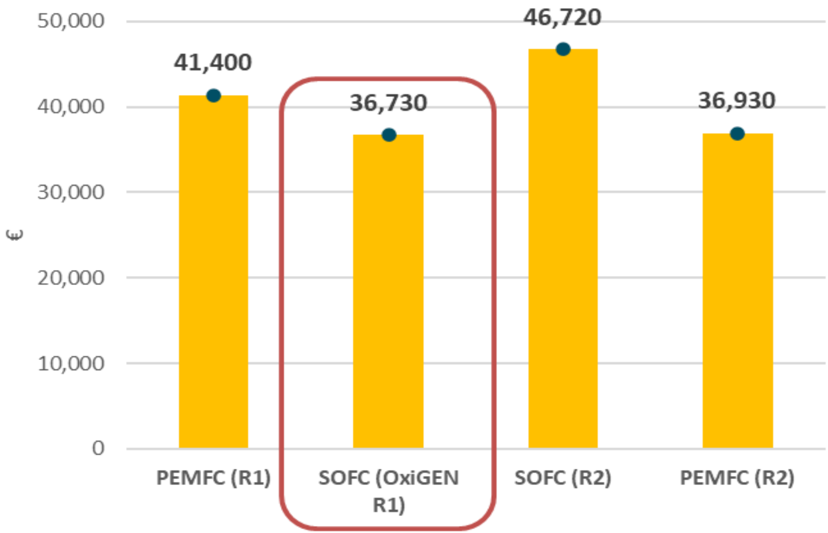
- The TCO of each FC m-CHP product is
  - the summation of the **initial capital cost** and **annual operation cost** (fuel and maintenance) multiplied by the **FC m-CHP lifetime**,
  - minus **electricity bill savings** and **benefits from incentives** (where applied).
- Output is given as a total spend in € over FC m-CHP 15-year lifetime.
- Report includes DE, FR, IT, UK

Example: France (residential products)

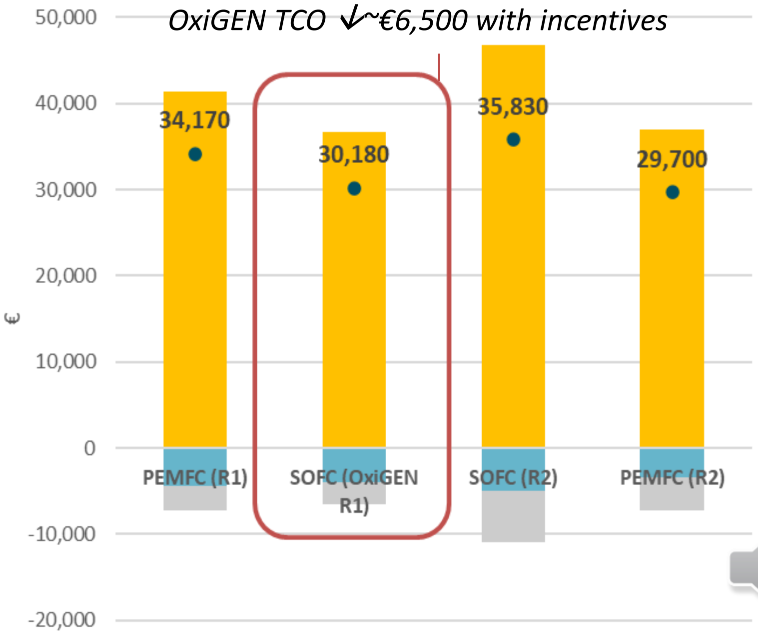


OxiGEN TCO vs. State-of-the-Art fuel cells (residential market)

Germany (Reference case)

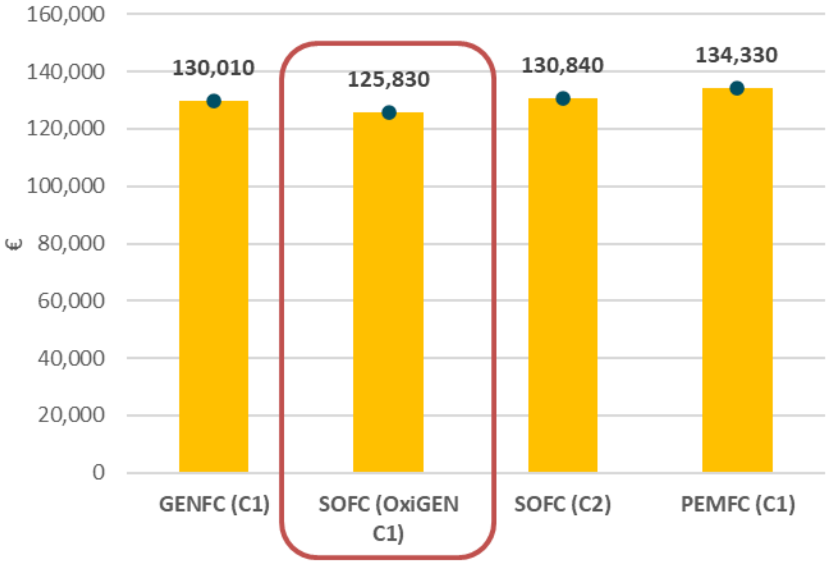


Germany (with incentives)

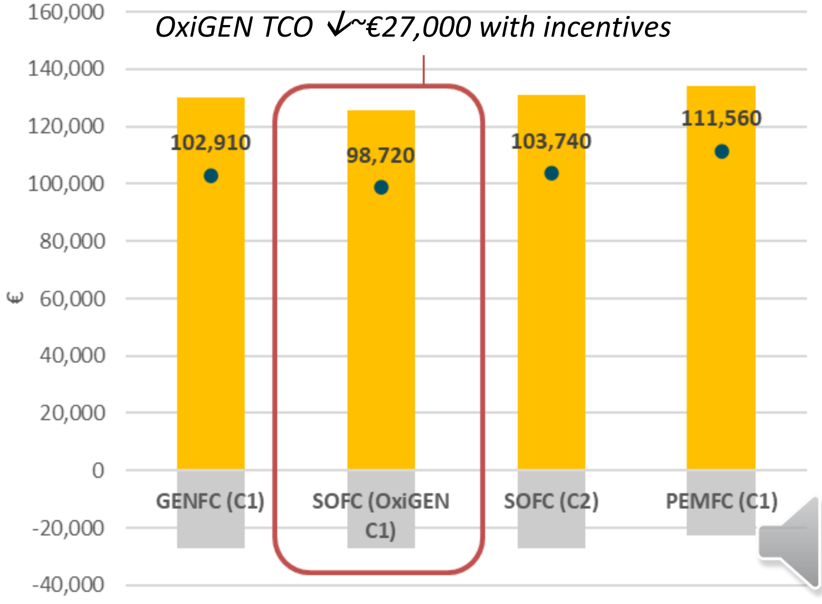


OxiGEN TCO vs. State-of-the-Art fuel cells (commercial market)

France (Reference case)



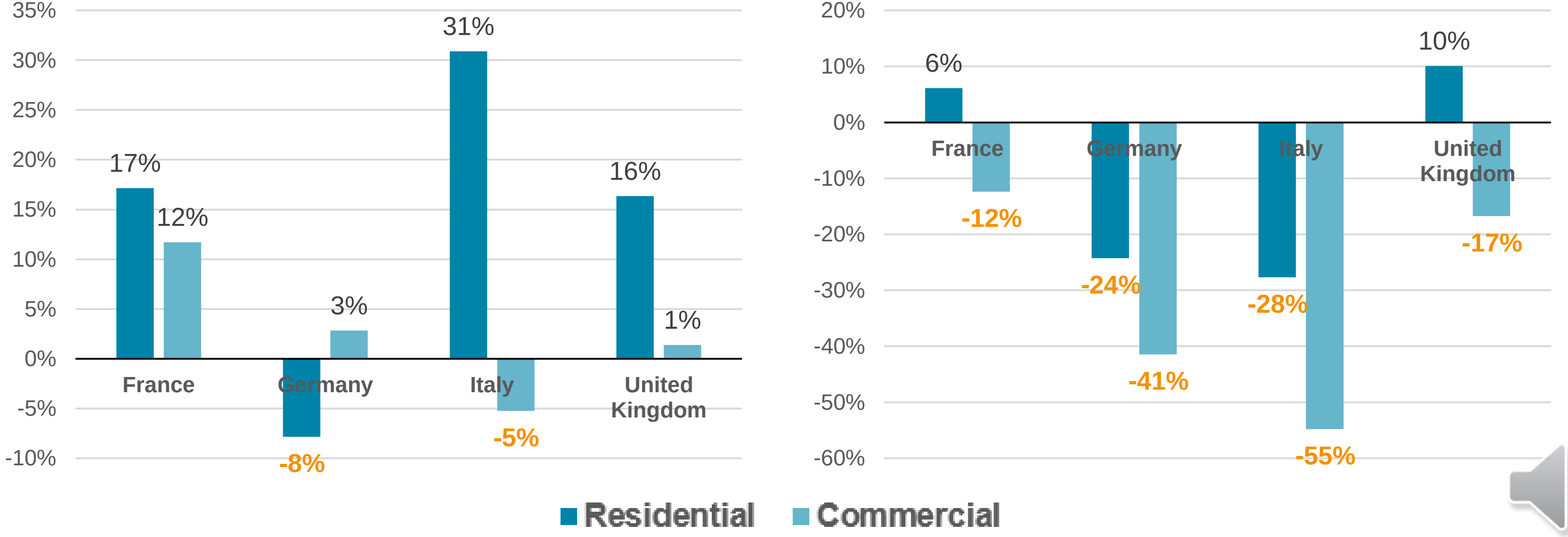
France (with incentives)



OxiGEN TCO vs. gas boiler

Reference case: OxiGEN vs. gas boiler (% difference)

With incentives: OxiGEN vs. gas boiler (% difference)



Summary of findings from TCO analysis

- **The OxiGEN systems regularly deliver a lower TCO** – Versus the SotA in fuel cell m-CHP. Reduced CAPEX & maintenance are key.
- **Compared to a gas boiler, the OxiGEN systems can have a lower TCO** e.g. in the German residential and Italian commercial sectors.
- **Key considerations for future**:
  - **Incentives significantly improve FC m-CHP attractiveness** – these may disappear / reduce / change / increase (high uncertainty).
  - **The base case for the customer will also likely change** – becoming more expensive (CAPEX) e.g. 'gas boiler plus', HPs, H_2 boilers, etc.
  - **Greater prioritization of self-consumption and electrification** in other sectors could favour in-situ electricity generation.

NEXT

Questions & Answers session