Reversible solid oxide Electrolyzer and Fuel cell for optimized Local Energy miX

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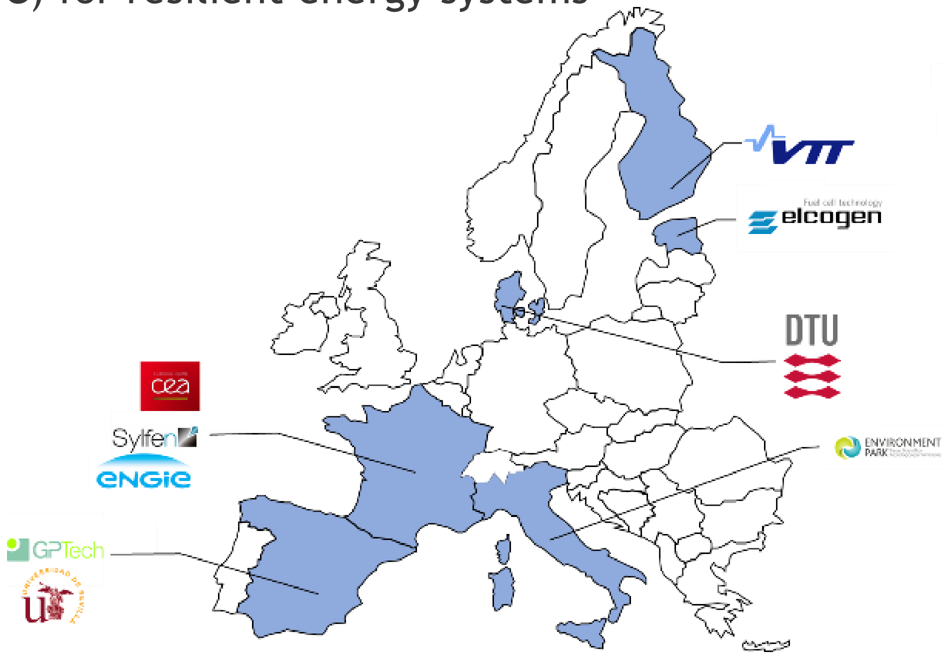
#PRD2020
#CleanHydrogen

European Hydrogen Week

Project Overview

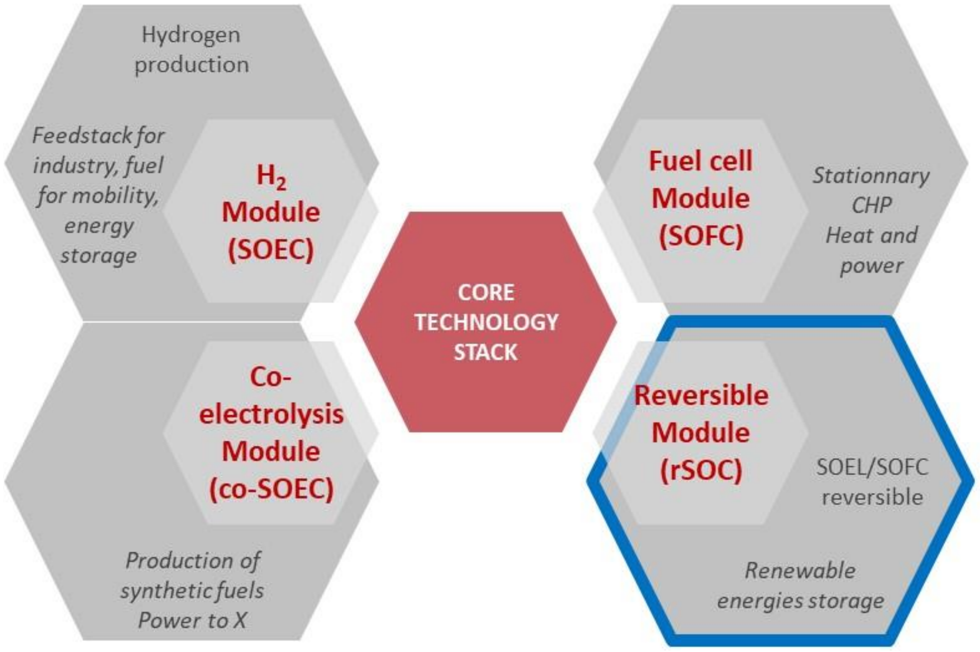
- Call year: 2017
- Call topic: FCH-02-3-2017 Reversible Solid Oxide Electrolyser (rSOC) for resilient energy systems
- Project dates: 01/01/2018-31/12/2021
- % stage of implementation 01/11/2019: 71%
- Total project budget: 2 999 575 €
- FCH JU max. contribution: 2 999 575.25 €
- Other financial contribution: 0 €
- Partners: CEA, DTU, VTT, GPTech, ELCOGEN, SYLFEN, ENGIE, ENVIPARK, Univ. Seville



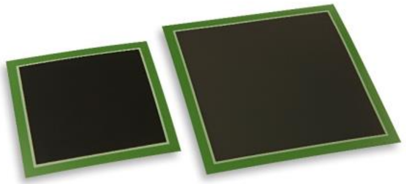
Project Summary

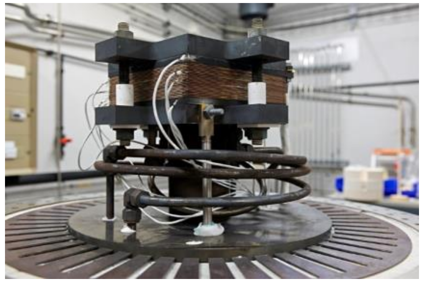
Main objectives

- Developing an innovative renewable energies storage solution, so-called "**Smart Energy Hub**",
  - based on reversible **rSOC** technology
  - completed with an electrochemical storage solution allowing fast response to the electrical energy needs



- rSOC core technology:
  - Ceramic cells assembled in stacks
  - rSOC= reversible solid oxide cell
- Operates at high T: 700°C
- Main advantages:
  - Flexibility of usage
  - High efficiency in all modes
  - Fuel flexibility

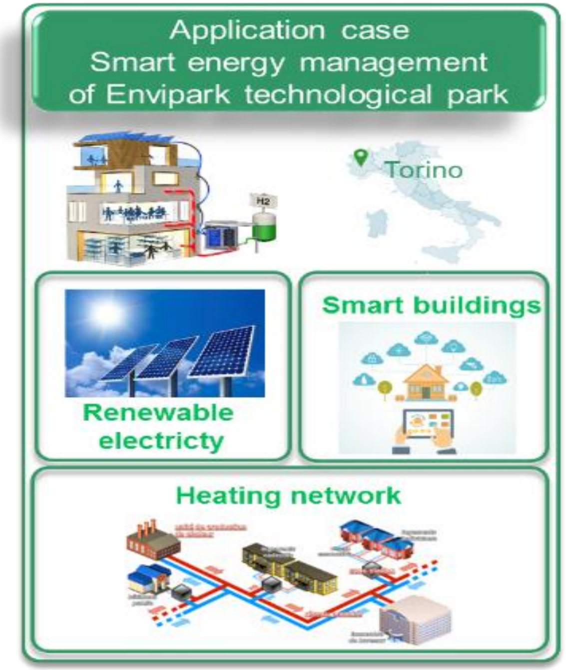


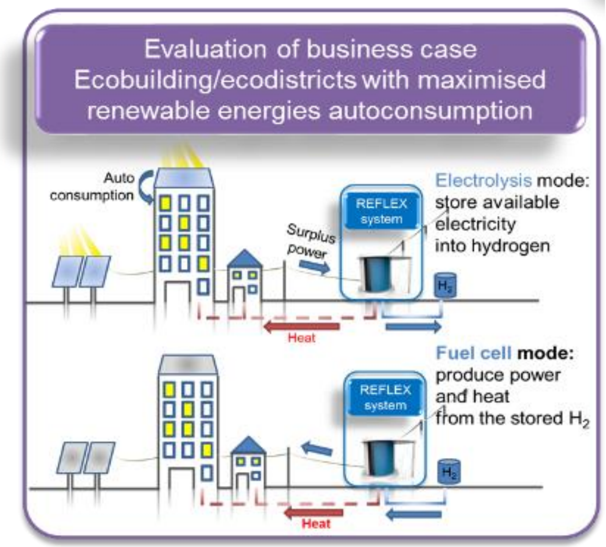


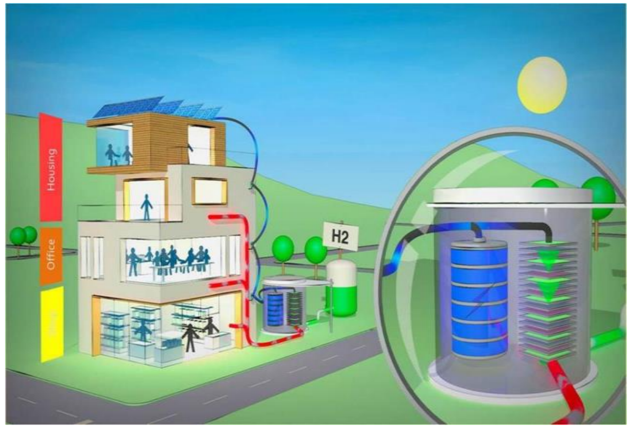
Project Summary

Main objectives

- **Demonstrate, in-field**, the high power-to-power (P2P) **round-trip efficiency** of this technology (as compared to other H_2 based solutions) and its flexibility and durability in dynamic operation (power transient and switch between electrolysis and fuel cell mode)
- Application and market area targeted: ecobuildings/ecodistricts with maximised renewable energies autoconsumption







Project Summary

Main objectives

Global positioning vs international SoA

- Develop an **upscaled rSOC system**
  - **15 kW SOFC**: efficiency > **55% LHV** with CH_4 fuel supply;
  - **80 kW in electrolysis** mode to produce 16 Nm^3/h of H_2: efficiency: **> 80% HHV**

Not largest rSOC system (cf Grinhy 150 kW_{SOEC})
But different business segment (ecobuildings)

- **Optimise cells and stacks** (to minimize CAPEX)
  - for operation at high fuel utilisation (> 85%) in both SOEC and SOFC
  - and at high current density: - 1.2 A/cm² in SOEC at 1.3 V (TNV) at 700°C, 0.6 A/cm² at 0.8V in SOFC

Highest performances reported so far

- **Optimise** the **high temperature heat exchangers** and **power electronics** to minimize energy losses in the BoP components

No specific developments available for rSOC technology

- Implement it in a **real site** to **provide electricity and heat to commercial buildings**

First in-field test of this kind

- Explore the electrolyser **operational flexibility at the demonstration site**
  - **power modulation** targeted between 50-100% in SOFC mode
  - and 70-100% in electrolysis mode

Large flexibility range planned so far

- **Operate** the system for **8000 hours** on site with a **degradation rate of less than 2% V/1,000 h**.

Longest test planned so far

- Evaluate and identify the most promising **business cases**

Extensive business cases analysis

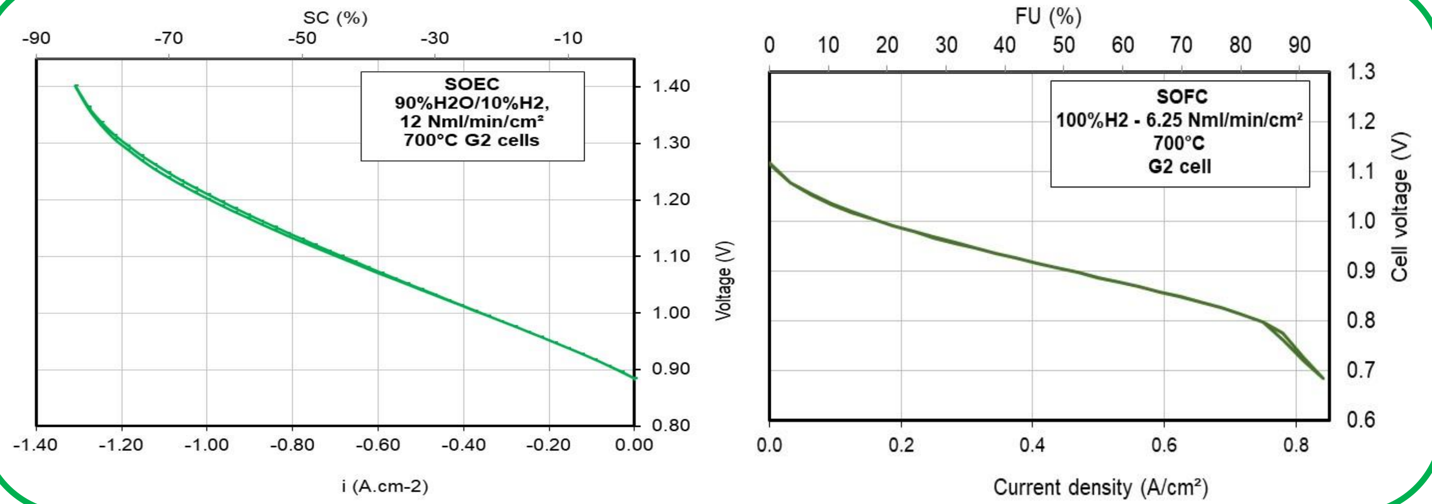
Project Progress/Actions - Cell and stack performances

Achievement to-date

- 1.0 A/cm² in SOEC at 1.3 V (U_{TN}), 0.5 A/cm² at 0.8V in SOFC FU = 50-60%

25% 50% 75%

- 1.2 A/cm² in SOEC at 1.3 V (TNV), 0.6 A/cm² at 0.8V in SOFC FU = 85%



Targets reached at 700°C with G2 cells (electrode supported cells) developed in the project

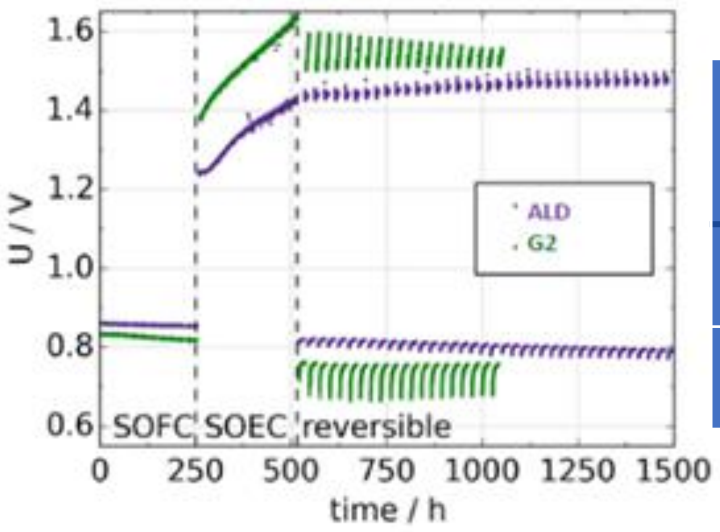
- No performance target in AWP and MAWP
- Fuel/steam utilization above AWP target (> 80%)
- According to literature:
  - Electrode supported cells
    - Similar levels of performances at higher T (750 or 800°C)
    - Or lower performances at same temperature
  - Electrolyte supported cells: lower performances

Project Progress/Actions - Cell and stack durability

A. Hauch et al., 14th European SOFC&SOE Forum 20-23 October 2020, Luzern B0903 (2020)
A. Ploner et al, ECS Transactions, 91 (1) 2517-2526 (2019)

Achievement to-date

Degradation above 5%/1000h (severe conditions) — 25% — 50% — 75% — Degradation < 2%/1000h



Test operated at 700℃, 80% FU, 0.6 A/cm² and -1.2 A/cm², respectively in SOFC and SOEC mode.

	Degradation - load cycling	
	SOFC degr.	SOEC degr.
ALD cell	31 mV/kh (3.7%/kh)	43 mV/kh (3.0%/kh)
G2 cell	11 mV/kh (1.4%/kh)	- 19mV/kh (-1.2%/kh)

Target reached with G2 cells developed in the project in rSOC
Degradation still high in SOEC in those severe conditions

- MAWP durability target: 2 years, 1.9%/1000h production loss for SOEC
- In AWP: < 2%/1000h for rSOC operation
- SOEC degradation >> SOFC degradation
- Fuel electrode main degrading component
- strong degradation decrease with daily rSOC cycles for SOEC steps: 0 to 3%/1000h
- G2 cell in stack: Degradation ~1.2%/1000h for SOEC step in rSOC operation, in milder conditions (-0.6 A/cm², SC=70% to stay at E_{tn})
- Degradation ~ 2.3 %/1000h at -0.6-0.7 A/cm², SC=50% in literature for electrode supported cells

Project Progress/Actions - Power modulation

Achievement to-date

Power modulation 50-100% SOFC, 70–100% SOEC
Power electronics (PE) efficiency : 20%loss

25% 50% 75%

Power modulation 50-100% SOFC, 70–100% SOEC
Power electronics efficiency : 5%loss

Power (%)	SOEC	SOFC-H2	SOFC-CH4
P min	58	23	13
P med	80	66	75
P max	100	100	100

Large power modulation validated at stack level in 3 modes:
SOFC: 13-100% in CH4, 23-100% in H2
SOEC: 58-100% in SOEC
Those setpoints will be used for system

PE efficiency: 91.5% = 8.5% loss
Will be improved with new algorithm under testing

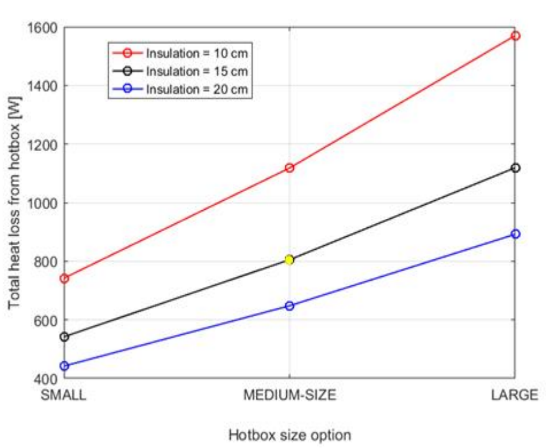
- MAWP: no target on power modulation or PE efficiency
- AWP: Power modulation 50 - 100 % in SOFC, 70 – 100 % in SOEC, nothing on PE efficiency
- Cycles between SOFC and SOEC in literature but not several power levels in each mode

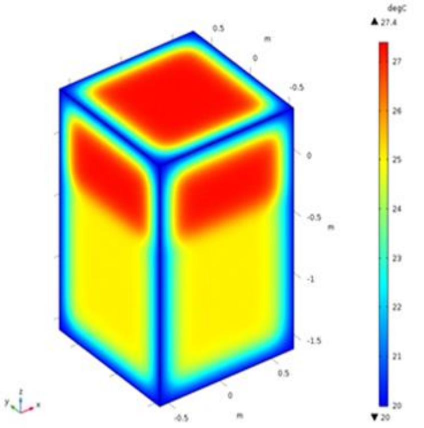
Risks, Challenges and Lessons Learned

		Measures taken
Risks	Delay in some tasks, mainly cells/stacks testing, stack manufacturing and system design and manufacturing	parallelisation of some tasks, rescheduling of overall project planning with extension
	regulatory issues with integration in the demo site	anticipation of preliminary works for installation, including permitting and risk analysis
Challenges	Thermal management with switching between SOFC and SOEC and with power modulations	Extensive modelling tasks supporting system design with several options investigated

FUEL LINE

code	FUNCTION	DEVIATION	CAUSE	EFFECTS	CAT	F	D	R	DETECTION	PREVENTION	MITIGATION	H2	NG	EL	SS
2.3.1	In SOFC mode of operation: deliver the fuel (natural gas, hydrogen, a mixture of also CO, CO2 and H2O after the recirculation loop and the reformer) to the stack unit for the electrochemical reaction; in SOEC mode of operation provide the steam (mixed with produced hydrogen) for the electrolysis reaction occurring in the stack	Not sufficient fuel flow supply or steam supply	Rupture in a fuel line due to accidentally shearing or due to fatigue; accidentally release from a valve	Off-design conditions in the stack unit due to lack of fuel species; impossibility to cover the load or the power	P	2	2		Control system of the module	Maintenance of the valves and of the lines	Depending on the position of the rupture, possibility of shutting down the system	X	X	X	X
2.3.2				Release of a gas stream rich in hydrogen (and natural gas and carbon monoxide for SOFC mode), with possibilities of fire and explosion in case of ignition	H	2	3		Control system of the module, sensing system for inflammable species in the atmosphere	Maintenance of the valves and of the lines	Shut-down system for limit if possible the released flowrate; evacuation of hydrogen (and other gases) towards vents; fire-fighting system	X	X	X	X
2.3.3		Non-desired outlet composition of the stream from the GPU to the fuel electrode of the stack	Failure or malfunction in the pre-reformer	Off-design conditions in the stack unit with possibility of damages	P	2	4		Monitoring of the fuel line gas composition exiting the GPU	Frequent maintenance of the pre-reformer chemical reactor	If possible, change parameters of the line for continuous operation; if fuel composition is dangerous for the stack, switch the lines and turn to safety position		X		





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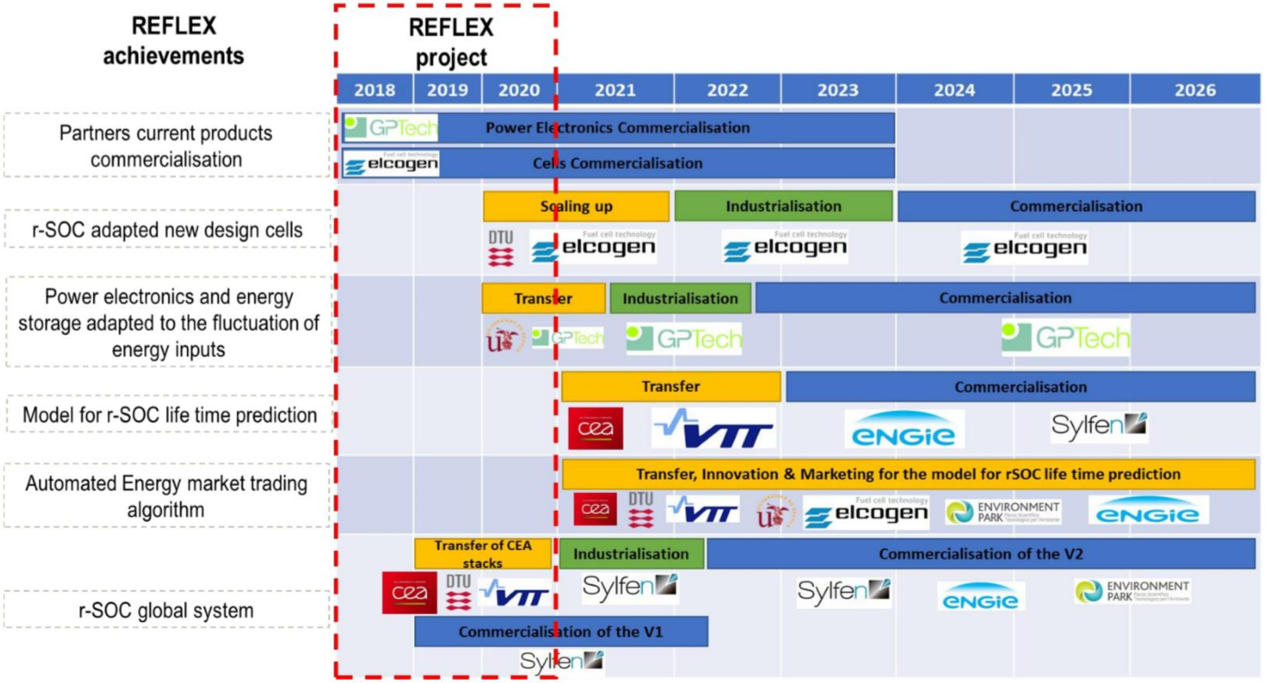
Exploitation Plan/Expected Impact

Exploitation

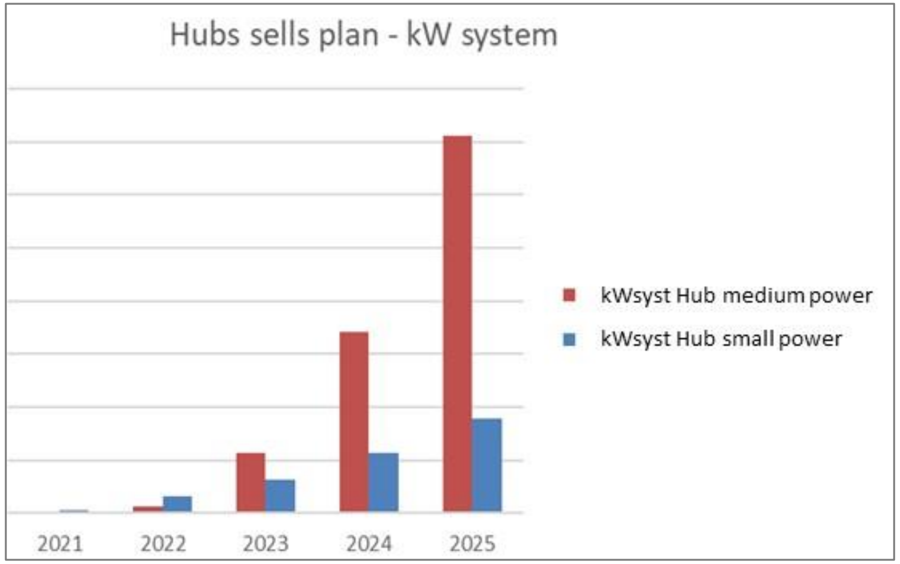
Projects partners on the whole value chain: each having its own stone



Impact

Most promising markets identified from a tech-eco point of view

Sales forecast performed for each individual components



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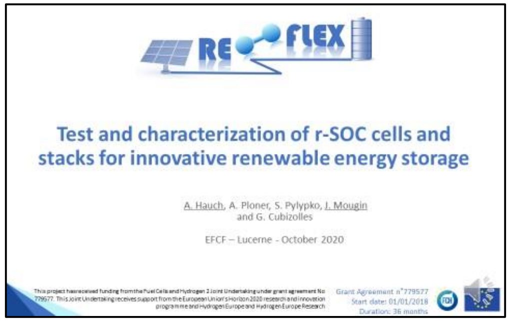
Communications Activities

Website: www.reflex-energy.eu
# of visitors: 3584 (10 Nov 2020)

Oral presentations at scientific conferences



Newletters and leaflets

International advisory board:

E4Tech, Schneider, Egis, IREN

Check of actions realised as compared to plans

Target groups	Indicators for measuring the effectiveness of the approach	Min target value	Planned M1-M18	Achieved M1-M18	Feedbacks expected
Research community *Hydrogen, Fuel Cell and electrolysis researchers and industries*	Publications at international conferences (M12 onwards)	10	2	2: Abstracts for SOFC-XVI conference (Kyoto, Sept. 2019) and IECON IEEE 2019 congress (Lisbon, Portugal).	Disseminate the latest results towards H2 and fuel cells actors Designing new collaborative research proposals. MoUs[1] concluded between research and industrial partners.
	Publications in international journals (M12 onwards)	7	2	2 (ECS Transaction and IEEE conference paper). Full journal papers to follow after M18.	
	Participation with presentation of results at international events with industry	3	1	1: Hannover Fair 2019	
	Workshop with Industrial Advisory Board	1	0	First meeting with IAB planned for 4th September 2019 and to take place at Engie (Paris)	
General public *Public and Private*	Non-scientific publications (articles, press releases) Participation in national events promoting new solutions for energy storage ad local energy in eco-buildings and districts	10	5	Non-scientific publications can be found here: www.reflex-energy.eu/downloads	Attract attention and to generate interests for an optimal exploitation of the project's results.
	Flyers/Poster: Distributed at Conferences, workshops, exhibitions	1000	300	~400	
	Project Website: Number of Visits All public deliverables will be made available	3000 200	1000 50	1029	
Customers *Local authorities, Companies Real Estate managers, Buildings industry; Suppliers of Renewable Power storage solutions &*	Customer request for other projects deployment	50	7	Discussions taking place at DTU booth Hannover Fair 2019. SmartHYes demonstrator (first prototype by Sylfen, prior to REFLEX), being tested at Engie Lab Crigen, has been shown to several customers (energy companies, building and engineering companies), mentioning the on-going REFLEX program.Several requests from customers (energy industry) received by Elcogen on results of rSOC operation of system developed within REFLEX project.	Discussions at our booth on industrial fairs (mainly Hannover Fair) Request for specific features
	Interest of industrial customers on Technology Exploitation via license models	10	4		

[1] Memoranda of Understanding

Poster presentations in booths at fairs and conferences

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