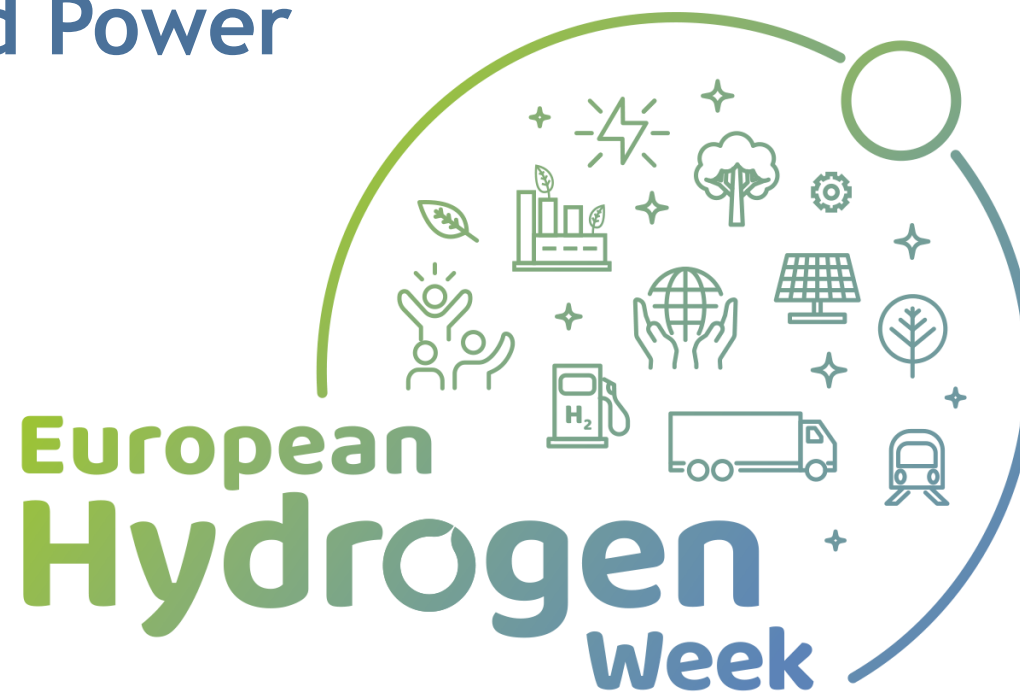


Clean Heat and Power



A. Aguilo
Project Officer

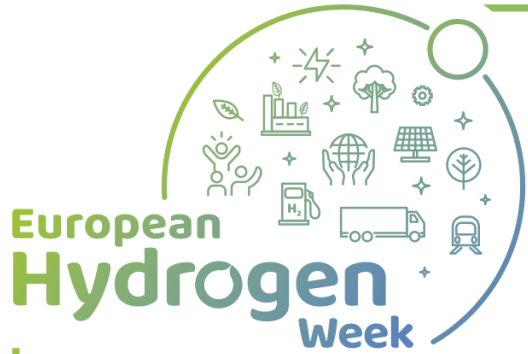


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#EUResearchDays
#PRD2022
#CleanHydrogen



PRD parallel sessions on Heat and Power

27 Oct. 16:00 - 17:45



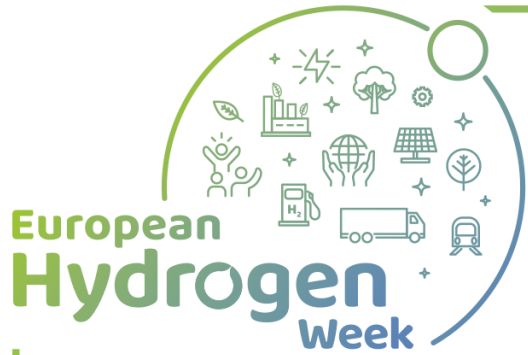
Clean Heat and Power



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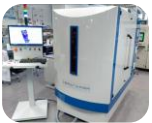
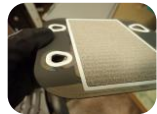
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Clean Heat and Power with Hydrogen

Residential, commercial buildings, service sector, industry

2008-2020
77 projects
257 M€
FCH
FUEL CELLS AND HYDROGEN JOINT INITIATIVE



Research

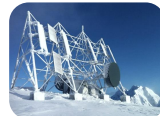
- Lifetime & performance
- Monitoring & Diagnostics
- Component and System aspects
- Materials & Manufacturing

Proof of Concepts



Trials and Demonstrations

End use ready solution, new business models for market introduction



Next Generation Products



2021-2027

Fuel cells

- 01: Reducing CAPEX and TCO of FCs
- 02: Next generation 0-100% H₂ and H₂-rich fuels
- 03: Improve flexibility with reversible fuel cells
- 04: Reducing critical raw materials and recycling
- 05: Mass manufacturing

Gas turbines + burners/furnaces

- 01: 0-100% H₂ (low NO_x, high eff., flexible op.)
- 02: Demos (retrofitting) + safety and plan integration



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Fuel cell for domestic heat and power

Europe market is in the order of 25,000s systems, ~12% increase since last year



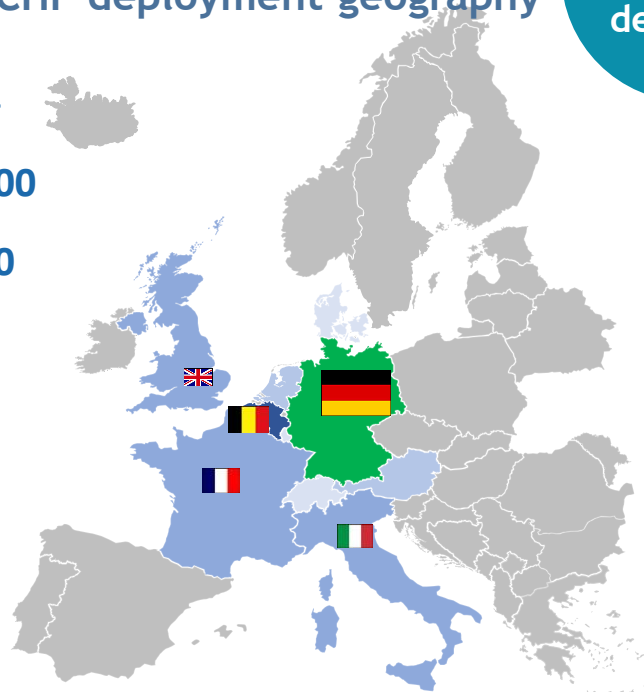
Complementary to heating system



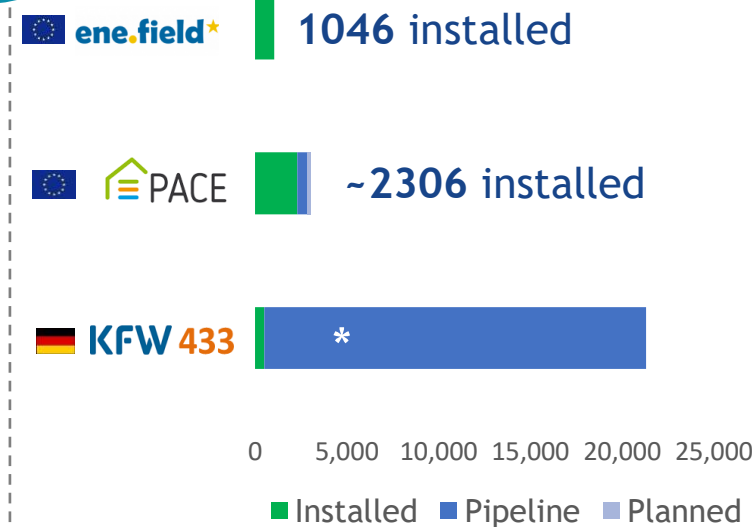
Replaces heating system

FC Micro-CHP deployment geography

- 20000+
- 400-3000
- 200-400
- 70-200
- 1-70



Planned
and
deployed



Long term operation confirms performance

... additional cost reductions (larger production volumes) and 100% H₂ units

Homes and small businesses¹

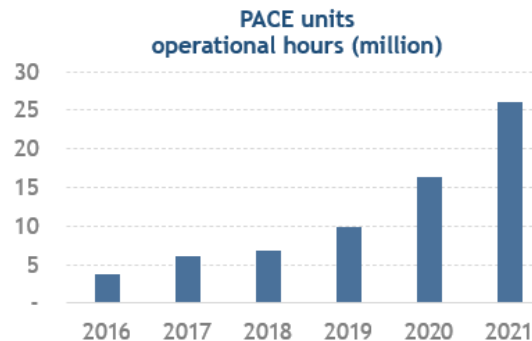
26 million hours operation

2,300 units/year manufacturing capacity²

40,000+ hours of continued operation for single fuel cell¹

¹based on data reported until Dec 2021

²for some OEMs in the project



MAWP 2024 KPIs

✓ 37 to 63% Power Efficiencies

⚠ 3.5 €ct/kWh O&M Costs

✓ 97% availability

✓ 60 khrs stack durability

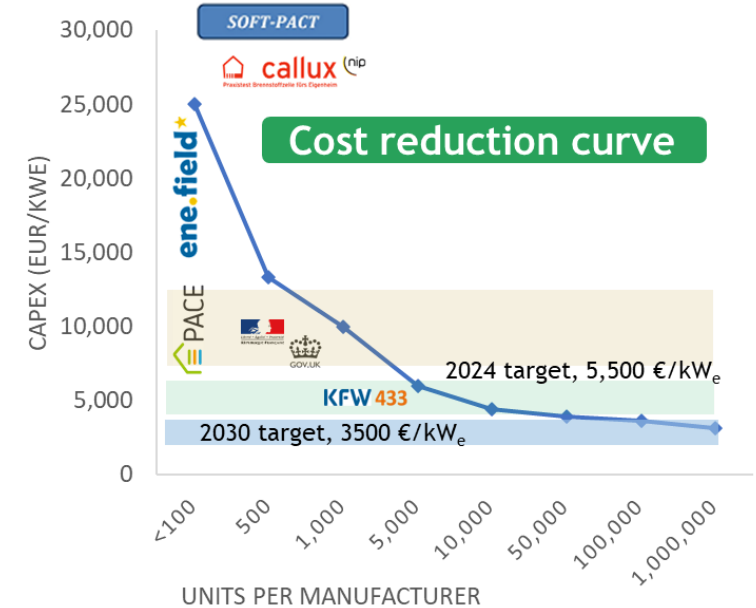
⚠ 100% H₂ tolerance

⚠ 5,500 EUR/kW_e CAPEX

SRIA 05 - Mass manufacturing

SRIA 01 - Reduce CAPEX and TCO of FCs

AWP 2022 - Innovative manufacturing for SOFC



Towards next generation of fuel flexible, high performance and cost-effective fuel cells

Supporting European industry to keep leadership

Flexi-fuel stationary SOFC

SO-FREE

Solid oxide fuel cell combined heat and power:
Future-ready Energy

W2W
Waste2Watts



- SOFC-based system for CHP production running on any mixture of natural gas, biogas and hydrogen
- Commercial kW_e SOFC on agro-biogas is prepared, as well as novel cryo-cleaning of biogas at 100m³/h scale
- 5 kW_e High-temperature methanol PEMFC built > 85% fuel processing efficiency achieved, prototype evaluation to start in Autumn 2022 / scale up 50-100 kW_e

Improving cost competitiveness of SOCs



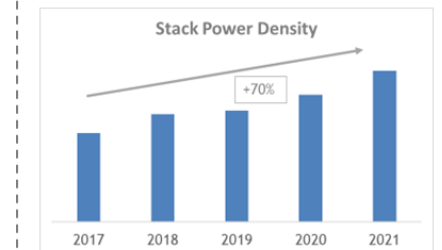
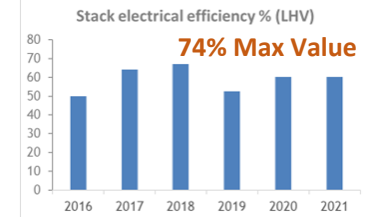
Improved performance, durability, and cost competitiveness of SOCs

- Validation of large cells and short-stacks
- Gathers EU Solid Oxide industry and research community

Advanced monitoring and control of FCs



- A new way to monitor and control fuel cell technologies by integrating hardware, stack diagnosis, control algorithms and fault detection algorithms
- Lifetime: 12 yrs (SOFC) and 15 yrs (PEMFC)



SRIA 02 - Next generation 0-100% H₂ and H₂-rich fuels

AWP 2022 - Ammonia Fuel Cells

Fuel cells for commercial buildings and service sectors

Operational data start to become available

European supply chain, targeting Europe and overseas market (Asia)

Demos of FCs for cogeneration and prime power in commercial buildings sub-100 kW_e units



Buildings, services & light industry, decentralised grids

450 kW_e capacity, 3 European OEMs

9 to 60 kW_e single FC systems

✓ 3 OEMs have finalised designs

✓ 9 systems installed (~300 kW_e)

✓ 6 systems operating (~190 kW_e)

⚠ 10 systems to be installed

⚠ Limited data reported

✓ 40-56% n_{el}

✓ 50% H₂ tolerance



MAWP 2020 KPIs

✓ 42 to 60% Power Efficiencies

✓ 97% availability

✓ 30 khrs stack durability

⚠ 1.8 €ct/kWh O&M Costs

⚠ 4,5-7,500 EUR/kW_e CAPEX

⚠ 100% H₂ tolerance

**E2
P2**

High power density SOFC fuel cell for data centres



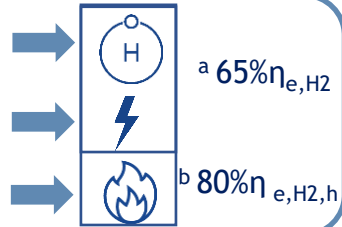
Offering flexibility to the energy system with Solix Oxide Cells

One of the objectives of the Clean Hydrogen partnership SRIA



Natural Gas/
Biogas

**Novel SOFC system
for trigeneration**
50kWe (SOFC)

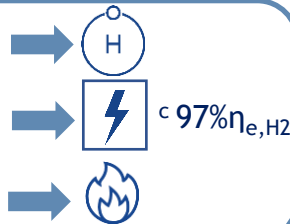


<https://ch2p.eu/>



Natural Gas/
Biogas

**Reversible
trigeneration**
25kWe(SOFC)/75kW (SOEC)



Autonomous, 100% renewables, modular

^a combined power & H₂ production, LSM efficiency

^b combined power, heat & H₂ production LSM efficiency

^c H₂ production efficiency, SOEC mode, LSM using waste steam



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✓ 20 kgH₂/day system tested in
a laboratory environment

✓ Reversible operation tested

✓ 0.26%/1000h efficiency
degradation, >600 hours test

Tests done in Large Stack
Module (LSM)

✓ 53 kg H₂/day (SOE)

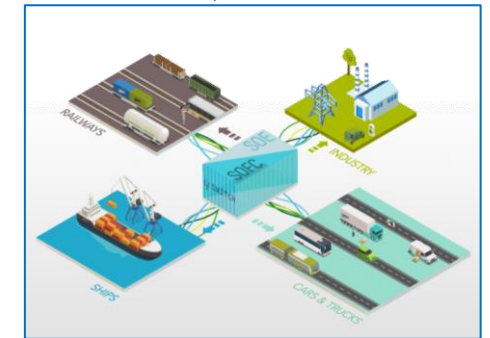
✓ +2100h tests

⚠ 2.8€/kgH₂ cost target

⚠ System under construction

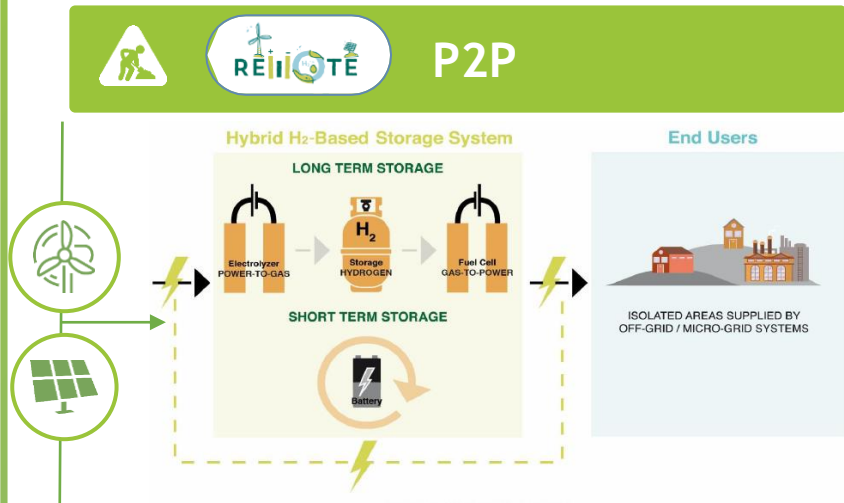
SRIA 03 - Improve flexibility with rFCS

AWP2022 - rSOC system



Power to Power for isolated micro-grid or off-grid remote areas

Autonomous, 100% renewables, modular, 2/3 demo-sites in operation



Higher CAPEX, lower OPEX

Zero local air emissions

Alternative to diesel generation

Basis for next-generation P2P systems

www.remote-euproject.eu

Demo Agkistro, Greece (45 kW_e FC, 25 kW H₂ prod.)

- Fuel cell: 181 hours, 45% system η_e ,
- H₂ production: 152 hrs, 10.8kgH₂/day @ 55% system η
- Availability: 99 % FC / 100% Electrolyser



Agri-food processing plant, avoiding new transmission line

Demo Rye, Norway (87 kW_e FC, 50 kW H₂ prod.)

- Fuel Cell: 270 hrs., 61% system η
- H₂ production: 1206 hrs, 6.4kgH₂/day @ 44.% system η
- Availability: 98 % FC / 97 % Electrolyser



Supporting loads for a fish farm by integrating RES

Demo Gran Canaria, Spain

- Wind & solar P2P (fuel cell + electrolyser + H₂ storage)
- Electricity supply for a milking facility, replacing diesel generation
- Grid extension restrictions, surrounded protected area



Milk factory



Clean Hydrogen
Partnership

EUROPEAN PARTNERSHIP



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FC-based containerized transportable gensets in operation

Clean power generation for temporary events, demonstration activities have started (Festivals, construction sites, urban events, shore power)



H2 Gensets



OBJECTIVES

4 x 25kW_e and 3 x 100 kW_e

5500 €/kW_e (CAPEX)

1.1 €/kWh (LCOE)

PROGRESS



2 gensets completed (25 kW_e and 100 kW_e) / 2 more to be delivered end 2022/beg 2023

100 kW_e genset demonstrated - Construction site in Spain, Moto GP Aragon Motorland, Port of Tenerife (next stop)

25 kW_e DoC issued - Demonstration activities in 2022-2023 (Hydrogen Energy Summit)

5500 €/kW_e (CAPEX), work in progress

Remote monitoring and control enabled

CONSTRUCTION SITE
DEMO, 100 kW_e



122 days demo period
86 site working days in such period
67 days genset available for operation
533 hours of effective operation
935 kWh supplied to construction site
247 kg of H₂ consumed



Get involved in
demo campaign

[Video tour of gensets](#)

Remote power with solid oxide fuel cells

Demo campaign has started: remote gas/oil infrastructure, telecom towers
Exporting European solutions abroad (North America)



Remote power



OBJECTIVES

Remote power generation in harsh climate conditions (-40 to +50°C)

49 units to be demonstrated

Cost and performance targets

PROGRESS



✓ 30 sub-kW_e units commissioned, >35% η_e

✓ 18,000 running hrs. for 9 systems

✓ Operation and start up in harsh conditions -40°C

✓ 5-10 years durability -> further improvement expected

✓ Maintenance frequency: 15 months

✓ Long term desulphurisation 15 months



CAPEX reduction



Greening industry using H₂ in MW scale PEMFCs

100 kW prototype tested, MAWP 2024 achieved for Elec Eff, CAPEX, stack durability, response time

100 kW_e system prototype built and validated

1 MW_e plant model developed and validated

1,500 EUR/kW_e for 2 MW_e unit @ 25 MW/year ✓



Next generation GRASSHOPPER plant

FAT finalised, plant shipped to final location

50% η_e (including dynamic operation) ✓

20% to 100% partial load operation (60 s) ✓

Automatic operation in response to demand



MEA development

80% reduction Pt content in the MEA

MEA designed for high volume manufacturing

Next generation stack

300 cm² active cell area short stack built
0.689 mV @ 1 A/cm², improved power density
20 khs stack durability ✓

27 kW_e stack design completed

450 EUR/kW_e @ mass product. (estimated)

High volume manufacturing design -> industrialisation

Conclusions

Supporting European actors to develop clean, renewable and flexible hydrogen-based heat and power generation solutions



Long term operation of units , +40,000 hrs. confirms performance of fuel cells for domestic applications, volume manufacturing needed to decrease costs further



SOFC generate power at 60% electrical effic, exporting EU technology abroad

Flexi-fuel fuel cell systems being developed (biogas, H₂, biofuels)

Reversible operation of Solid Oxide Cell tested



100 kW prototype representative of MW scale FCs have shown sound performances including at partial load, volume manufacturing ready



H₂ gensets being demonstrated across Europe

SOFC for remote power in harsh conditions proven, exporting EU technology abroad



Support in the period 2021-2027 extended to gas turbines and H₂ for heat
Preparing 0-100% H₂ gas turbines whilst keeping low emission, high efficiencies and flexible operation