CH2P

COGENERATION OF HYDROGEN AND POWER USING SOLID OXIDE BASED SYSTEM FED BY METHANE RICH GAS

Project ID:	735692
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-4-2016: Co-generation of hydrogen and electricity with high-temperature fuel cells (> 50 kW)
Project total costs:	EUR 7 239 100.08
Clean H_2 JU max. contribution:	EUR 3 999 896.00
Project period:	1.2.2017–30.4.2022
Coordinator:	Fondazione Bruno Kessler, Italy
Beneficiaries:	Deutsches Zentrum für Luft- und Raumfahrt EV, École Polytechnique Fédérale de Lausanne, HyGear BV, HyGear Fuel Cell Systems BV, HyGear Operations BV, HyGear Technology and Services BV, Shell Global Solutions International BV, SolydEra SA, SolydEra SpA, Vertech Group

https://ch2p.eu/

PROJECT AND OBJECTIVES

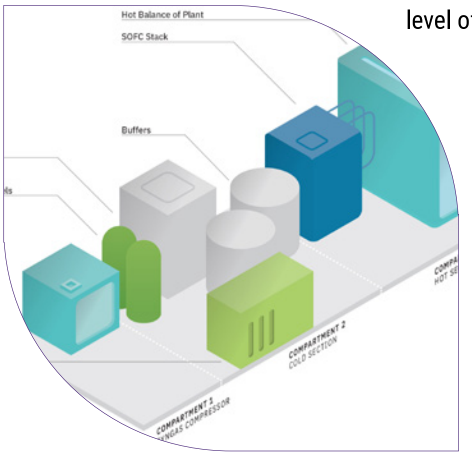
CH2P is designing, constructing and partially validating an innovative system prototype for hydrogen production. The system co-generates hydrogen, heat and electricity using solid oxide cell technology fuelled by carbon-lean natural gas or biomethane. The CH2P system operates in five modes, enabling flexibility in hydrogen and electricity supply. The prototype is placed in two 40-foot containers, and it is modular to support future upscaling. CH2P has been designed as a transition technology for application at hydrogen refuelling stations and has the ambition of producing hydrogen at < €4/kg.

NON-QUANTITATIVE OBJECTIVES

- CH2P targets six use cases.
- The project aims to co-generate hydrogen and electricity for hydrogen refuelling stations. With a single technology, CH2P will deliver natural gas, hydrogen and power – the fuels of the EU directive on alternative fuels infrastructure.

PROGRESS AND MAIN ACHIEVEMENTS

- The CH2P project designed, simulated, constructed and validated a novel system prototype for hydrogen production.
- The system produces 20 kg/day of hydrogen and 25 kW of electric power.
- The system operates in five modes and delivers hydrogen at 7 bar with a purity level of 5.0 N of hydrogen.



QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
AWP 2016	System size	kgH_2/day	20	25	✓
	Flexible co-generation of H_2 and POWER	%	50 + 50	30 + 30	
	System efficiency	%	65	66	
	Fuel utilisation and steam conversion rate at large stack module level	%	> 80 %	90	
	Stack voltage deviation	%		< 1 %	
	Gas purification unit producing 5 N of hydrogen	–	5N Purity CO < 200 ppb	5N Purity CO < 200 ppb	
	1 000 hours of testing in a real environment	hours	1 000	1 000	

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COMSOS

COMMERCIAL-SCALE SOFC SYSTEMS

Project ID:	779481
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-11-2017: Validation and demonstration of commercial-scale fuel cell core systems within a power range of 10–100 kW for selected markets/applications
Project total costs:	EUR 10 277 897.50
Clean H_2 JU max. contribution:	EUR 7 486 954.75
Project period:	1.1.2018–31.8.2023
Coordinator:	Teknologian tutkimuskeskus VTT Oy, Finland
Beneficiaries:	Convion Oy, Energy Matters BV, Politecnico di Torino, SolydEra SA, SolydEra SpA, Sunfire GmbH

https://www.comsos.eu/

PROJECT AND OBJECTIVES

The key objective of ComSos is to validate and demonstrate fuel-cell-based combined heat and power solutions (FC-CHP) in the mid-sized power ranges of 10–12 kW, 20–25 kW and 50–60 kW (referred to as mini FC-CHP). The core of the project consortium consists of three solid oxide fuel cell (SOFC) system manufacturers aligned with individual strategies along the value chain: SolydEra, Sunfire and Convion.

PROGRESS AND MAIN ACHIEVEMENTS

- All five Sunfire systems have been installed at the customer sites.
- Both Convion units have been installed at the customer sites.
- The first SOLIDpower (SolydEra) unit has been installed at the customer site.

FUTURE STEPS AND PLANS

- The Sunfire and Convion units are generating thousands of hours of demonstration data for project purposes.
- The rest of the SOLIDpower (SolydEra) units were expected to be installed during spring 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
MAWP addendum (2018–2020)	Electrical efficiency	%	> 50	> 50	✓
	NOx emission	mg/kWh	< 40	< 40	✓
	Durability	years	10	2	⚙
Project's own objectives	SME participation	%	25	50	✓

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E2P2

ECO EDGE PRIME POWER

Project ID:	101007219
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-9-2020: Fuel cell for prime power in data-centres
Project total costs:	EUR 4 053 460.38
Clean H_2 JU max. contribution:	EUR 2 499 715.50
Project period:	1.1.2021–28.2.2025
Coordinator:	Research Institutes of Sweden AB, Sweden
Beneficiaries:	Vertiv Croatia DOO za trgovinu i usluge, Vertiv, InfraPrime GmbH, Equinix Netherlands BV, Snam SpA, TEC4FUELS, SolydEra SpA

https://www.e2p2.eu/

PROJECT AND OBJECTIVES

The main objectives of E2P2 are to define the fuel cell prime power concept for data centres and to create an authoritative open standard for fuel cell adaptation to power data centres. E2P2 will demonstrate and validate a proof-of-concept fuel-cell-based prime power module for data centres and evaluate the opportunities for improved energy efficiency and waste heat recovery. The project strongly anticipates opportunities for the European fuel cell suppliers to increase their uptake across multiple markets, with improved energy efficiency and cost-effectiveness.

FUTURE STEPS AND PLANS

The main target is to get the demonstrator up and running.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
MAWP addendum (2018–2020)	Availability (% of plant available power)	%	97	
	Electrical efficiency	% LHV	42–62	
	CAPEX	€/kW	3 500–6 500	

EMPOWER

EUROPEAN METHANOL POWERED FUEL CELL CHP

Project ID:	875081
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-7-2019: Development of highly efficient and flexible mini CHP fuel cell system based on HTPEMFCs
Project total costs:	EUR 1 499 876.25
Clean H_2 JU max. contribution:	EUR 1 499 876.25
Project period:	1.1.2020–30.11.2023
Coordinator:	Teknologian tutkimuskeskus VTT Oy, Finland
Beneficiaries:	Blue World Technologies APS, Catator AB, THT Control Oy, Universidade do Porto

https://www.empower-euproject.eu/

PROJECT AND OBJECTIVES

The project will develop, manufacture and validate a methanol-fuelled 5 kWe combined heat and power (CHP) system based on high-temperature proton-exchange membrane fuel cell (HT-PEMFC) technology. The project will enhance the system's efficiency to target the mini-CHP market and provide a cost-competitive and low-carbon option. The developed CHP unit will be capable of fast start-up and fast dynamic response to help the integration of intermittent power production from renewable energy sources. Currently, the subsystems of the CHP system are being finalised by project partners. The integration of the final CHP system has started.

NON-QUANTITATIVE OBJECTIVES

- EMPOWER aims to increase the visibility and awareness of the potential of renewable methanol. The project results are being openly communicated and disseminated, for example through public deliverables and scientific publications. The project has also arranged an international summer school on hydrogen technologies.
- The project aims to conduct business analysis for the use of renewable methanol in CHP systems and other applications. Preliminary market analysis was performed in 2021, and this will be updated at the end of the project.
- EMPOWER aims to support knowledge exchange and production ramp-up through stakeholder identification, information sharing and linkages. An industry webinar was arranged for January 2021, a workshop was arranged to take place in Denmark in May 2022 and another is planned to take place in Finland in November 2023.
- The main goal of the project is to produce affordable and secure electricity with a low carbon footprint. The carbon footprint was analysed in December 2022.

PROGRESS AND MAIN ACHIEVEMENTS

- The HT-PEMFC stack has been designed for pressurised operation.
- The CHP system enclosure and system balance-of-plant components have been finalised.
- The automated quality control methods for stack components have been developed.
- The carbon footprint of the 5 kW HT-PEMFC CHP system has been analysed.
- Scientific studies on aqueous-phase-reforming catalysts have been finished and reported on.

FUTURE STEPS AND PLANS

- EMPOWER will demonstrate the project's 5 kW HT-PEMFC CHP system in the relevant end-user environment. The designed system will be demonstrated in summer/autumn 2023 in Finland to evaluate its performance and the project's key performance indicators.
- The HT-PEMFC subsystem will be integrated into the CHP system (planned for summer 2023).
- The system scale-up study (50–100 kW) and business analysis were expected to be performed in spring 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Stack electrical efficiency (LHV reformate gas)	%	55	N/A	⚙
	Fuel-processing efficiency	%	85	> 85	✓
MAWP addendum (2018–2020)	CHP electrical efficiency (LHV methanol)	%	37–67	N/A	⚙
	CAPEX	€/kWh	5 500	2 600	✓

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EVERYWH$_2$ERE

MAKINGHYDROGENAFFORDABLETOSUSTAINABLY OPERATE EVERYWHERE IN EUROPEAN CITIES

Project ID:	779606
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-10-2017: Transportable FC gensets for temporary power supply in urban applications
Project total costs:	EUR 6 827 124.45
Clean H_2 JU max. contribution:	EUR 4 999 945.76
Project period:	2.1.2018–31.10.2023
Coordinator:	RINA Consulting SpA, Italy
Beneficiaries:	Acciona Construcción SA, Delta1 gUG (Haftungsbeschränkt), FRIEM SpA, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Genport SRL – Spin Off del Politecnico di Milano, ICLEI European Secretariat GmbH (ICLEI Europasekretariat GmbH), Iren Energia SpA, Iren Smart Solutions SpA, Iren SpA, Linde Gas Italia SRL, Mahytec SARL, Parco Scientifico Tecnologico per l'Ambiente SpA, PowerCell Sweden AB, Swiss Hydrogen SA, Teknologian tutkimuskeskus VTT Oy, THT Control Oy

http://www.everywh2ere.eu/

PROJECT AND OBJECTIVES

EVERYWH$_2$ERE will integrate the previously demonstrated robust proton-exchange membrane fuel cell stacks and the low-weight, intrinsically safe pressurised-hydrogen technologies into easy-to-install, easy-to-transport, fuel-cell-based transportable gensets. Eight fuel cell 'plug and play' gensets fitted in containers will be produced and tested through a pan-European demonstration campaign in a demonstration-to-market approach. The prototypes will be tested at construction sites, music festivals and urban public events across Europe, demonstrating their flexibility and increased lifetimes.

NON-QUANTITATIVE OBJECTIVES

EVERYWH$_2$ERE aims to support the development of a regulatory framework for transportable hydrogen-fuelled systems.

PROGRESS AND MAIN ACHIEVEMENTS

- The first two fuel-cell-based transportable gensets (1 × 25 kW and 1 × 100 kW) and related hydrogen storage bundles have been validated.
- The assessments of conformity for the 110 kW and 25 kW gensets have been completed (declaration of conformity).
- The 100-01 genset has been demonstrated at the Acciona construction site (San Sebastian, Spain) and at Aragón MotorLand. Preliminary activities for the cold-ironing demonstration in the Port of Tenerife are being carried out.
- The 025-01 genset was demonstrated at the 2023 Hydrogen Energy Summit & Expo, in Bologna. Further demonstrations are being designed for use in Rome (lighting of a historical monument during a public event) and Genoa (electricity supply during a public event associated with The Ocean Race grand finale).
- Commissioning of the 100-02, 025-02, 100-03 and 025-03 gensets is ongoing, with their release expected at the start of spring 2023 for the second batch and the end of spring 2023 for the third batch, ready for the summer demonstration campaign.
- The second stakeholder workshop was planned for 23 March 2023.

FUTURE STEPS AND PLANS

- The definition of the final exploitation plan is ongoing. This includes the assignment of the gensets to technical partners after the end of the project, the identification of responsibilities for maintenance and support during operation, and potential involvement in follow-up funded projects.
- The summer demonstration campaign will be clusterised in order to reduce transportation and its related costs, not least because of the energy crisis.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Levelised cost of energy of the genset (identification of replication market with contractual costs ± 10 % of those of current power supply solutions)	€/kWh	1.1	N/A	⚙
	Noise emission of the full genset (not only the FC SuSy)	dB	< 65	60	✓
	Future manufacturing CAPEX (of the system)	€/kW	5 500	6 850	⚙

GRASSHOPPER

GRID ASSISTING MODULAR HYDROGEN PEM POWER PLANT

Project ID:	779430
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-7-2017: Development of flexible large fuel cell power plants for grid support
Project total costs:	EUR 4 387 063.75
Clean H_2 JU max. contribution:	EUR 4 387 063.75
Project period:	2.1.2018–31.3.2022
Coordinator:	Informatizacija Energetika Avtomatizacija DOO, Slovenia
Beneficiaries:	Abengoa Innovación Sociedad Anónima, Johnson Matthey Hydrogen Technologies Limited, Nedstack Fuel Cell Technology BV, Politecnico di Milano, Zentrum für BrennstoffzellenTechnik GmbH

http://www.grasshopperproject.eu/

PROJECT AND OBJECTIVES

The GRASSHOPPER project aims to create a next-generation MW-sized fuel cell power plant (FCPP) that is more cost-effective and flexible in power output than current FCPPs. The FCPP will be demonstrated in the field as a 100 kW submodule pilot plant, implementing newly developed balance-of-plant system components and stacks. A new stack design has been developed with increased power density, and short-stack testing has been concluded. The pilot plant is undergoing factory acceptance testing on hydrogen. A dynamic simulation model of the pilot plant has been developed to support optimisation in the field and the scaling up of the design.

NON-QUANTITATIVE OBJECTIVES

The project aims to ensure operation flexibility and grid stabilisation capability through fast responses. The operation strategy was defined considering the requirements in terms of response time for grid stabilisation.

PROGRESS AND MAIN ACHIEVEMENTS

- The project has developed, built and tested the next generation of proton-exchange membrane (PEM) fuel cells for industrial applications. The tests carried out to date have demonstrated automatic mode operation and power demand adaptation capabilities. 50 % electrical efficiency, even in dynamic operation, has been achieved. The pilot plant can achieve full power (100 kWe gross power, 80 kWe net power) over time and modulate from 50 % to 100 % in less than 20 seconds and from zero to full load in less than 60 seconds from a warm standby mode.
- Building on the experiences of the pilot plant, the GRASSHOPPER team designed a modular 2 MW-scale low-cost FCPP with grid-supporting capability. The CAPEX of a unitary 2 MW flexible and dynamic FCPP for grid balancing has been estimated to be €1 500/kW (assuming stack costs of < €450/kW). The mass production of several of these plants at a production scale of 25 MW/year could reduce the total costs further.
- The project has also achieved outstanding results at the membrane electrode assembly (MEA) and stack levels. MEA platinum content has been reduced by > 80 %. A cell with an active area of 300 cm^2 designed for mass manufacturing was finalised and tested in a short stack, showing a performance of 0.689 V at 1 A/cm^2, increasing the power density by 60 % relative to previous technology. This has allowed the design of single stacks of 27 kW nominal power, representing four times the power of the stacks used for the first generation of this type of power plant (developed and demonstrated in the Clean Hydrogen Joint Undertaking project DEMCOPEM-2MW).
- The pilot plant has been successfully transported and commissioned in Arnhem, the Netherlands, where testing will continue until the final site preparations are completed. The tests have already contributed significantly to the continuation of the development of stack and operation modes.

FUTURE STEPS AND PLANS

- The project activities will continue in the years to come. In the very short term, tests of the GRASSHOPPER fuel cell system prototype will continue in an operational environment. This should allow the GRASSHOPPER solution to reach TRL 7. Although the project has ended, the consortium has committed to report operational data to the Clean Hydrogen Joint Undertaking through the Technology Reporting Using Structured Templates (TRUST) platform.
- In parallel, and with the support of Dutch funding, it is expected that the GRASSHOPPER technology will be developed with a view to reaching TRL 8–9 by the end of 2025.
- In addition, support has been awarded (under the umbrella of the IPCEI Hy2Tech) to build a GW-scale factory, which should allow, among other activities, the mass manufacturing of the GRASSHOPPER solution.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	MEA cost reduction	%	65	65	✓
	Stack efficiency	%	55	55	
	Stack CAPEX	€/kWe	450	450	
	Operation flexibility	–	Load following capacity over a 20–100 % power range	Load following capacity of 20–100 % for stack and 0–100 % for FCPP	
			50 % power in < 20 seconds	50 % power in < 20 seconds	
			100 % power in < 60 seconds	100 % power in < 60 seconds	
	Availability	%	95	N/A	⚙
	System electrical efficiency	%	50	43	⚙
MAWP addendum (2018–2020)	System CAPEX	€/kWe	1 500	1 500	✓
AWP 2017	Stack lifetime	hours	20 000	N/A	⚙

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PACE

PATHWAYTOACOMPETITIVEEUROPEANFCMCHP MARKET

Project ID:	700339
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02.9-2015: Large scale demonstration µCHP fuel cells
Project total costs:	EUR 91 681 943.33
Clean H_2 JU max. contribution:	EUR 33 932 752.75
Project period:	6.1.2016–30.4.2023
Coordinator:	European Association for the Promotion of Cogeneration VZW, Belgium
Beneficiaries:	Baxi Innotech GmbH, BDR Thermea Group BV, Bosch Thermotechnik GmbH, Danmarks Tekniske Universitet, Element Energy, Element Energy Limited, ERM France, EWE AG, Fachhochschule Zentralschweiz – Hochschule Luzern, Hexis AG, Hexis GmbH, Remeha BV, Remeha GmbH, Remeha NV, Senertec Kraft-Wärme-Energiesysteme GmbH, SOLIDpower GmbH, SolydEra SpA, Sunfire Fuel Cells GmbH, Sunfire GmbH, Vaillant GmbH, Viessmann Climate Solutions SE, Viessmann Elektronik GmbH, Viessmann Werke Allendorf GmbH, Viessmann Werke GmbH & Co. KG

http://www.pace-energy.eu

PROJECT AND OBJECTIVES

PACE is unlocking the large-scale European deployment of the state-of-the-art smart energy solution for private homes: fuel cell micro-co-generation. PACE will see up to 2 800 households across Europe reaping the benefits of this home energy system. The project enables manufacturers to move towards product industrialisation and fosters market development at the national level by working with building professionals and the wider energy community. The project uses modern fuel cell technology to produce efficient heat and electricity in homes, empowering consumers in their energy choices.

NON-QUANTITATIVE OBJECTIVES

- Deploy new manufacturing processes for increased capacity.
- Develop efficient routes to market: innovation in sales, marketing and the consumer offer.
- Provide efficient field support.
- Identify potential revenue streams from participation in the power markets and the economic added value from the avoidance of grid expansions.
- Develop a platform approach to component standardisation for fuel cell micro combined heat and power (mCHP) units across the EU supply chain.
- Create the conditions for expansion of the market for fuel cell mCHP units across Europe.
- Increase awareness of fuel cell mCHP systems in European markets.

PROGRESS AND MAIN ACHIEVEMENTS

- The installation of units will continue until the end of the project.
- The project has increased the system lifetime to more than 15 years and improved the maintenance interval using new/improved components. The system (excluding stack) lifetime was 10 years at the start of project; this increased to a minimum of 15 years by the end of the project.
- By the end of the project, all partners will eliminate the need for stack replacement during a customer's 10-year service plan (the worst case is 7 years, as reported at the project's start).

FUTURE STEPS AND PLANS

- All of the 2 800 units to be deployed in the project will be installed.
- PACE will continue data collection and analysis to provide a fact-based understanding of the performance and benefits of the technology.
- The project will identify ongoing regulatory barriers to the deployment of mCHP units across Europe, and collaborate with industry and policymakers to remove such barriers.
- The project will develop use cases for fuel cell mCHP units relevant beyond the project finish point, including an assessment of the economic potential of fuel cell mCHP units.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	No of units sold	units	2 800	3 091	✓
	Time before stack replacement	years	10-year system lifetime with > 50 % reduction in stack replacement or no stack replacement during a 10-year service plan	15-year system lifetime with > 50 % reduction in stack replacement or no stack replacement during a 10-year service plan	✓
	Manufacturing capacity (average company level)	units per year per OEM	1 000	2 300	✓
	Availability	%	99	96.2–99	(for some units)

REMOTE

REMOTE AREA ENERGY SUPPLY WITH MULTIPLE OPTIONS FOR INTEGRATED HYDROGEN-BASED TECHNOLOGIES

Project ID:	779541
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-12-2017: Demonstration of fuel cell-based energy storage solutions for isolated micro-grid or off-grid remote areas
Project total costs:	EUR 6 740 031.40
Clean H_2 JU max. contribution:	EUR 4 995 950.25
Project period:	1.1.2018–30.6.2023
Coordinator:	Politecnico di Torino, Italy
Beneficiaries:	Ballard Power Systems Europe AS, Enel Green Power SpA, Engie EPS Italia SRL, Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Grupo Capisa Gestión y Servicios Sociedad Limitada, Hydrogenics Europe NV, Instituto Tecnológico de Canarias SA, Instrumentación y Componentes SA, Iris SRL, Orizwn Anonymh Techniki Etaireia, Powidian, Sintef AS, Stiftelsen Sintef, TrønderEnergi AS

https://www.remote-euproject.eu/

PROJECT AND OBJECTIVES

REMOTE is demonstrating the technical and economic feasibility of H_2-based energy storage solutions (integrated power-to-power (P2P) systems, non-integrated power-to-gas and gas-to-power systems (P2G + G2P), customised P2P systems) deployed in three demonstrations, based on renewable energy source (RES) inputs (solar, wind, hydro) in isolated microgrid or off-grid remote areas. In the 5 years of the project (up to December 2022), the design, procurement, installation, operation and analysis of two demonstrations (in Greece and Norway) have been assessed; the third demonstration (in Spain) is in the commissioning phase. The demonstration analysis and the exploitation plans are being finalised.

NON-QUANTITATIVE OBJECTIVES

- REMOTE aims to complete the demonstrations' design, installation and operation. REMOTE has created fundamental know-how for the next generation of P2Ps based on fuel cells and H_2 technologies adapted to the market and society's needs, making use of scientific advances in the management of off-grid areas and isolated microgrids.
- The project aimed to build experience throughout the value chain of P2P systems and validate real demonstration units in representative applications of isolated microgrid or off-grid areas. This enables suppliers, end users and general stakeholders to gain experience for the future deployment of these energy solutions.
- REMOTE aimed to gather technical data on the operation of H_2-based devices (PEMFC, electrolysers) in long-term real operation in P2P applications. The operation of the P2P systems (lasting more than a year) has generated learning experiences regarding the behaviour of technologies such as fuel cells and electrolysers in P2P applications. Companies now know what to improve.
- The project aimed to complete detailed life cycle analysis of RES-fed, H_2-based P2P systems in remote locations. The project allows for a detailed understanding of the complete life cycle analysis achieved by the RES-based P2P systems in remote areas, in terms of metrics such as global greenhouse gas reduction thanks to the adoption of H_2 in a local RES-storage system at seasonal range.

PROGRESS AND MAIN ACHIEVEMENTS

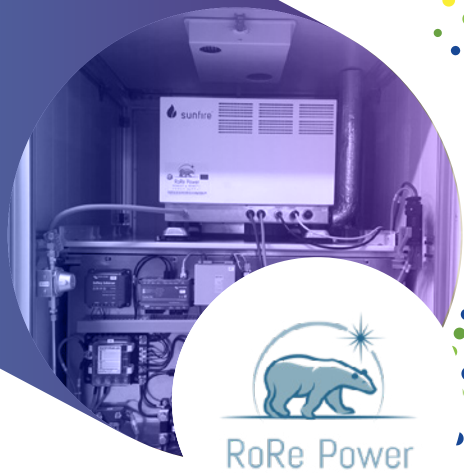
- REMOTE has achieved 1 year of experience of operation of the demonstration in Norway.
- It has achieved 2.5 years of experience of operation of the demonstration in Greece.
- The project has significant experience of the design, commissioning and operation of three H_2-based P2P plants.

FUTURE STEPS AND PLANS

- The running and full analysis of the demonstration in Norway have been completed. Technical analysis of the demonstration experience in terms of performance and lessons learned is being finalised.
- The running and full analysis of the demonstration in Greece have been completed. The technical analysis of the collected data is being finalised.
- REMOTE has finalised the installation of the new demonstration in Spain. The demonstrator has been commissioned and is operational.
- Complete techno-economic analysis of the demonstration experience has been performed with real data, to develop an understanding of how to optimise P2P plants in the future, with improved efficiency and reduced costs.
- A business analysis of the H_2-based P2P plants for remote locations is being developed and will be presented to the market stakeholders.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Targetachieved?	SoA result achieved to date (by others)	Year of SoA target
MAWP addendum (2018–2020)	Rated efficiency of the electrolyser (PEM)	kWh/kg	55 (2020) 52 (2024)	50	✓	50	2020
	Electrolyser footprint (PEM)	m²/MW	100 (2020) 80 (2024)	273	⚙	10	2018–2020
	Rated efficiency of the fuel cell (PEM)	% LHV	42–62 (2024)	45–55	✓	51	2018
	Rated efficiency of the electrolyser (Alkaline)	kWh/kg	50 (2020) 49 (2024)	55–60	⚙	55–60	2020



ROREPOWER

ROBUST AND REMOTE POWER SUPPLY

Project ID:	824953
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-3-2018: Robust, efficient long term remote power supply
Project total costs:	EUR 4 220 093.75
Clean H_2 JU max. contribution:	EUR 2 999 190.26
Project period:	1.1.2019–31.12.2023
Coordinator:	Teknologian tutkimuskeskus VTT Oy, Finland
Beneficiaries:	3E Energy Oy, European Fuel Cell Forum AG, SolydEra SpA, Sunfire Fuel Cells GmbH, Sunfire GmbH

https://rorepower.com/

PROJECT AND OBJECTIVES

The overall objective of this project is to further develop and demonstrate solid oxide fuel cell (SOFC) systems for off-grid power generation in markets – such as oil and gas infrastructure in remote regions – with harsh climate conditions (from – 40 °C to 50 °C), and the power supply of telecommunication towers, especially in emerging countries (e.g. telecommunication base stations or microwave transceivers). A total of 36 units had been installed at the customer sites by the end of 2022. RoRePower is further strengthening and building the European value chain for fuel cell technologies.

PROGRESS AND MAIN ACHIEVEMENTS

- A total of 36 units had been installed at the customer sites by the end of 2022.
- All customer sites have been identified.

FUTURE STEPS AND PLANS

The remaining RoRePower units will be installed before summer 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
AWP 2019	Electrical efficiency	%	> 35	> 35	✓
	Operation in harsh conditions	°C	– 40	– 40 can be achieved with the project solutions	✓
	Maintenance frequency	months	15	13.7	⚙
	Long-term desulphurisation	months	15	15	✓
	System start-up in harsh conditions	°C	– 40	– 40 can be achieved with the project solutions	✓

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RUBY

ROBUST AND RELIABLE GENERAL MANAGEMENT TOOL FOR PERFORMANCE AND DURABILITY IMPROVEMENT OF FUEL CELL STATIONARY UNITS

Project ID: 875047

PRD 2023: Panel 4 – H2 end uses – stationary applications

Call topic: FCH-02-8-2019: Enhancement of durability and reliability of stationary PEM and SOFC systems by implementation and integration of advanced diagnostic and control tools

Project total costs: EUR 3 037 430.00

Clean H_2 JU max. contribution: EUR 2 999 715.00

Project period: 1.1.2020–31.12.2024

Coordinator: Università degli Studi di Salerno, Italy

Beneficiaries: Ballard Power Systems Europe AS, Bitron SpA, Commissariat à l'énergie atomique et aux énergies alternatives, Communauté d'universites et d'établissements université Bourgogne-Franche-Comté, École Polytechnique Fédérale de Lausanne, Europäisches Institut für Energieforschung EDF Kit EWIV, Fondazione Bruno Kessler, Institut Jožef Stefan, SOLIDpower SpA, Sunfire Fuel Cells GmbH, Teknologian tutkimuskeskus VTT Oy, Université de Franche-Comté

https://www.rubyproject.eu/

PROJECT AND OBJECTIVES

RUBY aims to exploit electrochemical impedance spectroscopy (EIS) for developing, integrating, engineering and testing a comprehensive and generalised monitoring, diagnostic, prognostic and control (MDPC) tool. Thanks to the features of EIS, RUBY will improve the efficiency, reliability and durability of solid oxide fuel cell (SOFC) and proton-exchange membrane fuel cell (PEMFC) systems for stationary applications. The tool relies on advanced techniques and dedicated hardware, and will be embedded in the fuel cell systems for online validation in the relevant operational environment.

NON-QUANTITATIVE OBJECTIVES

The MDPC tool performs monitoring, diagnosis, prognosis and control and mitigation of the stack and balance of plant (BoP) for PEMFC in back-up applications and for SOFC for micro combined heat and power (micro-CHP) applications.

PROGRESS AND MAIN ACHIEVEMENTS

- Tests on the proton-exchange membrane (PEM) stack and system have been performed in nominal conditions.
- Tests on the SOFC stack have been commissioned.
- Preliminary tests on the SOFC system have been performed in nominal conditions.
- Preliminary versions of monitoring, diagnostics and prognostics algorithms have been developed and tested.
- The MDPC tool's hardware has been designed, manufactured and tested.
- The concept and preliminary design of the hardware for EIS perturbation stimuli have been produced.

FUTURE STEPS AND PLANS

- Tests on PEM stack and system in faulty conditions.
- Tests on the SOFC stack in nominal and faulty conditions.
- Tests on the SOFC system in faulty conditions.
- Integration of the MDPC tool algorithms into the hardware.
- Commissioning of hardware for EIS perturbation stimuli.
- Implementation and testing of the MDPC tool.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Lifetime of micro-CHP applications (SOFC)	years	15	10	⚙	10	2020
Project's own objectives	Lifetime of micro-CHP applications (SOFC)	% of the appliance	98.5	97.5	⚙	97.5	2020
Project's own objectives	Lifetime of backup applications (PEMFC)	years	15	12	⚙	12	2020
Project's own objectives	Lifetime of backup applications (PEMFC)	% of the appliance	99.99	99.99	✓	99.99	2020

SO-FREE

SOLID OXIDE FUEL CELL COMBINED HEAT AND POWER: FUTURE-READY ENERGY

Project ID:	101006667
PRD 2023:	Panel 4 – H2 end uses – stationary applications
Call topic:	FCH-02-4-2020: Flexi-fuel stationary SOFC
Project total costs:	EUR 3 100 605.00
Clean H_2 JU max. contribution:	EUR 2 739 094.00
Project period:	1.1.2021–31.8.2024
Coordinator:	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Italy
Beneficiaries:	AVL List GmbH, Elcogen Oy, Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung EV, ICI Caldaie SpA, Instytut Energetyki, Kiwa Limited, Kiwa Nederland BV, PGE Polska Grupa Energetyczna SA, Università degli Studi Guglielmo Marconi – Telematica

www.so-free.eu

PROJECT AND OBJECTIVES

The project's development and demonstration of a fully future-ready solid oxide fuel cell (SOFC)-based system for combined heat and power (CHP) generation allows for an operation window of 0–100 % of H_2 in natural gas, with additions of purified biogas. Furthermore, SO-FREE will endeavour to realise a standardised stack–system interface, allowing full interchangeability of SOFC stack types within a given SOFC CHP system.

NON-QUANTITATIVE OBJECTIVES

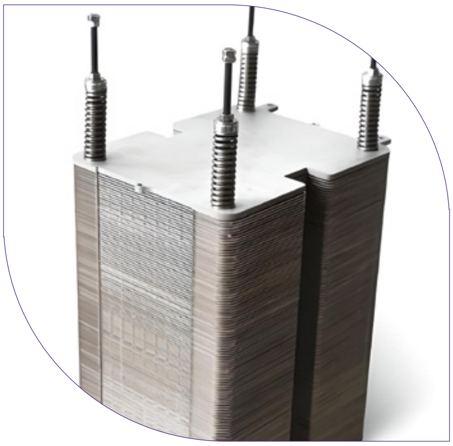
SO-FREE aims to realise a unique, standardised stack module–system interface for flexible system integration. The first alignment of two stack modules with a single interface has been proposed.

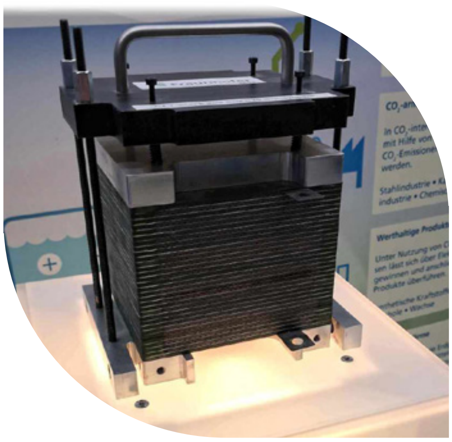
PROGRESS AND MAIN ACHIEVEMENTS

- The project has made two identical test stations for independent stack validation.
- SO-FREE has designed a unique stack module–system interface for flexible system integration.

FUTURE STEPS AND PLANS

- Stack validation and mapping were expected to be completed by February 2023.
- The final design of the system was due to be finalised in April 2023.
- Stack production and delivery are due to be completed in October 2023.
- The systems are expected to be ready for demonstration in December 2023.





QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
AWP 2020	Degradation	%	< 1	N/A	⚙
	Efficiency in H_2 consumption	%	48	53	✓
	CAPEX	€/kW	8 000	N/A	⚙

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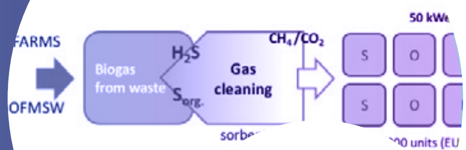

WASTE2WATTS

UNLOCKING UNUSED BIO-WASTE RESOURCES WITH LOW COST CLEANING AND THERMAL INTEGRATION WITH SOLID OXIDE FUEL CELLS

Project ID: 826234

PRD 2023: Panel 4 – H2 end uses – stationary applications

Call topic: FCH-02-7-2018: Efficient and cost-optimised biogas-based cogeneration by high temperature fuel cells

Project total costs: EUR 1 681 602.50

Clean H_2 JU max. contribution: EUR 1 681 602.50

Project period: 1.1.2019–30.9.2023

Coordinator: École Polytechnique Fédérale de Lausanne, Switzerland

Beneficiaries: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Arol Energy, Biokomp SRL, Commissariat à l'énergie atomique et aux énergies alternatives, EREP SA, Etudes et Applications d'Energies Renouvelables et d'Epuration, Paul Scherrer Institut, Politecnico di Torino, SolydEra SA, SolydEra SpA, Sunfire GmbH

https://waste2watts-project.net/

PROJECT AND OBJECTIVES

Waste2Watts is developing cleaning technologies for biogas to make the gas compatible with solid oxide fuel cells (SOFCs). It determines what needs to be cleaned from the gas and to what purity level to clean the gas. It also defines the appropriate scale for the best application of SOFCs with biogas, and the bioresources available at that scale. It assesses reformer catalysts and cells/stacks with biogas impurities and representative gas mixtures. A system layout proposes operating strategies without external water addition. A 6 kWe SOFC on agro-biogas has been prepared, and novel cryogenic cleaning of biogas at a scale of 100 m^3/h has been carried out.

NON-QUANTITATIVE OBJECTIVES

- Test runs with six or seven sorbents each at three different laboratories were conducted, under dry and wet conditions, with different contaminants. The best sorbent (among those tested) was tested in humid conditions with a multi-contaminant gas matrix. Retention capacity was 0.16 g COS, 3 g DMS, 19 g CH_4S and 223 g H_2S per kg of sorbent, which allows the sorbent volume to be calculated for a given biogas flow and contaminant content. However, it was also established that sorption capacity for non-H_2S compounds is much improved for dry biogas. For example, sorption of COS, the most critical compound in terms of removal difficulty, increased fivefold (to 0.8 g/kg sorbent). This guided the design of the cleaning in two steps: wet for H_2S, dry for the other contaminants, with a chiller in between.
- New reforming catalysts were fully tested with dry and mixed reformed biogas and H_2S and DMS contaminants.
- Cells tested with COS (1, 2, 5 ppm) show a 1–2 % performance drop. COS blocks the water–gas shift reaction. It reacts with steam to H_2S and with electrochemical oxygen to SO_2. Performance is partially recovered within 100 hours. It is likely to recover entirely over a longer period. It is clear that mixed reformed biogas behaves better than dry reformed biogas (i.e. steam must be added for reforming).

PROGRESS AND MAIN ACHIEVEMENTS

- Sorbents have been characterised specifically for biogas cleaning, allowing for the choice of an adapted cleaning solution. This point has been analysed by the Innovation Radar as an innovative solution.
- Reformer catalysts, cells and stacks characterised with specific sulphur compounds show resilience of up to 5 ppm of trace content.
- System cost analysis shows that biogas SOFC can achieve a levelised cost of electricity of < 0.15 ct€/kWhe, even at 20 kWe, for a 4-year stack life (stack cost €1 000/kWe).

FUTURE STEPS AND PLANS

- A cryogenic cleaning chain for biogas flow of 100 m^3/g has been mounted at Biokomp premises and has been prepared for shipping to the biogas site in Vilnius.
- The project is testing the 1.5 kWe SOFC at the agro-biogas site, with adapted biogas cleaning based on project sorbent results. This will involve looking for co-financing, preparing analysis of the biogas site and setting up a site visit to establish project connections.
- Long-term testing of cells and stacks will be performed with 3–5 ppm of sulphur. All set-ups, gas analytics and detailed electrochemical characterisation methods have been established. Stacks and cells are being tested for longer durations than they were previously (> 1 000 hours).
- The final cleaning cost will be updated from Biokomp and Arol after delivery and installation, for integration into the established system model.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
MAWP addendum (2018–2020)	SOFC CAPEX	€/kWe	3 500–6 500 (2024)	2 000–4 000	✓
Project's own objectives	Pollutant tolerance	ppm	5	3	⚙
	Pollutant nature and mix	Sulphur compounds	Identification	Critical compounds identified	✓
	Biogas cleaning	€/kWe	< 1 000	< 1 000	
	Levelised cost of energy	€/kWhe	< 15	0.09	
	Voltage loss under constant current (SOFC degradation on biogas reformate)	%/kh	0.4	0.7	⚙

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