24/7 ZEN

REVERSIBLE SOEC/SOEFC SYSTEM FOR A ZERO EMISSIONS NETWORK ENERGY SYSTEM

Project ID	101101418
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2022-04-03: Reversible SOC system development, operation and energy system (grid) integration
Project total cost	EUR 5 499 822.50
Clean H_2 JU max. contribution	EUR 5 499 822.50
Project period	1.2.2023–31.1.2026
Coordinator	Fundació Institut de Recerca en Energia de Catalunya, Spain
Beneficiaries	Bosal Emission Control Systems NV; Cluster Viooikonomias Kai Perivallontos Dytikis Makedonias; Diaxiristis Ethnikou Sistimatos Fisikou Aeriou Anonimi Eteria; Ethniko Kentro Erevnas Kai Technologikis Anaptyxis; Eunice Laboratories Monoprosopi Anonymi Etaireia; Fachhochschule Zentralschweiz – Hochschule Luzern; Idryma Technologias Kai Erevnas; Inerco Ingenieria; Tecnologia y Consultoria SA; Kiwa Cermet Italia SpA; Kiwa Creiven SRL; Ostschweizer Fachhochschule; Politecnico di Torino; SolydEra SA; SolydEra SpA

https://24-7zenproject.eu/

PROJECT AND GENERAL OBJECTIVES

24/7 ZEN aims to design and construct a highly efficient 33/100 kW reversible solid oxide cell (rSOC) power-balancing plant, showcasing its compatibility with both electricity and gas grids. The project consortium, comprising diverse expertise, leads innovation in energy management and rSOC system development.

The consortium pioneers advancements across the value chain, enhancing components from cell-level material to fully operational rSOC systems and plug-and-play grid interconnection ecosystems on the demonstration site. Key players include an organisation involved in renewable energy generation (EUNICE), a transmission system operator (DESFA) and an international quality assurance body (Kiwa). The 24/7 ZEN ecosystem will showcase efficient power-to-gas-to-power routes, utilising H_2 or natural gas as fuel, enabling H_2 grid injection, transitioning in less than 30 minutes and achieving a round-trip efficiency of 45 %, all while adhering to standards and safety regulations.

The consortium aims to develop and validate a scalable ecosystem applicable to multi-MW installations. Further research will focus on improving rSOC performance (targeting degradation rates of 0.4 %/kh for 1 000 hours and a current density of 1.5 A/cm² in both modes) and enhancing cost-competitiveness (reducing CAPEX from EUR 6 000 / kW to EUR 3 500 / kW).

The project partners that are well connected in the European hydrogen, electricity and grid services sector will disseminate newly developed business models and practices for renewable energy storage, including innovative approaches to delivering green hydrogen.

Through advancing rSOC technology towards commercial deployment, the project contributes to the realisation of renewable hydrogen deployment necessary for achieving a climate-neutral Europe, presenting viable scenarios for grid balancing and green hydrogen supply through conducting in-depth techno-economic analysis.

NON-QUANTITATIVE OBJECTIVES

- Identify requirements for a 24/7 ZEN ecosystem compatible with and connected to the grid.
- Enhance the performance of the 24/7 ZEN system by optimising rSOC cell and stack manufacturing.
- Design, manufacture and test to validate a complete, scalable rSOC system.
- Demonstrate the functioning of the entire 24/7 ZEN grid balance ecosystem for at least 4 months.
- Set out a roadmap exploiting project results for the scaling up and deployment of grid balance rSOC systems.

PROGRESS AND MAIN ACHIEVEMENTS

- Top-level requirements for rSOC system integration with electricity and gas grids have been defined, identifying three integration configurations.
- Significant advancements have been made in enhancing SOC components, particularly in electrode testing and interconnect development. The use of Co-free oxygen electrodes and new composition of Fe-AU doped fuel electrodes has achieved high current densities in both modes of operation
- rSOC stack and hot BoP design and development has led to the creation of detailed designs and simulations of the innovative stack together with the thermal management components on a single body solution.
- Ongoing activities in system integration and design, including conceptual engineering and detailed design, have been conducted to ensure seamless integration of components.
- System requirements and use cases have been clearly defined, addressing critical aspects such as electricity supply, water flow, and natural gas supply.

These results signify a significant step forward in the development of the rSOC system, bringing the project closer to its goal of creating a high-performing solution for sustainable grid management.

FUTURE STEPS AND PLANS

- Advancing scalability of outcomes.
- Scaling enhanced button cells to larger areas and stack levels.
- Integrating components like rSOC stack and heat exchangers into the module.
- Constructing the final system, including pre-designed balance of plant.
- Validating fully integrated rSOC system for grid balancing in Greek energy grid through a 4-month demonstration test.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Efficiency in SOFC mode	%	57		0.5	2019
	Transient time (SOFC/SOEC)	minutes	30		N/A	N/A
	Electricity consumption at nominal capacity	kW/kg	38.7		40.3	2023
	Round-trip efficiency	%	45		37.90	2019
	Reversible capacity	%	33		0.25	N/A
	Current density of SOFC/SOEC	A/cm²	1.5		1.1	2023
	Degradation rate of SOFC/SOEC	%/kh	0.4		1 (SOFC) / 2 (SOEC)	Current density under co-SOEC
	Current density under co-SOEC	A/cm²	1		N/A	N/A
	Total system power in rSOC	kW	33/100		25/75	N/A
	CAPEX	€/kW	3 500		2 130	N/A
	Efficiency in SOEC mode	%	80		0.81	2021

Clean Hydrogen Partnership
Co-funded by the European Union

ACHIEVE

ADVANCING THE COMBUSTION OF HYDROGEN–AMMONIA BLENDS FOR IMPROVED EMISSIONS AND STABILITY

ACHIEVE

Project ID	101137955
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2023-04-02: Research on fundamental combustion physics, flame velocity and structure, pathways of emissions formation for hydrogen and variable blends of hydrogen, including ammonia
Project total cost	EUR 2 994 200.00
Clean H_2 JU max. contribution	EUR 2 994 200.00
Project period	1..1.2024–30.6.2027
Coordinator	Sapienza Università di Roma, Italy
Beneficiaries	CentraleSupelec, Centre national de la recherche scientifique, King Abdullah University of Science and Technology, Phoenix Biopower AB, Phoenix Biopower Switzerland GmbH, State Enterprise Zorya Mashproekt Gas Turbine Research and Production Complex, Technische Universität Berlin, Technische Universiteit Delft, Università degli Studi di Firenze, Zabala Innovation Consulting SA

https://cordis.europa.eu/project/id/101137955

PROJECT AND GENERAL OBJECTIVES

The main objective of Achieve is to enable the reduction of pollutant gases (CO_2 and NOx) from current and future gas turbine installations by providing a broad knowledge base and set of validated (technology readiness level 4) solutions for the combustion of unconventional H_2 blends in gas turbines – that is, with combinations of H_2, NH_3, CH_4, N_2 and H_2O. Focused dissemination of and efforts to exploit results within the research and industry communities will allow those conducting the project to build on these results to (i) develop technology and solutions for current gas turbine engines equipped with conventional swirl-stabilised dry low emission combustion systems; and (ii) develop novel combustor systems for future gas turbines with significantly lower emissions and better operability than current engines over a wider range of unconventional H_2 blends.

H_2 is envisaged by many as the main substitute for natural gas in the short/medium term when produced from renewable or low-carbon energy sources, particularly when these are in excess. However, there are several challenges with the combustion of H_2, which include higher chances of static (flashback) and dynamic (thermoacoustic) instabilities, and the strong sensitivity of hydrogen flames to pressure. Critically, there are also significant challenges related to the storage and transport of hydrogen due to its high reactivity and low energy density, making widespread implementation economically and technically difficult.

NH_3 can act as a carbon-free carrier of hydrogen. NH_3 flame speeds are much lower than those of hydrogen, and the infrastructure and knowledge required to produce, transport and store large quantities of ammonia are already established, as NH_3 is used extensively in fertilisers. However, NH_3 has a low burning velocity, has a narrow flammability limit, can produce a very high level of NOx and can be toxic, limiting its use in practical combustion applications. Blends of ammonia and hydrogen have been studied as means to combine the benefits of both fuels while mitigating their limitations. These blends can be tailored to have more favourable combustion characteristics, for example flame speeds, flammability limits and NOx emissions, than pure NH_3, and better safety than pure H_2 flames.

One promising pathway is to utilise NH_3 for the transport and storage of renewable energy. Others are the (partial) local conversion of NH_3 into H_2, and the combustion of H_2/NH_3 mixtures for power generation.

Clean Hydrogen Partnership
Co-funded by the European Union

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
	Ability to handle H_2 content fluctuations	-	For stable operation with H_2 fluctuations, around 30 %vol./min (TUB burner)	
	NOx emissions	-	65 % reduction in NOx in premixed operations; 80 % in non-premixed operations (jet-in-hot-coflow burner)	
	Ability to handle H_2 content fluctuations	%vol./min	Stable combustion of H_2 blends with 20 % NH_3 (TUB burner)	
	Range of H_2 content in gas turbine fuel	%mass	100 in conventional swirl-stabilised and novel burners	
	Ability to handle H_2 content fluctuations	-	Low combustion instabilities (lower than 0.15 % of the operating) for 100 % H_2	
	NOx emissions	ppm	< 100 with up to 20 % NH_3 (TUB burner)	
	Events presenting the project per year and links with other EU projects	number	3	
SRIA (2021–2027)	Range of H_2 content in gas turbine fuel	%vol.	Up to 20 % NH_3 (TUB burner)	
	Ability to handle H_2 content fluctuations	-	Stable operation with H_2 fluctuations around 30 %vol./min (TUB burner); no instabilities p_RMS/p_op < 0.15 %; no flashback; no lean blowout, with a real-time monitoring system to achieve stable operation	
	Peer-reviewed papers published	number	12	
	Range of H_2 content in gas turbine fuel	%vol.	Validation of models to within 5 % accuracy (KPI 2.1)	
	NOx emissions	ppmv at 15 % O_2 (dry)	Validation of models to within 10 % accuracy	
	Ability to handle H_2 content fluctuations	%mass/min	Stable combustion with 100 % H_2 (TUB burner)	
	Validated computational singular perturbation skeletal-mechanism- and virtual-chemistry-mechanism-derived mechanisms for a use case	-	28 % thermal cracking of NH_3 yielding 32.8 % H_2, 10.9 % N_2 and 56.3 % NH_3 by volume	
	NOx emissions	mg/MJ fuel	< 25 ppm with 100 % H_2 (TUB burner)	

AMON

DEVELOPMENT OF A NEXT GENERATION AMMONIA FC SYSTEM

Project ID	101101521
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2022-04-02: Ammonia powered fuel cell system focusing on superior efficiency, durable operation and design optimisation
Project total cost	EUR 4 293 653.75
Clean H_2 JU max. contribution	EUR 3 998 028.75
Project period	1.1.2023–31.12.2025
Coordinator	Fondazione Bruno Kessler, Italy
Beneficiaries	Alfa Laval Aalborg AS, Alfa Laval SpA, Alfa Laval Technologies AB, Danmarks Tekniske Universitet, École polytechnique fédérale de Lausanne, European Fuel Cell Forum AG, Fachhochschule Zentralschweiz – Hochschule Luzern, Kiwa Cermet Italia SpA, Kiwa Nederland BV, Sapio Produzione Idrogeno Ossigeno SRL, SolydEra SpA, Teknologian Tutkimuskeskus VTT Oy

https://amon-project.eu/

PROJECT AND GENERAL OBJECTIVES

AMON will develop a novel system for the utilisation of ammonia and conversion of it into electric power with high efficiency using a solid oxide fuel cell system. The project will deal with the design of the basic components of the system, including the fuel cell, an ammonia burner and ammonia-resistant heat exchangers; the engineering of the whole balance of plant; and the validation of compliance with ammonia use of all parts and components. Optionally, depending on system needs, an ammonia cracker and anode gas recirculation system will be developed.

The general objectives of the project are to:

- design and develop a fuel cell stack module at a scale of 8 kWel, tested and certified to convert ammonia into power, possibly using the internal reforming capacity of a solid oxide cell operating at a high temperature and managing the power output through the control of the cell's fuel utilisation;
- certify all the components and related materials of a system as 100 % tolerant to ammonia;
- aim to make the system 70 % electrically efficient;
- certify the system for at least 3 000 hours' operation, demonstrating an ammonia availability of 90 % in the operating hours and a degradation rate less than 3 % with nominal power, measured over 1 000 hours of continuous operation.

NON-QUANTITATIVE OBJECTIVES

- Diversify and secure the energy supply.
- Unlock wide market potential and foster efficient conversion systems to decarbonise hard-to-abate sectors such as the maritime and autonomous power systems sectors, in which volumetric density and long-term storage solutions are key requirements.
- Raise industrial interest in ammonia and foster the development of new markets and new jobs.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Partial load operation	% of nominal load	Dynamic range of operation for 30–100 % of nominal load		N/A	N/A
	FC system tolerance to ammonia	%	System fed by 100 % ammonia as fuel		N/A	N/A
	Degradation at CI and FU = 75 %	%/1 000 h	≤ 2.5		4	2019
	Efficiency	%	70–65		52.1	2020
	Availability	%	> 90		N/A	N/A
SRIA (2021–2027)	CAPEX 5–50 kWe	€/kW	5 000		N/A	N/A

NB: KPI, key performance indicator.

Clean Hydrogen Partnership
Co-funded by the European Union

CLEANER

CLEAN HEAT AND POWER FROM HYDROGEN

Project ID	101137799
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2023-04-01: Development and validation of high power and impurity tolerant fuel cell systems ready to run on industrial quality dry hydrogen
Project total cost	EUR 3 949 959.50
Clean H_2 JU max. contribution	EUR 3 949 959.50
Project period	1.1.2024–31.12.2027
Coordinator	SINTEF AS, Norway
Beneficiaries	Albert-Ludwigs-Universität Freiburg, Eurogas, Ferrexpo Services LLC, Fondazione Bruno Kessler, National Gas Transmission plc, PowerCell Sweden AB, Pretexo, Schiphol Nederland BV, Teknologian Tutkimuskeskus VTT Oy, Ukrgasvydobuvannya JSC

http://cleaner-h2project.eu

PROJECT AND GENERAL OBJECTIVES

Hydrogen storage in underground salt cavern structures is very limited; there are three in the United States and one in the United Kingdom. Since the hydrogen mainly originates from steam methane reforming (SMR), the purity is around 95 %. Rock caverns (sealed) are being developed, one of them within the Hybrit project in Sweden, where clean hydrogen from electrolysis will be stored. In most geological storage areas and pipelines, hydrogen will be already, or become, contaminated with substances not suitable for use in all types of fuel cells (e.g. N_2, CO, CO_2, hydrocarbons and sulphur compounds). Hydrogen produced through electrolysis is considered clean; the only impurities are oxygen and water. However, other sources of hydrogen, such as natural gas reforming, have impurities remaining from the production process.

While repurification of this H_2 can and should be done for some applications, for example by pressure swing adsorption, it adds cost and complexity, and is not in all use cases economically feasible. Currently, there is no standard for the quality of H_2 coming from geological storage or pipelines, and knowledge of which contaminants are present in hydrogen from these storage sites is extremely limited.

Large-scale stationary fuel cells in the MW range should be able to operate on such industrial-quality H_2 without repurification. They can offer a low-cost clean alternative both for large-scale (peak) power and heat production and for small, medium and large-scale back-up power units for the critical infrastructure, thereby also improving the resilience of the energy system. The H_2 quality standard under development is expected to become around 98 %, with CO and sulphur compounds the main relevant poisoning impurities, in addition to inert gases such as CO_2 and N_2, so the fuel cell systems must tolerate these.

Cleaner will develop:

- lower-cost and impurity-tolerant catalyst materials, mitigating operating strategies to avoid the impact of potential impurities, and evaluation of new fluorine-free membranes;
- a stationary proton-exchange membrane fuel cell system > 100 kW capable of operating with industrial-quality hydrogen.

NON-QUANTITATIVE OBJECTIVES

Ensure economically and environmentally sustainable development of materials, components and system.

FUTURE STEPS AND PLANS

In the first 7 months of the project, Cleaner will perform a hydrogen impurity survey, mapping the potential impurities expected in the hydrogen value chain. This will serve as a basis for the first material development and testing. Preparations are ongoing on the fuel cell system by PowerCell and at the test facilities of VTT. Tests are planned to start during summer 2025.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
SRIA (2021–2027)	O & M costs	€ct/kWh	< 1.7	⚙	5	2020
	Electrical efficiency	% LHV	52		50	
	Degradation at CI	%/1 000 h	< 0.2		0.4	
	Non-recoverable CRM as catalyst	mg/Wel	< 0.05 gr/kWe for Pt-based catalysts < 0.025 gr/kWe for IrRu single-site catalysts at the anode. Assumptions: Pt catalysts: anode 0.1 mg(Pt)/cm², cathode 0.4 mg(Pt)/cm², Pt recovery rate > 90 % and nr-PGM in the project < 0.05 mg/cm² (i.e. at 1)		0.1	
	Warm start time	seconds	< 15		60	
	CAPEX	€/kW	< 1 000		1 900	
	Availability	%	> 98		98	

Clean Hydrogen Partnership
Co-funded by the European Union

COMSOS

COMMERCIAL-SCALE SOFC SYSTEMS

Project ID	779481
PRR 2024	Pillar 4 – H_2 end uses: stationary application
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 cost	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, Solidpower GmbH, SolydEra SA, SolydEra SpA, Sunfire GmbH

https://www.comsos.eu/

PROJECT AND GENERAL OBJECTIVES

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

NON-QUANTITATIVE OBJECTIVES

The overall objectives of the Comsos project were as follows:

- demonstrate and validate a mini-FC-CHP solution;
- promote the worldwide leadership of the EU in the mini-FC-CHP market;
- leverage micro-CHP volumes and cost reductions in additional fuel cell applications;
- confirm the presence of investment opportunities for additional job creation for mini-FC-CHP solutions.

PROGRESS AND MAIN ACHIEVEMENTS

During the project, 321 kWe of SOFC power was installed in customer sites when the requirement was 450 kWe. Sunfire (150 kWe) and Convion (120 kWe) reached the installation target but SolydEra did not (51 kWe). However, an additional 81 kWe of SOFC power was constructed by SolydEra but not installed in customers' sites before the end of the project. These already-constructed units were planned to be installed in customer sites after the project. Total SOFC power constructed during the project was therefore around 400 kWe. In addition, not all installed units achieved 9 000 demonstration hours, but at least one unit from each manufacturer could have reached the 9 000-hour requirement if end users had run the systems all the time. However, for an unknown reason some end users shut down the systems every now and then. For these users, the 9 000-hour target was not always reached in practice, even if from the point of view of the system it was possible.

- All five Sunfire systems (150 kW) were installed at customers' sites.
- Both Convion systems (120 kW) were installed at a customer's site.
- The first three Solidpower (SolydEra) systems (51 kW) were installed at a customer's site.

Each unit type from the manufacturers fulfilled the performance and emission targets of the Comsos project: an electrical efficiency greater than 50 % and NOx emissions lower than 40 mg/kWh.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
MAWP (2014–2020)	Electrical efficiency	%	> 50	> 50	✓
	NOx emissions	mg/kWh	< 40	< 40	✓
	Durability	years of plant operation	10	2	⚙
Project's own objectives	SME participation	%	25	50	✓

E2P2

ECO EDGE PRIME POWER

Project ID	101007219
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02-9-2020: Fuel cell for prime power in data-centres
Project total cost	EUR 3 576 409.45
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	Equinix Netherlands BV, InfraPrime GmbH, Snam SpA, SolydEra SpA, TEC4FUELS GmbH, Vertiv, Vertiv Croatia d.o.o.

https://e2p2.eu/

PROJECT AND GENERAL OBJECTIVES

The main objectives of E2P2 are to define the concept of fuel cells for prime power for data centres and create an authoritative open standard for the adaptation of fuel cells 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 European fuel cell suppliers to increase the uptake of their fuel cells across multiple markets, with improved energy efficiency and cost-effectiveness.

NON-QUANTITATIVE OBJECTIVES

- Define the concept of fuel cells for prime power for data centres.
- Create an authoritative open standard for adapting fuel cells to power data centres.
- Demonstrate and validate a proof-of-concept fuel-cell-based prime power module for data centres.
- Collect extensive operational data to support the use of fuel cells as a prime power source for data centres.
- Analyse the combined social, environmental and commercial impacts on the European market.
- Evaluate opportunities for improved energy efficiency and waste heat recovery.
- Generate effective market uptake and create a business strategy.

PROGRESS AND MAIN ACHIEVEMENTS

Vertiv, TEC4FUELS, and SolydEra have successfully developed their modules for the E2P2 project, with meticulous attention to detail. Comprehensive drawings and installation plans have been meticulously crafted. The location has been carefully selected as the Equinix ML 5 site outside Milan, Italy. Substantial data have been gathered for the life-cycle assessment, ensuring thorough analysis.

FUTURE STEPS AND PLANS

The subsequent phase involves conducting factory acceptance testing for the modules, followed by their shipment to Milan for installation. Research Institutes of Sweden will facilitate network connectivity to enable seamless data collection. Once all modules are installed, site acceptance testing will be performed. Subsequently, the E2P2 proof of concept will undergo rigorous testing under full operational conditions for 1 year.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
MAWP (2014–2020)	CAPEX	€/kW	3 500–6 500	
	Availability	% of available plant power	97	
	Electrical efficiency	% (LHV)	42–62	
Project's own objectives	Tolerated H_2 content in natural gas	%	0.2	
	Land use / footprint	m^2/kW	0.11	

Clean Hydrogen Partnership
Co-funded by the European Union

EMPOWER

EUROPEAN METHANOL POWERED FUEL CELL CHP

Project ID	**875081**
PRR 2024	**Pillar 4 – H_2 end uses: stationary application**
Call topic	**FCH-02-7-2019: Development of highly efficient and flexible mini CHP fuel cell system based on HTPEMFCs**
Project total cost	**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://cordis.europa.eu/project/id/875081

PROJECT AND GENERAL OBJECTIVES

Empower was a project dedicated to developing a highly efficient and versatile mini combined heat and power (CHP) system based on high-temperature proton-exchange membrane fuel cells (HT-PEMFCs). The primary objective of the project was to design and demonstrate a methanol-fuelled mobile CHP system utilising HT-PEMFC technology for simultaneous heat and electricity generation.

Designed to function as a backup or off-grid solution in both industrial and residential settings, the Empower system aimed to provide utility-grade electricity, with waste heat repurposed for space heating and providing domestic hot water. The overarching goal was to enhance the efficiency of systems, specifically targeting the mini-CHP market, while ensuring cost-competitiveness and a low carbon footprint.

The methanol-fuelled CHP system was developed to replace diesel generators, lowering CO_2 emissions, reducing noise and generating heat. Methanol's liquid form enables cost-effective storage and seamless distribution through existing infrastructure, fostering renewable production and reducing dependence on imported fossil fuels.

NON-QUANTITATIVE OBJECTIVES

- Increase visibility and awareness of renewable methanol potential.
- Arranged an international summer school on hydrogen technologies.
- Developed business analysis for renewable methanol use in CHPs and other applications.
- Supported knowledge exchange and production ramp-up through stakeholder searching and information linkage.
- Introduced concept to produce affordable, secure electricity with low carbon footprint.

PROGRESS AND MAIN ACHIEVEMENTS

- Improving materials for fuel cell stacks and refining their quality control methods;
- Studying the novel concept of aqueous-phase reforming as a technology utilised prior to the reforming of methanol;
- Development of a highly efficient gas-phase reformer;
- Development of a custom-made fuel cell system for demonstration purposes;
- Development of a mobile CHP container, acting as a platform for fuel cell systems;
- Integration and short-term testing of CHP system;
- Conduct of final demonstration activities focusing on stand-alone demonstration of the performance of fuel cell systems in relevant conditions;
- Proving the scalability, cost reduction, low carbon footprint and business potential of the project concept.

FUTURE STEPS AND PLANS

"The project has finished.

Opportunities for further research include:

- Integration of a 5 kW fuel cell system with a heat pump for 20–30 kW heat production;
- Design of a bipolar plate to ensure gasket stability;
- Design of a mechanical endplate and compression system;
- Refinement of gasket material;
- Selection of balance-of-plant components for the fuel cell system;
- Integration of a thermoelectric generator in the fuel cell system;
- Use of a Gaussian process regression unit for reforming methanol.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Stack electrical efficiency (LHV for reformate gas)	%	55	53.7	⚙
	Degradation of the system	%	0.4	1.06	⚙
	Fuel-processing efficiency	%	85	> 85	✓
MAWP (2014–2020)	CAPEX	€/kWh	5 500	2 600	✓
	System electrical efficiency (LHV for methanol)	%	37–67	38.1	✓

Clean Hydrogen Partnership
Co-funded by the European Union

EVERYWH2ERE

MAKING HYDROGEN AFFORDABLE TO SUSTAINABLY OPERATE EVERYWHERE IN EUROPEAN CITIES

Project ID	779606
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02-10-2017: Transportable FC gensets for temporary power supply in urban applications
Project total cost	EUR 6 770 248.74
Clean H_2 JU max. contribution	EUR 4 999 945.76
Project period	1.2.2018– 31.12.2023
Coordinator	RINA Consulting SpA, Italy
Beneficiaries	Acciona Construccion SA, Delta1 gGmbH, FRIEM SpA, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Genport SRL, 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, Teknologian Tutkimuskeskus VTT Oy, THT Control Oy

https://www.everywh2ere.eu/

PROJECT AND GENERAL OBJECTIVES

The EVERYWH2ERE project integrated 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. Six fuel cell – plug and play – gensets fitted in containers were produced and tested through a pan-European demonstration campaign in a demonstration-to-market approach. The prototypes were tested at construction sites, music festivals and urban public events all around Europe, demonstrating their flexibility and their increased lifetimes.

NON-QUANTITATIVE OBJECTIVES

EVERYWH2ERE aimed to support the development of a regulatory framework for transportable hydrogen-fuelled systems.

PROGRESS AND MAIN ACHIEVEMENTS

EVERYWH2ERE was a 71-month project. The project ended after having demonstrated fuel-cell-based gensets of 25 kW and 100 kW.

Despite the COVID-19 crisis, the project achieved its objectives.

In particular, the activities related to the achievement of the project's main objective were:

- realisation and validation of three batches of fuel-cell-based gensets of 25 kW and 100 kW;
- implementation of the San Sebastian demonstration in Spain targeting construction sites, the Tenerife demonstration in Spain targeting the cold ironing sector and several demonstrations at events across Europe;
- investigation of the regulatory framework and declaration of conformity for the 100 kW genset;
- development and testing of a second and third batch of gensets;
- engagement of stakeholders in demonstrations in ports, at music festivals, in cities, etc.;
- conduct of the first life-cycle assessment of the EVERYWH2ERE gensets compared with traditional diesel-fuelled gensets;
- mapping of hydrogen supply points in the EU and conduct of a preliminary analysis of logistic aspects;
- definition of contractual models to be proposed to engaged demonstration sites and identification of short-term rental as the most relevant market for EVERYWH2ERE gensets;
- determination of potential business models;
- drafting of EVERYWH2ERE's gensets replication strategy;
- running of a robust dissemination campaign to engage the organisers of music festivals and other events, as well as cities, in the project;
- identification of the film industry as another sector in which EVERYWH2ERE's gensets could be demonstrated;
- identification of the project's key exploitable results and analysis of partners' exploitation intentions and of the intellectual property rights framework.

Effective and appropriate project communication was performed through the project's website, social media, flyers and posters, and dedicated events. A strong effort was made to reach the maximum number of key players in the relevant industries, potential end users and members of the general public who were interested in EVERYWH2ERE solutions. Such efforts resulted in the EVERYWH2ERE consortium being acknowledged through three relevant Fuel Cells and Hydrogen Joint Undertaking (FCH JU) awards:

- FCH JU Best Outreach Award 2020;
- FCH JU Best Innovation Award 2021;
- Atlantic Project Award 2023.

FUTURE STEPS AND PLANS

The project has finished."

External stakeholders showed interest in the future replication of EVERYWH2ERE gensets in additional demonstration activities at public events (FERCAM-run events in Italy and Expo 2025 in Japan) and offshore (at the Oceanic Platform of the Canary Islands in Spain). In addition, a non-binding letter of intent in which RINA Consulting, Parco Scientifico Tecnologico per l'Ambiente SpA, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Genport and PowerCell Sweden commit to following up with the activities related to the EVERYWH2ERE project prototypes is in the process of being signed. This letter sets out the interests of the partners in keeping the prototypes and considers them free to operate them and demonstrate their functionality or to move them to other locations for further research or demonstrations.

Clean Hydrogen Partnership
Co-funded by the European Union

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	CO_2eq emission savings compared with grid supply	kgCO_2eq	–	242 (Acciona); 75.6 (Motorland); 24.9 (port of Tenerife)	
	Project website visits	number	–	< 1 000	
	Contractual costs for rental compared with diesel or fossil-fuel-based gensets	%	Around 10	N/A	
	GHG emission savings compared with fossil-fuel-based gensets	kgCO_2eq	–	> 2 500 (Acciona); 230 (Motorland); 75.9 (port of Tenerife)	
	Stack efficiency	%	50	50.2	
	Reduction of manufacturing costs and time	%	– 20	N/A	
	PBT for a construction company purchasing a genset and using it at its construction sites	years	–	N/A	
	Weight	kg	–	8 600	
	Volume	m^3	–	32	
	Number of social media interactions	–	–	1 500	
	FC peak voltage	V	–	270–480	
	LCOE of the genset (identification of replication market with contractual costs ± 10 % of those of current power supply solutions)	€/kWh	1.1	N/A	
	OPEX for maintenance and hydrogen supply	%	– 10	N/A	
	Festivals and events hosting EVERYWH2ERE's H2 Corner	number	3	4	✓
	Cities involved	number	20	> 20	✓
	Festivals and events hosting EVERYWH2ERE gensets	number	3–6	2 for 25 kW; 5 for 100 kW	✓
	Future manufacturing CAPEX (of the system)	€/kW	5 500	2 394 for 100 kW genset; 5 500 for 25 kW genset	✓
	FC peak current	A	–	250–450	✓
	Stack durability	equivalent operating hours	20 000	20 000	✓
	Noise emission of the full genset (not only the FC SuSy)	dB	< 65	60	✓
	Installation time	hours	6	N/A	✓
	Stakeholder events attended	–	3	19	✓

FLEX4H2

FLEXIBILITY FOR HYDROGEN

Project ID	101101427
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2022-04-04: Dry low NOx combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications
Project total cost	EUR 4 872 197.50
Clean H_2 JU max. contribution	EUR 4 178 517.25
Project period	1.1.2023–31.12.2026
Coordinator	Ansaldo Energia SpA, Italy
Beneficiaries	Ansaldo Energia Switzerland AG, Arttic Innovation GmbH, Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique, Deutsches Zentrum für Luft- und Raumfahrt EV, Edison SpA, European Turbine Network, SINTEF Energi AS, Zürcher Hochschule für Angewandte Wissenschaften

https://flex4h2.eu/

PROJECT AND GENERAL OBJECTIVES

FLEX4H2 will design, develop and validate a highly fuel-flexible sequential combustion system capable of operating with any concentration of hydrogen admixed with natural gas up to 100 % at H-class operating temperatures, with the aim of maintaining rated power and efficiency. FLEX4H2 will tackle challenges related to H_2 combustion by developing combustion technology through a combination of design optimisation, analytical research and validation in a relevant environment.

FLEX4H2 will validate scaled and full-size prototypes of the combustor through dedicated atmospheric and high-pressure tests campaigns up to technology readiness level 6. The tests will seek to demonstrate the combustor's ability to operate in the presence of any mixture of hydrogen and natural gas without diluents and while complying with emission limits. In addition, the possibility of starting up an engine with any amount of H_2 in natural gas will be demonstrated.

NON-QUANTITATIVE OBJECTIVES

FLEX4H2 will assess the replicability of the scientific methodologies applied and the transferability of the results to different gas turbine classes.

PROGRESS AND MAIN ACHIEVEMENTS

H2-Optimised Prototypes Design and Testing:

- First generation of H2-optimised prototypes successfully designed and tested.
- Testing activities were completed according to the project plan, demonstrating all target results.
- Further testing with H2 up to 100% was conducted, demonstrating the combustor's fuel and operational flexibility.

Numerical Modelling:

- Platform for exchange of burner geometry/data between CERFACS-ANSALDO has been established.
- First DLR validation case has been selected for 2nd combustion stage, rig geometry has been transferred.
- Initial testing on commercially-relevant CBB configuration has been conducted.

Thermoacoustics:

- Experimental rig geometry has been finalized through network modelling tool.
- Thermoacoustic measurements in Full Can Setup has been carried out.

FUTURE STEPS AND PLANS

Combustion System Development and Testing:

- Focus on second generation H2-optimised prototypes development and validation.
- Utilize data from first development cycle for refinement of burner design.
- Use fullscale atmospheric and high-pressure combustion tests to enhance combustor operation.
- Optimize hardware design considering cooling and mechanical integrity requirements for reproducing full-engine boundary conditions.

Numerical Modelling:

- Perform large eddy simulation on both combustion stages.
- Refine model in first stage (MBFS) to represent burner flashback behaviour and flame stabilisation.
- Enhance modelling activities for thermo-acoustic assessment and modelling.
- Improve second-generation geometry, focusing on aerodynamic improvement of the mixing section.

Thermoacoustics:

- Convert experimental rig geometry to a network modelling tool to reduce model and measurements deviation.
- Expand first-stage-only network model to FCS to prove first-stage-only behavior from experimental data.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
SRIA (2021–2027)	NOx emissions	ppmv at 15 % O_2 (dry)	< 25 by 2024 and < 25 by 2027	⚙
		mg / MJ fuel	< 29 by 2024 and < 24 by 2027	
	Range of H_2 content in gas turbine fuel	%mass	0–100	
		%vol.	0–100	
	Maximum H_2 content of fuel during start-up	%mass	0–100	
		%vol.	0–100	
	Ability to handle H_2 content fluctuations	%mass/min	± 5.11	
		%vol./min	± 15 by 2024 and ± 30 by 2030	
	Minimum ramp rate	%load/min	10 at 100 % H_2	
	Maximum reduction in efficiency of H_2 operation	percentage points	< 2 at 100 % H_2	

Clean Hydrogen Partnership
Co-funded by the European Union

H2AL

FULL-SCALE DEMONSTRATION OF REPLICABLE TECHNOLOGIES FOR HYDROGEN COMBUSTION IN HARD TO ABATE INDUSTRIES: THE ALUMINIUM USE-CASE

Project ID	101137610
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2023-04-04: Hydrogen for heat production for hard-to-abate industries (e.g. retrofitted burners, furnaces)
Project total cost	EUR 7 005 639.25
Clean H_2 JU max. contribution	EUR 5 993 812.38
Project period	1.1.2024–31.12.2026
Coordinator	Université libre de Bruxelles, Belgium
Beneficiaries	2A SpA, Bluenergy Revolution SCARL, EKW GmbH, European Aluminium, Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung EV, Fundacion Tecnalia Research & Innovation, Gas- und Wärme-Institut Essen EV, GHI Hornos Industriales SL, Nippon Gases Industrial SRL

https://cordis.europa.eu/project/id/101137610

PROJECT AND GENERAL OBJECTIVES

The overall objective of the H2AL project is to develop, validate, implement and demonstrate at full scale in real operational conditions a set of technologies, such as an integrated hydrogen burner and support systems, refractory materials and sensors, within heating furnaces in hard-to-abate industries – aluminium ingot and internal scrap recycling – by retrofitting an existing furnace at the demonstration site (2A facilities). The demonstration will run for more than 6 months – with at least one trial of 100 hours at 100 % H_2 and with a thermal output of at least 2 MWth – ensuring that technology readiness level 7 is achieved at the end of the project. The impact of H_2 combustion on the refractory materials, overall furnace structure and product quality (aluminium) will also be investigated, and measures to minimise its effects will be implemented. H2AL will also develop and implement a set of data, documentation and guidelines ensuring that the project outcomes can be replicated in other industrial sites (in other hard-to-abate industries) in a cost-effective, sustainable and safe way.

NON-QUANTITATIVE OBJECTIVES

- Understanding hydrogen combustion and its effects.
- Developing safe and efficient H_2 combustion systems for industrial plants.
- Providing insights into the physics of H_2 combustion and its impact on process parameters, using laboratory-scale experiments and simulations.
- Developing a burner for 100 % H_2 and H_2 / natural gas mixtures.
- Redesigning two state-of-the-art oxy-fuel burner technologies to use 100 % H_2 and H_2 / natural gas blends without compromising on aluminium quality, process efficiency or NOx emissions.
- Operating under non-conventional conditions to deliver high efficiency, excellent heat transfer characteristics and low NOx emissions.
- Retrofitting a furnace with the developed burner, optimal refractory materials and sensing solutions.
- Retrofitting 2A's furnace with newly developed oxy-fuel burners, optimised refractory materials and sensors for monitoring the H_2 combustion process.
- Carrying out a full-scale demonstration of H2AL technologies in the aluminium industry.
- Demonstrating the effectiveness and feasibility of H2AL's technologies in the aluminium industry at full scale in 2A facilities.
- Running the demonstration for at least 6 months, operating for at least 100 hours at 100 % H_2.
- Implementing standard operating procedures for safety and plant integration.
- Developing and implementing standard operating procedures to safely integrate H_2 combustion systems in industries that are difficult to decarbonise.
- Shifting conventional industrial processes to hydrogen-based systems.
- Comprehensively evaluating H_2 substitution for fossil fuels in furnaces and other hard-to-abate sectors.
- Investigating potential impacts on process performance, product quality, equipment operation and maintenance.
- Conducting techno-economic analyses to replicate the solution in other industrial sites and industries.
- Studying the impact of H_2 on final product costs and CO_2 emission reduction in final product price under the emissions trading scheme programme.
- Developing and promoting new business models for the widespread exploitation of H_2-based solutions in heat generation in high-tech areas (hard-to-abate industries).
- Developing new business models inspired by traditional industrial energy efficiency energy service company models and energy/gas utility ones.
- Developing a techno-economic tool to assess the economic viability of the proposed solution with different types of H_2 supply.
- Paving the way for the large-scale demonstration of H_2 technologies in burners and furnaces.
- Collaborating with industry stakeholders and regulatory bodies to identify the best approach to adopting these technologies financially sustainably.

Clean Hydrogen Partnership
Co-funded by the European Union

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives, SRIA (2021–2027) and AWP 2023	Application of H_2 burners with low NOx emissions	mg/Kg	< 100 mg/kg, for example as low as 20 mg/kg for SNCR-enhanced flameless regenerative burners)	
	Enabling the utilisation of H_2-based heat production	-	Enabling the utilisation of H_2-based heat production at the 2A foundry and in other aluminium and hard-to-abate industries	
	Insights into process	-	Insights into the effect of, for example, H_2/O_2 ratio, flame temperature and emissions on process	
	Safety protocol and risk assessment	-	Systematic analysis and application of safety protocol and risk assessment for the use of H_2 at the testing and demonstration site	
SRIA (2021–2027) and AWP 2023	TRL 9 roadmap	-	TRL 9 roadmap for further industry integration, including business model opportunities for replication in other scenarios, including GIS data	
	Comprehensive evaluation of the KPI H_2 combustion	-	Comprehensive evaluation of H_2 combustion	
	Technology roadmap for the effective integration of 100 % H_2 combustion	-	Technology roadmap for the effective integration of 100 % H_2 combustion for heat production in the aluminium industry	⚙
	Roadmap for 100 % elimination of fossil fuel combustion in the aluminium industry	-	Roadmap for 100 % elimination of fossil fuel combustion in the aluminium industry	
Project's own objectives and SRIA (2021–2027)	Technology roadmap and industry best practices	-	Technology roadmap and industry best practices to (at least) maintain the quality of the final product (aluminium) in terms of melt quality, porosity, dimensional accuracy and mechanical properties	
	Full-scale operational demonstration	hours	Full-scale operational demonstration at the 2A foundry, running for at least 100 hours at 100 % H_2	
	Understanding of H_2 utilisation	-	Better understanding of H_2 utilisation	
	Optimised combustion models	-	Optimised combustion models to further improve the consortium's simulation tools for H_2 combustion mechanisms	
	Plant integration processes and procedures	-	Documented demonstrator at 2A facilities, including plant integration processes and procedures	
	New burners	% H_2	New burners capable of using 0–100 % of H_2 / natural gas mixtures	

Clean Hydrogen Partnership
Co-funded by the European Union

HELIOS

STABLE HIGH HYDROGEN LOW NOX COMBUSTION IN FULL SCALE GAS TURBINE COMBUSTOR AT HIGH FIRING TEMPERATURES

Project ID	101101462
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2022-04-04: Dry low NOx combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications
Project total cost	EUR 3 984 187.50
Clean H_2 JU max. contribution	EUR 3 984 187.00
Project period	1.3.2023–28.2.2027
Coordinator	Technische Universiteit Eindhoven, Netherlands
Beneficiaries	Centro di Combustione Ambiente SpA, Deutsches Zentrum für Luft- und Raumfahrt EV, OPRA Engineering Solutions BV, OPRA Turbines International BV, Technische Universiteit Delft, Thomassen Energy BV

https://www.h2gt-helios.eu/

PROJECT AND GENERAL OBJECTIVES

In addition to its technical advancements, Helios will play a crucial role in fostering a vast innovative ecosystem and facilitating the future adoption and commercialisation of this technology on a cost-effective and scalable basis. As Europe transitions towards renewable energy sources, the repurposing of existing power generation assets to decarbonised alternatives becomes essential. Gas turbines, providing grid inertia and stability along with dispatchable firming capacity, are pivotal in balancing the inherently intermittent renewable energy sources. The Helios project addresses these challenges, contributing significantly to securing, competitively pricing, cleaning, flexibly managing and resiliently shaping Europe's energy system.

The Helios consortium, comprising five partners across three European countries is highly complementary.

Helios aims to achieve the following objectives:

- enable low-NOx combustion of hydrogen-enriched fuels in gas turbines;
- operate the system across a wide range of mixtures, from 100 % natural gas to 100 % hydrogen;
- achieve low NOx emissions (below 9 ppmv);
- modify existing combustors to safely operate at high firing temperatures using 100 % H_2, based on Thomassen Energy's FlameSheet technology;
- provide the combustor as either a newly built option or a retrofit for existing gas turbine systems ranging from 1 MW to 500 MW;
- make the combustor applicable to various industrial and heavy systems, as well as industrial-scale gas turbines.

NON-QUANTITATIVE OBJECTIVES

The Helios project aims to advance the scientific understanding and feasibility of hydrogen-enriched fuels in gas turbines, utilising the FlameSheet combustor framework. Economically, it strengthens European industrial technology by enhancing hydrogen-enriched gas-turbine technology and testing facilities, promoting Europe's leadership position and generating new industrial activities. Financially, it accelerates sustainable energy generation by retrofitting existing gas turbines, minimising social impact and ensuring job security. Environmentally, Helios addresses societal acceptance through socioeconomic evaluation and stakeholder involvement. Overall, Helios improves EU energy security by widening gas turbine operation capabilities, ensuring grid stability and enhancing supply reliability.

PROGRESS AND MAIN ACHIEVEMENTS

Preliminary data from a high-pressure campaign indicated good results. They showed improvements in firing temperatures, particularly with 100 % hydrogen. Preliminary data indicated promising results in terms of flashback resistance. As data are preliminary, it is essential to double-check and verify the findings.

FUTURE STEPS AND PLANS

Helios has been running now for more than 1 year. At the end of the project, we shall deliver a handbook of requirements and recommendations for the implementation of high-hydrogen gas turbines, as one of the key outcomes.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives and SRIA (2021–2027)	NOx emissions	ppmv at 15 % O_2 (dry)	< 9		< 25	2020
		mg / MJ fuel	8.7		31	
	Range of H_2 content in gas turbine fuel	%mass	0–100		0–5	
		%vol.	0–100		0–30	
	Ability to handle H_2 content fluctuations	%mass/min	2.21		1.4	
		%vol./min	15		10	
	Reduction in maximum efficiency in H_2 fuel cell operation	percentage points	< 10 at 100 % H_2		10 at 30 % H_2	
	Minimum ramp rate	%load /min	15 at 100 % H_2		10 at 30 % H_2	
	Maximum H_2 content of fuel during start-up	%mass	100		0.7	
		%vol.	100		5	

Clean Hydrogen Partnership
Co-funded by the European Union

HYPOWERGT

DEMONSTRATING A HYDROGEN-POWERED GAS-TURBINE ENGINE FUELLED WITH UP TO 100 % H_2

Project ID	101136656
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	HORIZON-JTI-CLEANH2-2023-04-03: Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion
Project total cost	EUR 12 269 095.00
Clean H_2 JU max. contribution	EUR 6 000 000.00
Project period	1.1.2024–31.12.2027
Coordinator	SINTEF Energi AS, Norway
Beneficiaries	Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique, Equinor Energy AS, European Turbine Network, Lucart SpA, Nuovo Pignone Tecnologie SRL, SNAM SpA, TotalEnergies OneTech, Zürcher Hochschule für Angewandte Wissenschaften

http://hypowergt.eu

PROJECT AND GENERAL OBJECTIVES

The HyPowerGT project aims to push technological boundaries to enable gas turbines to operate on hydrogen without diluting it. The core technology is a novel dry low-emission combustion technology (DLE H_2) capable of handling mixtures of natural gas and hydrogen with concentrations up to 100 % H_2. The combustion technology was successfully validated at technology readiness level (TRL) 5 (in early 2021), retrofitted on the combustion system of a 13 MWe industrial gas turbine (NovaLT12). Besides ensuring low emissions and high efficiency, the DLE H_2 combustion technology offers fuel flexibility and response capability on a par with modern gas turbine engines fired with natural gas.

The new technology will be fully retrofittable to existing gas turbines, thereby providing opportunities for refurbishing existing assets in industry (combined heat and power) and offering new capacities in the power sector for load-levelling the grid system (unregulated power) and for mechanical drives. The DLE H_2 technology adheres to the strictest specifications for fuel flexibility, NOx emissions, ramp-up rate and safety, as stated in the strategic research and innovation agenda 2021–2027.

The new DLE H_2 combustion technology will be further refined and developed and, towards the end of the project, demonstrated at TRL 7 on a 16.9 MWe gas turbine engine (NovaLT16) fired with fuel blends mixed with hydrogen from 0 % to 100 % H_2. Within this wide range, emphasis is placed on meeting pre-set targets for (i) fuel flexibility and handling capabilities, (ii) concentration of hydrogen fuel during the start-up phase, (iii) ability to operate at varying hydrogen contents, (iv) minimum ramp speed and (v) safety aspects at any level with regard to related systems and applications targeting industrial gas turbine engines in the 10–20 MWe class.

A digital twin will be developed to simulate performance and durability characteristics, emulating the cyclic operations of a real cogeneration plant in the Italian paper industry.

NON-QUANTITATIVE OBJECTIVES

- **To provide a safe and efficient low-emission H_2 combustion system retrofittable to gas turbine engines in the 10–20 MWe class.** The project will provide a novel dry low-emission hydrogen combustion system retrofittable to gas turbines in the 10–20 MWe class, aimed at offering response power to stabilise and increase the reliability of the electrical energy system. Emphasis is placed on the ability to retrofit the existing heat and power generation systems with gas turbines capable of operating with up to 100 % H_2, while guaranteeing high efficiency, low NOx emissions and operational flexibility in line with typical values obtained under conditions similar to those of natural gas combustion, pursuant to the call.
- **To demonstrate the operating capabilities of a simple-cycle gas turbine in full operating conditions with fuel compositions admixed with hydrogen up to 100 % H_2.** The key enabling technology will first be refined and demonstrated in a relevant environment at TRL 6. Then, a demonstration system will be planned, developed and built into an operational environment, and subsequently demonstrated at TRL 7. This endeavour will require at least 60 aggregated fired hours. The following characteristics of the system will be concluded and documented. Emphasis is placed on (i) gas turbine flexibility, (ii) the content of hydrogen fuel during the start-up phase, (iii) the ability of the system to operate at varying hydrogen contents, (iv) minimum ramp speed and (v) an appropriate safety level with regard to related systems and applications.
- **To present pathways for decarbonised power generation through retrofitting and exploiting the project's results.** The project will present credible ways in which its results can best be utilised, both commercially and economically. The work includes assessing the methods used and the transferability of the results to other gas turbine types and brands, and evaluating the market for retrofitting.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and SRIA (2021–2027)	Fuel flexibility with full operational (load) capability	%vol. H_2	0–100	
		%mass H_2	0–100	
	NOx emissions for 30–100 %vol. H_2	ppmvd at 15 % O_2	< 25	
Project's own objectives	Variability of the rate of H_2 admixing with natural gas	H_2 volume / minute	±30 %	
	Maximum H_2 content during start-up	%mass	100	
		%vol.	100	
	NOx emissions for 0–30 %vol. H_2	ppmvd at 15 % O_2 (dry)	< 15	
		mgw/MJ of heat	< 26	
	Minimum ramp-up rate	% of load / minute	10	
	Efficiency loss in H_2 operations mode	percentage points	< 2	
	Maximum power reduction in H_2 operations mode	%	< 2	
	NOx emissions for 30–100 %vol. H_2	mgw/MJ of heat	< 43	

Clean Hydrogen Partnership
Co-funded by the European Union

PACE

PATHWAY TO A COMPETITIVE EUROPEAN FC MCHP MARKET

Project ID	700339
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02.9-2015: Large scale demonstration µCHP fuel cells
Project total cost	EUR 91 681 934.33
Clean H_2 JU max. contribution	EUR 33 932 752.75
Project period	1.6.2016–30.4.2023
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 Limited, Environmental Resources Management France, EWE AG, Fachhochschule Zentralschweiz – Hochschule Luzern, HEXIS AG, HEXIS GmbH, New Enerday GmbH, Remeha BV, Remeha GmbH, Remeha NV, SenerTec Kraft-Wärme Energiesysteme GmbH, Solidpower GmbH, SolydEra SpA, 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 GENERAL OBJECTIVES

PACE unlocked the large-scale European deployment of the state-of-the-art smart energy solution for private homes: fuel cell micro-cogeneration. PACE aimed to see up to 2 650 households across Europe reaping the benefits of this home energy system. The project enabled manufacturers to move towards product industrialisation and fostered market development at the national level by working together with building professionals and the wider energy community. The project used modern fuel cell technology to produce efficient heat and electricity at home, empowering consumers in their energy choices.

NON-QUANTITATIVE OBJECTIVES

Deploy new manufacturing processes to increase capacity.

Develop efficient routes to market, including innovation in sales, marketing and consumer offers.

Provide efficient field support.

Identify potential revenue streams from participation in the power markets and the economic added value of the avoidance of grid expansions.

Develop a platform approach to component standardisation for fuel cell micro combined heat and power (CHP) across the EU supply chain.

Create the conditions for expansion of the market for fuel cell micro-CHP across Europe.

Increase awareness in European markets of micro-CHP fuel cells.

PROGRESS AND MAIN ACHIEVEMENTS

A total of 2 674 units were commissioned (3 095 units sold) by the end of April 2023.

The project has increased the lifetime of the system to 15–20 years and improved the maintenance interval using new/improved components. The system (excluding stack) lifetime was 10–15 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 virtually eliminated the need for stack replacement during a customer's 10-year service plan (the worst case is 7 years at the project's start).

FUTURE STEPS AND PLANS

The project has finished.

Establish an alliance that will gather major European manufacturers in the area of stationary fuel cells and other relevant industry and research stakeholders to develop evidence and advocacy, with a view to promoting this solution at the EU level and supporting national initiatives.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Units sold	number	2 800	3 091	✓	1 046	2017
	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	✓	N/A	N/A
	Manufacturing capacity (average at the company level)	units per year per OEM	1 000	2 300	✓	150	N/A
	Availability	%	99	96.2–99	⚙	99	2017

Clean Hydrogen Partnership
Co-funded by the European Union

REMOTE

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

Project ID	779541
PRR 2024	Pillar 4 – H_2 end uses: stationary application
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 cost	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 SL, 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 GENERAL OBJECTIVES

Remote demonstrated 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 (G2P), customised P2P systems) deployed in three demonstrations, based on renewable energy source (RES) inputs (solar, wind and hydroelectric power) 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) was commissioned in 2023.

NON-QUANTITATIVE OBJECTIVES

- Remote aimed to complete the demonstrations' design, installation and operation. The project has generated fundamental knowledge 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 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 enabled 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 (proton-exchange membrane fuel cells, 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 analyses 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 power in a local RES seasonal storage system.

PROGRESS AND MAIN ACHIEVEMENTS

- Remote has operated a demonstration for 1 year in Norway.
- The running and full analysis of the demonstration in Norway was completed. A technical analysis of the demonstration experience in terms of performance and lessons learned was conducted.
- It has operated a demonstration for 2.5 years in Greece.
- The running and full analysis of the demonstration in Greece was completed. The technical analysis of data collected was finalised.
- The project has also involved the design, commissioning and operation of H_2-based P2P plants.
- Remote finalised the installation and running of the new demonstration in Spain.
- 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 was developed and presented to the market stakeholders.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
MAWP (2014–2020)	Rated efficiency of electrolyser (alkaline)	kWh/kg	50 (2020); 49 (2024)	55–60	⚙	55–60	2020
	Rated efficiency of electrolyser (PEM)	kWh/kg	55 (2020); 52 (2024)	50	✓	50	2020
	Electrolyser footprint (PEM)	m^2/MW	100 (2020); 80 (2024)	273	⚙	10	2018–2020
	Rated efficiency of fuel cell (PEM)	% (LHV)	42–62 (2024)	45–55	✓	51	2018

Clean Hydrogen Partnership
Co-funded by the European Union

RORE POWER

ROBUST AND REMOTE POWER SUPPLY

Project ID	824953
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02-3-2018: Robust, efficient long term remote power supply
Project total cost	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 GENERAL OBJECTIVES

Fuel cells can play a major role in the energy market as a clean, highly efficient way to produce energy in decentralised power generation. Reliable fuel cell systems for continuous, off-grid energy supply provide very promising export markets for the European fuel cell industry. The applications of this kind of fuel cell technology are characterised by key requirements such as low maintenance, the long service life of components, the possibility of remote monitoring, and reliable operation in critical applications such as oil, gas or safety infrastructure. In addition, they are able to cope with harsh climate conditions in both cold and hot regions. The overall objective of this project is to further develop and demonstrate solid oxide fuel cell systems for off-grid power generation in markets, such as the gas and oil infrastructure in remote regions with harsh climate conditions (from − 40 to + 50 °C), and the supply of power to telecommunication towers, especially in emerging countries (e.g. telecommunication base stations or microwave transceivers). In addition, one objective was to demonstrate the functioning of 47 solid oxide fuel cell (SOFC) units in remote sites.

The project developed and demonstrated the reliable operation of two off-grid, remote power systems from three manufacturers. The requirements of the generators were:

- start-up and operation at − 40°C to + 50 °C ambient temperature for natural gas;
- high electrical efficiency (> 35 %);
- long-term validation and demonstration in a relevant environment to gain reliable data from the field (> 24 months);
- high availability (98.5 %);
- defined service and maintenance concept (maintenance frequency of 15 months);
- fulfilment of the regionally different normative requirements with a modular design;
- increase in the reproducibility of production stages of fuel cell systems in large quantities (> 90 %);
- training course for less-educated personnel (two courses from each manufacturer);
- service contract concept for the end customer (one concept per manufacturer).

NON-QUANTITATIVE OBJECTIVES

The other objectives were:

- application of a standard remote communication/monitoring solution;
- meeting of the regionally different normative requirements with a modular design.

PROGRESS AND MAIN ACHIEVEMENTS

Fifty SOFC remote units have been installed and demonstrated in end user sites, and those units have achieved almost all project targets. This indicates that progress in the project has been good. In comparison with the state-of-the-art achievements, a significant reduction in the total cost of ownership has been achieved by reducing the cost of the balance-of-plant component, and the stack and its periphery. In addition, the common supply chain and joint procurement for the system manufacturer in the case of the generic component and spare parts have reduced the total cost of ownership by a remarkable amount. Furthermore, harmful emissions (CO_2, SOx, NOx, particulate matter), noise, vibrations and the risk of soil contamination by liquid fuels have been reduced and higher power supply security has been reached. Moreover, systems have operated in harsh conditions: Sunfire fuel cells have operated at − 40 °C with natural gas and at − 40 °C with propane; SolydEra has operated at 15 °C with natural gas. All systems have good electrical efficiency, high availability and reasonable maintenance frequency.

FUTURE STEPS AND PLANS

The project has finished.

Original equipment manufacturers are continuing to commercialise their remote SOFC systems: they sell and service fuel cell devices for off-grid energy supply. The most interesting market is the telecommunication sector. However, other markets and applications are also being considered.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
AWP 2018	Temperature of operation in harsh conditions	°C	− 40	− 40 can be achieved with project solutions	✓
	Temperature of system start-up in harsh conditions	°C	− 40 with natural gas and − 15 with LPG	Sunfire has achieved − 40 for start-up with natural gas and LPG. SolydEra has achieved − 15 with natural gas but has not verified a temperature with LPG because there are no units in cold areas	
	Long-term desulphurisation	months	15	15	
	Electrical efficiency	%	> 35	> 35	
	Maintenance frequency	months	15	12	⚙

Clean Hydrogen Partnership
Co-funded by the European Union

RUBY

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

Project ID	875047
PRR 2024	Pillar 4 – H_2 end uses: stationary application
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 cost	EUR 2 999 715.00
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, 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 GENERAL OBJECTIVES

The RUBY project 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 EIS's features, RUBY will improve the efficiency, reliability and durability of solid oxide fuel cells (SOFCs) and polymer electrolyte fuel cell 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 relevant operational environments.

NON-QUANTITATIVE OBJECTIVES

The MDPC tool performs monitoring, diagnosis, prognosis control and mitigation of the stack and balance of plant for polymer electrolyte fuel cell systems in back-up applications and for SOFCs for micro combined heat and power applications.

PROGRESS AND MAIN ACHIEVEMENTS

- Tests on polymer electrolyte membrane stacks and systems have been performed in nominal conditions.
- Tests on SOFC stacks have been commissioned.
- Preliminary tests on SOFC systems have been performed in nominal conditions.
- Preliminary versions of monitoring, diagnostics and prognostic algorithms have been developed and tested.
- Hardware (HW) for the MDPC tool has been designed, manufactured and tested.
- The concept and preliminary design of HW for EIS perturbation stimuli have been determined.

FUTURE STEPS AND PLANS

- The project will acquire conventional and advanced signals. The tool measures conventional signals from the balance of plant and stack (voltage, current, temperature, etc.) and the EIS for the stack.
- RUBY will advance the MDPC tool's activities. The tool monitors the state of health of the stacks and the systems, detects faults at the stack and balance-of-plant levels, estimates the stacks' lifetimes, applies advanced control actions and proposes mitigation strategies at the system level.
- Tests will be conducted on the polymer electrolyte membrane stacks and systems in faulty conditions.
- Tests will be performed on SOFC stacks in nominal and faulty conditions.
- Tests will be carried out on the SOFC system in faulty conditions.
- MDPC tool algorithms will be integrated into the HW.
- HW will be commissioned for EIS perturbation stimuli.
- The MDPC tool will be implemented and tested.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Lifetime of back-up applications (PEM)	years of operation	15	12		12	2020
	Electrical efficiency of back-up applications (PEM)	% (LHV)	45	45		45	
	Reliability of back-up applications (PEM)	BX–Y	B10–15	B25–12		B25–12	
	Lifetime of micro-CHP applications (SOFC)	years of operation	12	10		10	
	Maintenance costs of back-up applications (PEM)	€/year	452	617		617	
	Availability of micro-CHP applications (SOFC)	%	99	97		97	
	Availability of back-up applications (PEM)	%	99 999	99.99		99.99	
	Electrical efficiency of micro-CHP applications (SOFC)	% (LHV)	39	35		35	
	Stack durability of micro-CHP applications (SOFC)	hours	40 000	30 000		30 000	

Clean Hydrogen Partnership
Co-funded by the European Union

SO-FREE

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

Project ID	101006667
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02-4-2020: Flexi-fuel stationary SOFC
Project total cost	EUR 3 045 355.00
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 Ltd, Kiwa Nederland BV, Polska Grupa Energetyczna SA, Università degli Studi Guglielmo Marconi

www.so-free.eu

PROJECT AND GENERAL OBJECTIVES

The development and demonstration of a fully future-ready system based on solid oxide fuel cells (SOFCs) for combined heat and power generation allows for an operational 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 the full interchangeability of SOFC stack types within a given SOFC combined heat and power system.

NON-QUANTITATIVE OBJECTIVES

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

PROGRESS AND MAIN ACHIEVEMENTS

- Those involved in the SO-FREE project have set up two identical test stations for independent stack validation and designed a unique stack module–system interface for flexible system integration.
- Stack validation and mapping were completed in February 2023, and the final design of the system in April 2023.

FUTURE STEPS AND PLANS

- Stacks will be produced and delivered in April 2024.
- System demonstrations are planned for October 2024.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Durability of stack	kh	> 30	N/A		30	2020
	CAPEX	€/kW	< 3 000	N/A		10 000	
	Thermal efficiency	% (LHV)	40–55	N/A		30–55	
	Electrical efficiency	% (LHV)	55–60	N/A		35–50	
	Availability	%	> 98	N/A		97	
AWP 2020	Degradation	%	< 1	N/A		0.4 % / kh degradation rate for Elcogen E350 stacks has been measured with a fifty–fifty H_2–N_2 mixture and 100 % natural gas	
	Efficiency of H_2 consumption	%	48	0.53		47	

Clean Hydrogen Partnership
Co-funded by the European Union

SWITCH

SMART WAYS FOR IN-SITU TOTALLY INTEGRATED AND CONTINUOUS MULTISOURCE GENERATION OF HYDROGEN

Project ID	**875148**
PRR 2024	**Pillar 4 – H_2 end uses: stationary application**
Call topic	**FCH-02-3-2019: Continuous supply of green or low carbon H_2 and CHP via solid oxide cell based polygeneration**
Project total cost	**EUR 3 746 753.75**
Clean H_2 JU max. contribution	**EUR 2 992 521.00**
Project period	**1.1.2020–31.3.2024**
Coordinator	**Fondazione Bruno Kessler, Italy**
Beneficiaries	**Deutsches Zentrum für Luft- und Raumfahrt EV, École polytechnique fédérale de Lausanne, HyGear BV, Shell Global Solutions International BV, SolydEra SA, Sweco Polska Sp z.o.o.**

https://switch-fch.eu/

PROJECT AND GENERAL OBJECTIVES

The Switch project aims to design, build and test a 25 kW (solid oxide fuel cell (SOFC)) /75 kW (solid oxide electrolyser cell (SOEC)) system prototype for hydrogen production, operating in an industrial environment for 5 000 hours. The Switch system will be a stationary, modular and continuous multisource H_2 production technology designed for H_2 refuelling stations. The core of the system will be a reversible solid oxide cell operating in electrolysis mode (SOEC) and fuel cell mode (SOFC).

NON-QUANTITATIVE OBJECTIVES

- Switch aims to ensure the reliability and stability of power and hydrogen supply. A system with cogeneration potential with substantial dynamic behaviour can deliver reliable and stable production of hydrogen and power to match demand-side management, securing the form of energy needed and connecting the generation profile to the end user.
- The project aims to ensure modularity through the development and validation of two modules, each producing 50 kg of H_2 per day. This will be achieved by integrating modules composed of high-reliability stack modules provided by SolydEra.
- Switch aims to ensure that the hydrogen purity level complies with ISO 14687. Hydrogen will be purified to within the range of 99.70 % to 99.99 %, and will have a water content of less than 5 ppm.
- In-field testing in a relevant environment will be assured, installing the final Switch system prototype in a bench infrastructure and in a real operational environment. The system will be operated for 5 000 hours in the relevant environment.
- A life-cycle analysis and life-cycle cost analysis will help to evaluate the benefits of the Switch technology in comparison with state-of-the-art steam methane reforming and other H_2 production technologies (electrolysis).

PROGRESS AND MAIN ACHIEVEMENTS

École polytechnique fédérale de Lausanne (EPFL) has performed the life-cycle assessment and life-cycle costing on the Switch system (SOEC). The Switch system was compared with competing technologies, including proton exchange membrane, alkaline water electrolyser and anion exchange membrane electrolysis.

The following were considered in the analysis:

- all electrolyser manufacture processes and environmental impact of 1 kW electrolyser unit;
- different types of renewable electricity (wind, solar and hydroelectric power);
- electricity mix of different countries;
- degradation impact (for final outcomes).

Three different hydrogen storage methods have been tested and compared through life-cycle analyses. EPFL conducted life-cycle costing and a sensitivity analysis on the pilot plant's operation and performed various case studies to meet the EUR 5/kgH_2 target.

EPFL reported that the segmented short stack test with daily SOFC/SOEC switching showed no degradation but instead a slight improvement during operation. This was confirmed by local impedance measurement data. The local mapping of current density, voltage and temperature also confirmed that the thermoneutral operating point of 1.3 V provides the most homogeneous regime and is therefore the best target for operation in SOEC mode. Regimes of feed starvation (SOFC or SOEC) were also diagnosed and quantified during this test.

The control system was finalised and the PLC/SPLC was delivered and installed.

New communication materials (factsheets) were designed. This activity was led by Fondazione Bruno Kessler, which also launched a 'factsheet campaign' on social media. The campaign resulted in a large increase in followers on LinkedIn.

In 2023, Switch received the Energy Globe Award (application submitted by Fondazione Bruno Kessler). In addition, Elena Crespi (who conducted research as part of the Switch project) won the Young Scientist Award 2023.

FUTURE STEPS AND PLANS

The prototype will be tested and a final event will be held.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved (by others)	Year in which SOA result was reported
Project's own objectives	Low switching time	minutes	30	15	✓	N/A	N/A
	Fuel cell conversion efficiency	%	75	0.66	⚙	80	2021
	Cost of H_2	€/kg	5	N/A		11.2	2020
	Electrolyser conversion efficiency	%	75	78		80	2021
	Stack lifetime	hours	10 000	N/A		3 000	2021

Clean Hydrogen Partnership
Co-funded by the European Union

WASTE2WATTS

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

Waste2Watts

Project ID	826234
PRR 2024	Pillar 4 – H_2 end uses: stationary application
Call topic	FCH-02-7-2018: Efficient and cost-optimised biogas-based cogeneration by high-temperature fuel cells
Project total cost	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; Etudes et Applications d'Energies Renouvelables et d'Epuration; Paul Scherrer Institut; Politecnico di Torino; SolydEra SA; SolydEra SpA; Sunfire GmbH

https://cordis.europa.eu/project/id/826234

PROJECT AND GENERAL OBJECTIVES

There is a huge amount of biogas available in the agriculture sector in Europe for use by small-scale SOFCs (50 kWe, in theory 0.5 million units or 25 GWe, or 1 500 PJ, equal to 8 % of the EU's natural gas).

WASTE2WATTS aim was to develop cleaning technologies for biogas to make the gas compatible with solid oxide fuel cells (SOFCs). The technology determines what needs to be cleaned from the gas and to what purity level it must be cleaned. It also defines the proper 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 1.5 kWe SOFC running on agro-biogas was prepared, and a novel cryogenic system for cleaning biogas at a scale of 100 m^3/h was installed.

NON-QUANTITATIVE OBJECTIVES

- The project compiled a sorbents database.
- Sorbents' behaviour was analysed in relation to specific contaminants. COS is the most critical contaminant (< 1 g/kg of sorbent).
- If SOFC cells are run with COS, the outlet gases are H_2S and SO_2; the water–gas shift reaction is affected.
- New catalysts for biogas reforming were tested (Ni_4Fe, Ru-doped SmCeCoO). They can cope with poisonings up to 25 ppm for short durations.
- Retention capacity was 0.16 g COS, 3 g DMS, 19 g CH_4S and 223 g H_2S per kilogram of sorbent. Th sorption capacity for non-H_2S compounds was much improved (5 times better) for dry biogas.
- Mixed reformed biogas behaves better than dry reformed biogas; therefore, 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 (IR).
- Reformer catalysts, cells and stacks characterised with specific sulphur compounds show resilience up to 5 ppm of trace content.
- System cost analysis showed that biogas SOFC can achieve a LCOE of < 15 ct€/kWhe, even at 20 kWe, for a 4-year stack life (stack cost 1 000€/kWe)
- The reformer catalysts can be considered for the Innovation Radar.
- A market evaluation was performed that concluded that >100 000 SOFC units of 50 kWe could be installed in the countries CH, DE, FR, IT unlocking presently unused biogas resource.
- Total testing amounted to >7000h for sorbents, >11 000h for reformer catalysts, 27 000h for cells, >20 000h for stacks, that is,. total on-stream testing of 65 000h mainly by 4 Laboratories during 4 years.
- W2W installed a cryogenic cleaning chain for biogas flow of 100 m^3/g on a real biogas site. It needs further running to test the effectiveness of contaminant removal by this method.
- W2W installed a 1.5 kWe SOFC on an agro-biogas site, which ran for 1 month before being shut down. A new gas-cleaning kit was built and will be deployed on the site, after which the testing will resume for 1–2 years with different sorbents. This will require follow-up financing.
- SolydEra started the production of 10 kWe stacks that can be assembled to offer 50–300 kWe SOFC systems, including to the biogas market. A total of 50 kWe has been identified as a promising market size, in which competition from engines is the lowest.
- The cost calculation for cleaning was refined with results from the field tests.
- Alternative ways of gas cleaning (to form solid sorbents) were investigated.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Pollutant nature and mix	Sulphur compounds	Identification	Critical compounds identified	
	Cost of biogas cleaning	€/kWe	< 1 000	< 1 000	
	LCOE	€/kWh	< 15	0.09	
	SOFC degradation on biogas reformate (voltage loss under constant current)	%/kh	0.4	0.2–0.5	✓
	Pollutant tolerance	ppm	3	3	
MAWP (2014–2020)	SOFC CAPEX	€/kWe	3 500–6 500	2 000–4 000	
	Electrical efficiency	%	35–60	55	

Clean Hydrogen Partnership
Co-funded by the European Union