24_7 ZEN

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

Project ID	101101418
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-04-03
Project Total Costs	5 499 822.50
Clean H_2 JU Max. Contribution	5 499 822.50
Project Period	01-02-2023 - 31-01-2026
Coordinator Beneficiary	FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES
Beneficiaries	DIAXIRISTIS ETHNIKOU SISTIMATOS FISIKOU AERIOU ANONIMI ETERIA. HELLENIC GAS TRANSMISSION SYSTEM OPERATOR, KIWA CREIVEN S.R.L., OST - OSTSCHWEIZER FACHHOCHSCHULE, EUNICE LABORATORIES MONOPROSOPI ANONYMI ETAIREIA, KIWA CERMET ITALIA SPA, CLUSTER VIOOIKONOMIAS KAI PERIVALLONTOS DYTIKIS MAKEDONIAS,INERCO INGENIERIA, TECNOLOGIA Y CONSULTORIA, SA, SOLYDERA SPA, BOSAL EMISSION CONTROL SYSTEMS NV, SOLYDERA SA, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, POLITECNICO DI TORINO,IDRYMA TECHNOLOGIAS KAI EREVNAS

https://24-7zenproject.eu/

PROJECT AND GENERAL OBJECTIVES

24_7 ZEN aims to design and construct a highly efficient 33/100kW 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, from cell-level material to fully operational rSOC systems and plug-and-play grid interconnection ecosystems on the demo site. Key players include an organisation involved in renewable energy generation (EUNICE), a transmission system operator (DESFA), and international quality assurance (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/cm^2 in both modes) and enhancing cost-competitiveness (reducing CAPEX from EUR 6 000 / kW to EUR 3 500 / kW).

NON-QUANTITATIVE OBJECTIVES

- Identify requirements for a 24_7 ZEN ecosystem compatible and interconnected to grid.
- Enhance 24_7 ZEN system performance by optimising rSOC cell and stack manufacturing.
- Design, manufacture and test to validate a scalabe full rSOC system.
- Full-scale demonstration of the 24_7 ZEN grid balancing ecosystem sustained for over 4 months.
- Set out a roadmap exploiting project results for the scaling up and deployment of grid balance rSOC systems.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Top-level requirements for rSOC system integration with electricity and gas grids have been defined, identifying three integration configurations. Establishment of the control strategy and energy management system based on operational profiles.
- Significant advancements have been made in enhancing rSOC 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 the scalability of the achieved outcomes.
- Scale-up of enhanced button cells to larger cell areas and stack levels to support increased power output and integration potential.
- Integration of key developed components, including the rSOC stack and heat exchangers, into the full system module, incorporating the pre-designed Balance of Plant (BoP).
- Final system integration activities to assemble a fully functional rSOC system module suitable for grid-scale application.
- Validation through demonstration testing of the fully integrated rSOC system within the Greek energy grid over a four-month period, focusing on its grid-balancing capability.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
Project's own objectives	Efficiency on SOFC mode	%	57		50	2019
	Transient Time (SOFC/SOEC)	min	30		N/A	N/A
	Degradation rate cycling SOFC/SOEC	%/khr	0.4	⚙	1 (SOFC) 2 (SOEC)	N/A
	Current Density under Co-SOEC	A/cm^2	1		N/A	N/A
	Total System Power in rSOC	kW	33/100		25/75	N/A
	Efficiency on SOEC mode	%	80		81	2021

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ACHIEVE

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

Project ID	101137955
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-04-02
Project Total Costs	2 994 200.00
Clean H_2 JU Max. Contribution	2 994 200.00
Project Period	01-01-2024 - 30-06-2027
Coordinator Beneficiary	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA, IT
Beneficiaries	STATE ENTERPRISE ZORYA MASHPROEKT GAS TURBINE RESEARCH AND PRODUCTION COMPLEX, PHOENIX BIOPOWER SWITZERLAND GMBH, PHOENIX BIOPOWER AB, CENTRALESUPELEC, KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, ZABALA INNOVATION CONSULTING SA, UNIVERSITA DEGLI STUDI DI FIRENZE, TECHNISCHE UNIVERSITEIT DELFT, TECHNISCHE UNIVERSITAT BERLIN, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

https://achieve-project.eu/

PROJECT AND GENERAL OBJECTIVES

ACHIEVE (Advancing the Combustion of Hydrogen-AmmonIa blEnds for improVed Emissions and stability) aims to accelerate the transition of the gas turbine power generation industry from carbon-based natural gas combustion to carbon-free fuel blends. ACHIEVE seeks to achieve zero-carbon emissions, ultra-low NO_x emissions, and stable gas turbine operation by focusing on hydrogen (H_2) and ammonia (NH_3) mixtures. The project follows a three-pronged approach:

- Experimental campaigns to investigate combustion stability, emissions, and performance under increasingly realistic conditions.
- Numerical modeling to address challenges such as chemical kinetics, flame dynamics, and combustion instabilities.
- Engagement with industry stakeholders, including OEMs and end users, to facilitate technology adoption.

ACHIEVE aims to advance the technology readiness level (TRL) to 4, demonstrating its feasibility in a controlled environment and laying the groundwork for future industrial implementation.

NON-QUANTITATIVE OBJECTIVES

- Develop a deeper fundamental understanding of hydrogen-ammonia combustion processes.
- Investigate the stability, emissions, and operational feasibility of unconventional hydrogen-based fuel blends to overcome key scientific and technological barriers that currently limit widespread adoption.
- Focus on efficient burning while minimising harmful emissions and preventing flame instability, flashback, and thermoacoustic oscillations.
- Create advanced numerical modeling techniques that enhance the predictive capabilities of combustion simulations, contributing to more accurate and reliable gas turbine designs.
- Foster strong collaboration between academia, industry, and policymakers, ensuring that the project's findings are aligned with real-world energy demands and regulatory requirements and to support a smooth transition toward sustainable energy solutions, ultimately contributing to global decarbonisation efforts.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

ACHIEVE has made significant progress in the following:

- Understanding and implementation of hydrogen-ammonia combustion for gas turbines meeting key deliverables and milestones, including the completion of preliminary experimental and numerical studies aimed at improving combustion stability, reducing NO_x emissions, and optimising fuel blends for practical applications.
- Testing to assess the feasibility of hydrogen-based fuels under varying operating conditions, providing valuable insights into their behavior and potential integration into energy systems.
- Computational modeling efforts focusing on refining predictive tools for flame dynamics, emissions, and thermoacoustic stability, enhancing the accuracy of combustion simulations.
- Dissemination activities, with multiple publications and presentations showcasing results in scientific and industrial forums.

FUTURE STEPS AND PLANS

- Conduct more extensive experimental campaigns at progressively higher pressures and power levels to simulate real-world gas turbine conditions more accurately to refine the understanding of static and dynamic combustion stability, emissions control, and operational efficiency, ensuring that the proposed fuel blends meet industrial standards.
- Enhance combustion models by integrating improved chemical kinetics, turbulence-chemistry interactions, and predictive tools for NO_x emissions and thermoacoustic instabilities, contributing to more reliable and optimised simulations.
- Prioritise knowledge dissemination through scientific publications, conference presentations, and stakeholder engagement activities to maximise impact.

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ACHIEVE

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	H_2 range in gas turbine fuel	% mass	100% in conventional swirl-stabilised and novel burners	
	H_2 range in gas turbine fuel	% vol.	Up to 20% NH_3 (TUB burner)	
	H_2 range in gas turbine fuel	% vol.	Validation of models to within 5% accuracy	
	NO_x emissions	-	65% reduction NO_x in premixed, 80% in non-premixed operation (jet in hot coflow)	
	NO_x emissions	NO_x ppmv@15%O_2/dry	Validation of models to within 10% accuracy	
	NO_x emissions	NO_x mg/MJ fuel	NO_x < 25ppm with 100% H_2 (TUB burner)	
	NO_x emissions	NO_x mg/MJ fuel	NO_x < 100ppm with up to 20%NH_3 (TUB burner)	
	Ability to handle H_2 content fluctuations	% mass/min	Stable combustion with 100% H_2 (TUB burner)	
	Ability to handle H_2 content fluctuations	% vol./min	Stable combustion of H_2 blends with 20%NH_3 (TUB burner)	
	Ability to handle H_2 content fluctuations	% vol./min	Low combustion instabilities (lower than 0.15 % of the operating) for 100% H_2	
	Ability to handle H_2 content fluctuations	% vol./min	+/- 30 (TUB burner)	
	Ability to handle H_2 content fluctuations	% vol./min	Low combustion instabilities (lower than 0.15 % of the operating) for 100% H_2	
	Ability to handle H_2 content fluctuations	% vol./min	Stable operation with H_2 fluctuations +/- 30%vol./min (TUB burner), no instabilities p_RMS/p_op < 0.15%, no flashback, no lean blowout - Real-time monitoring system to achieve stable operation	
	Validated Computational Singular Perturbation (CSP) skeletal, and virtual-chemistry reduced mechanisms for a use case	-	28% thermal cracking of NH_3 yielding 32.8% H_2 / 10.9% N_2 / 56.3% NH_3 by volume	
	Events presenting the project per year and links with other EU projects	Number	3	
	Peer-reviewed papers published	Number	12	

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AMON

DEVELOPMENT OF A NEXT GENERATION AMMONIA FC SYSTEM

Project ID	101101521
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-04-02
Project Total Costs	4 130 784.25
Clean H_2 JU Max. Contribution	3 998 028.75
Project Period	01-01-2023 - 31-03-2027
Coordinator Beneficiary	FONDAZIONE BRUNO KESSLER, IT
Beneficiaries	ALFA LAVAL SPA, KIWA CERMET ITALIA SPA, SAPIO PRODUZIONE IDROGENO OSSIGENO SRL, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, KIWA NEDERLAND BV, SOLYDERA SPA, EUROPEAN FUEL CELL FORUM AG, ALFA LAVAL TECHNOLOGIES AB, ALFA LAVAL AALBORG AS, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, DANMARKS TEKNISKE UNIVERSITET

https://amon-project.eu/

PROJECT AND GENERAL OBJECTIVES

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

The general objectives are to:

- Design and develop a fuel cell stack module at a scale of 8 kWel, tested and qualified to convert ammonia into power, possibly using the internal reforming capacity of a solid oxide cell operating at high temperature and managing the power output through the control of the cell 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 3000 hours of operation, demonstrating an ammonia availability of 90% in the operating hours and a degradation rate less than 3% with nominal power measured over 1000 hours of continuous operation.

NON-QUANTITATIVE OBJECTIVES

- Diversify and secure the energy supply.
- Unlock wide markets potential and foster efficient conversion systems to decarbonise hard-to-abate sectors such as maritime and autonomous power systems, where 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.
- Increase visibility and awareness of renewable hydrogen and ammonia potential.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Development of a conceptual system design, providing the targeted efficiency of more than 70 % and a safe system without so-called nitriding.
- Development of a multiscale multiphysics model concept to more precisely foresee possible challenges and obtain designs to avoid these.
- Implementation of single cell testing at EPFL to set a benchmark for the future testing of improved cells. The tests were done with ammonia (NH_3), a mixture of 75% H_2 and 25% N_2 mimicking fully cracked ammonia, and pure H_2 for comparison. Each test lasted 1000h in steady polarisation at 0.5 A/cm^2 and 750°C.
- Definition of testing protocols for ammonia-fuelled SOFC to establish common procedures and tests conducted during the project.
- Execution of experimental and numerical investigation of ammonia cracking demonstrating that the ammonia cracking rate is crucial for developing the external cracker and the importance to understand the internal cracking of ammonia in direct ammonia-fuelled SOFCs.
- Implementation of numerous activities with regards to communication and dissemination to lay the basis for a proper communication strategy and tools, such as definition of a dissemination and communication plan, creation of a visual identity and logo for AMON project as part of a communication toolkit, activation of the project website, participation at several conferences, fairs and workshops, organisation of a workshop at the Sustainable Shipping in July 2024.

FUTURE STEPS AND PLANS

- Techno-economic analysis.
- Design of the system at the tens of MW scale.
- Validation and testing of ammonia-fuelled 8 kW stack module.
- Design of advanced controls to operate the ammonia fuel cell system.
- Webinars.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
Project's own objectives	FC system tolerance to Ammonia	%	System fed by 100% ammonia as fuel		N/A	N/A
	Pillar Heat and Power/ table 20: KPIs for Solid Oxide Stationary Fuel Cells: Degradation @CI and FU=75%	%/1 000 h	≤2.5		4	2019
	KPIs for Solid Oxide Stationary Fuel Cells: Efficiency	%	70-65		52.1	2020
	Pillar Heat and Power/ table 20: KPIs for Solid Oxide Stationary Fuel Cells: Availability	%	>90		N/A	N/A

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CLEANER

CLEAN HEAT AND POWER FROM HYDROGEN

Project ID	101137799
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-04-01
Project Total Costs	3 949 959.50
Clean H_2 JU Max. Contribution	3 949 959.50
Project Period	01-01-2024 - 31-12-2027
Coordinator Beneficiary	SINTEF AS, NO
Beneficiaries	FERREXPO SERVICES LLC, NATIONAL GAS TRANSMISSION PLC, UKRGASVYDOBUVANNYA JOINT STOCK COMPANY, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, PRETEXO, Powercell Sweden AB, FONDAZIONE BRUNO KESSLER, ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, EUROGAS - EUROPEAN UNION OF THE NATURAL GAS INDUSTRY, SCHIPHOL NEDERLAND BV

http://cleaner-h2project.eu

PROJECT AND GENERAL OBJECTIVES

Hydrogen storage in underground salt caverns structures is very limited; there are three sites in the USA and one in the United Kingdom. Since the hydrogen mainly origins 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 storages and pipelines hydrogen will be already, or become, contaminated with substances not suitable for use in all types of fuel cells (like N_2, CO, CO_2, hydrocarbon 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 re-purification 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 the 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 for both 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 as 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 a stationary 100 kW PEMFC module capable of operating on industrial quality hydrogen.

NON-QUANTITATIVE OBJECTIVES

- Ensure economically and environmentally sustainable development of materials, components and system.
- Exploit project results through dissemination to and dialogue with key stakeholders.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

CLEANER will:

- Develop lower-cost and impurity-tolerant catalyst materials, mitigation operating strategies to avoid the impact of potential impurities.
- Evaluate new fluorine-free membranes.
- Develop a stationary PEM fuel cell system of more than 100 kW capable of operating with industrial-quality hydrogen.

FUTURE STEPS AND PLANS

In the first 12 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 basis for the first material development and testing. Preparations are ongoing on the fuel cell system by PowerCell and at VTT's test facilities.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
Project's own objectives	O&M cost	€ct/kWh	< 1.7		5	2020
	Electrical Efficiency ηel	% LHV	52		50	
	Degradation @ 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)/cm^2, cathode 0.4 mg (Pt)/cm^2, Pt recovery rate > 90 % à nr-PGM in the project < 0.05 mg/cm^2,		<0.1	
	Warm start time	sec	<15		60	
	CAPEX	€/kW	< 1 000		1 900	
	Availability	%	>98		98	

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E2P2

ECO EDGE PRIME POWER

Project ID	101007219
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	FCH-02-9-2020
Project Total Costs	3 576 409.45
Clean H_2 JU Max. Contribution	2 499 715.50
Project Period	01-01-2021 - 30-04-2026
Coordinator Beneficiary	RISE RESEARCH INSTITUTES OF SWEDEN AB, SE
Beneficiaries	VERTIV CROATIA DOO ZA TRGOVINU I USLUGE, VERTIV, INFRAPRIME GMBH, EQUINIX NETHERLANDS B.V., SNAM S.P.A., TEC4FUELS, SOLYDERA SPA

https://e2p2.eu/

PROJECT AND GENERAL OBJECTIVES

The main objectives of E2P2 are to define the concept of fuel cell 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 the 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 prime power for data centres.
- Analyse the combined social, environmental and commercial impact on the European market.
- Evaluate opportunities for improved energy efficiency and waste heat recovery.
- Generate effective market uptake and create a business strategy.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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, with Equinix ML 5 site outside Milan, Italy. Substantial data has 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 one year.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Tolerated H_2 content in NG	%	20	

FLEX4H$_2$

FLEXIBILITY FOR HYDROGEN

Project ID	101101427
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-04-04
Project Total Costs	4 872 197.50
Clean H_2 JU Max. Contribution	4 178 517.25
Project Period	01-01-2023 - 31-12-2026
Coordinator Beneficiary	ANSALDO ENERGIA SPA, IT
Beneficiaries	EUROPEAN TURBINE NETWORK, ARTTIC INNOVATION GMBH, ANSALDO ENERGIA SWITZERLAND AG, EDISON SPA, ENERGY AND TURBOMACHINERY NETWORK, ZURCHER HOCHSCHULE FUR ANGEWANDTE WISSENSCHAFTEN, SINTEF ENERGI AS, CENTRE EUROPEEN DE RECHERCHE ET DEFORMATION AVANCEE EN CALCUL SCIENTIFIQUE, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

https://flex4h2.eu/

PROJECT AND GENERAL OBJECTIVES

FLEX4H$_2$ 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.

FLEX4H$_2$ will:

- Tackle the challenges related to H_2 combustion by developing combustion technology through a combination of design optimisation, analytical research, and validation in a relevant environment.
- Validate scaled and full-size prototypes of the combustor through dedicated atmospheric and high-pressure test campaigns up to technology readiness level 6.
- Demonstrate the combustor's ability to operate in the presence of any mixture of hydrogen and natural gas during testing, without diluents while complying with emission limits.
- Demonstrate the possibility to start-up the engine on any amount of H_2 in natural gas.

NON-QUANTITATIVE OBJECTIVES

FLEX4H$_2$ will assess the replicability of the scientific methodologies applied and the transferability of the results to different gas turbine classes and evaluate the wider retrofit markets.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Combustion system development and testing

- Execution of full-scale high-pressure testing, showing the possibility to operate the FLEX4H$_2$ prototypes with natural gas, hydrogen and all intermediate blends.
- Completion of high-pressure combustion tests in the small-scale optically accessible rig, providing characterisation of the flame stabilisation mechanism of hydrogen auto-ignition driven flames, enabling validation of the latest numerical simulations and providing valuable information for operation of gas turbines fired with high hydrogen contents or pure hydrogen.
- Design of second generation full-scale H_2-optimised prototypes, with an optimised injection system and mixing section aiming at improved operation with higher firing temperatures.
- Atmospheric testing of optimised first-stage burners, showing very promising results for wider flashback margin and improved flexibility.

Numerical modelling

- Execution of advanced high-resolution Large-Eddy Simulation of Ansaldo's 1st and 2nd stage combustors with realistic fuel injection pattern.
- Execution of model refinement to achieve best representation of flame stabilisation and flashback behaviour in the first combustion-stage.
- Conduction of additional numerical-modelling activities for thermo-acoustic assessment and low-order modelling (acoustic forcing of the flame).
- Execution of advanced high-resolution LES calculations of fuel-oxidiser mixing efficiency in second-generation geometry, focusing on aerodynamic improvement of the mixing section.
- Selection of DLR-rig experimental cases from October-2024 FLEX4H$_2$ campaign for additional second combustion-stage numerical model validation on stabilization of undiluted-hydrogen reheat flame.
- Sharing new geometry with SINTEF to conduct the Large Eddy Simulation calculations in 2025.

Thermoacoustics

- Conversion of the exact experimental rig geometry to a network modelling tool capable of predicting the system's overall behaviour regarding velocity and pressure fluctuations to reduce the deviation between model and measurements.

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- Establishment of an algorithm to relate the developed first-stage-only (FOS) network model to the full can setup (FCS), which includes the sequential combustor and additional geometry, to extract FSO behaviour from experimental data which was gained in the FCS configuration.

FUTURE STEPS AND PLANS

Combustion system development and testing:

- Testing of second-generation prototypes (Gen2) at high pressure conditions, focusing on operation with high hydrogen contents (>90%vol) and pure hydrogen.
- Design of Gen3 prototypes for demonstration and achievement of technology readiness level 6.
- Refinement of the burner design based the first two development cycles to optimise mixing section, injection schemes, cooling systems and damping configuration.
- Exploitation of full-scale high-pressure combustion tests to enhance combustor operation.
- Optimisation of the combustion system design considering cooling and mechanical integrity requirements for industrialisation of the developed technology.

Numerical Modelling:

- Execution of advanced high-resolution Large-Eddy Simulation (LES) of H_2-fired simplified 1st-stage burner using a dedicated reduced chemistry scheme (for NO_x-emissions prediction) at selected conditions of interest.
- Execution of thermoacoustically forced LES calculations of the simplified 1st-stage to retrieve the Flame-Transfer Function for model validation versus atmospheric-pressure measurements.
- Validation of LES model against the 2024 FLEX4H_2 DLR-rig measurements of hydrogen flame stabilisation at reheat conditions (relevant to Ansaldo's 2nd-stage combustor).
- Use of thermoacoustically forced LES calculations of the simplified 2nd-stage burner to retrieve the Flame-Transfer Function for model validation versus high-pressure measurements.
- Exploitation of advanced high-resolution LES calculations of fuel-oxidiser mixing efficiency in the third-generation geometry focusing on aerodynamic improvement of the mixing section.

Thermoacoustics:

- Conclusion of ongoing computational fluid dynamics simulation and evaluation of the Flame-Transfer Function (FTF) so as to relate heat release fluctuations to acoustic quantities.
- Improvement of the existing low order network models by inclusion of the FTF.
- Validation of the updated model with hot cases, i.e., experiments with a flame instead of just heated air.
- Setup and execution of an additional LES with adjustments to the boundary layer assumptions and similar configuration elements based on recent experiences and results. The resulting FTF is then used to improve the existing low order network models further.
- Setup of network model for Full Can Setup (FCS) to reflect real world behaviour for both cold and hot cases. This provides insight into the respective contributions and potential modifications of the first stage geometry/ flame and the sequential stage.
- Damper manufacturing and testing as part of the second-generation configuration aiming at stable operation of the full-scale system in the upcoming high-pressure tests.

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H2AL

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

Project ID	101137610
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-04-04
Project Total Costs	7 005 639.25
Clean H_2 JU Max. Contribution	5 993 812.38
Project Period	01-01-2024 - 31-12-2026
Coordinator Beneficiary	UNIVERSITE LIBRE DE BRUXELLES, BE
Beneficiaries	BLUENERGY REVOLUTION SCRL, EKW GESELLSCHAFT MIT BESCHRANKTER HAFTUNG, NIPPON GASES INDUSTRIAL SRL, GHI HORNOS INDUSTRIALES, SL, 2A SPA, GASWARME-INSTITUT ESSEN EV, EUROPEAN ALUMINIUM, FUNDACION TECNALIA RESEARCH and INNOVATION, FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV

PROJECT AND GENERAL OBJECTIVES

H2AL has the overall objective 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 six 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 TRL7 is achieved at the project's end. 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

H2AL aims to develop and demonstrate safe, efficient hydrogen combustion technologies for the aluminium industry, with broader applications in hard-to-abate industrial sectors. Key goals include:

- Understanding hydrogen combustion: Conduct experiments and simulations to study H_2 combustion effects on process efficiency, emissions, and equipment wear.
- Burner development: Design burners compatible with 100% hydrogen and H_2/natural gas blends, achieving low NO_x emissions and high efficiency.
- Furnace retrofit: Equip an industrial furnace with new burners, optimised materials, and sensors for real-time monitoring and performance optimisation.
- Full-scale demonstration: Retrofit and operate a commercial-scale aluminium furnace on 100% hydrogen for at least 100 hours to reach TRL7.
- Safety procedures: Develop standard operating procedures for safe hydrogen integration in industrial settings.
- Impact assessment: Evaluate technical, economic, and environmental impacts of hydrogen substitution in industrial processes.
- Business models: Create viable business models and tools for scaling hydrogen-based heat solutions, promoting wider adoption in industrial decarbonisation.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

H2AL has achieved key milestones advancing hydrogen combustion technologies for aluminium production and beyond.

- Completed technology baseline analysis, system requirements, safety assessments, and updated hydrogen standards. Defined key performance indicators and a techno-economic baseline for hydrogen use.
- Developed and validated computational fluid dynamics models; conducted material testing to identify optimal refractory materials under hydrogen combustion conditions.
- Finalised H_2 supply system design via tube trailers, secured safety approvals, and initiated infrastructure preparations including gas regulation panels.
- Carried out a techno-economic analysis, showing external H_2 supply is more viable than on-site production for now. Assessed 2A's relevance as a model for EU foundries.

The project has also established strategic collaborations, enhancing its potential for replication and broader industrial impact. H2AL is on track to deliver cost-effective, safe, and scalable hydrogen solutions for industrial decarbonisation.

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FUTURE STEPS AND PLANS

H2AL will advance by adapting the combustion model to the specific burner geometry, focusing on pure hydrogen combustion. Experimental tests will be conducted at GWI, alongside further optimisation of refractory materials under H_2 and steam-rich atmospheres (up to 1 000°C), including microstructural analysis and the role of barium.

Infrastructure efforts will include:

- Building the pressure-reducing panel.
- Completing technical and safety documentation to obtain final approval from the Turin Fire Brigade.
- Securing the CE mark for the retrofitted furnace.

Strategic tasks ahead:

- Finalising EU aluminium foundry archetypes.
- Identifying replication sectors with similar burner needs.
- Finalising EU aluminium foundry archetypes.
- Identifying replication sectors with similar burner needs.

PROJECT TARGETS

Target source	Parameter	Target achieved?
Project's own objectives	Roadmap for 100% elimination of fossil fuels combustion in aluminium industry.	
	Enabling the utilisation of H_2-based heat production at 2A foundry and other aluminium and hard-to-abate industries.	
	Insights on process effect of e.g., H_2/O_2 ratio, flame temperature, emissions.	
	Comprehensive evaluation of KPI of H_2 combustion.	
	Technology roadmap for effective integration of 100% H_2 combustion for heat production in the aluminium industry.	
	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 of the finished products.	
	Full-scale operational demonstration at 2A aluminium foundry, running at least 100h at 100% H_2.	
	Application of H_2 burners with low NO_x emissions (<100mg/kg, e.g.: as low as 20 mg/kg for SNCR enhanced flameless regenerative burners).	
	Better understanding of H_2 utilisation.	
	Systematic analysis and application of safety protocol and risk assessment applied to the use of H_2 in testing and demonstration site.	
	Optimised combustion models to further improve the consortium's simulation tools for H_2 combustion mechanisms.	
	Documented demonstrator at 2A including plant integration processes and procedures.	
	TRL9 roadmap for further industry integration, including business model opportunities for replication in other case scenarios, including GIS information.	
	New burners capable of using 0-100% of H_2/NG mixtures.	

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HELIOS

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

Project ID	101101462
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-04-04
Project Total Costs	3 984 187.50
Clean H_2 JU Max. Contribution	3 984 187.00
Project Period	01-03-2023 - 28-02-2027
Coordinator Beneficiary	TECHNISCHE UNIVERSITEIT EINDHOVEN, NL
Beneficiaries	OPRA TURBINES INTERNATIONAL B.V., THOMASSEN ENERGY B.V., OPRA ENGINEERING SOLUTIONS BV, CENTRO COMBUSTIONE AMBIENTE SPA, TECHNISCHE UNIVERSITEIT DELFT, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

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. HELIOS 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 NO_x 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 NO_x emissions (below 9ppmv).
- 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 retrofit for existing gas turbine systems ranging from 1MW to 500MW.
- Make the combustor applicable to various industrial and heavy systems, as well as industrial-scale gas turbines.

NON-QUANTITATIVE OBJECTIVES

HELIOS aims to advance 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 socio-economic evaluations and stakeholder involvement. Overall, HELIOS improves EU energy security by widening gas turbine operation capabilities, ensuring grid stability, and enhancing supply reliability.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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

FUTURE STEPS AND PLANS

Helios has been running since 2023. At the end of the project, we will 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 to date (by others)	Year for reported SoA result
Project's own objectives	NO_x emissions	NO_x mg/MJ fuel	8.7		31	2020
	Max. efficiency reduction in H_2 operation	% points	< 10@100%H_2		10@30% H_2	
	Ability to handle H_2 content fluctuations	%vol/min	15		10	
	Minimum ramp rate	% load/min	15@100%H_2		10@30%H_2	
	H_2 range in gas turbine fuel	%mass	0 - 100	✓	0 - 5	
	Max H_2 fuel content during startup	%mass	0-100	✓	0.7	

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HYCOFLEX

HYDROGEN FOR COGENERATION IN FLEXIBLE OPERATION

Project ID	101138002
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-04-03
Project Total Costs	7 073 275.00
Clean H_2 JU Max. Contribution	4 442 550.75
Project Period	01-02-2024 - 31-10-2026
Coordinator Beneficiary	SIEMENS ENERGY GLOBAL GMBH and CO. KG, DE
Beneficiaries	SMURFIT KAPPA PAPER SERVICES BV, ARTTIC INNOVATION GMBH, SIEMENS ENERGY SAS, ENGIE ENERGIE SERVICES, SMURFIT WESTROCK PAPER SERVICES B.V., CENTRAX LIMITED, SIEMENS ENERGY INDUSTRIAL TURBOMACHINERY LIMITED, EQUINOR ENERGY AS, BELGISCH LABORATORIUM VAN ELEKTRICITEITSINDUSTRIE, ETHNICON METSOVION POLYTECHNION, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

PROJECT AND GENERAL OBJECTIVES

HyCoFlex is developing a retrofittable decarbonisation solution package for combined heat and power plants by enabling gas turbines to operate on up to 100% hydrogen. This cutting-edge technology will be seamlessly integrated into an industrial cogeneration system at the Saillat-sur-Vienne site in France, where it will be demonstrated and validated.

Expanding on the achievements of the HYFLEXPOWER project, HyCoFlex will further enhance an industrial scale power-to-hydrogen-to-power facility, refining its infrastructure to improve efficiency and adaptability. HyCoFlex will:

- Develop operational strategies and flexible protocols tailored to the dynamic requirements of industrial cogeneration plants.
- Play a key role in accelerating the transition towards a low-carbon industrial and energy landscape by establishing viable pathways for scaling and replicating this solution.

NON-QUANTITATIVE OBJECTIVES

Enhancing advance plant concept for hydrogen cogeneration operation:

- HyCoFlex will upgrade of the power-to-H_2-to-power cogeneration plant developed for the HYFLEXPOWER initiative at Saillat-sur-Vienne, enabling its gas turbine to operate up to 100% hydrogen. The upgrades will focus on improving safety and plant integration, and enhancing monitoring accuracy through advanced fuel composition and exhaust analysis systems. Additional modifications will facilitate precise fuel blending via new gas lines and updated control systems.

Development and validation of H_2 gas turbine combustion technology:

- HyCoFlex will design, develop, and validate a highly fuel-flexible Dry-Low Emissions (DLE) combustion system capable of operating with hydrogen concentrations ranging from 0% to 100%. This includes:
  - An optimisation of the Siemens Energy's existing hydrogen DLE technology through advanced design techniques, analytical research, and validation in relevant environments and gas turbine operating conditions.
  - An enhanced burner with improved safety, operational flexibility, and emissions compliance in line with the Clean Hydrogen Strategic Research and Innovation Agenda (SRIA).
  - High-pressure rig tests followed by engine testing to validate optimal performance at the full-scale industrial plant.

Demonstration of enhanced operational flexibility in the cogeneration plant:

- Development of a demonstration gas turbine with a combustion system designed for 100% hydrogen operation.
- Two demonstration campaigns at the industrial cogeneration plant in Saillat-sur-Vienne to test the turbine's performance across various loads and fuel mixtures. These tests will validate the advanced plant with the H_2 gas turbine, confirming its efficiency with hydrogen concentrations up to 100% and showcasing the plant's enhanced operational flexibility for future hydrogen applications.

Pathways to decarbonised power generation using gas turbines:

- Development of a flexible dynamic simulation and optimisation tool to analyse the operational performance of the Saillat-sur-Vienne cogeneration unit under transient conditions. This tool will also be applied to upscaled cogeneration units to evaluate the scalability and replicability of hydrogen-based retrofitting solutions.
- Assessment of circularity and sustainability aspects, focusing on efficiency improvements, economic viability, and environmental impact.
- Simulation of real-world operations through digital twins.
- Identification of optimal sites across Europe for implementing HyCoFlex's decarbonisation solutions through an information mapping tool.

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PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Power-to-H_2-to-power advanced plant concept:

- Execution of preliminary studies, including process design analyses and updated safety reviews with risk assessments related to hydrogen combustion.
- Identification of key measurements, such as temperatures and emissions, and preparations for their implementation are ongoing.
- Execution of maintenance of existing installations, and preparation of necessary modifications to the mixing station, including the ordering of long lead items.

Combustion system:

- Identification of gaps in project key performance indicators based on insights through the HYFLEXPOWER demonstration engine test experience.
- Identification of operational improvements with hydrogen based on numerical simulations, manufacturing of new combustion system hardware, and high-pressure tests at the Siemens Energy combustion test facility Clean Energy Center (CEC).
- Manufacturing of combustion system components for validation in the gas turbine during the first demonstration campaign at the Saillat site, scheduled for 2025.

Demonstration and validation of the advanced plant concept:

- Utilisation of existing measurements from HYFLEXPOWER for preparation of a comprehensive data monitoring for the 2025 Test Campaign.
- Establishment of a detailed test schedule for the 2025 Test Campaign.
- Securing the test engine for the 2025 Test Campaign.
- Finalisation of the engine build specifications.
- Manufacturing and procurement of essential components, including burners, are ongoing.
- Performance of a works acceptance test of a test engine with a comparable H_2 combustor, using natural gas, to establish engine control parameters for transient operation, guiding the site testing strategy.

Dynamic simulations and upscaled scenarios:

- Establishment of the requirements and boundary conditions for the dynamic simulation framework of the power-to-H_2-to-power unit.
- Development of dynamic models to analyse the transient behaviour of the advanced plant.
- Performance of a multi-objective optimisation to minimise the Levelized Cost of Hydrogen and/or Hydrogen Carbon Intensity.
- Determination of the necessary capacity for the proton exchange membrane electrolyzer and hydrogen storage unit based on preliminary results for cost-optimal base load gas turbine operation at 50% H_2 by volume.

FUTURE STEPS AND PLANS

The initial test campaign is set and will last approximately 12 weeks. During this period, the operational and flexible performance of the gas turbine will be validated, starting with natural gas and progressively increasing to 100% hydrogen. The campaign will also include initial tests with the heat recovery steam generator. Key focus areas will include:

- The stability of the fuel supply system at varying hydrogen concentrations.
- Identification of operational limits.
- Correlation of the rig to engine combustor performance (including emissions).
- Safety considerations related to flashback and flameout detection.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Advance the HYFLEXPOWER plant concept and infrastructure for 100% H_2 cogeneration operation.	% H_2	up to 100	
	Design, develop and validate a safe and efficient, low-emission H_2 GT combustion system.	-	HyCoFlex will validate the combustor design at relevant gas turbine pressures and temperatures in dedicated high-pressure rig test campaigns at TRL6 and then finally achieve TRL7 by the 2nd engine validation test.	
	Demonstrate and validate the retrofitted cogeneration advanced plant for operational flexibility at varying natural gas/hydrogen mixtures and loads while achieving state-of-the-art efficiency and low NO_x emissions.	NO_x emission in ppm @ 15% O_2; Ramp rate in load/min; H_2 content fluctuations % vol. / min; power reduction in %points,	NO_x emission: <15 (0-30% H_2), <25 (30-100% H_2) ramp rate: >10, H_2 fluctuations ±30 % vol. / min power reduction 0.5-2	
	Present pathways for decarbonised power generation from gas turbines through retrofits, upscaling and uptake while addressing circularity aspects.	-	Technoeconomic and Environmental Assessment. Digital twins simulating annual operation in transient conditions of up to three real large scale cogeneration units. Information Mapping Tool	

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HYPOWERGT

DEMONSTRATING A HYDROGEN-POWERED GAS-TURBINE ENGINE FUELLED WITH UP TO 100% H_2 – (HYPOWERGT)

Project ID	101136656
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-04-03
Project Total Costs	12 269 095.00
Clean H_2 JU Max. Contribution	6 000 000.00
Project Period	01-01-2024 - 31-12-2027
Coordinator Beneficiary	SINTEF ENERGI AS, NO
Beneficiaries	EUROPEAN TURBINE NETWORK, LUCART SPA, TOTALENERGIES ONETECH, NUOVO PIGNONE TECNOLOGIE SRL, SNAM S.P.A., EQUINOR ENERGY AS, ENERGY AND TURBOMACHINERY NETWORK, ZURCHER HOCHSCHULE FUR ANGEWANDTE WISSENSCHAFTEN, CENTRE EUROPEEN DE RECHERCHE ET DEFORMATION AVANCEE EN CALCUL SCIENTIFIQUE

http://hypowergt.eu

PROJECT AND GENERAL OBJECTIVES

HyPowerGT aims at to push technological boundaries to enable gas turbines to operate on hydrogen without dilution. 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 het 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, NO_x 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 HyPowerGT, demonstrated at TRL7 on a 16.9 MWe gas-turbine engine (NovaLT16) fired with fuel blends mixed with hydrogen from 0-100% 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 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. HyPowerGT 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% hydrogen, while guaranteeing high efficiency, low NO_x emissions, and operational flexibility at the level of typical values obtained under conditions similar to those of natural gas combustion, pursuant to the call.
- To demonstrate operating capabilities of a simple-cycle gas turbine at 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 relevant environment at TRL6. Then a system demonstrator will be planned, developed, and built into an operational environment, and subsequently demonstrated at TRL7. This endeavour will require at least 60 aggregated fired hours, and the following characteristics of the system will be concluded and documented. Emphasis is placed on (i) gas turbine flexibility, (ii) content of hydrogen fuel during the start-up phase, (iii) ability to operate at varying hydrogen content, (iv) minimum ramp speed, and (v) proper safety level with regard to related systems and applications.
- To present pathways for decarbonised power generation through retrofits and uptake of project's results. HyPowerGT will present credible ways in which its results can best be utilised, both commercially and economically. The work includes assessing the methods used, transferability of the results to other gas turbine types and brands, and evaluating the market for retrofitting.

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PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Project execution tools in place to facilitate the project implementation and internal financial and technical reporting.
- Performance of direct numerical simulations performed, increasing robustness of burning-rate scaling and improving flashback model predictions.
- Finalisation of designs for experimental setup, and development of purchase order.
- TRL 6 test campaign instrumentation and rig refurbishment on track for demonstration tests at the end of 2025.
- Establishment of health, safety and environment procedures and safety plan.
- Performance of preliminary de-risking simulations of H_2 operated GT and FMECA workshop.
- Start of road mapping work for positioning H_2 gas turbines towards the European energy transition initiated.
- Preparation of dissemination material including website, social media profile and presentation of the project at international conferences and other meetings.

FUTURE STEPS AND PLANS

- TRL 6 Demonstration tests at the end of 2025.
- Monitoring the safety engineering of the test campaigns.
- Application of available models and tools for risk assessment.
- Strengthen cooperation with sister projects.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Maximum H_2 content during start up	%vol H_2	100	
	Variability of H_2 admixing rate with natural gas	%H_2 volume/minute	±30	
	Maximum H_2 content during start up	%mass H_2	100	
	Minimum ramp up rate	% of load/minute	10	
	Efficiency loss in H_2 operations mode	% points	<2	
	Maximum power reduction in H_2 operations mode	%	<2	
	Fuel flexibility with full operational (load) capability - H_2 volume fraction	%vol H_2	0-100	
	Fuel flexibility with full operational (load) capability - H_2 mass fraction	%mass H_2	0-100	
	NO_x emission 0-30% vol H_2	mgw/MJth	< 26	
	NO_x emission 30-100% vol H_2	mgw/MJth	<43	

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RUBY

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

Project ID	875047
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	FCH-02-8-2019
Project Total Costs	3 024 715.00
Clean H_2 JU Max. Contribution	2 999 715.00
Project Period	01-01-2020 - 31-08-2025
Coordinator Beneficiary	UNIVERSITA DEGLI STUDI DI SALERNO, IT
Beneficiaries	NEW ENERDAY GMBH, BITRON ELECTRONICS SPA, MINERVAS SRL, COMMUNAUTE D' UNIVERSITES ET ETABLISSEMENTS UNIVERSITE BOURGOGNE - FRANCHE - COMTE, NEW ENERDAY GMBH, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SOLIDPOWER SPA, BITRON SPA, BALLARD POWER SYSTEMS EUROPE AS, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, FONDAZIONE BRUNO KESSLER, UNIVERSITE DE FRANCHE-COMTE, INSTITUT JOZEF STEFAN, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

http://www.rubyproject.eu

PROJECT AND GENERAL 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 EIS features, RUBY will improve the efficiency, reliability and durability of solid oxide fuel cell (SOFC) and polymer electrolyte 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 environments.

NON-QUANTITATIVE OBJECTIVES

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

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Tests on proton exchange membrane stacks and systems have been performed in nominal conditions.
- Tests on SOFC stacks have been commissioned.
- Preliminary tests on SOFC system have been performed in nominal conditions.
- Preliminary versions of monitoring, diagnostics and prognostics algorithms have been developed and tested.
- Hardware of the MDPC tool has been designed, manufactured and tested.
- Concept and preliminary design of hardware for EIS perturbation stimuli have been determined.

FUTURE STEPS AND PLANS

- RUBY 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 monitoring, diagnostic, prognostic and control (MDPC) activities. The tool monitors the state of health of the stacks and the systems, detects faults at stack and balance-of-plant levels, estimates the stacks lifetimes, applies advanced control actions and proposes mitigation strategies at system level.
- Tests will be performed on proton exchange 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 hardware.
- Hardware 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 to date (by others)	Year for reported SoA result
Project's own objectives	Lifetime of back-up applications (PEM)	years	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	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)	%	99.99	99.99		99.99	
	Electrical efficiency of micro-CHP applications (SOFC)	% LHV	39	35		35	

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SO-FREE

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

Project ID	101006667
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
Call Topic	FCH-02-4-2020
Project Total Costs	2 835 807.75
Clean H_2 JU Max. Contribution	2 739 094.00
Project Period	01-01-2021 - 30-09-2025
Coordinator Beneficiary	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, IT
Beneficiaries	INSTYTUT ENERGETYKI, KIWA TECHNOLOGY BV, KIWA LIMITED, ELCOGEN OY, KIWA NEDERLAND BV, UNIVERSITA DEGLI STUDI GUGLIELMO MARCONI - TELEMATICA, PGE POLSKA GRUPA ENERGETYCZNA SA, I.C.I CALDAIE SPA, INSTYTUT ENERGETYKI - PANSTWOWY INSTYTUT BADAWCZY, AVL LIST GMBH, FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV

http://www.so-free.eu

PROJECT AND GENERAL OBJECTIVES

The development and demonstration of a fully future-ready system based on solid oxide fuel cells (SOFC) for combined heat and power 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 combined heat and power system.

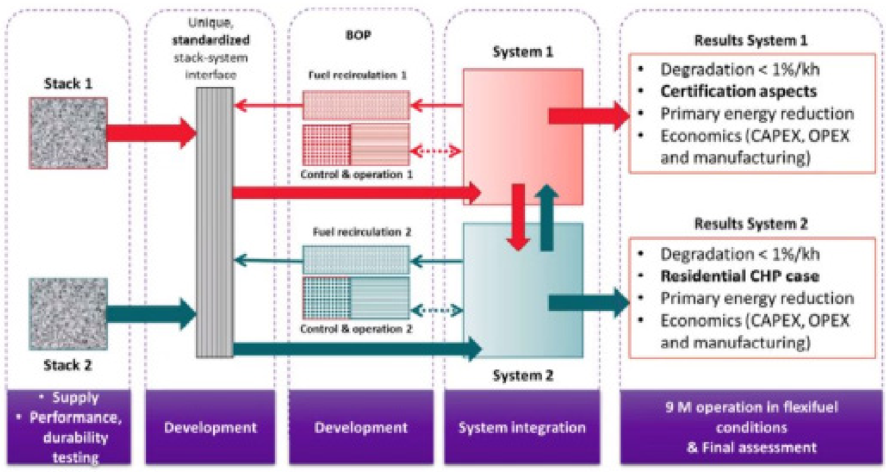
NON-QUANTITATIVE OBJECTIVES

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, MAIN ACHIEVEMENTS AND RESULTS

SO-FREE has made 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.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
Project's own objectives	Electrical efficiency in CH_4	% LHV	40-55		35-55	2020
	Electrical efficiency in H_2	% LHV	48		47	

Clean Hydrogen Partnership
Co-funded by the European Union