Clean Hydrogen Partnership

End-uses: Clean Heat and Power

Pushing the boundaries of hydrogen combustion in gas turbines

Decarbonising Europe's power and industrial sectors is essential to achieving climate neutrality by 2050. Hydrogen combustion in gas turbines offers one of the few viable paths to zero-emission, high-performance power generation that is independent of weather conditions and has a fast start-up time.

Two Clean Hydrogen Partnership-supported projects, FLEX4H2 and HELIOS, are at the forefront of this transition. They are developing advanced combustor technologies capable of operating with 100% renewable hydrogen in modern gas turbines. Together, the projects are proving that hydrogen-fuelled power is not only technically feasible - it is fast becoming a market-ready solution for flexible, dispatchable clean electricity.

Tackling flame flashback and dynamic instability

Hydrogen is a highly reactive fuel that burns faster than natural gas, which creates complex challenges for combustion systems. Maintaining flame stability, preventing flashback, and controlling emissions at high pressure are all critical hurdles that FLEX4H2 and HELIOS are working to overcome.

"These projects are proof that 100% hydrogen combustion in gas turbines is not just a concept, it's fast becoming a practical solution for clean, reliable energy."

Valérie Bouillon-Delporte, Executive Director of the Clean Hydrogen Partnership

The FLEX4H2 project builds on Ansaldo Energia's constant pressure sequential combustion (CPSC) technology, already in use in heavy-duty gas turbines. FLEX4H2 has completed the design and successful testing of a first-generation combustor capable of operating at 100% hydrogen with a stable flame and ultra-low emissions. The design also enables smooth switching between natural gas and hydrogen, offering the fuel flexibility that operators need.

Meanwhile, HELIOS is advancing Thomassen Energy's FlameSheet™ technology - a commercially proven system that features an aerodynamically stabilised flame and ultra-low NOx emissions. The project has already completed high-pressure tests with 100% hydrogen and developed a quartz-glass burner model to visualise flashback events for the first time under these conditions.

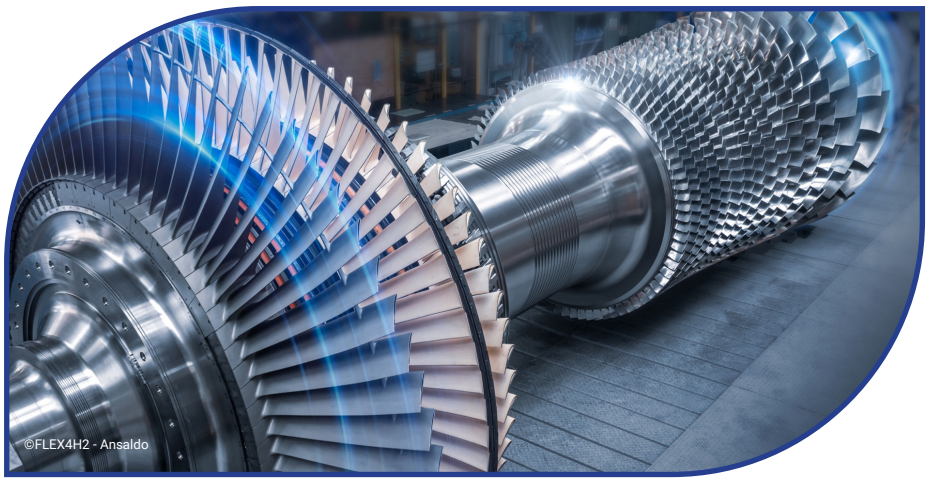
From lab tests to full-scale demonstration

Both FLEX4H2 and HELIOS follow an iterative design, test, and validation approach that moves progressively toward real-world application. In FLEX4H2, each development cycle ends with high-pressure tests under engine-representative conditions, using detailed modelling to guide next steps, with second- and third-generation combustors to be tested at high-pressure conditions using fuel blends of up to 90% and eventually 100% hydrogen. During the final year, the project aims to demonstrate a technology readiness level 6 capability at full load using 100% hydrogen in a heavy-duty turbine.

HELIOS has also mapped out three design and testing stages, using a combination of lab-based fundamental research, optical diagnostics, and numerical modelling to improve understanding of hydrogen flame dynamics. With each iteration, the team is refining the FlameSheet™ design to improve reliability and scalability under commercial conditions. This work will culminate in a final testing campaign using the latest design, conducted at high pressure and 100% hydrogen.

The goal To develop high-efficiency, low-emission gas turbine combustors that can operate on 100% renewable hydrogen - paving the way for clean, flexible power generation compatible with Europe's energy system and climate goals.

Key results FLEX4H2 and HELIOS have demonstrated stable hydrogen combustion at high pressures, created new tools for controlling flame flashback, and laid the groundwork for gas turbine retrofits that can dramatically reduce carbon intensity in the power sector.



KEY ACHIEVEMENTS

FIRST-GEN COMBUSTOR
achieved stable 100% hydrogen operation at full pressure with low NOx

VISUALISATION OF FLASHBACK
using a quartz-glass model under high-pressure conditions

SMOOTH FUEL SWITCHING
between hydrogen and natural gas demonstrated in FLEX4H2

ADVANCED MODELLING
with LES and CFD techniques to guide combustor optimisation

ULTRA-LOW NOx
burners under development in both projects

IMPACTS

DECARBONISATION PATHWAY
for large-scale gas turbines and industrial energy systems

RETROFIT POTENTIAL
offers a cost-effective route to hydrogen conversion

INNOVATION IN COMBUSTION SCIENCE
through experimental and modelling breakthroughs

POLICY ALIGNMENT
with EU goals under the Renewable Energy Directive (RED II) and the Emissions Trading System

FIND OUT MORE

https://www.clean-hydrogen.europa.eu/projects-dashboard/projects-repository_en
https://flex4h2.eu/
https://www.h2gt-helios.eu/

Clean Hydrogen Partnership

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