HYFLEXPOWER

IGTC 2023
October 11th, 2023

HYFLEXPOWER: Demonstration project of power-to-H_2-to-power advanced plant concept

Ertan Yilmaz, Ian Amos, Benjamin Witzel - Siemens Energy
Gaël Carayon – Engie Solutions
Peter McCaig – Centrax Ltd.
Nikolaos Skordoulias, Sotirios Karellas - National Technical University of Athens

HYFLEXPOWER has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884229.

Table of Contents

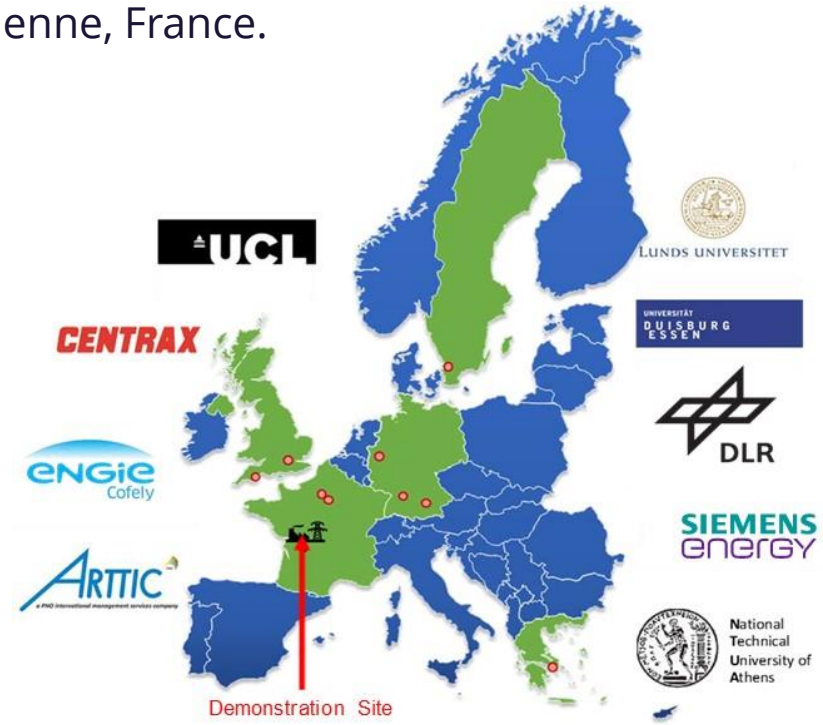
Introduction

HYFLEXPOWER Project Overview

EU Framework Horizon 2020 Funded

World-first demonstration of a **power-to-H_2-to-power path for CO_2-free** power generation pilot including an advanced **H_2 gas turbine**

- Decarbonizing papermill by modernizing combined heat and power plant in Saillat-sur-Vienne, France.



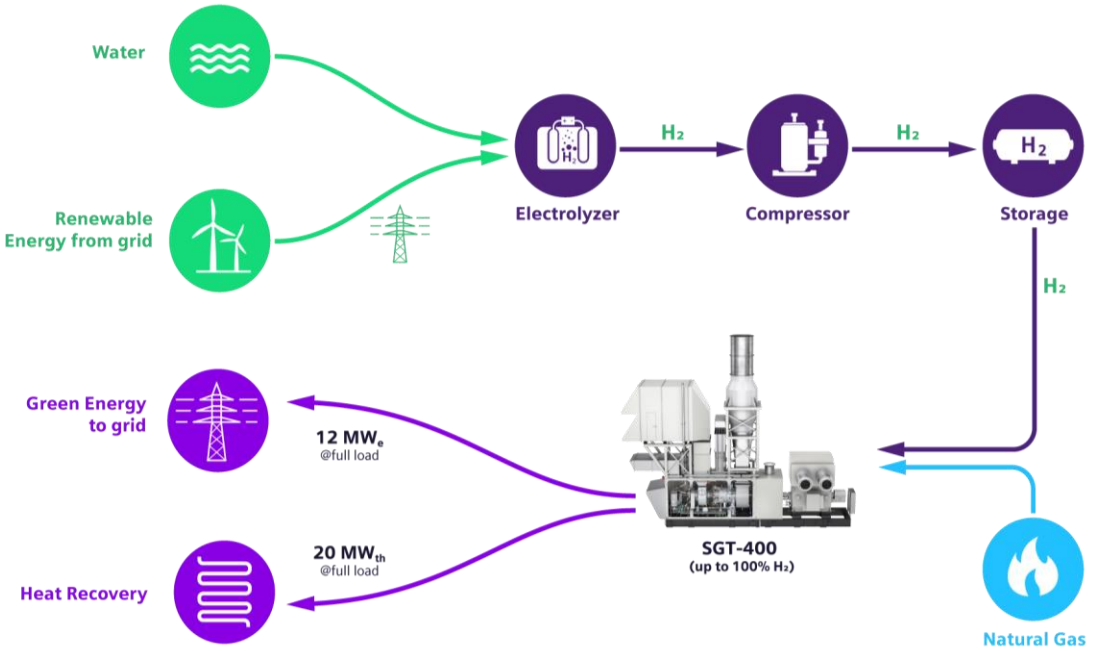
- Siemens Energy led consortium with project volume of 15.2 M€
- Project Start: May 1st, 2020 -Duration: 4 years
- Partners include: Engie Solutions, Centrax Ltd., Siemens Energy, Arttic, German Aerospace Center. Universities: Duisburg-Essen, Lund-Sweden, University College London, National Technical University of Athens.

Customer, academia and OEM formed strong consortium demonstrating CO_2-free power generation

Power-to-H_2-to-Power
Advanced Plant Concept

HYFLEXPOWER Power-to-H_2-to-Power Project

Advanced Plant Concept & Key Milestones



Smurfit Kappa plant in Saillat-sur-Vienne, France: Pilot Cogeneration SGT-400 Plant

- **Engie:** Develop advanced plant concept with H_2 storage and supply
- **Siemens Energy**: Development H_2 SGT-400; Electrolyser
- **Centrax**: H_2 gas turbine package upgrade
- **Academia:** DLR, Universities UCL, Duisburg-Essen and Lund to support H_2 GT technology development
- **NTUA:** Economic, environmental social assessments
- **Arttic:** Support in PM and communication activities

Milestones

2021 ✓

- Installation of the **H_2 production, storage** & supply facility at site

2022 ✓

- Initial demonstration of **advanced plant concept** with NG/H_2 mixtures

2023 ✓

- Pilot up to **100% H_2 for carbon-free energy production** from stored excess renewable energy (CO2 saving 65,000t/yr.)

Power-to-H_2-to-Power Advanced Plant Concept

Existing Cogeneration Plant Upgrade

- Development, construction, integration of plant with hydrogen generation, storage, supply and gas turbine re-electrification technologies:
  - Electrolyzer
  - Hydrogen compressor
  - Hydrogen storage
  - H_2/NG fuel mixing skid
  - GT Package
- Obtained all necessary authorization to operate the demonstrator plant with H_2.

100% H_2 Gas Turbine

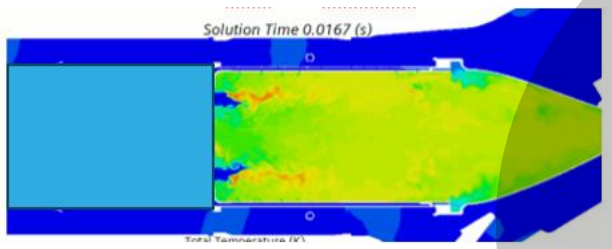
100% H_2 Gas Turbine
DLE Combustion System Development

HYFLEXPOWER

High Fidelity Simulations

Full system assessment

- Massively parallel computations with > 1000 CPUs for ~2 weeks



Automated design optimization

- Enabling > 1000 design iterations

Detailed design analysis

- >100.000.000 cells
- Conjugate heat transfer
- Detailed purge flow analysis

Rapid Prototyping using AM

Additive manufacturing enables

- Monolithic prints
- Complex internal purging features for extended flashback margin
- Internal cooling features due to high H_2 reactivity
- Advanced mixing concepts for low emissions
- Fast design iterations due to rapid prototyping

26 Hardware variants have been tested

Iteration Loop

Design Validation

High-pressure combustion tests at CEC in Berlin

48 Test Days In 5 campaigns

2 SGT-400 engine tests at customer site

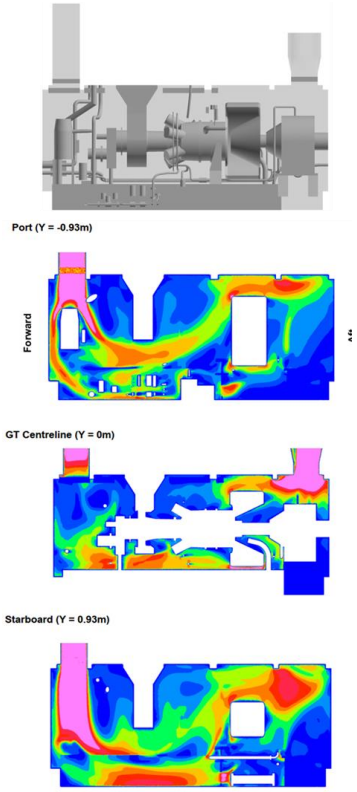
2 Test Campaigns with Natural Gas in Lincoln

Demonstrated at CEC a DLE combustion system capable of operation with 100% H_2 at SGT-400 engine conditions

100% H_2 Gas Turbine
Package Upgrade

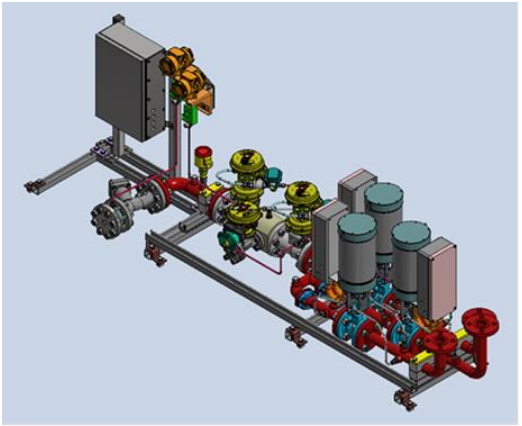
HYFLEXPOWER

CFD Analysis of the Air Flow in Package Enclosure

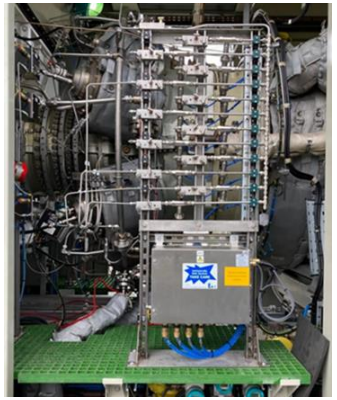


- Ventilation System and Gas Detection
  - Enclosure integrity
  - Gas detection safety
- Fire System Risk Assessment
  - Fire detection
  - Fire suppression
- Gas Fuel System Upgrade
- Engine Monitoring System

Three-Stream Gas Fuel Module



Monitoring System with GT package



GT Package assessed and upgraded for 100% H_2 operation

2022 Demonstration Campaign

2022 Demonstration Campaign

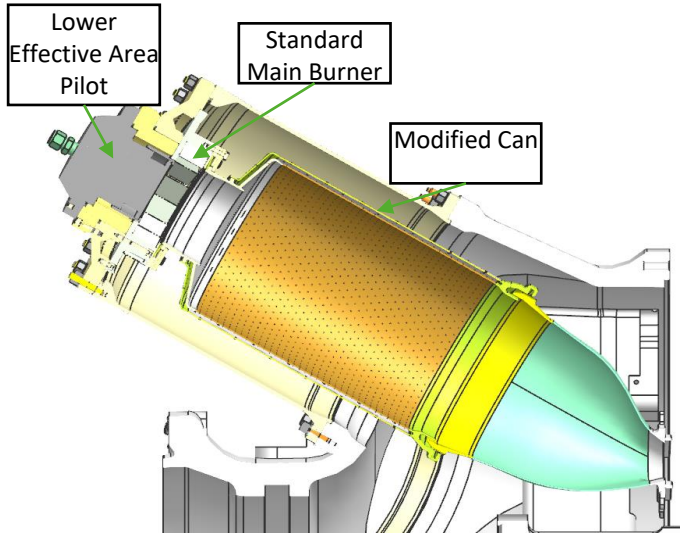
Gas Turbine Demonstrator Core Build

HYFLEXPOWER

Power-to-H_2-to-Power SGT-400 Demonstrator Core Engine

Supplied SGT-400 demonstration core build with 30 vol.% H_2 capability to support commissioning of integrated advanced plant concept.

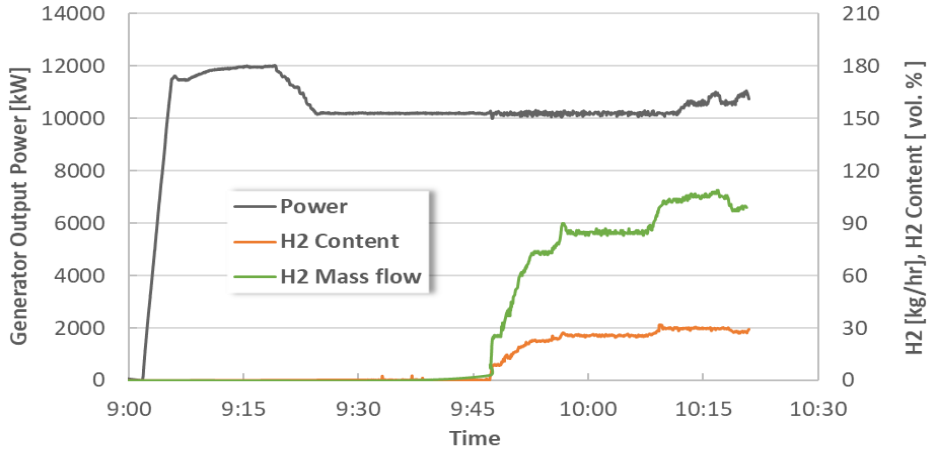
- Demonstration engine built with modified combustion geometry.
- Factory tested in Lincoln with natural gas and released for HYFLEXPOWER demonstration.
- Core engine shipped, installed and commissioned at site.
- Testing with H_2 blends conducted in August/September 2022.

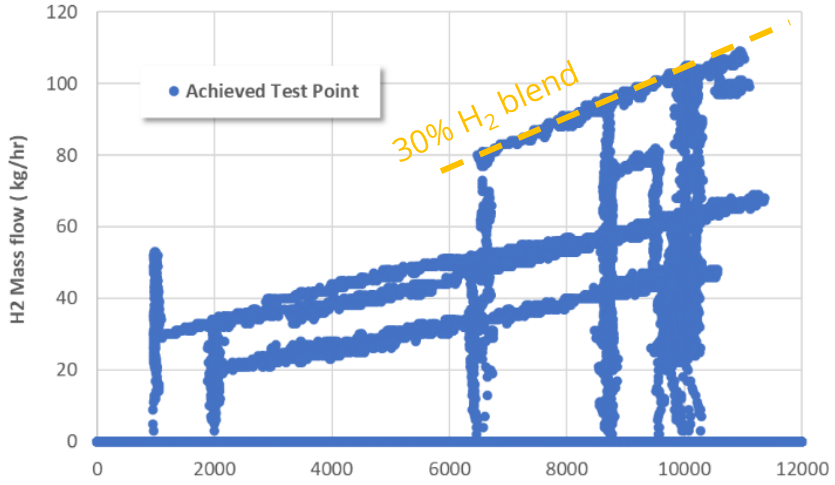


Engine ready for build to support 2022 test campaign

2022 Demonstration Campaign

Summary of Testing





Outcomes and Observations

- Start up on natural gas.
- Controllable fuel blend in mixing station.
- Blends up to 30% H_2 have only a minor impact on performance.
- Increase in NOx as expected with higher H_2 blends, but still below 15ppmV target.

Demonstration campaign objectives achieved

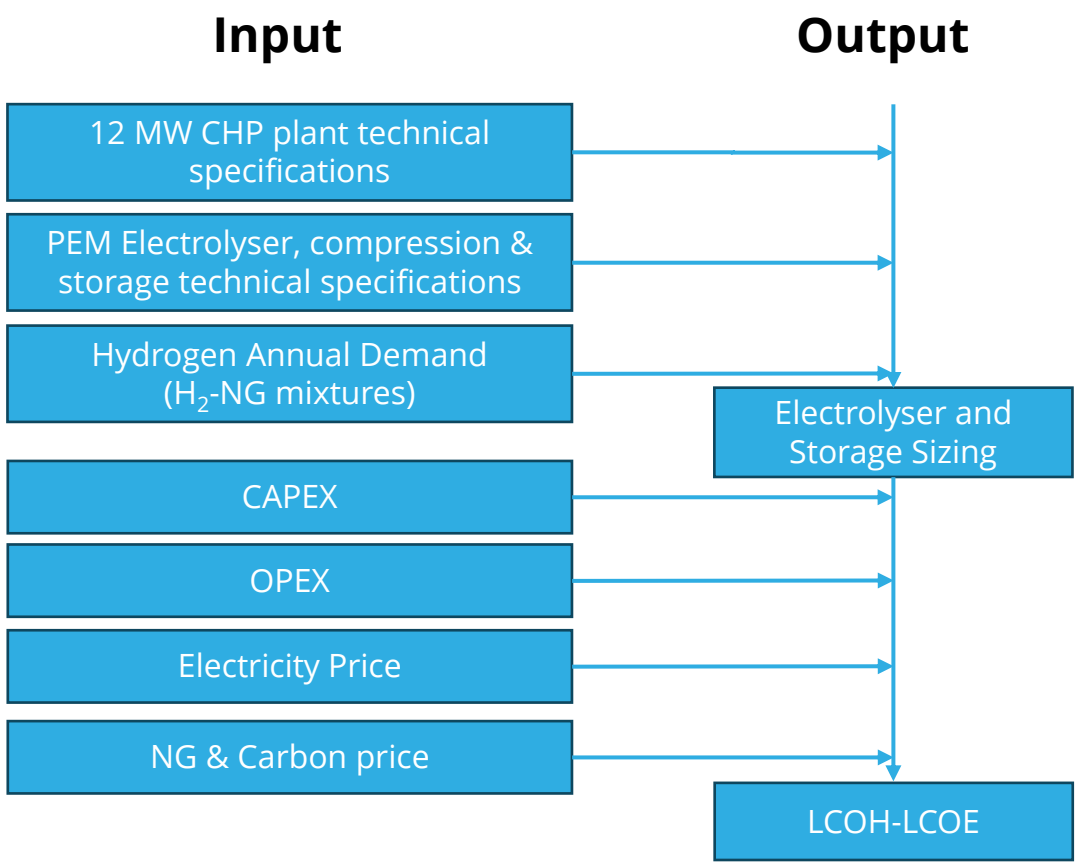
- Commissioned new data monitoring and acquisition system.
- Successfully commissioned and demonstrated first industrial-scale power-to-H2-to-power solution with a turbine.
- Tested H2/NG blends up to 30% H_2 across a wide engine operating range.

Demonstrated industrial-scale power-to-H_2-to-power solution with SGT-400 up to 30% H_2 & wide operating envelope

Techno Economic Analysis

Techno-Economic Analysis

Assumptions and Objective



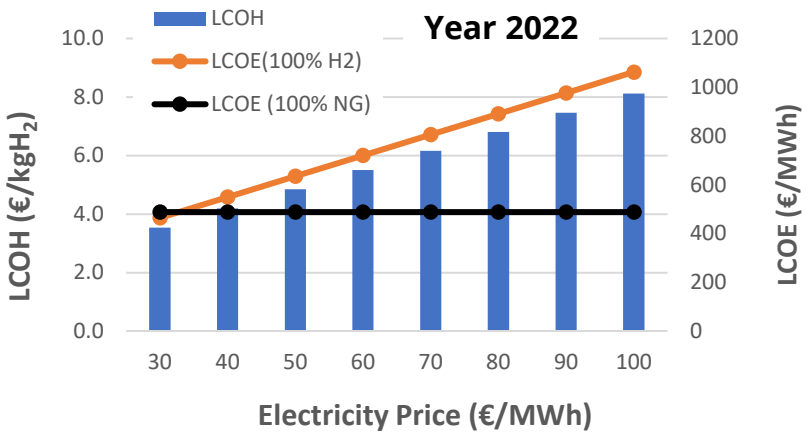
Assumptions

Parameter	Reference Year 2022	Reference Year 2030
CAPEX PEM Electrolysis System (€/kW)	**1500**	**800**
Stack Replacement Cost (Stack lifetime 80.000 h of operation)	30% $CAPEX_{PEM, ES}$	30% $CAPEX_{PEM, ES}$
Cost of Water (€/m^3)	3.8	3.8
Cost of Electric Power (€/MWh)	40	40
Scaling factor	0,9	0,9
Annuity (%)	8	8
OPEX PEM Electrolysis System (€/MWh)	3	3
PEM Electrolysis System Maintenance Cost	2% $CAPEX_{PEM, ES}$	2% $CAPEX_{PEM, ES}$
Cost of CO_2 (€/tCO_2)	**90**	**150**
OPEX Costs of Open Cycle Gas Turbine (€/MWh)	4	4
Cost of Natural Gas (€/MWh)	90	90

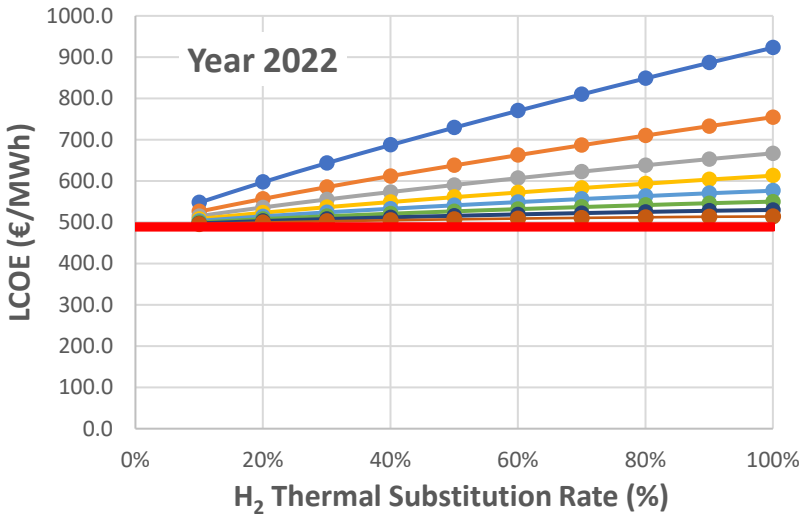
Analysis of economic feasibility of green H_2 production, storage, distribution, and utilization in an integrated CHP

Techno-Economic Analysis

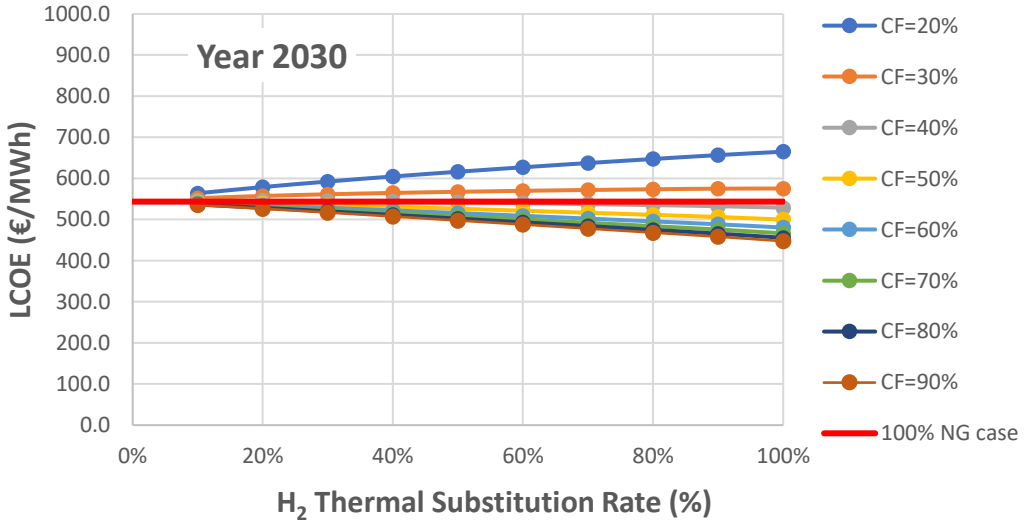
Results



Break even point for 100% green H_2 compared with natural gas (NG) can be achieved for electricity prices below 35 €/MWh and LCOH below 3.71 €/kgH_2.



- Decreased Electrolyzer Capex
- Increased Cost of CO_2



Green H_2 integration in existing CHP plants can achieve price parity with NG for electrolyzer CF above 30%

Conclusions

Conclusions

- Designed, constructed and commissioned a power-to-H_2-to-power advanced plant concept at an existing CHP plant in Saillat-sur-Vienne, France.
- Successfully demonstrated this first-ever industrial-scale power-to-H_2-to-power plant solution with an SGT-400 gas turbine burning up to 30 vol. % H_2.
- Developed and demonstrated at CEC a DLE combustion system capable of operation with 100% H_2 at SGT-400 engine conditions.
- Technoeconomic assessment indicates viable business case for decreased CAPEX of electrolysis system, higher CO2 costs, and low power prices for H_2 production.

HYFLEXPOWER

2023 Progress

STOP PRESS

Phase 2 demonstration campaign has just concluded at end of September 2023

…. New H_2 combustors with dry low emissions (DLE) technology tested at CEC in Berlin, manufactured, and built into SGT-400 demonstrator core engine.

…. Factory tested demonstrator engine in Lincoln with natural gas and deployed at HYFLEXPOWER site for 2023 demonstration campaign.

…. Target engine operation across full blend from 100% natural gas to 100% H_2 in same combustor on 12MW SGT-400 gas turbine.

…. Target demonstration of power-to-H_2-to-power solution pilot with 100% H_2 for carbon-free energy production from stored excess renewable energy.

More details to be reported in subsequent publications.

Contact page

Thank you!

Dr. Ertan Yilmaz

Siemens Energy

ertan.yilmaz@siemens-energy.com

www.siemens-energy.com

HYFLEXPOWER has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884229.