Laborelec

RESEARCH & INNOVATION

Hydrogen integration into thermal assets

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RPM Green fuel integration in thermal assets

RESTRICTED | INTERNAL | SECRET

Hydrogen integration into thermal assets

*) also includes ammonia and diesel/gas engines

- In May 2021, ENGIE announced its ambition to become Net Zero by 2045, covering all emissions across its value chain.
- Decarbonisation strategy for energy generation relies of 5 core levels

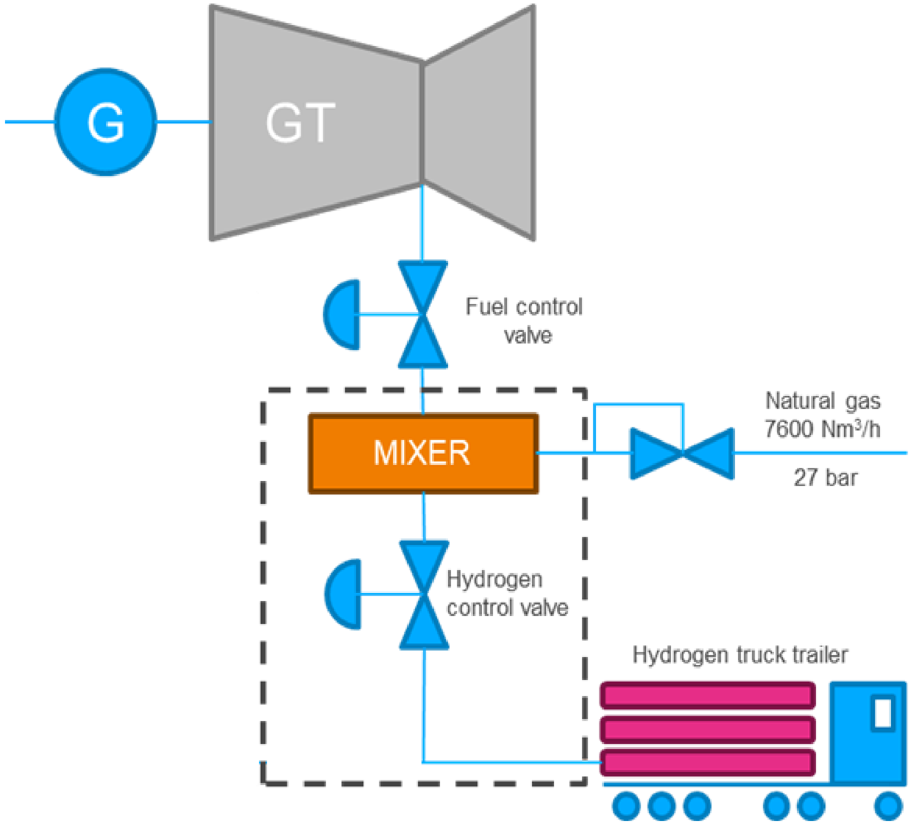
    1. Increase of renewable power generation
    2. Sustainable growth in low-carbon distributed infrastructure
    3. Complete coal phase out
    4. Progressive reduction of gas unit load factors (baseload to capacity and flexibility services to complement the intermittent generation of RES)
    5. Gas units progressively fueled by green gas* or equipped with CCUS

- ENGIE has positioned itself as a major player in renewable hydrogen and operates along the entire length of the hydrogen value chain – from production of renewable energies to end uses

Hydrogen integration into thermal assets

Demonstrating the ability to inject a H2/NG blend in the GT

- The H2 co-combustion in gas turbine project covers an energy transition pathway with green hydrogen as driver to reach lower carbon emissions for existing thermal power plants or cogeneration units
- A hydrogen truck trailer is connected to the unloading station and in-house developed hydrogen pressure reducing and gas mixing skid
- The hydrogen is mixed with natural gas before it is injected into the gas turbine
- Test to be performed with existing hardware, i.e. no change or modification of the turbine hardware



Hydrogen integration into thermal assets

Demonstrating the ability to inject a H2/NG blend in the GT

- Finding the safe limits of NG/H2 blend combustion in the SGT-600 2nd generation gas turbine with ramping up 2.5 vol% H2 at base and part load and constant heat input
- NG/H2 blend combustion in the gas turbine with ramping up at base load and constant gas flow
- Combustion tuning at base and part load at different hydrogen percentages
- Transient base load/part load operation at different hydrogen percentages

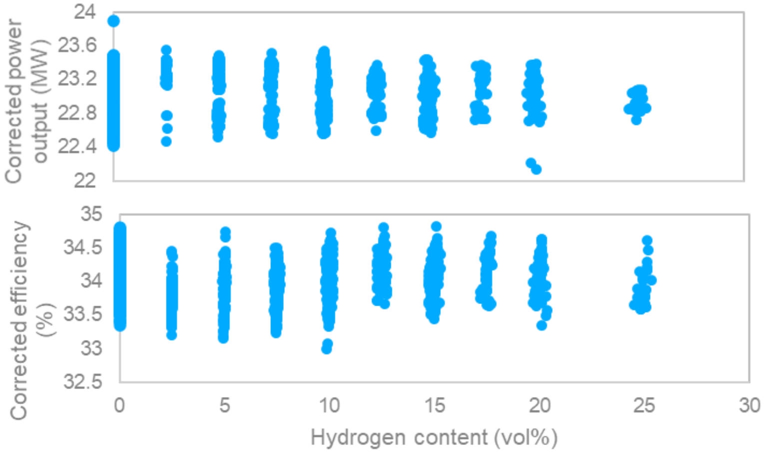
Siemens set the limit to ~10 vol%

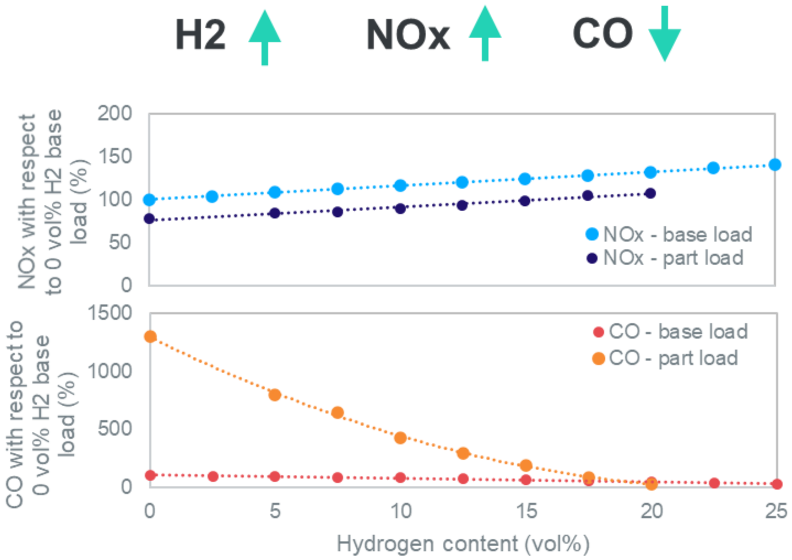
Hydrogen integration into thermal assets

- Full de-risking campaign incl. burner test in burner rig
- 9 truck loads of 250 kg were used for the test
- All test have been performed online without start/stop

- Hydrogen up to 25 vol% was mixed with natural gas and injected in the gas turbine
- No significant impact on power output and efficiency
- Load cycling (base load and part load with constant H2 vol%) has no impact on performance

- NOx emissions increased by ~40% at 25 vol% H2
- At 10 vol% of hydrogen, combustion tuning allowed to mitigate the NOx emissions to the reference emission levels
- An additional 5% turndown was possible with 10 vol% hydrogen
- CO2 reduction of 11% was achieved





ASME journal-of Engineering for Gas Turbines and Power
Demonstration of natural gas and hydrogen co--combustion in an industrial gas turbine

Hydrogen integration into thermal assets

- To test an entirely green hydrogen-based power supply for a completely carbon-free energy mix
- Technical objectives
  1. Conversion of excess RES power to chemical energy (H2) through electrolysis of water
  2. Integration of H2 storage into the demonstration plant
  3. Development of an advanced gas turbine capable of running on high-hydrogen fuels
  4. Development and demonstration of an advanced plant concept
  5. Running of two extensive pilot plant demonstration campaigns
- 12 MW unit: 30 vol% in 2022 and 100 vol% hydrogen in 2023

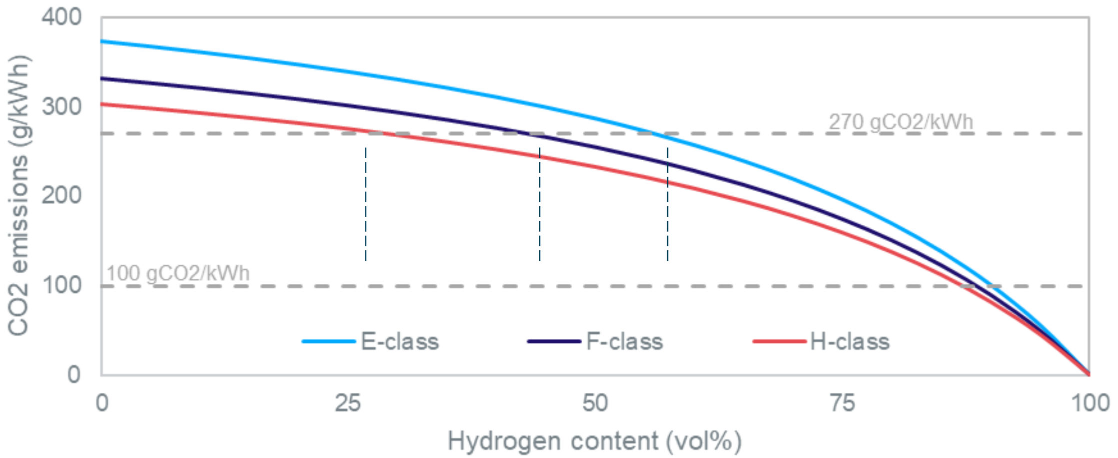
HYFLEXPOWER

Hydrogen integration into thermal assets

- EU taxonomy for new CCGT's
- Green-labeled power plants must use blends containing 30% renewable or low-carbon gases as of 1 January 2026, and at least 55% of renewable or low-carbon gases as of 1 January 2030. They must completely switch to renewable or low-carbon gases by 31 December 2035.

CO_2 emissions (gCO_2/kWh)	Remark
< 100	Sustainable limit. Any power plant operating below the 100 g/kWh is consistent with the NZE pathway, and is making a substantial contribution to the EU meeting its Paris commitments
< 270	No harm limit. Power plants are not considered doing any harm to the goals
> 270	Significant harm limit. Any power plant operating above 270 g/kWh increases average EU emissions from current levels and risks harming the Paris Agreement

What is needed to decarbonise the existing fleet and what is required to be below 270 gCO2/kWh?

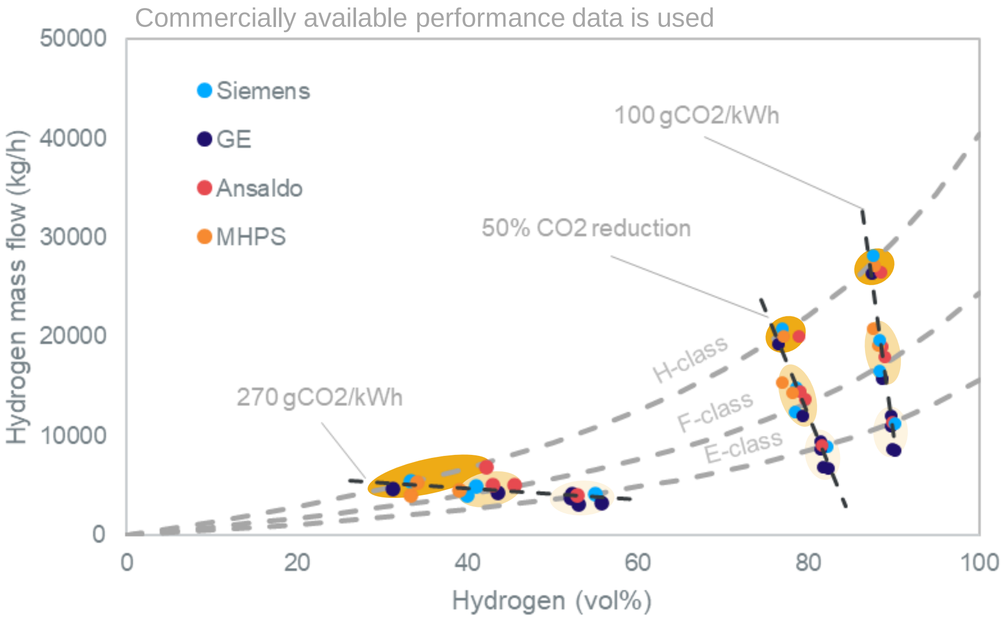


Hydrogen integration into thermal assets

- Hydrogen admixture needed to meet 270 gCO_2/kWh
  - E-class: 50-60 vol%
  - F-class: 40-50 vol%
  - H-class: 30-35 vol%
- Hydrogen admixture needed to meet 100 gCO_2/kWh
  - E-class: 90 vol%
  - F-class: 89 vol%
  - H-class: 88 vol%
- Going from 270 gCO_2/kWh to 100 gCO_2/kWh requires 3 to 6 times more hydrogen
- Going from 100 gCO_2/kWh to 0 gCO_2/kWh requires an additional 40% of hydrogen

270 gCO_2/kWh threshold requires 4000-5000* kgH_2/h for 50Hz CCGT regardless of technology class

*) 16-20 hydrogen truck trailers and or
175-220 MWh green hydrogen production capacity

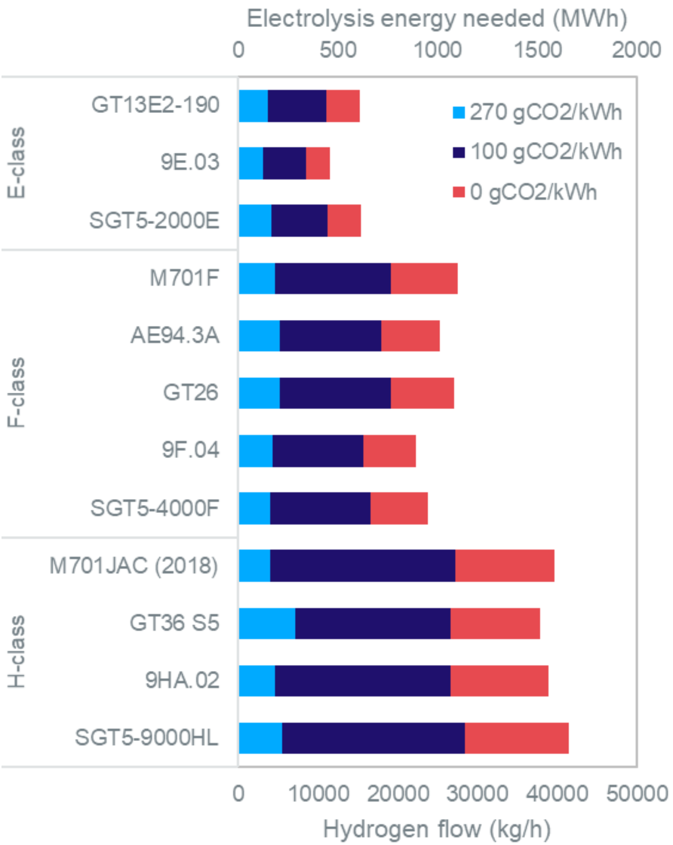


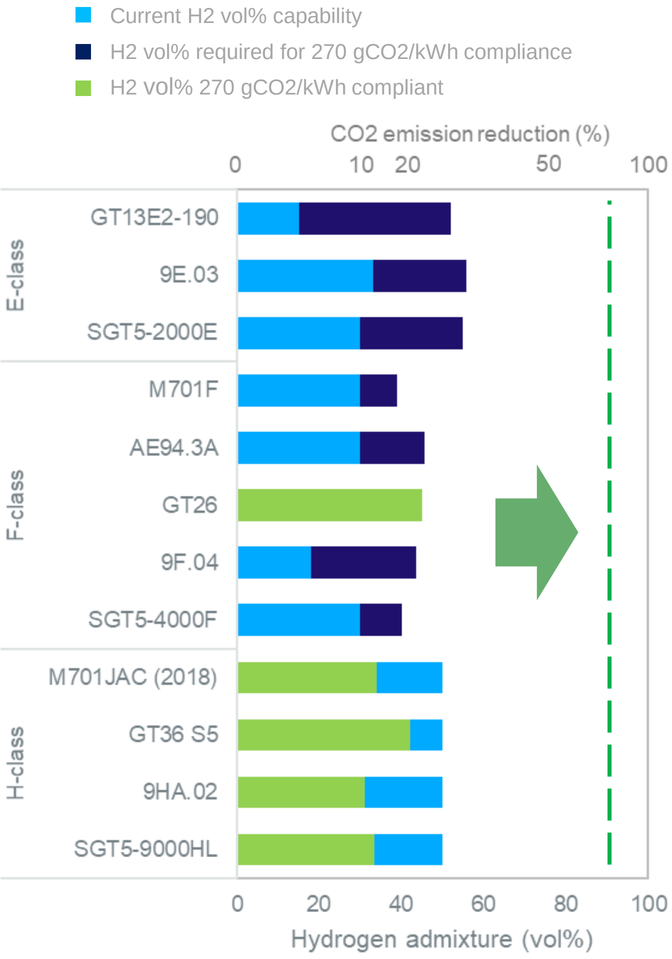
OEM	E-class	F-class	H-class
Siemens	SGT5-2000E	SGT5-4000F	SGT5-9000HL
GE	9E.03, GT13E2	9F.03	9HA.02
Ansaldo	AE94.2	AE94.3A, GT26	GT36-S5
MHPS	-	M701F3	M701JAC

Hydrogen integration into thermal assets

- Today, most gas turbines are not capable of reaching the 270 gCO2/kWh threshold with hydrogen co-combustion
- Currently, the F-class GT26 is the only CCGT capable of reaching the 270 gCO2/kWh limit
- Significant quantities of hydrogen are required
- Large hydrogen production plants are needed to fuel a gas turbine

What does it mean to integrate hydrogen in a CCGT plant?





Hydrogen integration into thermal assets

What does it mean to integrate large volumes of hydrogen in a combined cycle power plant?

Will it happen soon?

1. Availability of hydrogen
2. Cost & business case
3. Safety
4. Hardware modifications
5. Fuel & mixing skid/valves/piping manifold
6. Impact of flue gas on component longevity
7. Impact on HRSG
8. …

* Via ammonnia or e-fuel

Table is based on Liebreich Associates - BloombergNEF

Unavoidable ↔ Uncompetitive

Label	Chemical & processes	Power system	Aviation & shipping	Land transport	Heating
A	Fertiliser, hydrogenation, methanol, hydrocracking, desulphurisation				
B	Steel, chemical feedstock	Long-term storage	Shipping*	Off-road vehicles	
C	Local CO2 remediation		Long-haul aviation*, coastal & river vessels	Remote trains, vintage vehicles*	
D			Medium-haul aviation*	Long distance trucks and coaches	High-temperature industrial heat
E		Island grids, clean power imports, UPS	Short-haul aviation, local ferries		Commerical heating
F			Light aviation	Rural trains, regional trucks	Mid/low-temperature industrial heating, domestic heating
G				Local transport, H2FC cars, urban delivery, 2 & 3-wheelers, bulk e-fuels	

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