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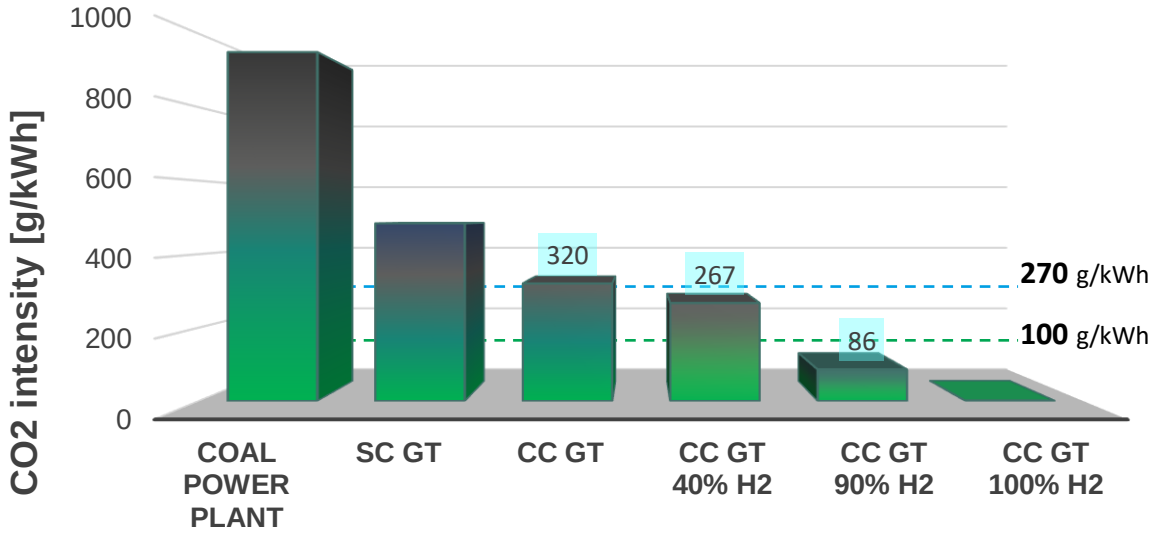
Hydrogen gas turbines for power generation

Andrea Ciani – 23rd April 2024

- Introduction
- Hydrogen Gas Turbines to support the decarbonization of power generation
- Sequential Combustion and its intrinsic fuel flexibility
- Switzerland and EU joining forces in the “FLEX4H2” project
- Outlook

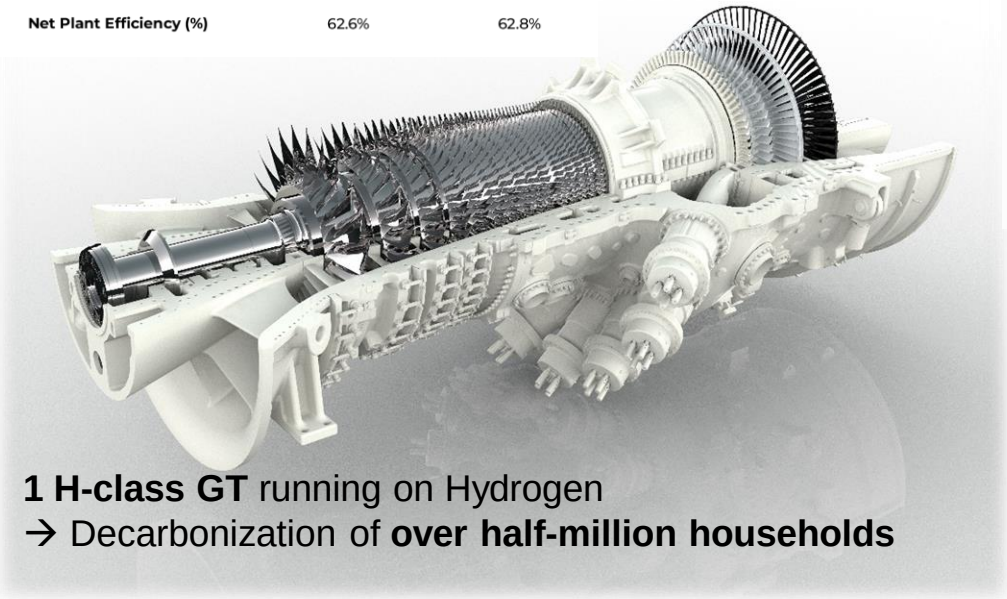
Power Generation Outlook – CO_2 Intensity

- GTs already bring a major CO_2 reduction compared to coal power plants
- Firing GTs with H_2 based fuels can further help decarbonization
- For a substantial effect large percentage of H_2 in NG are needed

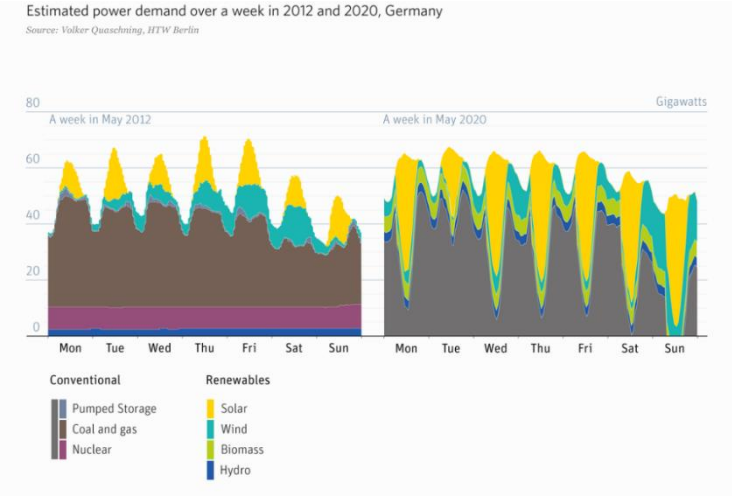


Low CO_2 Dispatchable Power Generation

Optimized combined cycle	GT36 S5 1+1	GT36 S5 2+1
Net Plant Power Output (MW)	800+	1600+
Net Plant Efficiency (%)	62.6%	62.8%



1 H-class GT running on Hydrogen
→ Decarbonization of **over half-million households**



GTs as a unique technology to complement growing renewable energy production, fluctuating by nature

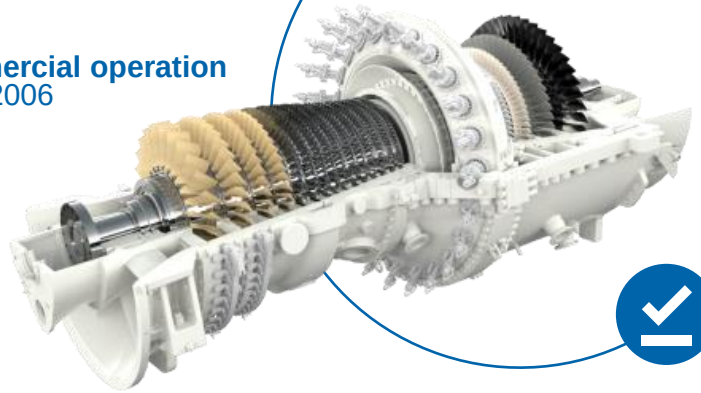
Experience with H2 projects: AE94.3A

AE94.3A

2 Units in CCPP

H_2 supplied by a Chemical Plant next to CCPP

Commercial operation since 2006



H_2 content in premixed mode validated up to **25%** vol.

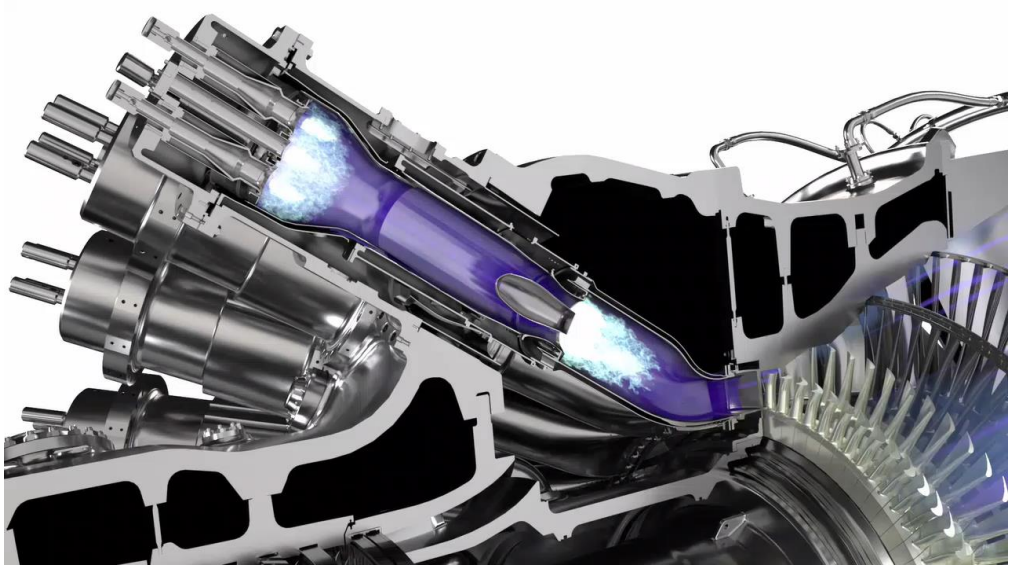
CO_2 savings up to **40,000** tons/year

300,000 operating hours

Roadmap: short-term→**40% H_2** capability
mid-term → full range

Commercial operation on H2 blends since 2006

Sequential Combustion as technology enabler for H2 combustion



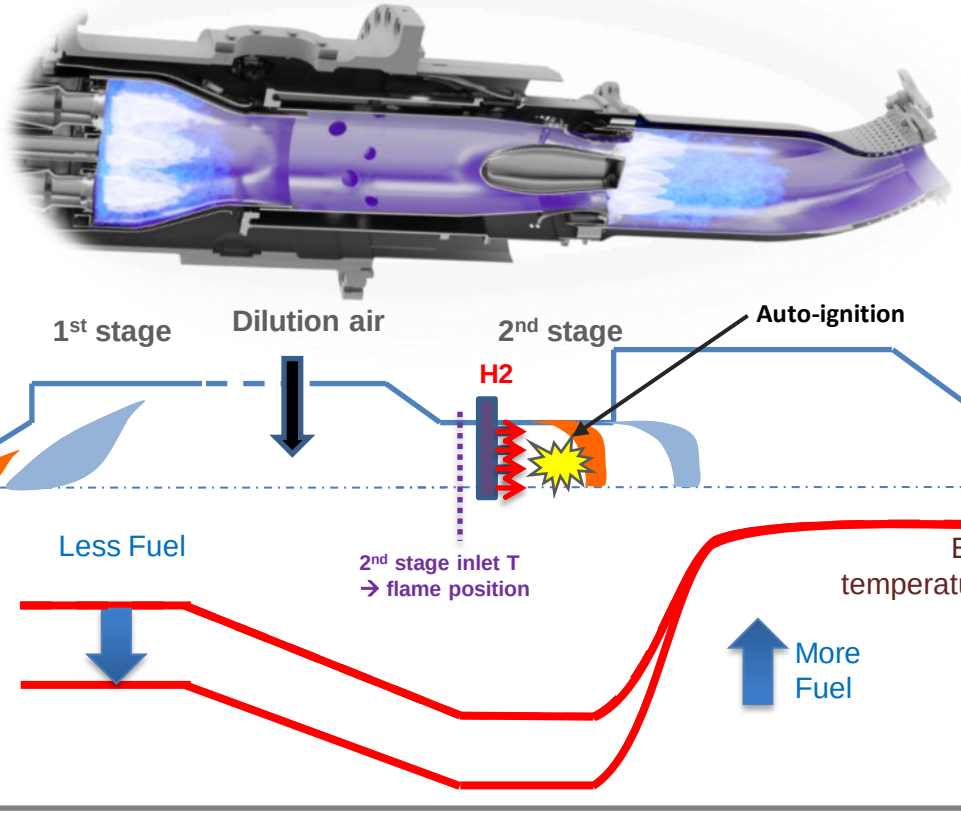
- 29 years proven technology
- Pioneered reheat combustion technology in F class products (ABB ALSTOM GT24 and GT26)
- Fuel gas flexibility
- H class technology evolution in can-based system for best upgradability and service
- Wide turndown

Sequential combustion: proven technology developed through ABB, Alstom and several international projects

Sequential Combustion Flexibility

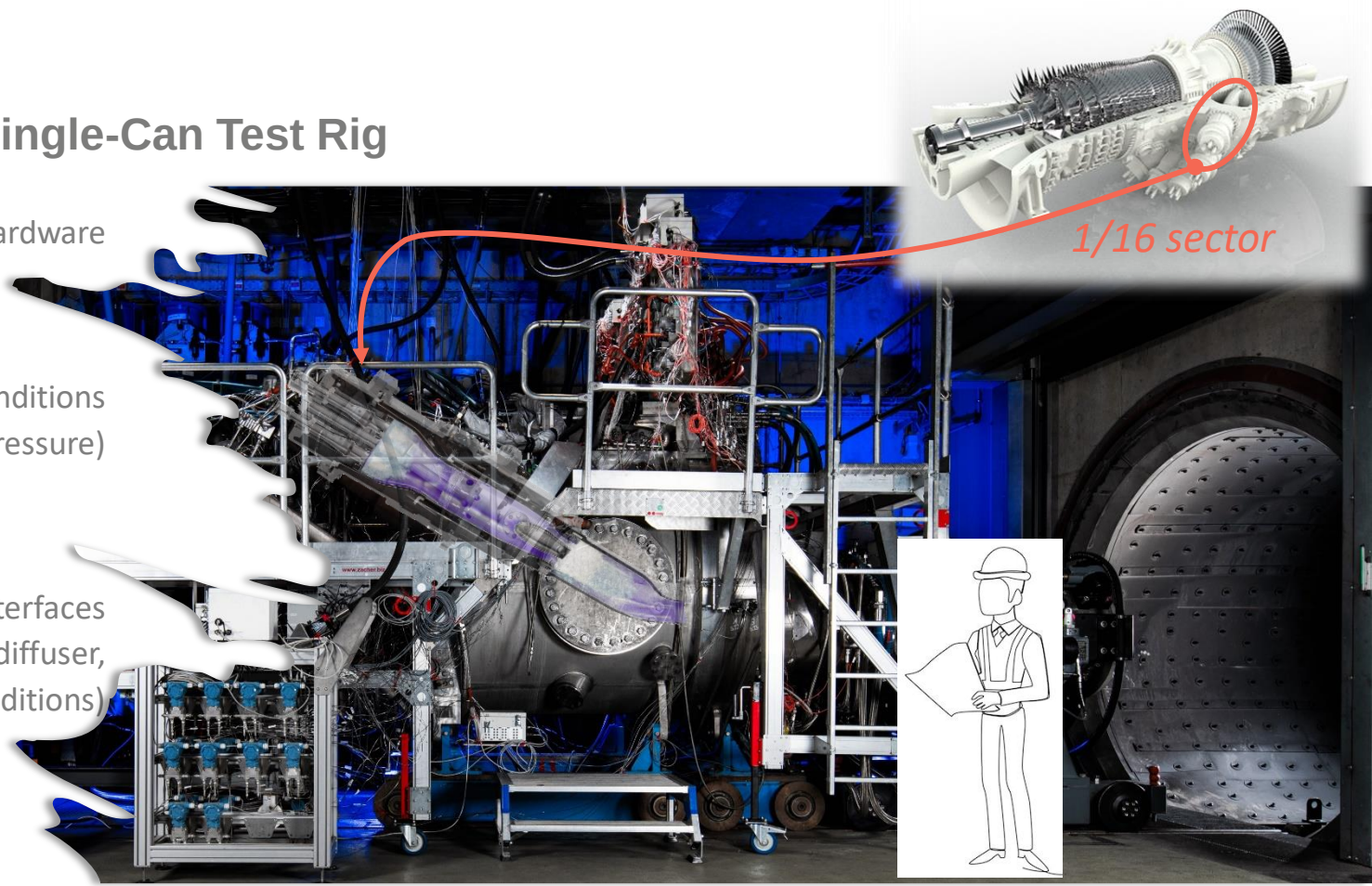
Sequential combustion systems with H2:

- Decrease 1st stage flame temperature
  → compensating higher H2 reactivity on the 1st stage
  → reducing the 2nd stage inlet temperature
  → compensating the 2nd stage H2 auto-ignition
- Increase 2nd stage fuel (power)
  → compensating power loss from the first stage
  → maximizing engine performance

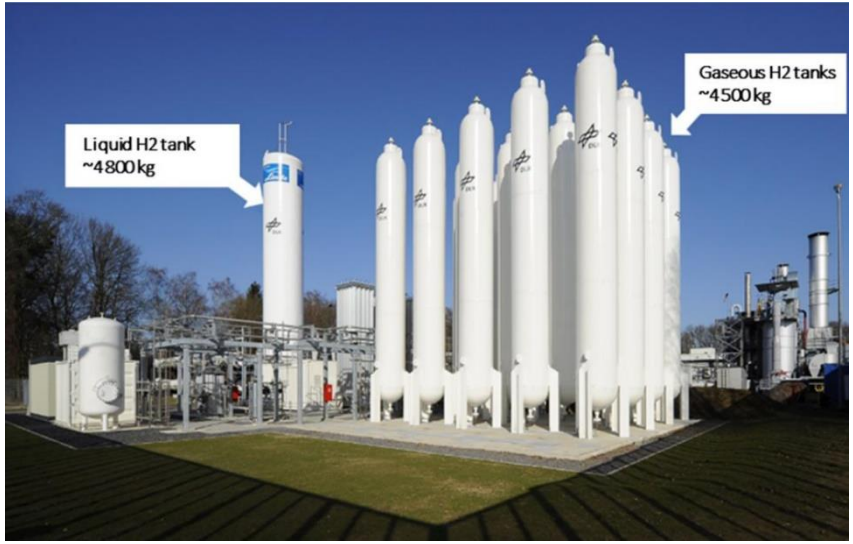


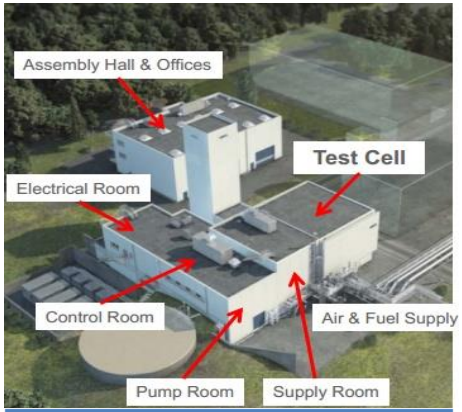
Full-Scale Single-Can Test Rig

- Full-scale hardware
- Full engine conditions (temperature, pressure)
- Engine interfaces (compressor diffuser, turbine inlet conditions)



High Pressure Validation





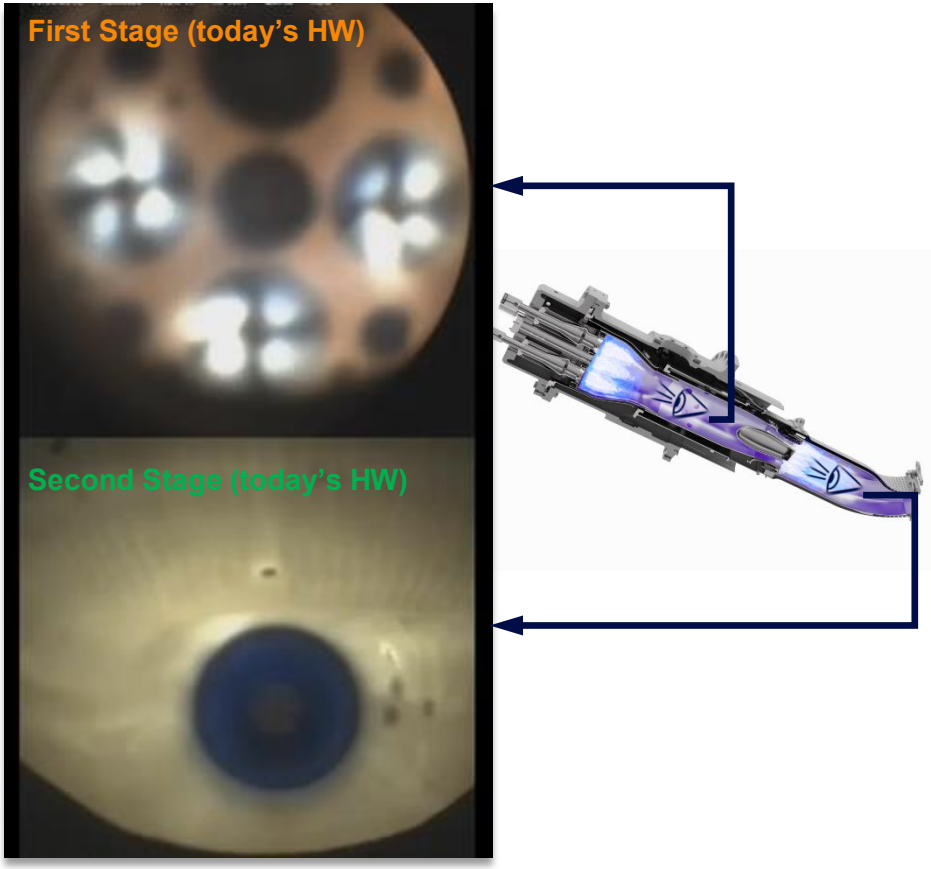
Main Parameters	
Air mass flow	70 kg/s
Pressure	40 bar
Preheat temperature	700°C
Hotgas temperature	2000K
Fuel types	Gaseous and liquid
Thermal power	125 MW

- Hydrogen handled: up to 4 tons / day
- Data acquisition with live monitoring of >1000 parameters
- Remote data transmission (Baden, Switzerland)

Testing infrastructure capable to reproduce full engine conditions

HP Testing: a Replay

Video showing a sweep from natural gas to a blend with 90%v. H2 demonstrating the possibility to adjust the fuel reactivity on the two stages simultaneously



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«FLEX4H2»: Flexibility for Hydrogen Switzerland and EU joining forces

- Hydrogen combustion system development
  - Safe
  - Flexible
  - Efficient
- Validation and **«demo» by 2026**
  - Test with up to 100% H2 on **full scale** prototypes
  - «Technology Readiness Level» (TRL) 6 by 2026

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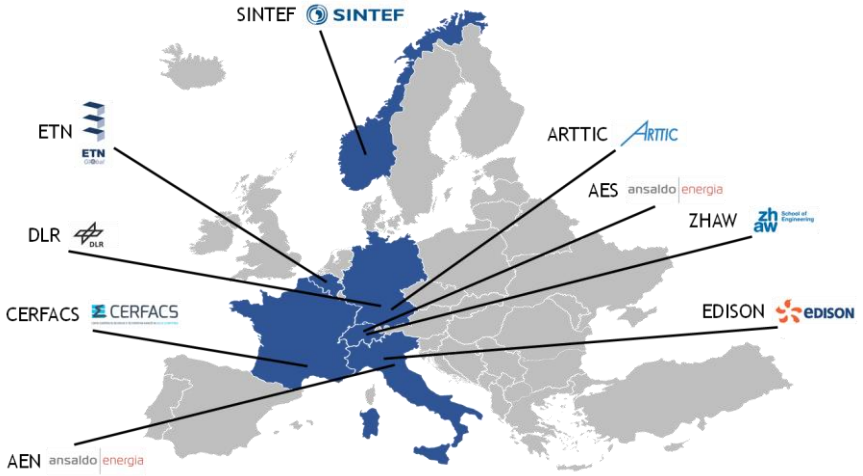
- **Pathway ahead**
  - credible pathways for comprehensive exploitation of the project's results
  - firm contribution to the EU Green Deal towards **decarbonization of the electric power sector by 2030**



Clean Hydrogen Partnership
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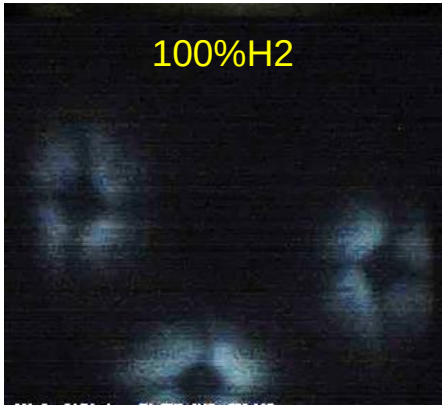
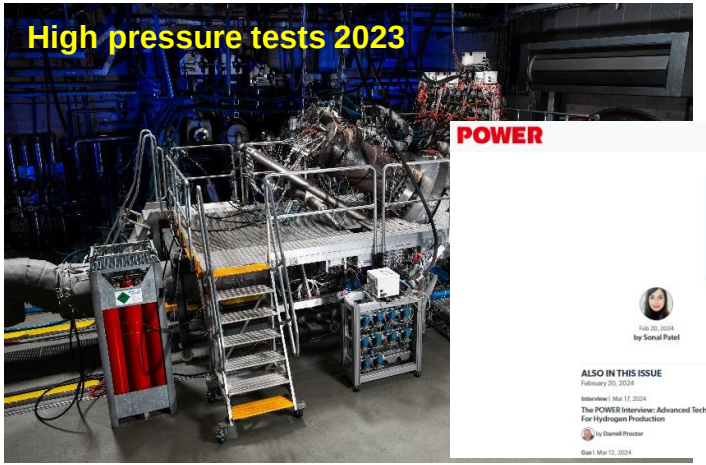
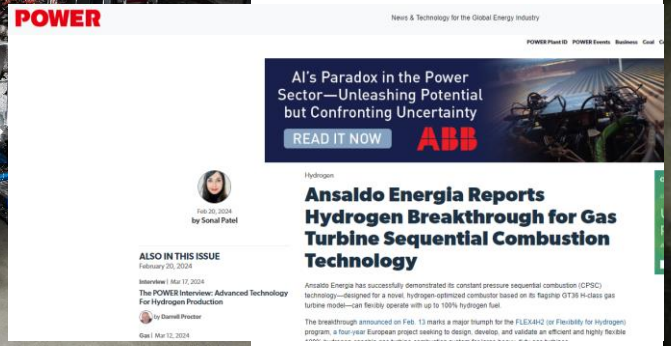
This project is supported by the Clean Hydrogen Partnership and its members Hydrogen Europe and Hydrogen Europe Research (GA 101101427), and the Swiss Federal Department of Economic Affairs, Education and Research, State Secretariat for Education, Research and Innovation (SERI)

Sequential combustion system demonstrated 100%H2 capability in the HP rig

- Sequential burner prototypes developed within the FLEX4H2 program
- October 2023: Full range of natural gas and hydrogen tested in the HP rig







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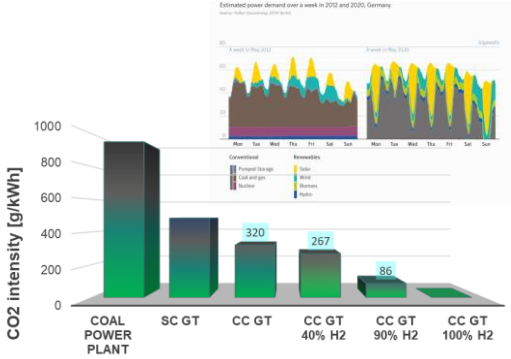
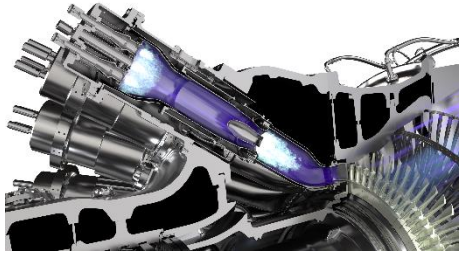
Conclusions

- **Hydrogen GTs** offer an enormous potential to **decarbonize power generation**
- Hydrogen combustion properties are posing **major challenges to modern premix systems**
- **Sequential combustion** systems offer an intrinsic advantage for fuel flexibility, capable to cover the **full range of natural gas and hydrogen blends**
- Optimized system being developed targeting **100% H_2** operation through **EU/Swiss** funded **“FLEX4H2”** project
  - **TRL6 by 2026 enabling 60+% efficiency**
  - Available for **commercial** application **~2030**





FLEX4H2

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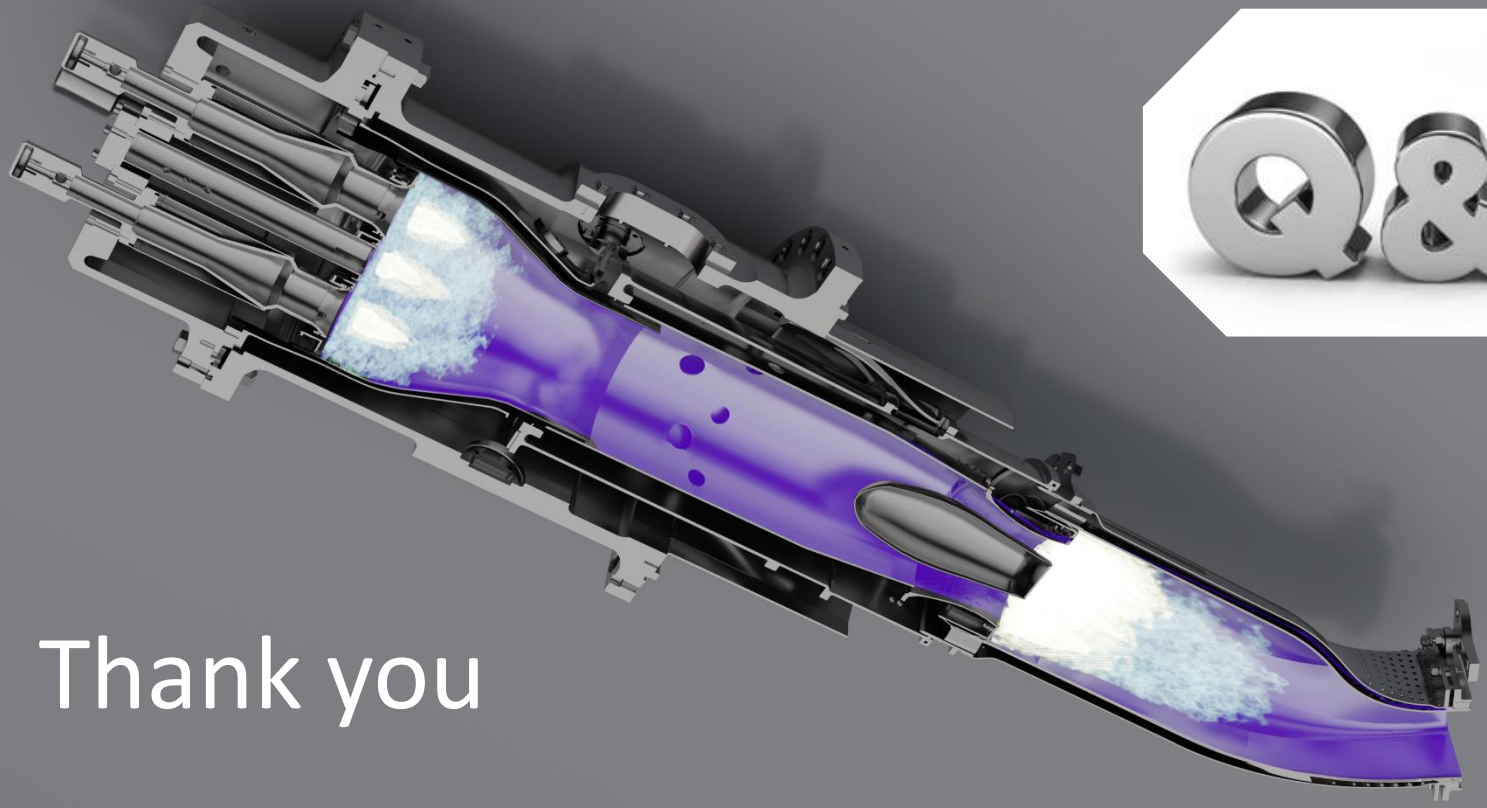

Thank you