Vätgasturbiner för framtidens hållbara energisystem

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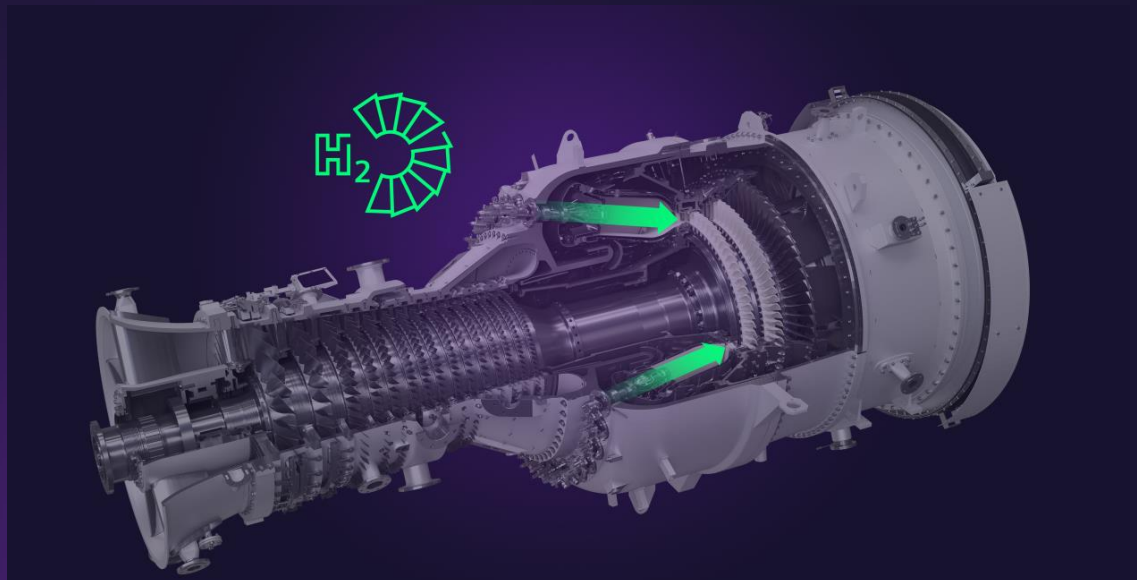
Gas turbines on hydrogen - What's the point?

1. There are enormous initiatives around the globe to change to **climate neutral energy systems** and Sweden needs to contribute with high technology

2. Gas turbines can operate fossil free on hydrogen and hydrogen-based fuels due to high **fuel flexibility. "**H2-ready" gives us new orders, market is growing

3. Gas turbines are a perfect complement in renewable energy systems, providing stability and resilience with **operational flexibility**

4. We see large **opportunities for research and development** to support the energy transition



Siemens Energy Gas Turbine SGT-800

Germany announces "*Kraftwerksstrategie*" for 24 GW capacity

Hydrogen power plants – incentives up to 876 h / year

2024 — 2025 — 2026 — 2030 — 2035

Finalization of framework

Tenders to start

Expected first plants in commerical operation

- Green H2 "*sprinter*" power plants — *4,4 GW*
- H2 power plants with co-located hydrogen storage — *4,4 GW*
- "H2-ready" natural gas power plants — *10-15 GW*

up to 24 GW

*Expected dates TBD

Germany to issue tenders for up to 23.8GW of hydrogen-fired power plants by 2035 | Hydrogen news and intelligence (hydrogeninsight.com)

What we found in our own research

1. **Hydrogen reduces average electricity costs in decarbonized energy systems**

2. **Hydrogen gas turbines provide plannable electricity in wind-dominated power systems**

3. **Hydrogen-based power plants can be critical for ensuring electrical grid stability**

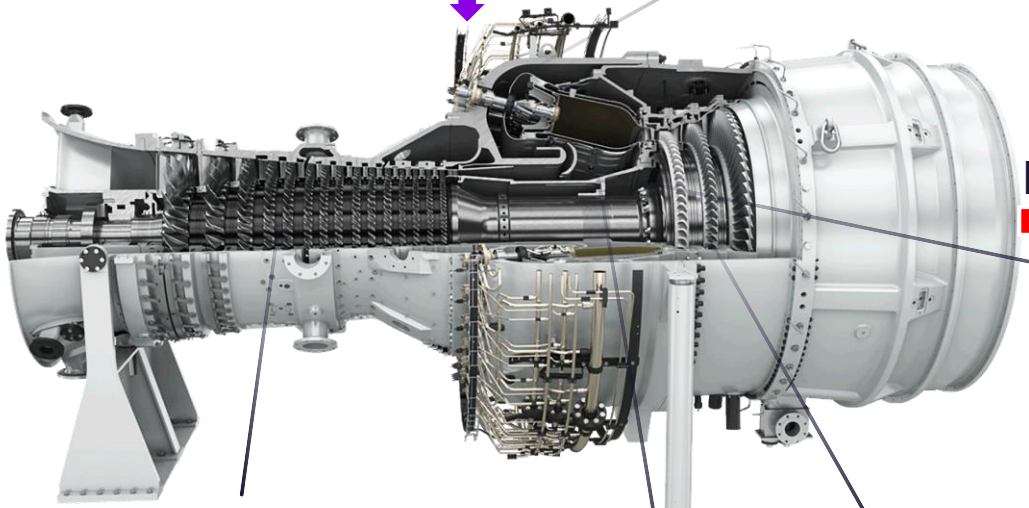
4. **Liquid green fuels are a valuable complement to hydrogen**

Gas turbine fuel flexibility enables stepwise transition to fossil free electricity and heat

Green fuel, e.g. H_2

Shaft power

Heat

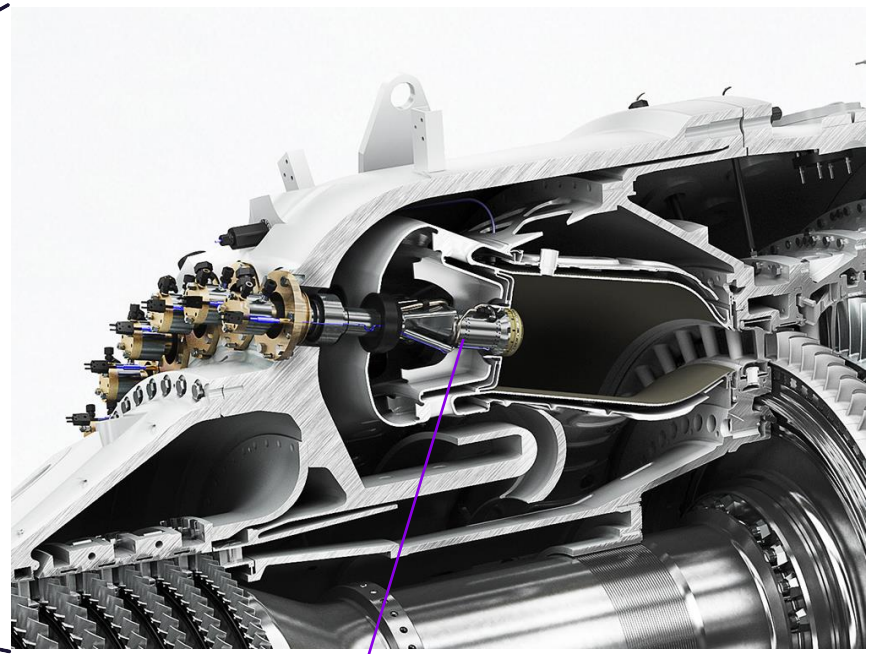


Compressor

Combustor

Turbine

OK NOx
No CO!



3rd generation DLE burner technology

Hydrogen in gas turbines
Fuel characteristics

Hydrogen ignites/burns fast

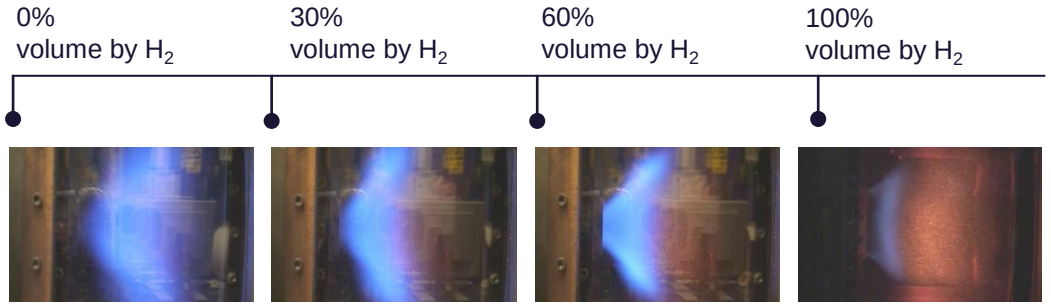
H_2 combustion moves flame closer to injector – avoidance of “flash-back” by optimizing air and fuel distribution.

Hydrogen has a wide flammable region

Much wider range of fuel/air-ratio to burn compared to natural gas. Adaption of ventilation and gas detection system as well as fuel system.

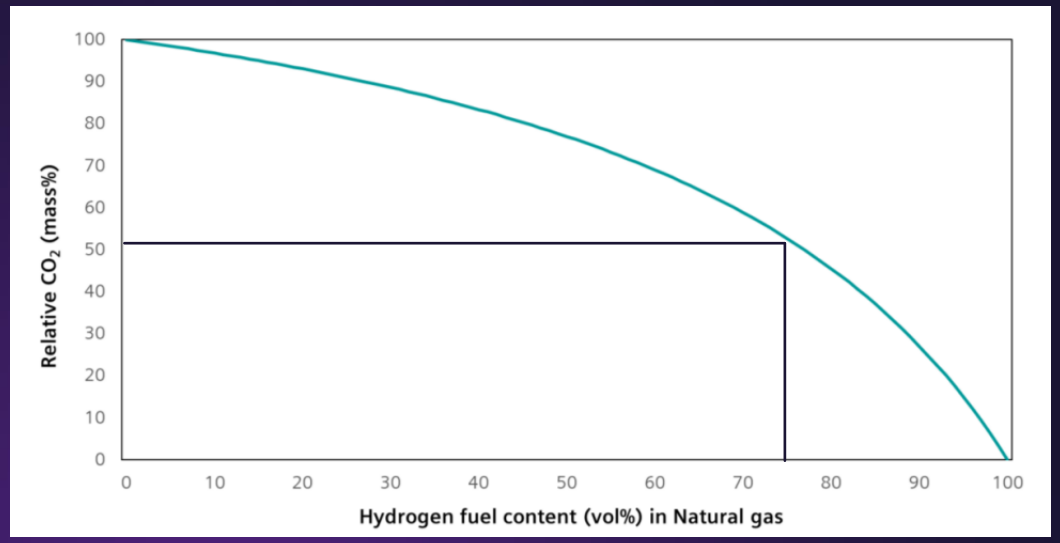
Hydrogen has a low ignition energy

Only a fraction of the ignition energy is needed to get H_2 “going” compared to methane.



Hydrogen has lower density

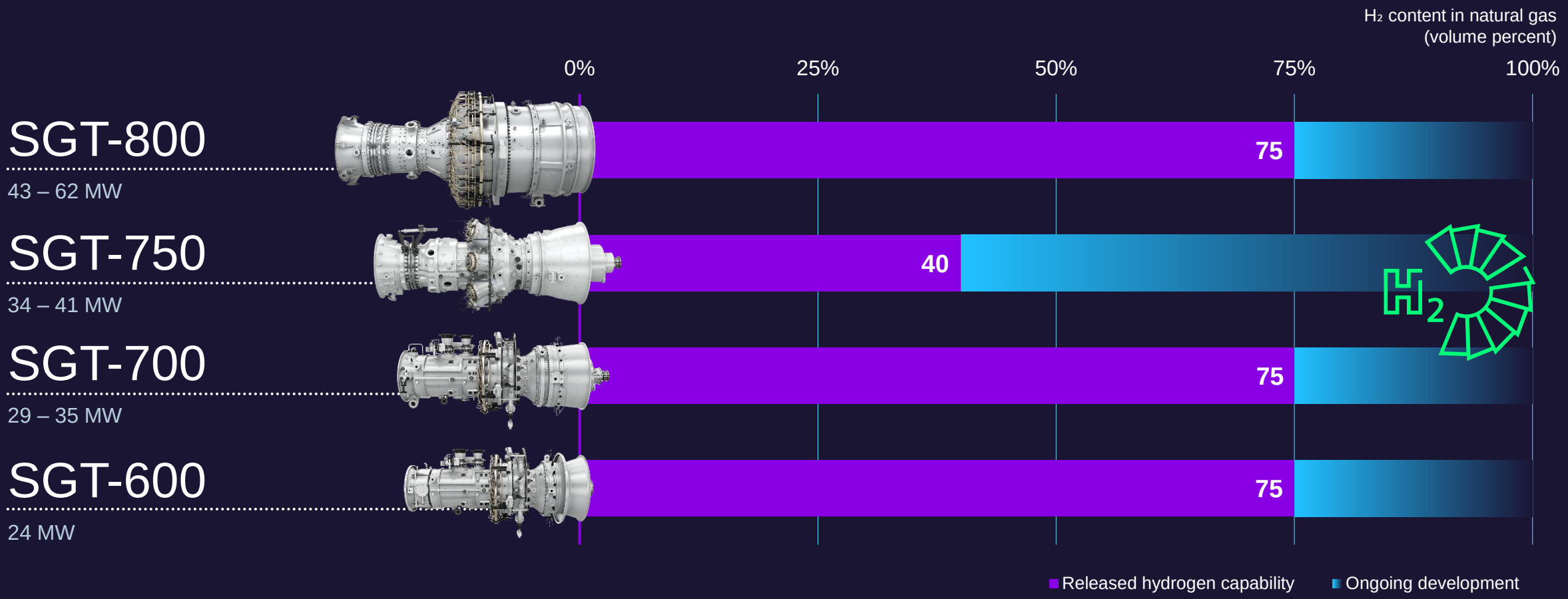
… but fortunately, the Wobbe Index remains in natural gas range, i.e., 37 – 49 MJ/Nm³.



For a hydrogen/methane mix the relationship between CO_2 reduction and H_2 content is non-linear. The H_2 molecule has 2.5 times the energy content of methane by mass, but one third on a volumetric basis.

Link: Siemens Energy Decarbonization Calculator

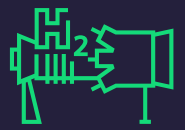
Hydrogen capability in Siemens Energy medium size gas turbines



All turbines equipped with DLE burner technology
Power output in MW at ISO ambient conditions and natural gas, includes both new units and existing fleet

Green fuels roadmap – Medium sized gas turbines

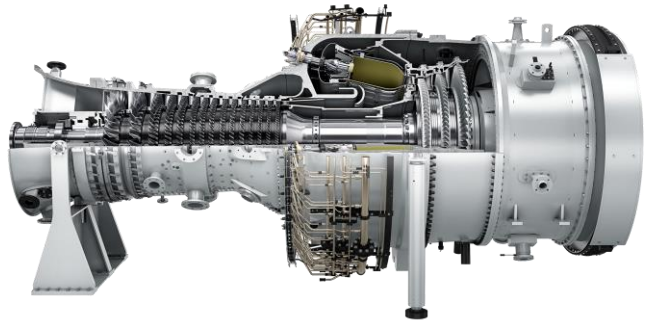
Acceleration through collaboration and partnership

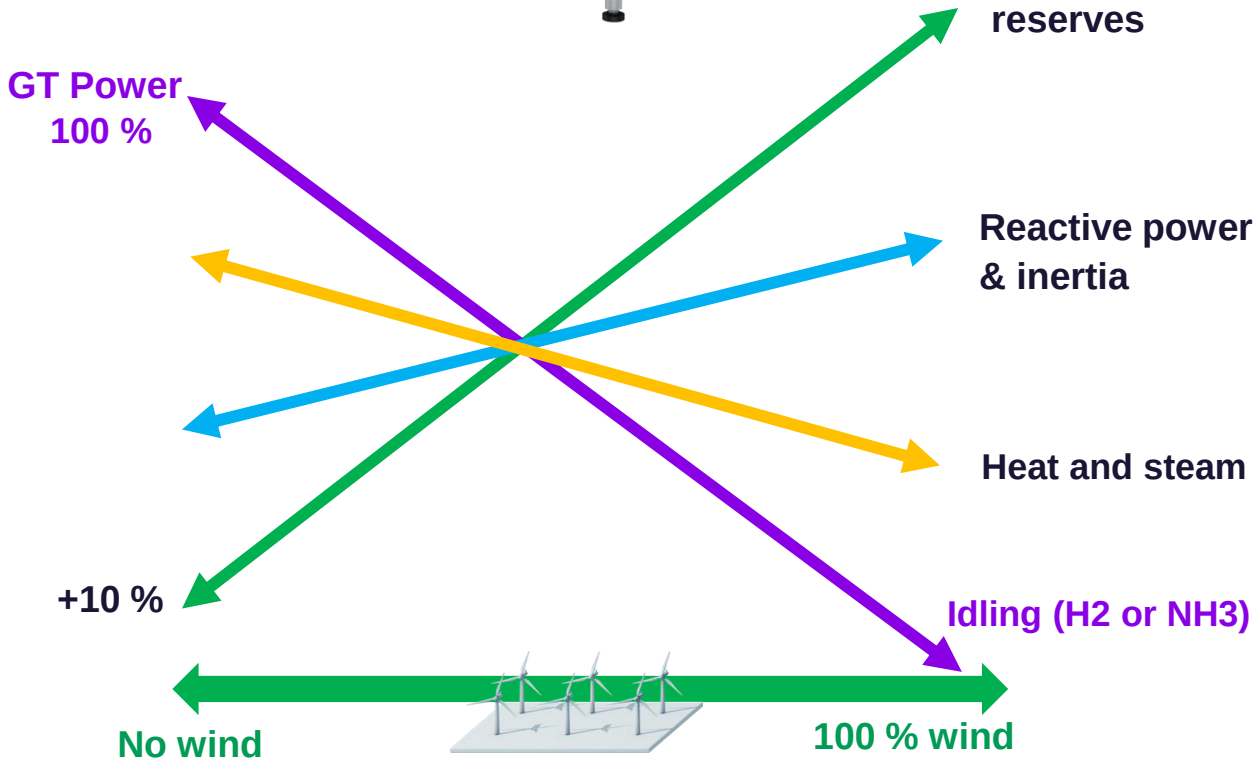
	Current	Near term	Roadmap
Gas phase	H_2 40 – 75% 	H_2 100% (target 2025) SGT-800 / 700 / 600	H_2 100% (latest 2030)
	Biogas		
	50% cracked ammonia[1]	100% cracked ammonia[1]	Ammonia
Liquid phase	Biodiesel HVO100[2] / FT[4]	Methanol FAME[3] (i.e., RME)	Ethanol SAF[5]

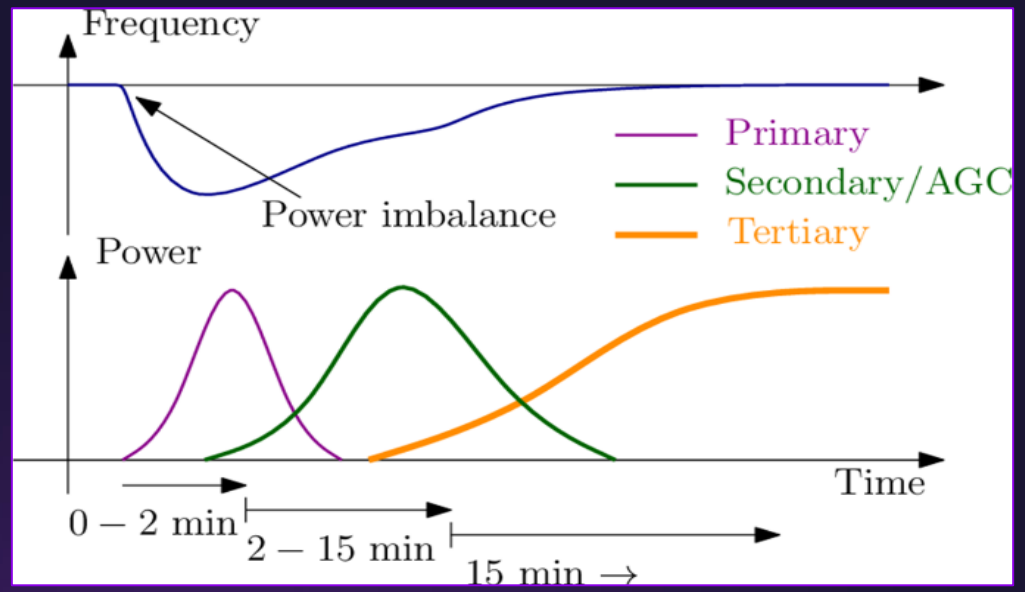
1: Fully cracked (hydrogen/nitrogen mix)
2: HVO = Hydrogenated Vegetable Oil
3: FAME = Fatty Acid Methyl Ester
4: Fischer-Tropsch diesel
5: Sustainable Aviation Fuel

Gas turbines for continuous grid support

Green fuel e.g. H2







Grid services (Svenska kraftnät):

- FFR: Fast Frequency Reserve — very fast
- FCR: Frequency Containment Reserve (D-disturbance, N - normal) — fast, planned
- FRR: Frequency Restoration Reserve (a- automatic, m-manual) — planned

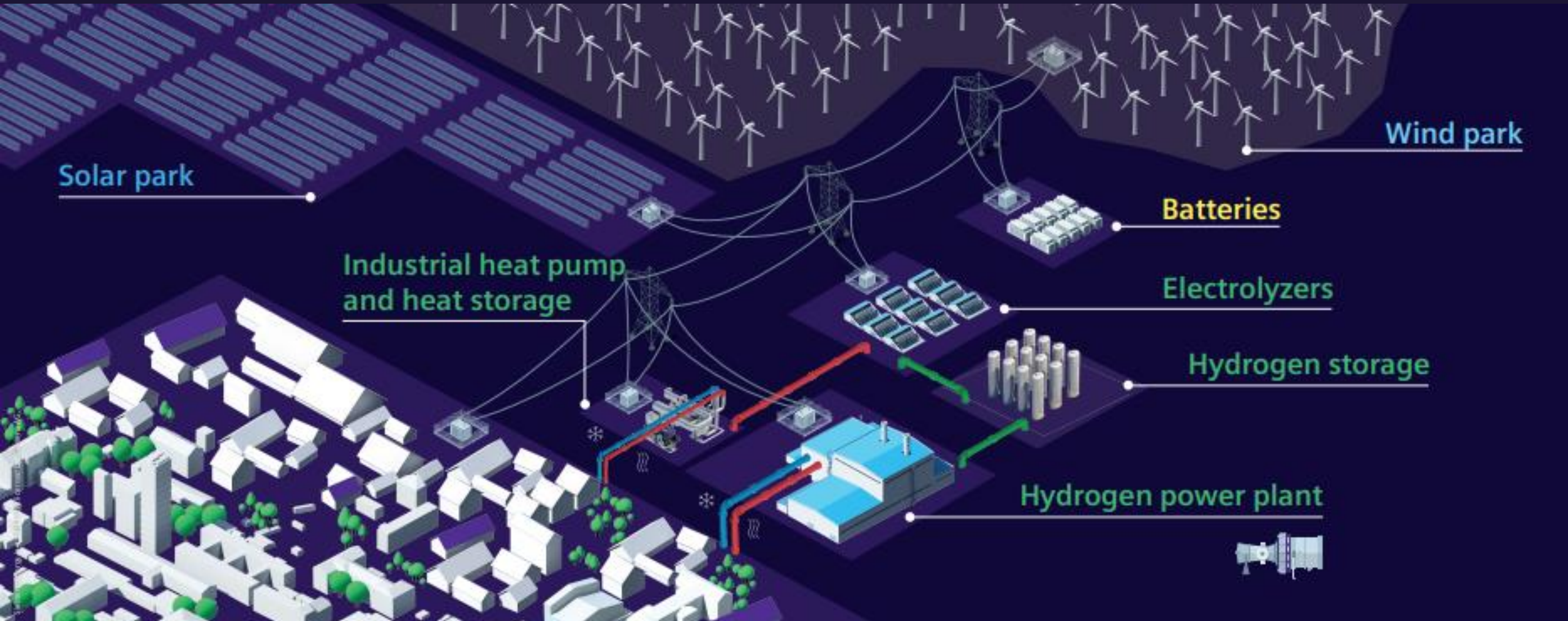
A Net Zero City

100%
fossil-free electricity
plus additional heat and cooling

80%
direct wind and solar

15%
combined cycle
hydrogen power plant

5%
battery

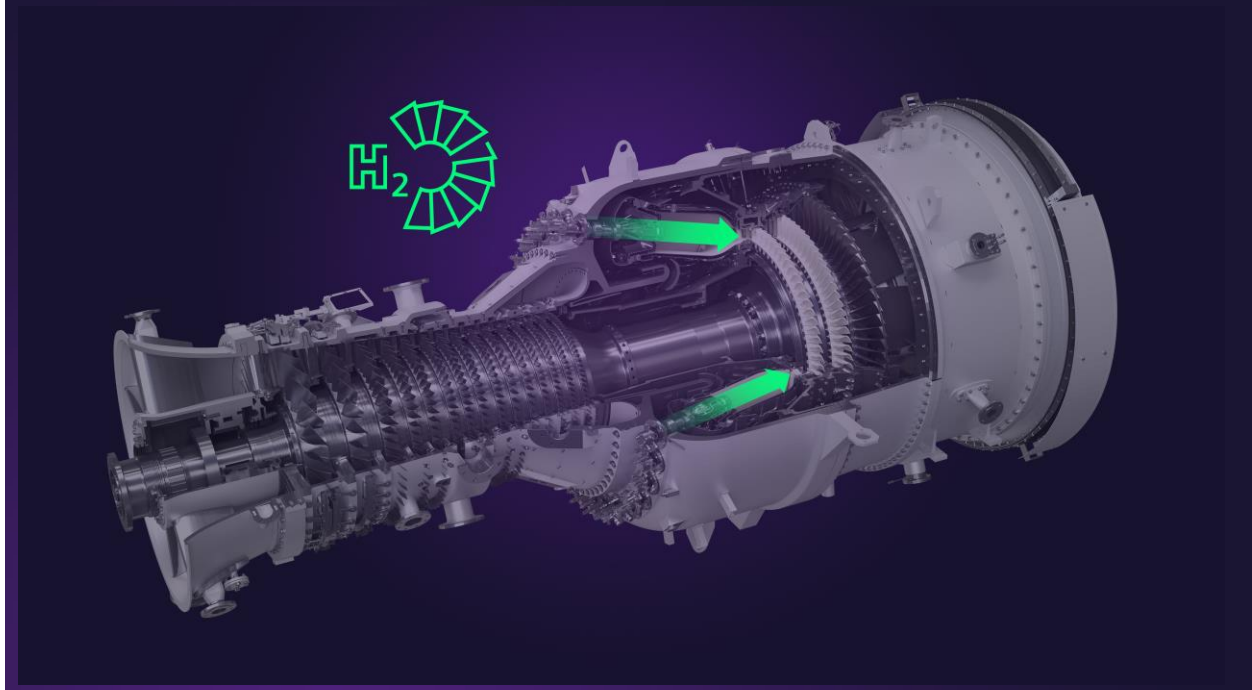


Summary

Gas turbines can be a “Swiss knife” of a sustainable and reliable energy system with

- Fuel flexibility
- Operational flexibility
- Plannable electricity
- Multiple value streams

We have all opportunities to provide hydrogen technology “Made in Sweden” together and accelerate decarbonization globally



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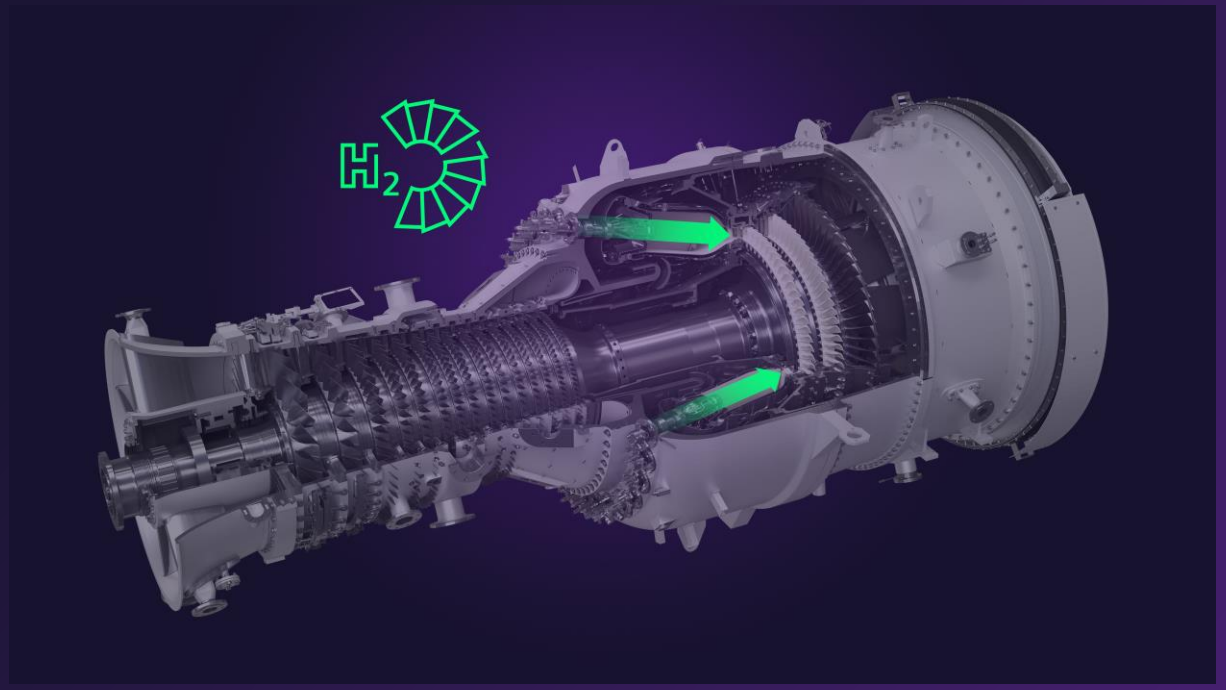

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