Zero Emission Hydrogen Turbine Center

- Hydrogen Gas Turbines in Zero Emission Energy Systems

ERA-Net SES 22-10-19

Welcome

- Todays meeting:
  - Please mute your microphone unless you are asked to by moderator
  - Turn on camera if you are presenting/speaking
  - Write your comments/questions in the chat – moderator will check these if time allows it

Workshop check-in:
- Which sector do you represent?

Write in the chat

Goals for the session

- Learn about:
  - key conclusions from a technical, academic and governance perspective
  - research on hydrogen and energy systems
  - possible scale up scenario of the tested energy system

- Discuss!
  - Challenges ahead
  - Opportunities
  - Possible future

Agenda

- Session start up – Welcome! – 5 min
- Workshop check-in – 5 min
- Hydrogen Demonstration plant – Hydrogen demo plant – Description and key conclusions, Siemens Energy – 10 min
    - Discussion 1 – 10 min
- Hydrogen in the European energy system, Chalmers University - 15 min
    - Discussion 2 - 10 min
- Feedback and closure – 5 min

Overall project targets

1) **Decarbonization contribution of the gas turbine test facility**

2) **Knowledge sharing – Hybrid, P2G, Smart microgrids**

3) **Demonstrating solutions – Flexible power, P2G, storage and smart grids, gas turbines**

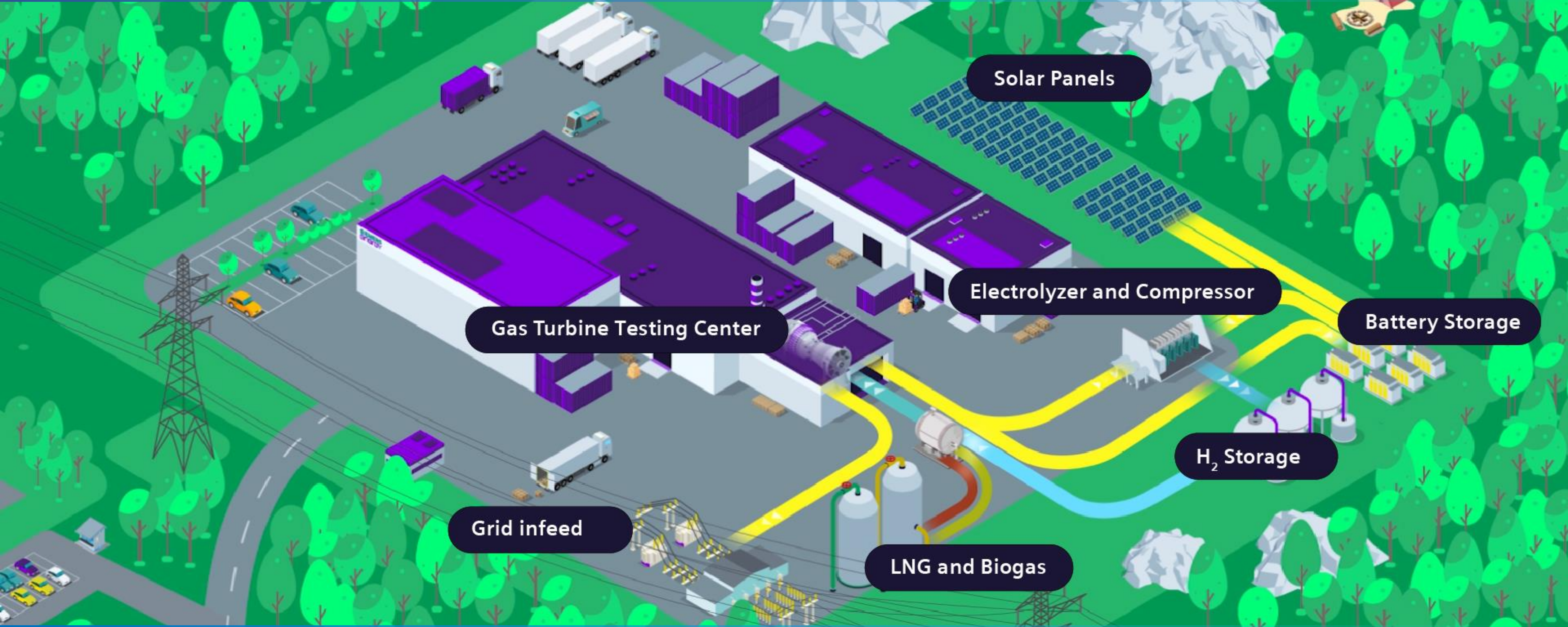
4) **Develop competences – Gas turbines role in a future energy system, P2G, storage, microgrids**

5) **Contribute to the development of a sustainable society regionally, nationally, globally**

Hydrogen Demonstration plant Description and key-conclusions

Siemens Energy

The ZEHTC concept



Electric power   Hydrogen flow   Naturalgas and biogas flow

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ZEH2TC   Swedish Energy Agency   Smart Energy Systems ERA-Net

Turbine testing

Solar PV panels

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Hydrogen production

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Battery and controls

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ZEHTC

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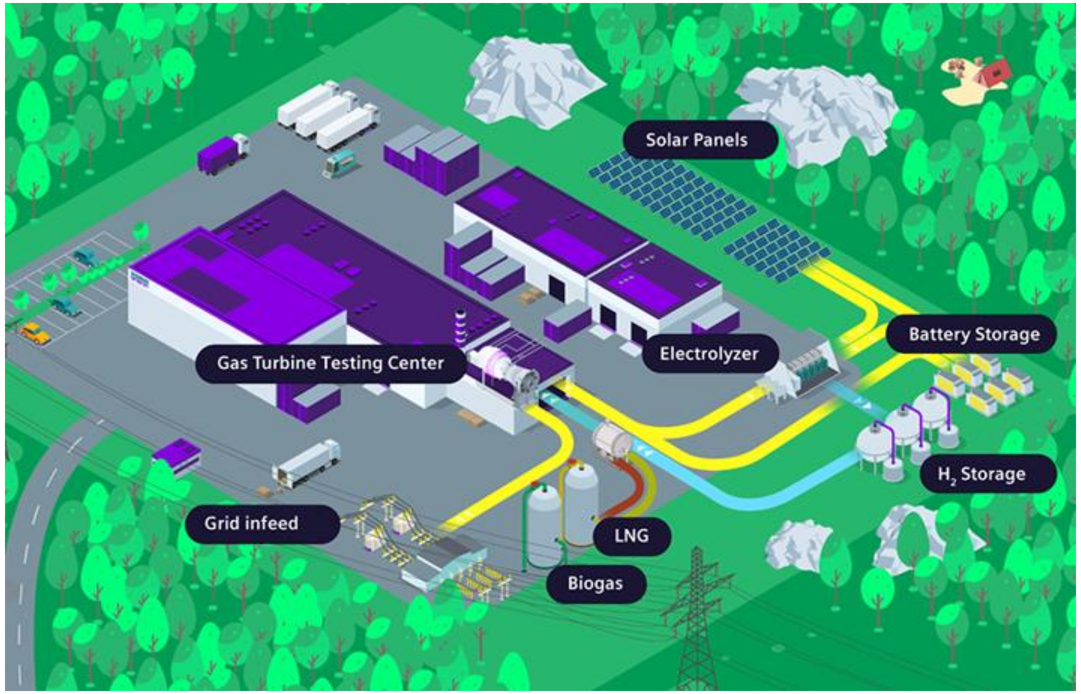
Installations ticker

- Summer/autumn 2020: Civil work
- December 2020: Delivery of hydrogen storage
- January 2021: Installation solar field
- March/April 2021: Delivery compressor & electrolyser
- April – October 2021: Completion & commissioning
- Hand-over to regular operation and testing/evaluation

Key conclusions 1 - design and operation

- Design and build of a hydrogen integrating energy system is well **feasible and demonstrated**.
- The hydrogen production is successfully integrated with the gas turbine test facility where the hydrogen is used as **fuel and an enabler for further R&D**.
- Storage is the limiting part in hydrogen-based systems, but **technology is mature and available**.
- Hydrogen **is well controllable** from a safety perspective but confidence and regulations are still in development and need to be considered early in such projects.



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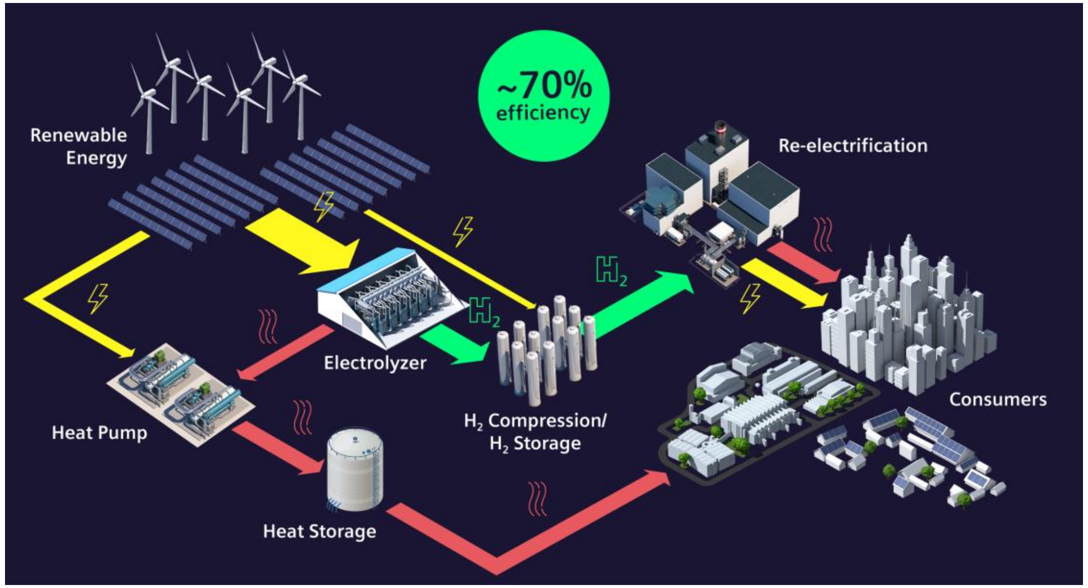
Key conclusions 2 – scale up and market

- The project enables the development of hydrogen offerings and **hydrogen ready concepts**

- The plant is base for **scale up** design of future energy systems

- Increased focus **on other green fuels** including liquid - Bio-fuel (biogas, biodiesel) and e- fuels (ammonia, methanol) are beneficial to complement hydrogen.

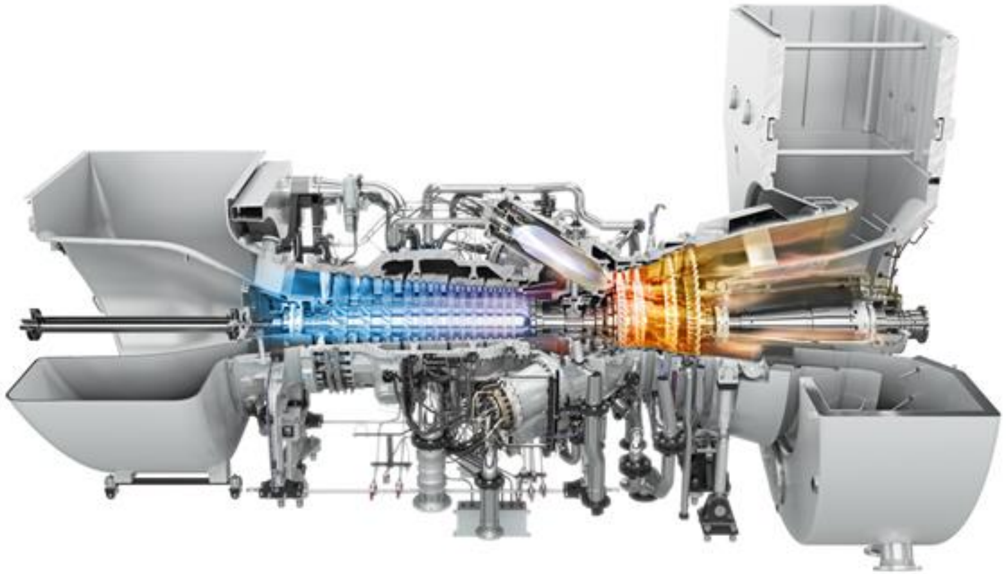
- Fuel diversity improves availability of green fuels and storage capability for **long duration storage**.



A possible energy system © Siemens Energy, 2022

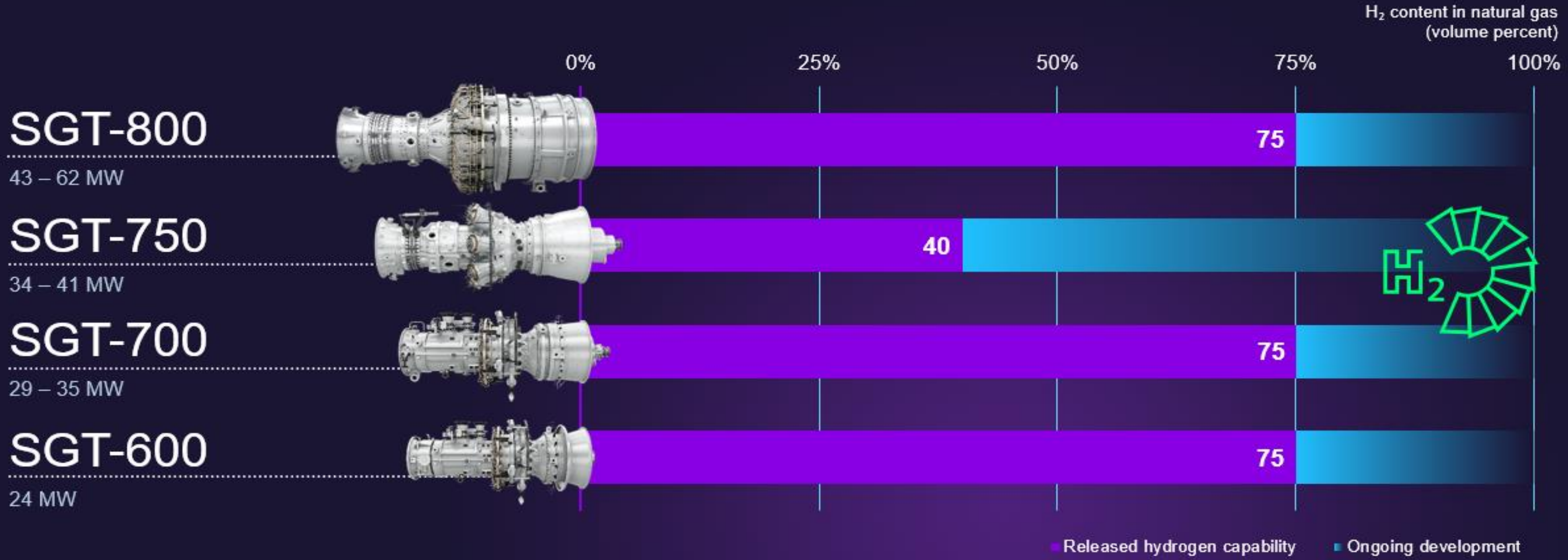
Key conclusions 3- knowledge sharing

- Very valuable **learning interaction** both internally and with customers, projects, stakeholders - several visitors every week
- Better understanding of hydrogen **re-electrification** system and the role of gas turbines to complement renewables helps dialogues in energy community.
- The plant is driving the energy community and Siemens Energy to accelerate and clarify the way forward for hydrogen driven turbines - sharpened roadmap for hydrogen readiness – **100% H2 in 2025**



Gas turbine SGT-750 © Siemens Energy, 2022

Hydrogen capability in Siemens Energy medium size gas turbines
targeting 100% latest 2025



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

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Discussion 1
Questions to consortium panel

Hydrogen in the European energy system

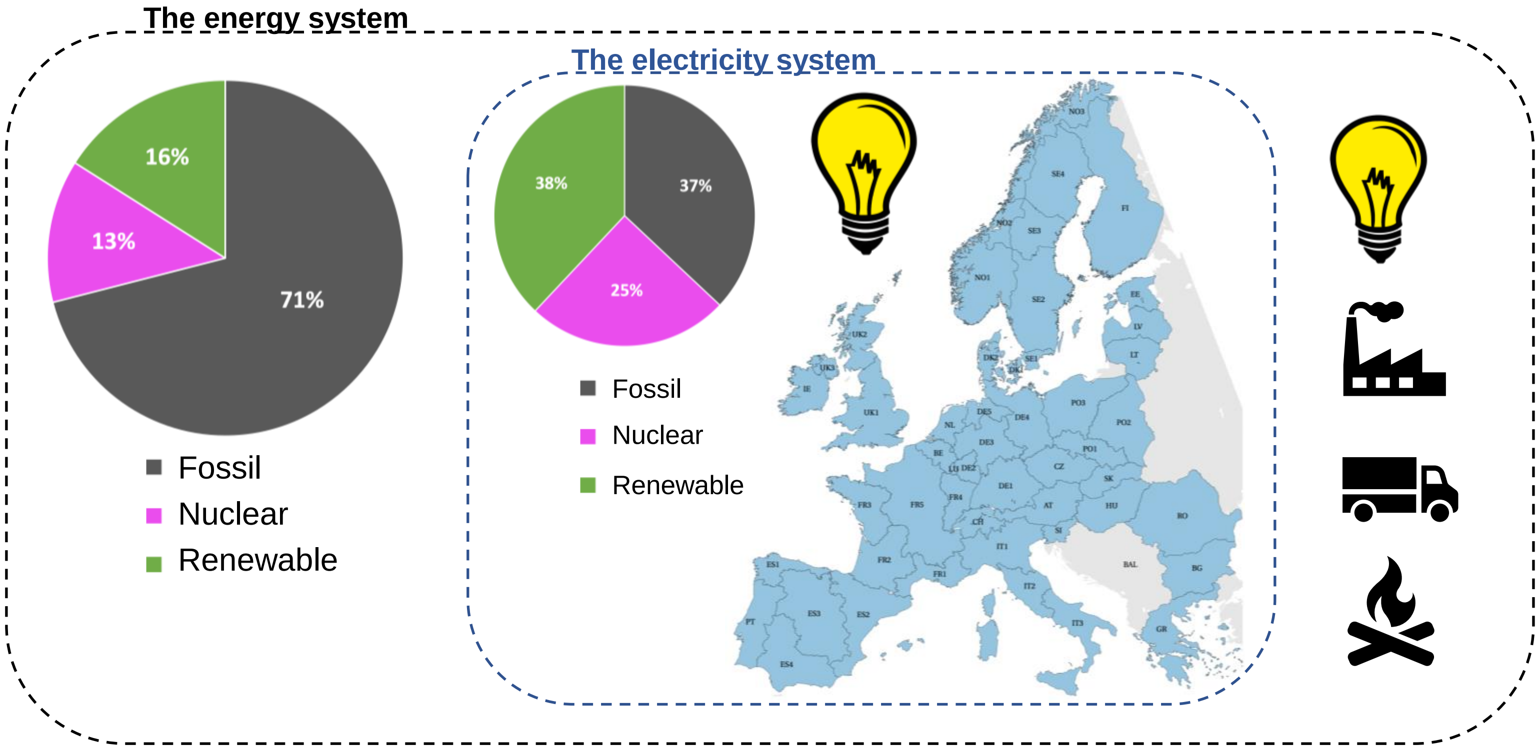
Chalmers University of Technology – Simon Öberg

CHALMERS
UNIVERSITY OF TECHNOLOGY

Swedish Energy Agency

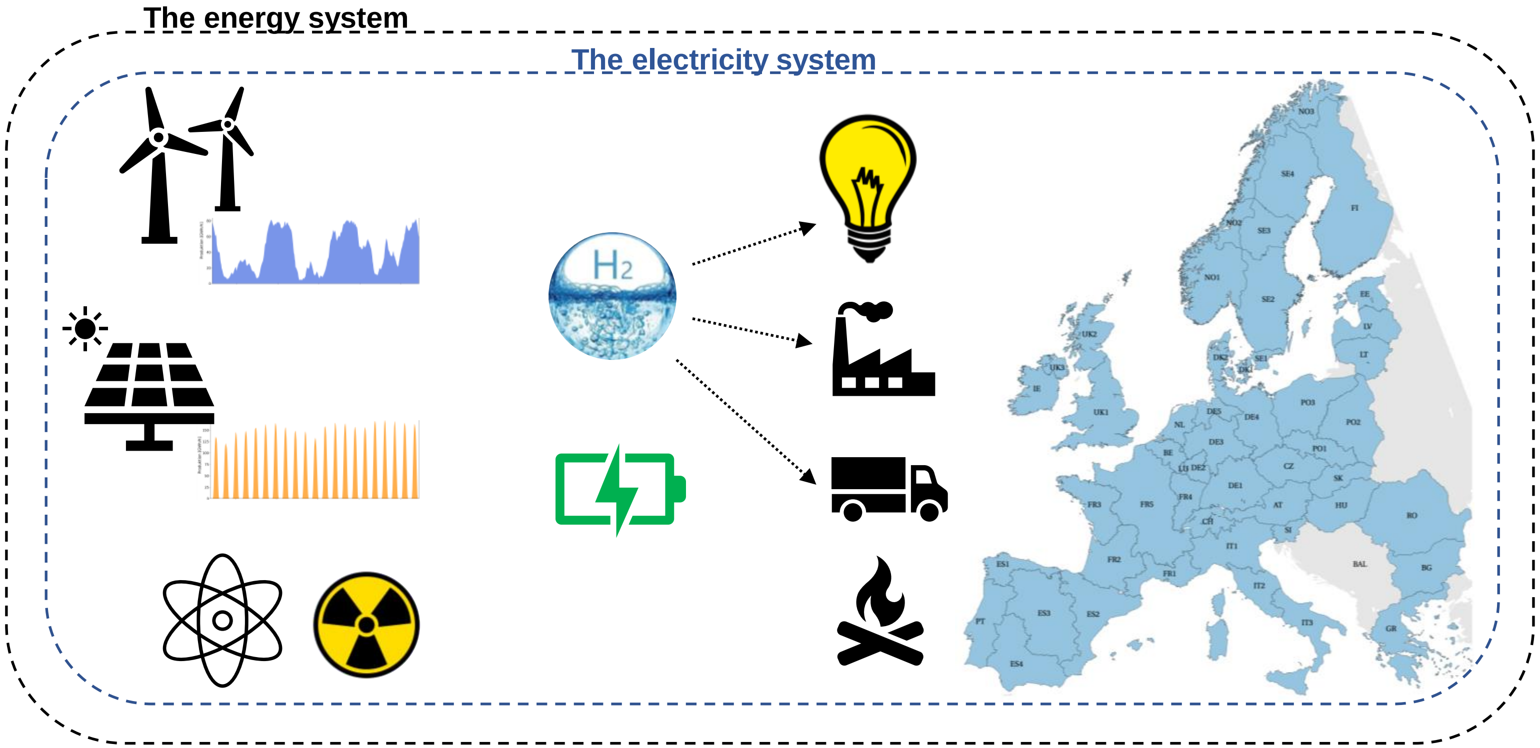
Smart Energy Systems ERA-Net

Background



The energy system
The electricity system
16%
13%
71%
Fossil
Nuclear
Renewable
38%
37%
25%
Fossil
Nuclear
Renewable

Background

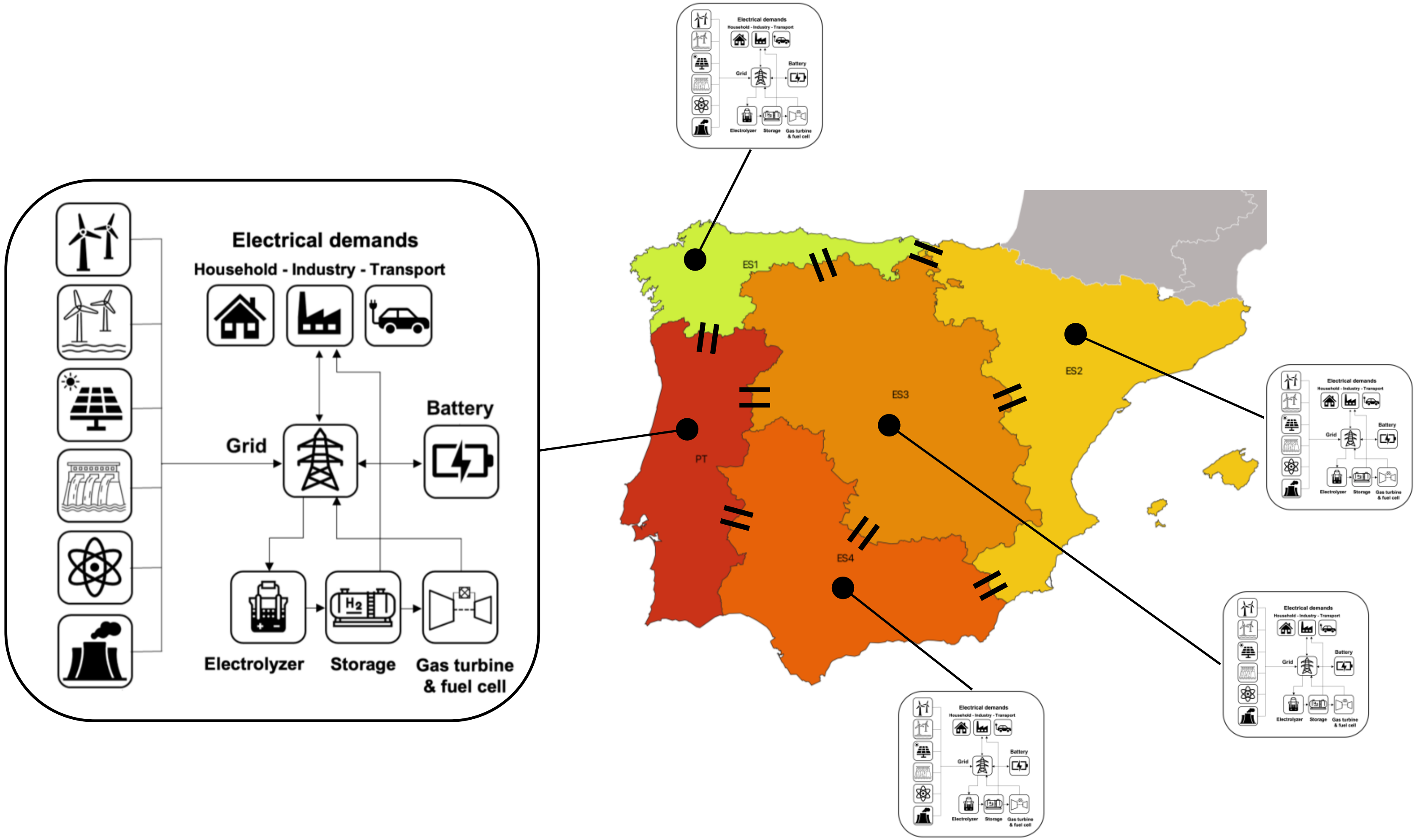


Modelling

- Investments in technologies
- Dispatch of generation (and storage)
- Minimizing the total system cost

Subjected to:

- Energy balance
- Emission limitations
- Potential for wind and solar PV
- Weather data for wind och solar
- Cost structure for technologies
- Ramp-rates for thermal processes



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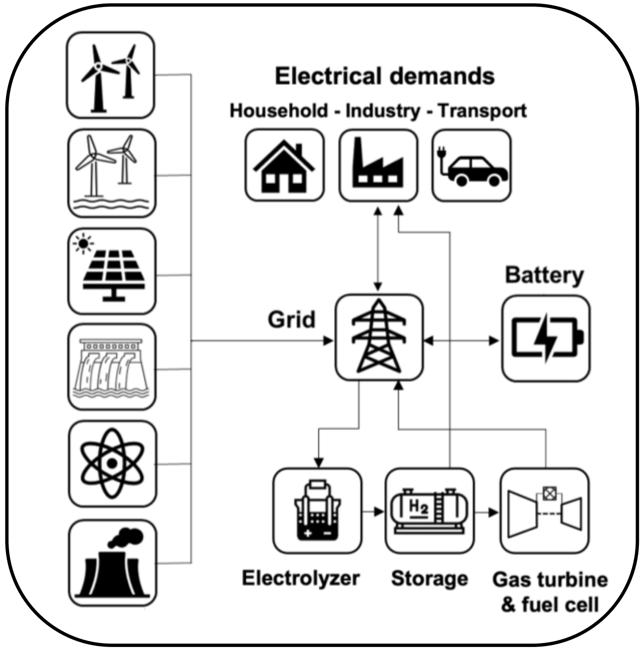
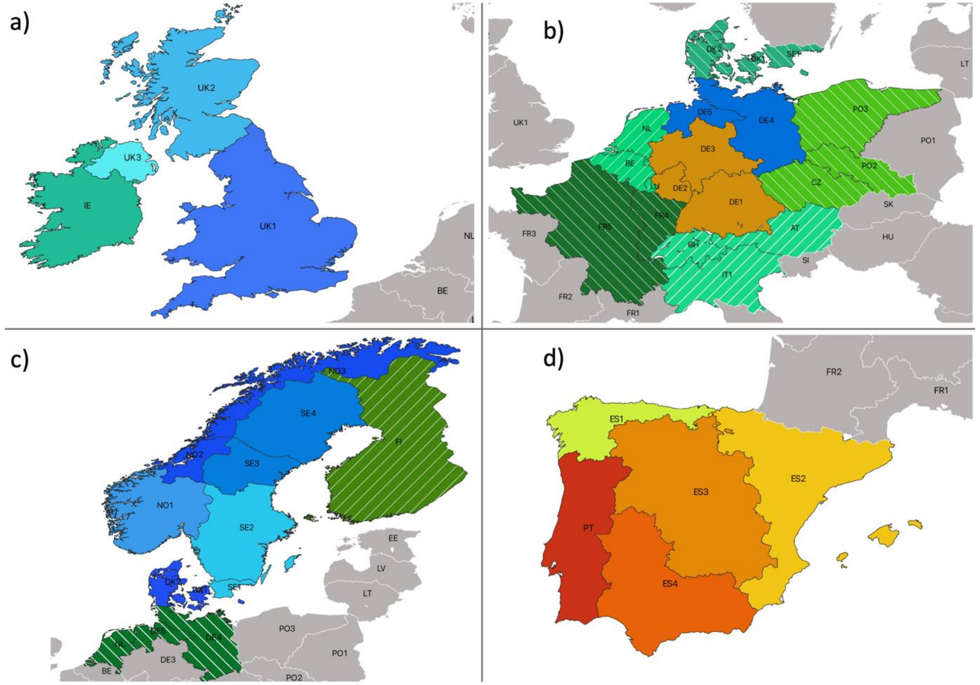
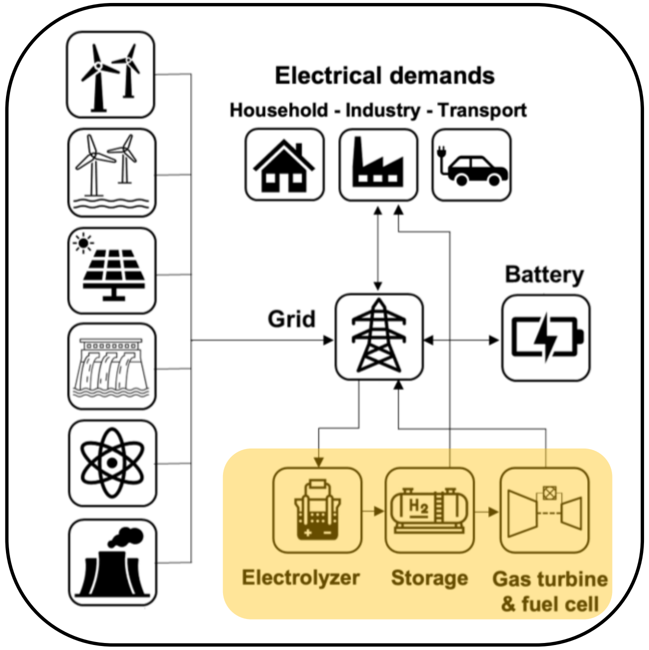
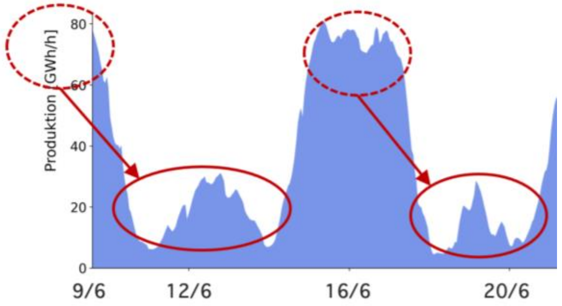


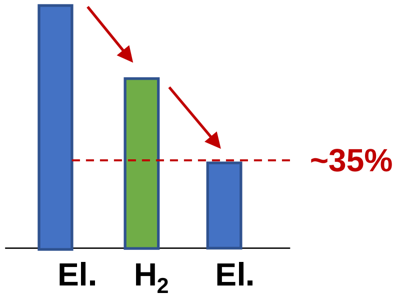


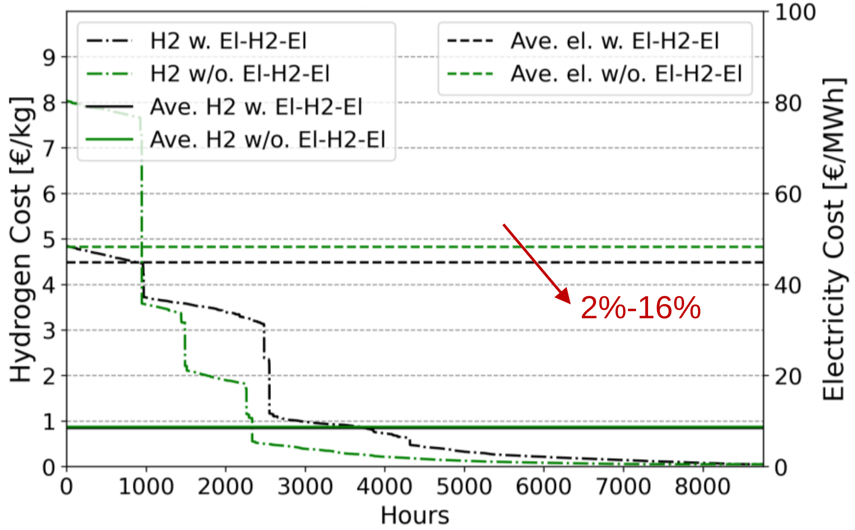
Time-shifting of generation

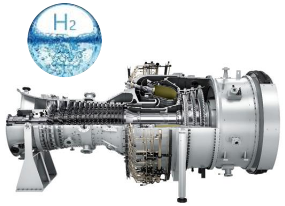


Wind power



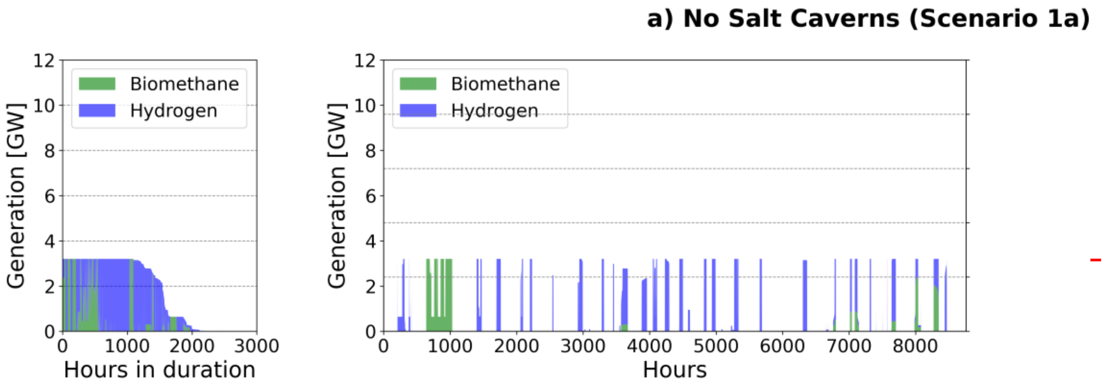




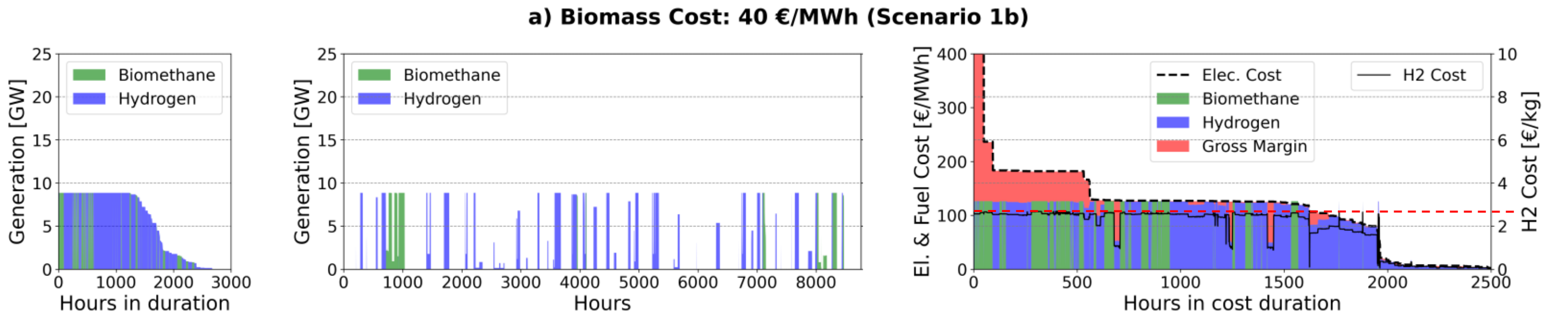


Combined Cycle Gas Turbine
with flexible mixing up to 100% H_2.

Hydrogen-fueled gas turbines



Hydrogen-fueled gas turbines

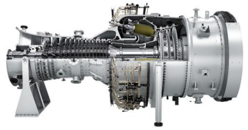


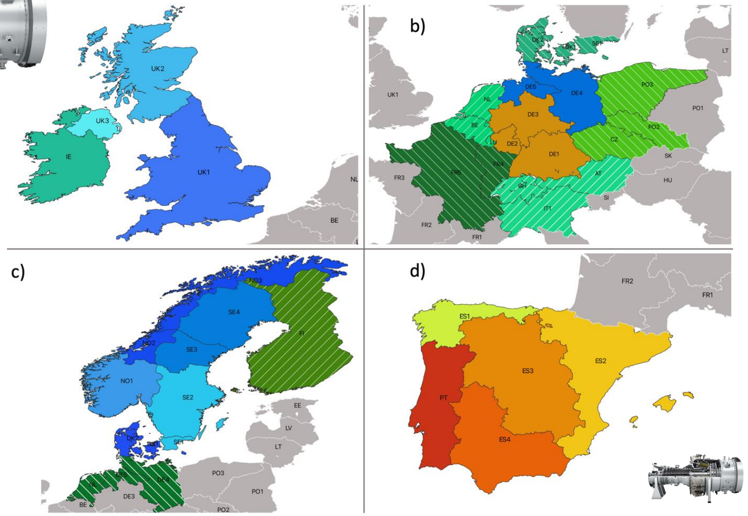
$2.5 \times H_{2,\text{average-cost}}$

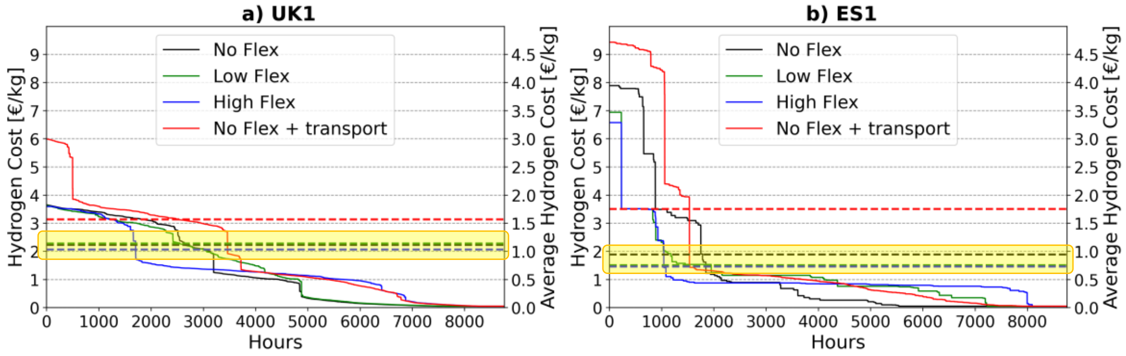
$3.5 \times H_{2,\text{average-cost}}$

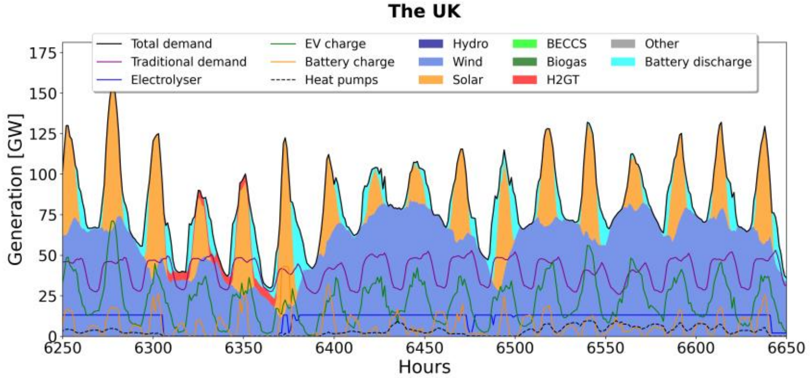
$\sim 5 \times H_{2,\text{average-cost}}$

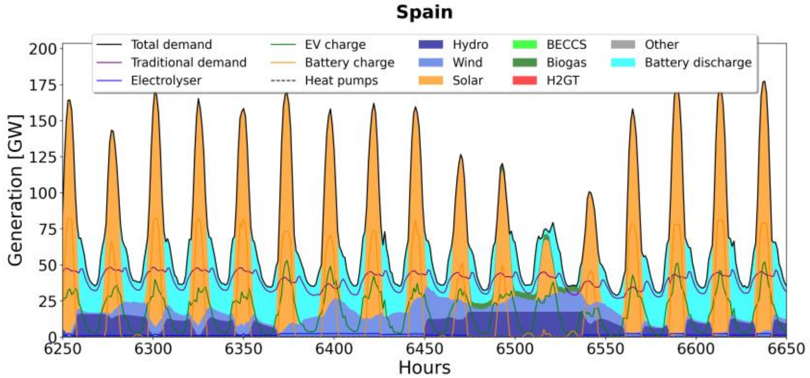
Competitiveness of hydrogen gas turbines



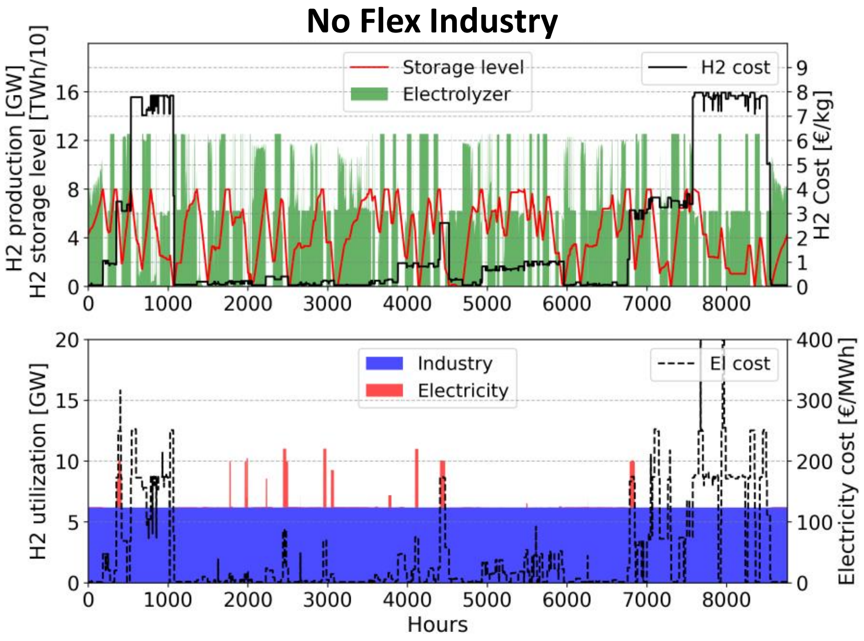


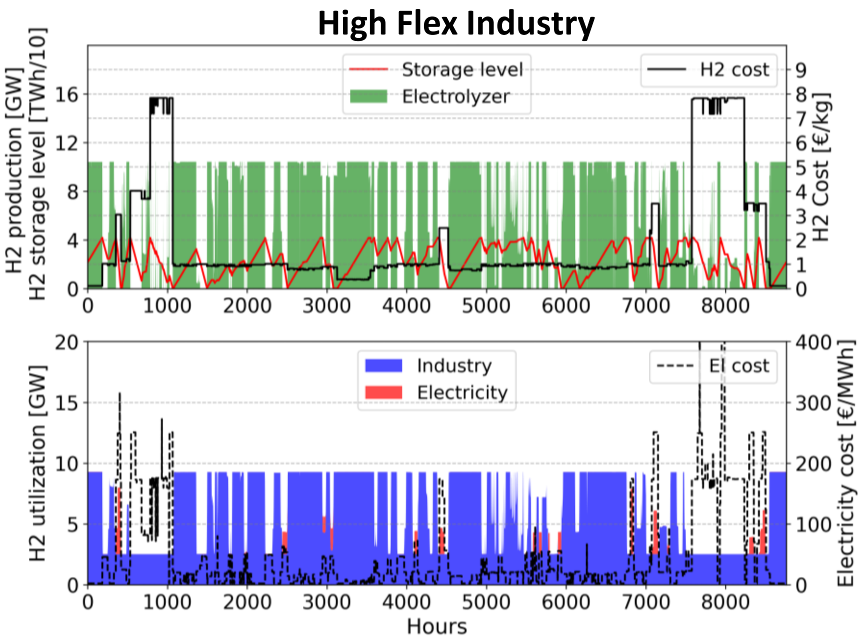






The cost of hydrogen



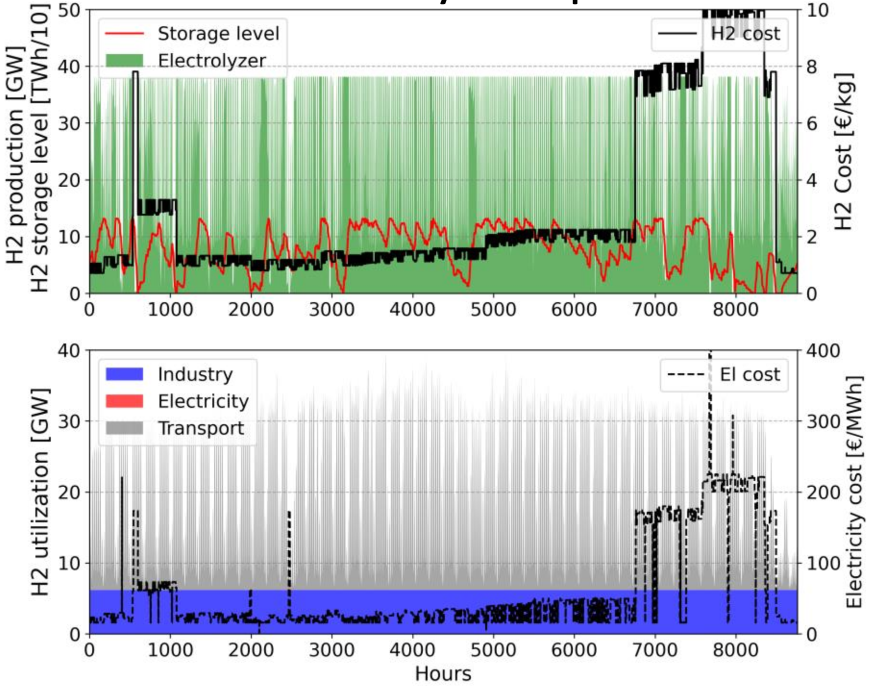


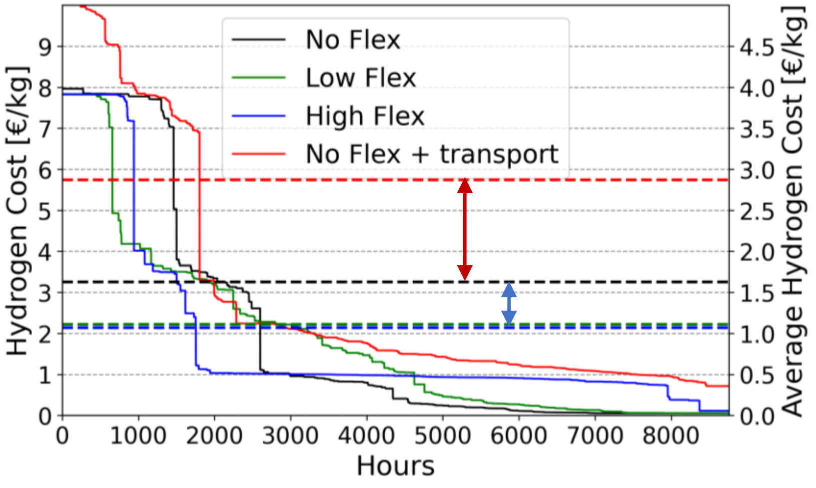
Parameters influencing the cost of hydrogen:

- The cost of electricity.
- The cost-optimal electrolyzer capacity.
- The cost-optimal hydrogen storage capacity.
- The alternative cost of changing the industrial production in time.

The cost of hydrogen

No Flex Industry + Transport





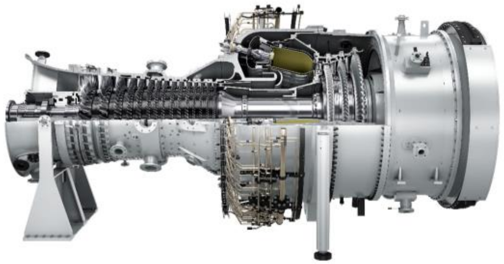
Parameters influencing the cost of hydrogen:

- The cost of electricity.
- The cost-optimal electrolyzer capacity.
- The cost-optimal hydrogen storage capacity.
- The alternative cost of changing the industrial production in time.
- The characteristics of the hydrogen demand profile.

Conclusion

- Hydrogen-fueled gas turbines are most competitive in electricity systems with **high shares of wind power**.
- **Flexible mixing** of hydrogen is an important factor as the investment cost can be recovered also when the marginal cost of hydrogen is too high to generate a gross margin.
- The **willingness-to-pay** for hydrogen:
    - Under the assumptions given, the maximum willingness-to-pay for hydrogen is $\mathbf{5 \times H_{2,average\text{-}cost}}$.
    - Significant amounts of hydrogen are used in gas turbines at a cost of $\mathbf{3\text{–}4 \times H_{2,average\text{-}cost}}$.
    - The largest impact on the willingness-to-pay comes from the **cost of biomass** (used to produce biomethane).
- The cost of hydrogen is **highly dynamic** and influenced by several parameters, where e.g., the hydrogen demand profile has a considerable impact.

Paper I:	*Exploring the competitiveness of **hydrogen-fueled gas turbines** in future energy systems.*
Paper II:	*The value of **flexible fuel mixing** in hydrogen-fueled gas turbines – a techno-economic study.*
Paper III:	*The **cost dynamics** of hydrogen supply in future energy systems – a techno-economic study.*
Paper IV:	*How do **inter-annual weather variations** impact the competitiveness of hydrogen-fueled gas turbines?*



Discussion 2
Questions to consortium panel

Feedback and closure

Thank you for your attention!

Facts sheet

ZEHTC

01	PEM Electrolyzer 225 kW	47 Nm^3/h hydrogen production capacity @nominal operation, which would give about 100 kg per day in full time operation
02	Diaphragm compressor 15,5 kW	Compress the hydrogen from 30 bar to 200 bar
03	Hydrogen Storage	24,000 liter @200 bar, which is about 360 kg
04	Battery	75 kW / 76 kWh – enables island operation of the system (decoupled from external electricity grid)
05	Solar Panels	133kW peak (DC); 100 kW (AC); about 1500 m^2 ground area
06	Gas turbine operation @15 % vol Hydrogen	One hour of full load test operation consumes about 150 kg hydrogen and saves 360 kg fuel gas and about 1 ton $C0_2$ emissions (based on 30-35MWel gas turbine)

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