Siemens – Hydrogen and Power to X

RQEI Online Seminar

August 26th, 2020

Agenda

1	Hydrogen Introduction	Chris Norris
2	Siemens Electrolyzers	Omar Rubio
3	Reelectrification in Gas Turbines	Dr. Vinayaka Nakul Prasad
4	Wrap-Up and Q&A	Chris Norris

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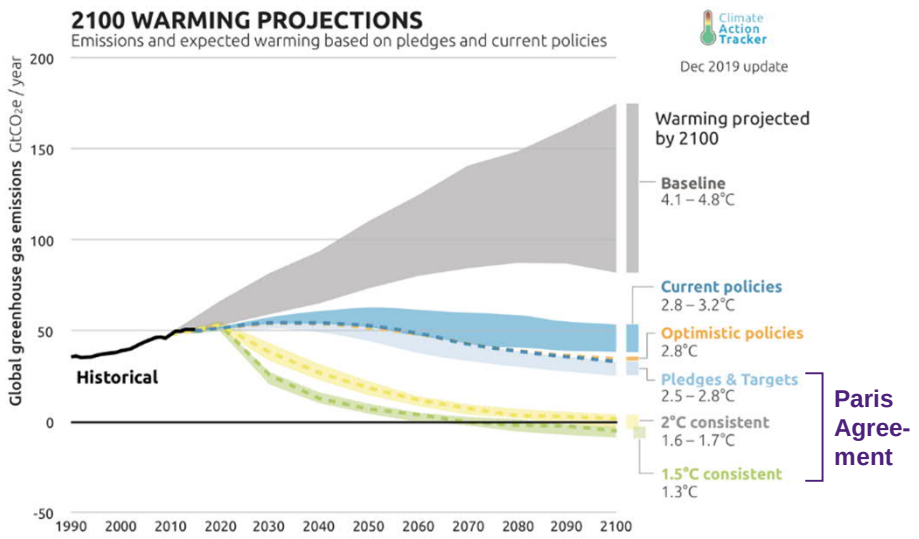
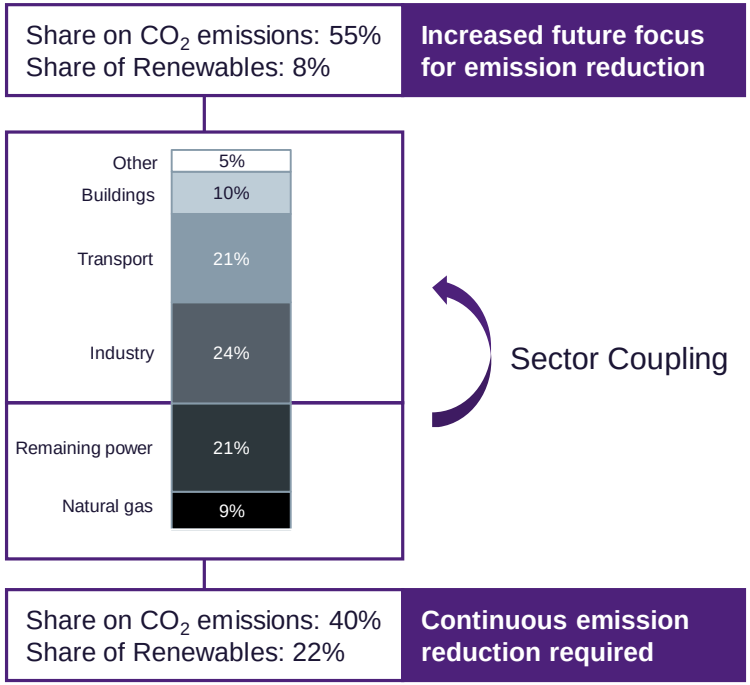
CO_2 emissions reduction has so far been focused on power, but all sectors in economy must contribute

Global CO_2 emissions and projections



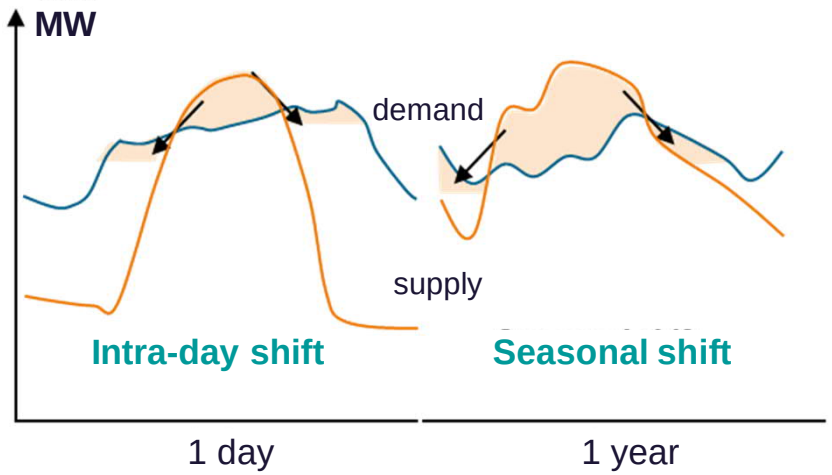
Shares in global CO_2 emissions by sectors



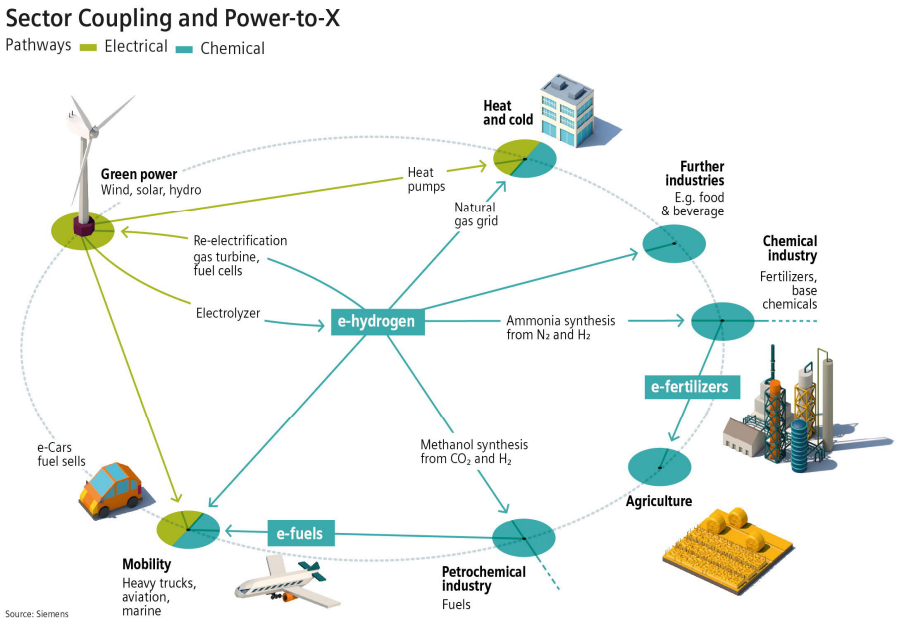
Hydrogen solves two problems – time-shifting of energy and feedstock for chemical processes

SIEMENS energy

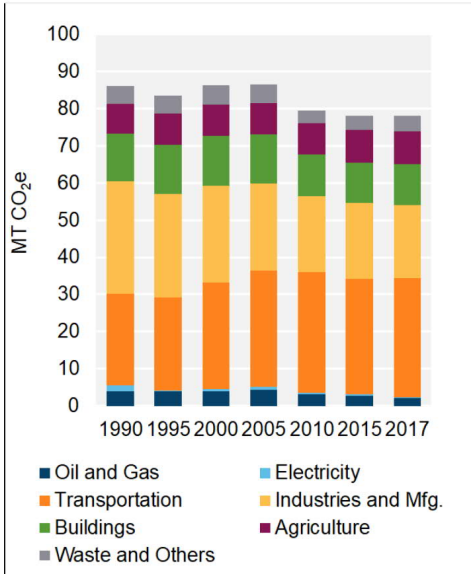
Hydrogen can time-shift energy…

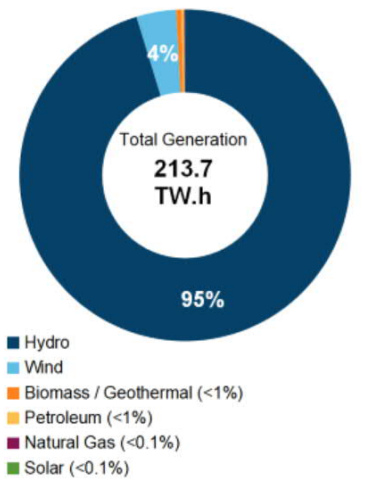


… and use this stored energy to displace carbon-intensive hydrogen in chemical and other processes

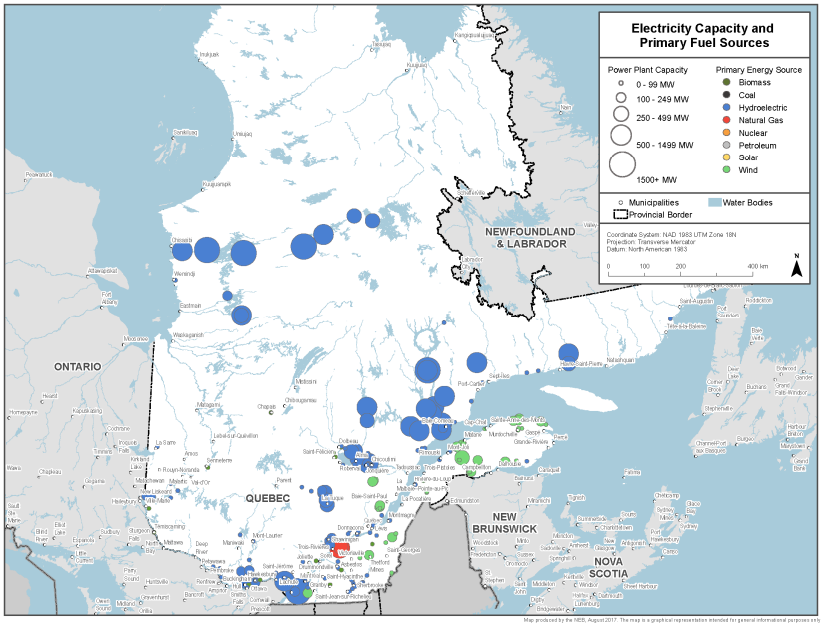


Québec is well poised to be a key player in the green hydrogen space



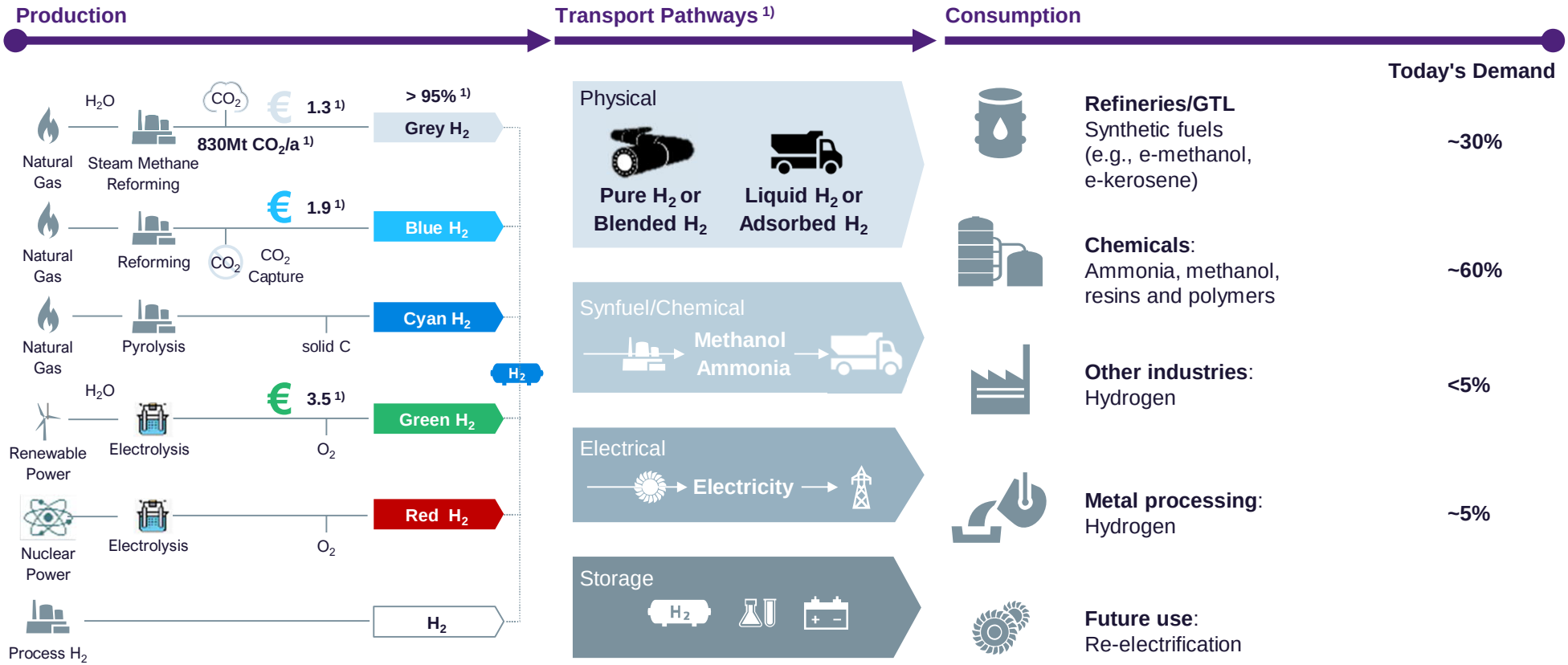


Installed capacity of 36.9 GW



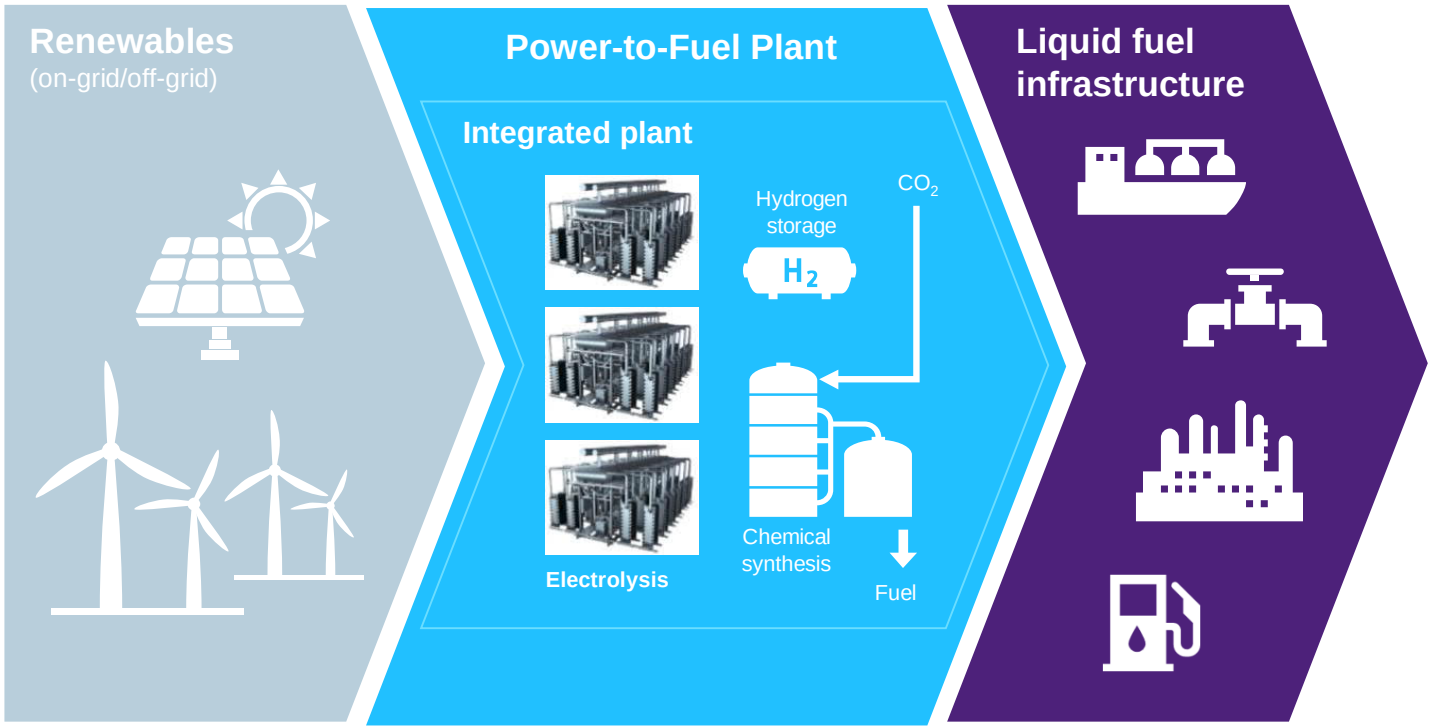
https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/qc-eng.html?=undefined&wbdisable=true
https://www.hydroquebec.com/generation/

Hydrogen economy will support CO2 reduction… depending on legislation and emergence of scalable solutions



1) Source: IEA (2019) – average hydrogen cost today

Power-to-Fuel plants as missing link for electricity based fuels and utilization of existing liquid fuel infrastructure



200 MW wind farm 560 GWh_{el}

280 GWh green fuel

Air traffic
App. 9 Mio. Km air mileage = fleet with 6 planes for one year

OR

Road transport
App. 85 Mio. km road mileage = fleet with 2,000 trucks for one year

OR

Heating
25,000 flats in existing buildings (150 kWh/m²/a, 80 m²) for one year

Numbers derived from own assumptions

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Silyzer portfolio scales up by factor 10 every 4-5 years driven by market demand and co-developed with our customers

Silyzer portfolio roadmap

0.1 MW → 1 MW → 10 MW → 100 MW → 1000 MW

2011

Silyzer 100
Lab-scale demo
~4.500 OH[1],
~150k Nm³ of H_2

2015

Silyzer 200
~86.500 OH [1)]
~7.3 mil. Nm³ of H_2

World's largest Power-to-Gas plants with PEM electrolyzers in 2015 and 2017 built by Siemens!

2018

Silyzer 300

Biggest PEM cell in the world built by Siemens!

2023+

Next generation
Under development

2030+

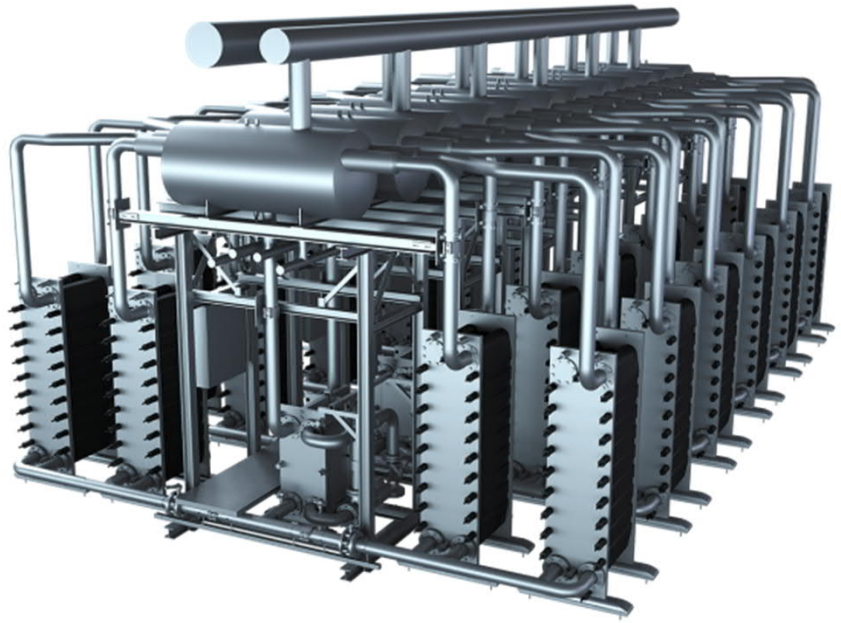
First investigations in cooperation with chemical industry

1) Operating Hours; Data OH & Nm³ as of Dec 2019

Silyzer 300
The next paradigm in PEM electrolysis

17.5 MW	Power demand per full Module Array (24 modules)
75%	System efficiency[1] (higher heating value)
24 modules	To build a full Module Array
340 kg	Hydrogen per hour per full Module Array (24 modules)

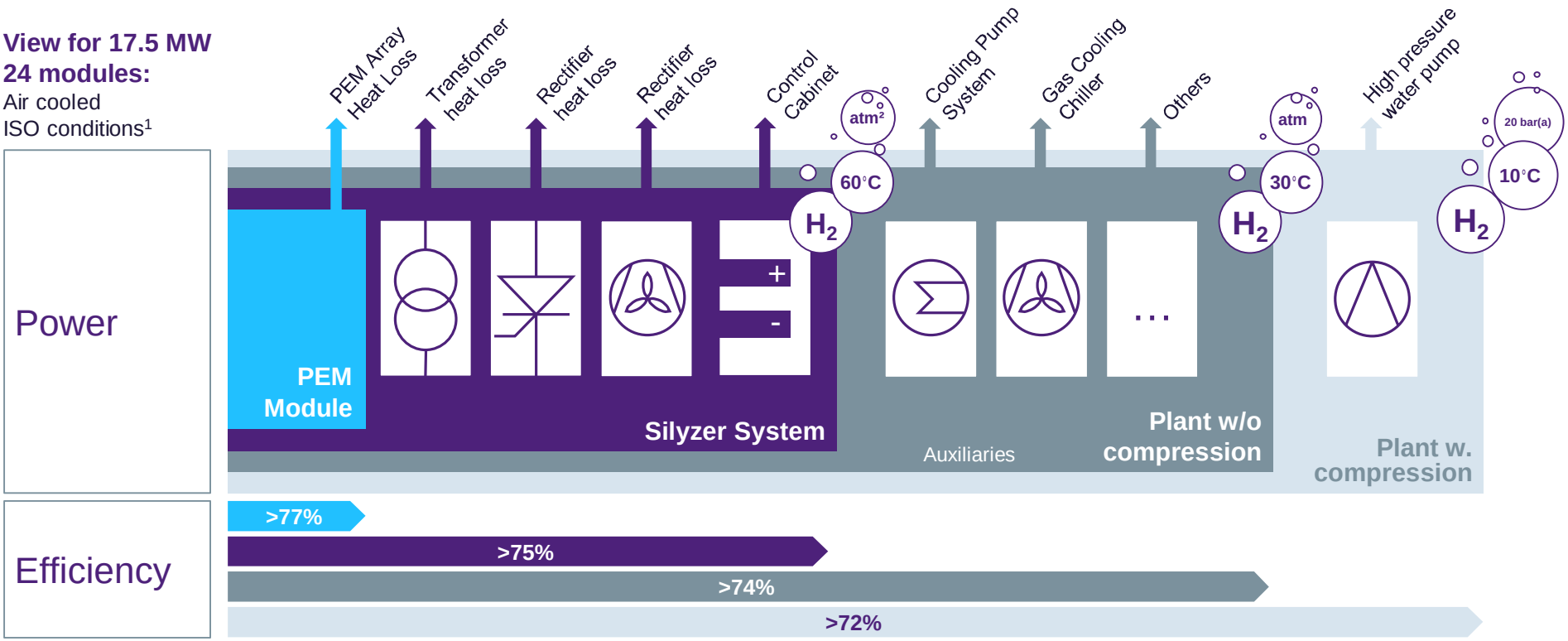
Silyzer 300
Module Array (24 modules)



1 Ambient temperature 15° C, air cooled

With the Silyzer 300 you get a highly efficient plant

View for 17.5 MW
24 modules:
Air cooled
ISO conditions[1]

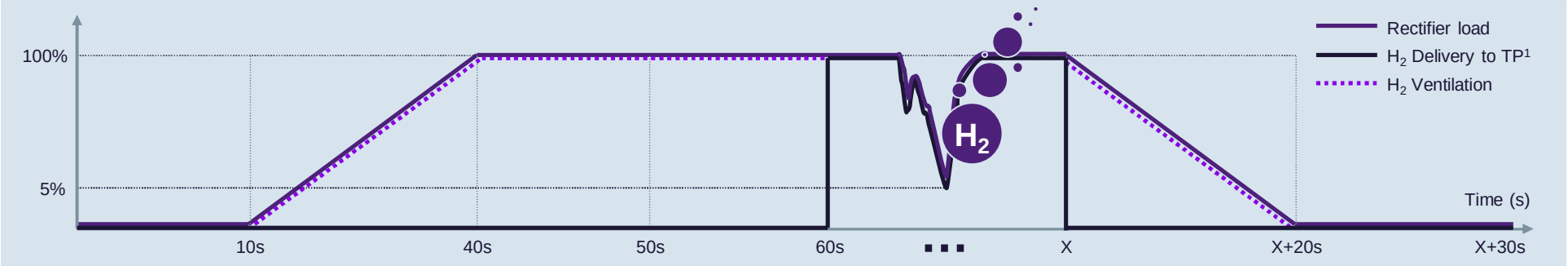


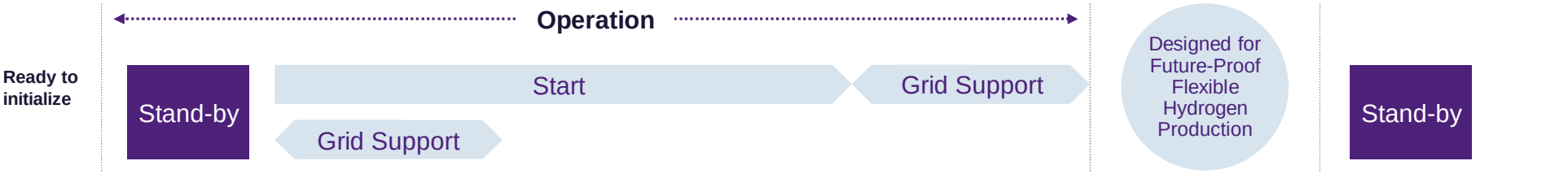
! Cooling system site specific optimized

1 ISO conditions: 15° C, 1013 mbar, 0 m, 60% rel. humidity | **2** Atmospheric

The Silyzer 300 enables grid support services with efficient hydrogen yield and maximum dynamics

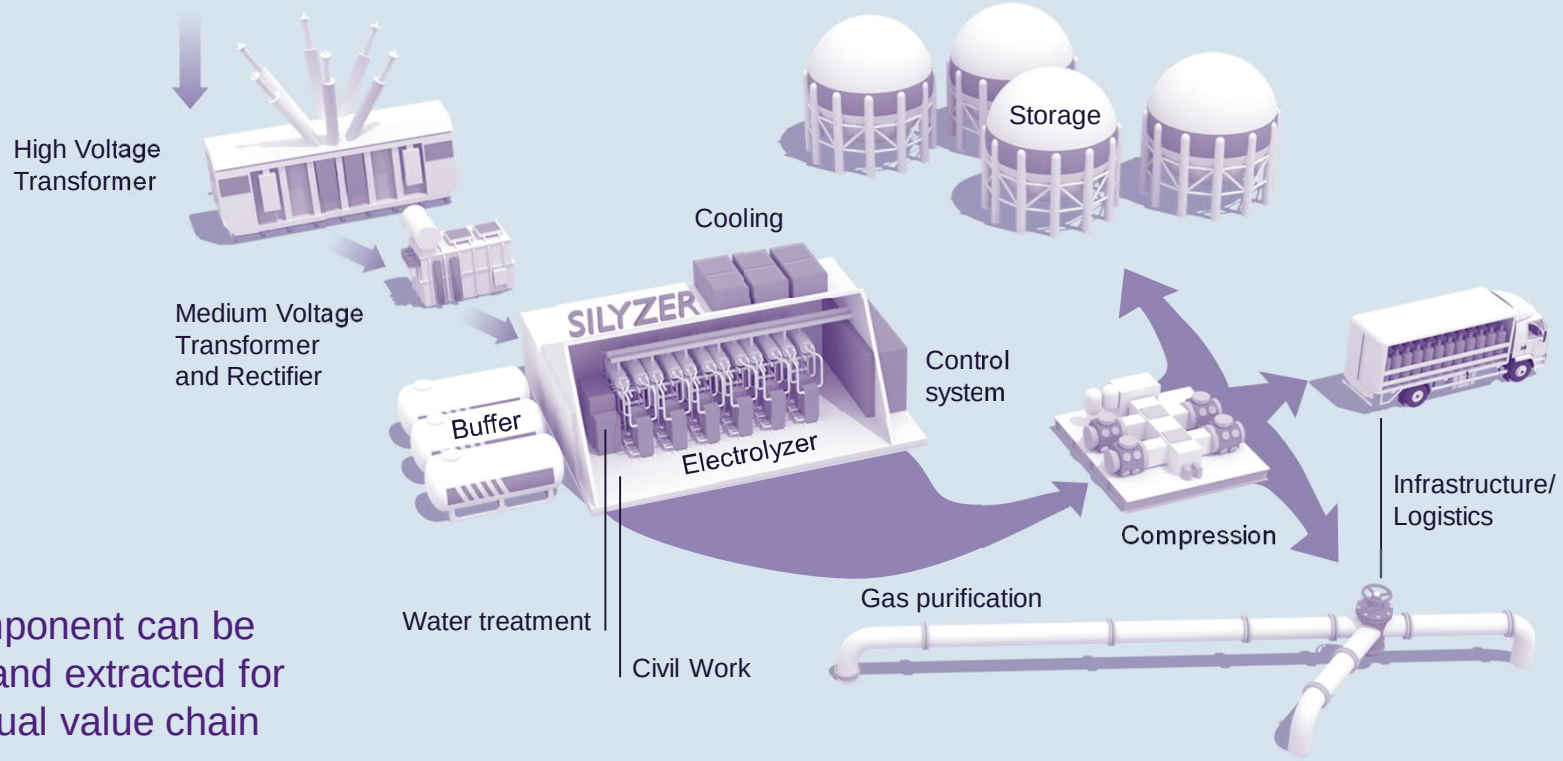
	Start 0 – 100% H_2	<1 min, enabled grid support
	Dynamics in range	10%/s in range 0 – 100%





1 Terminal Point

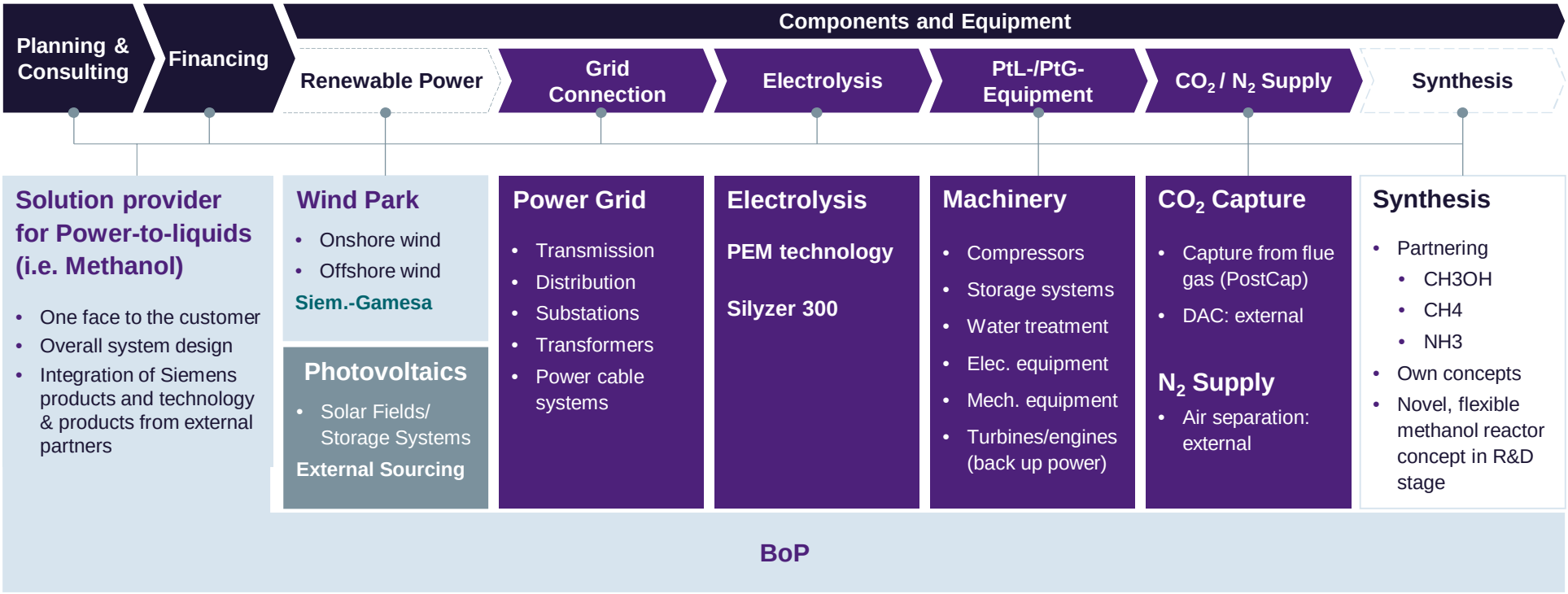
Hydrogen generation
More than just an electrolyzer



Each component can be selected and extracted for an individual value chain

What can Siemens offer to the P2X customers?
Siemens competence along the value chain

Siemens covers important parts of the value chain to deliver Power-to-X projects on turnkey basis



DAC: Direct air capture: Under development; no Siemens activities **| CCU:** Carbon Capture and Utilization **|** typical share in value addition

Energiepark Mainz
World’s largest PEM electrolysis facility in 2015

3.75 MW

Power demand/6.0 MW peak power (limited in time) based on three Silyzer 200

Project

- Customer: Energiepark Mainz (JV of Linde and Mainzer Stadtwerke)
- Country: Germany
- Installed: 2015
- Product: Silyzer 200

Use cases

Green hydrogen is fed into the local natural gas grid

Delivery to surrounding industrial companies

Hydrogen for regional filling stations

Challenge

- Installation of world’s first PEM electrolysis plant in the multiple megawatt range
- Provision of balancing energy
- High degree of automation

Solutions

- Installation of three Silyzer 200 with a maximum power consumption of 6 MW
- Highly dynamic power consumption
- State-of-the-art process control technology based on SIMATIC PCS 7
- Hydrogen processing, condensing, and storage (provided by Linde)

H2FUTURE

A European Flagship project for generation and use of green hydrogen

Project

- Partner: VERBUND (coordination), voestalpine, Austrian Power Grid (APG), TNO, K1-MET
- Country: Austria
- Installed: 2019
- Product: Silyzer 300

Use cases

- Hydrogen for the steel making process
- Supply grid services

Challenge

- Potential for “breakthrough” steelmaking technologies which replace carbon by green hydrogen as basis for further upscaling to industrial dimensions
- Installation and integration into an existing coke oven gas pipeline at the steel plant
- High electrolysis system efficiency of 80%

Solutions

- Operation of a 12-module array Silyzer 300
- Highly dynamic power consumption – enabling grid services
- State-of-the-art process control technology based on SIMATIC PCS 7

6 MW

Power demand based on Silyzer 300

1,200 Nm^3

of green hydrogen per hour

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735503. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovative programme and Hydrogen Europe and NERGHY

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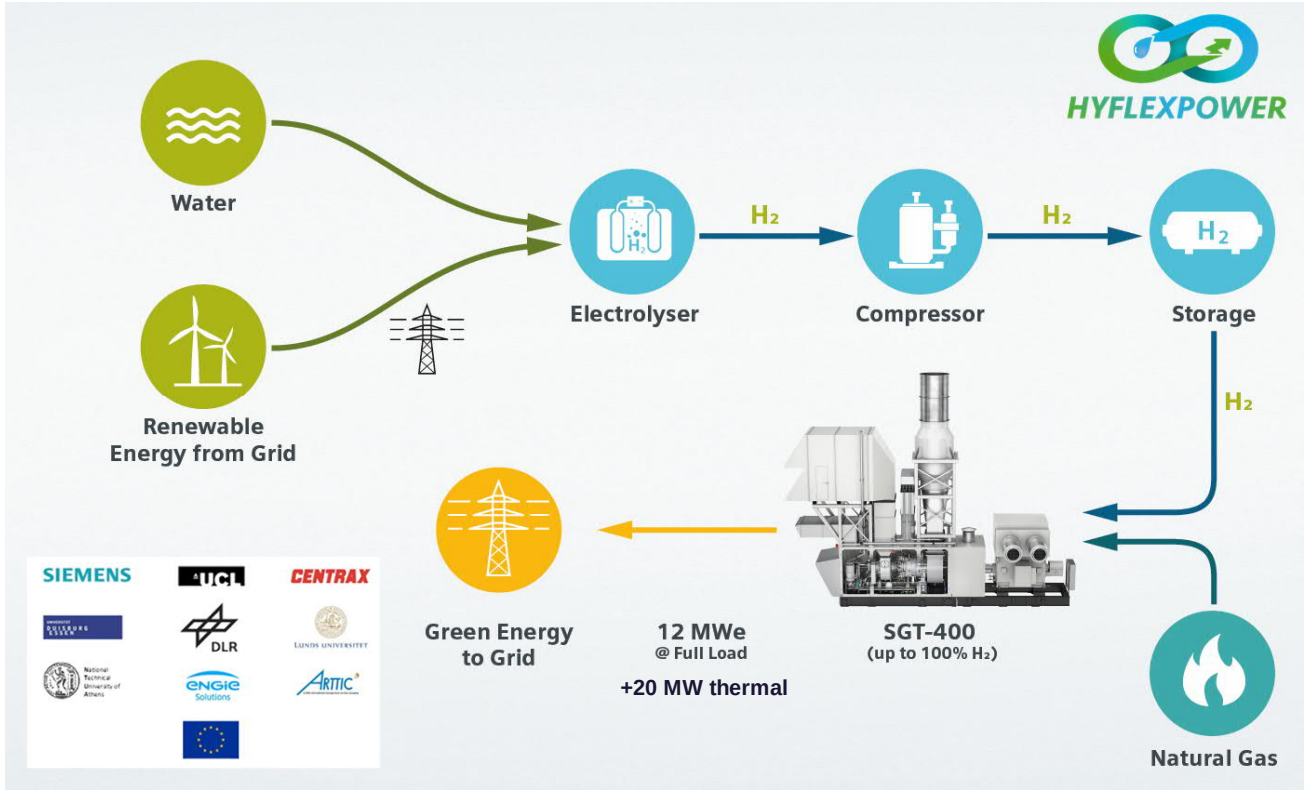
EU funded HYFLEXPOWER Project – a CO_2 free power-to-power path using gas turbines with DLE combustion systems



- May 2020: Contract finalization and start of engineering development.
- 2021: Installation of the hydrogen production, storage and supply facility at pilot demonstration site.
- 2022: Installation of the gas turbine for natural gas/hydrogen mixtures and initial demonstration of advanced pilot plant concept.
- 2023: Pilot demonstration with up to 100 percent hydrogen for carbon-free energy production from stored excess renewable energy.

http://www.hyflexpower.eu/

Siemens Hydrogen Gas Turbines for our sustainable future

The mission is to burn 100% hydrogen

Gas turbine model		Power Output [1]	H_2 capabilities in vol. %
50Hz	SGT5-9000HL	593 MW	30
	SGT5-8000H	450 MW	30
	SGT5-4000F	329 MW	30
	SGT5-2000E	187 MW	30
60Hz	SGT6-9000HL	405 MW	30
	SGT6-8000H	310 MW	30
	SGT6-5000F	215 to 260 MW	30
	SGT6-2000E	117 MW	30
50Hz or **60Hz**	SGT-A65	60 to 71/58 to 62 MW	15 – 100
	SGT-800	48 to 62 MW	50
	SGT-A45	41 to 44 MW	100
	SGT-750	40/34 to 41 MW	40
	SGT-700	33/34 MW	55
	SGT-A35	27 to 37/28 to 38 MW	15 – 100
	SGT-600	24/25 MW	60
	SGT-400	10 to 14/11 to 15 MW	10 – 65
	SGT-300	8/8 to 9 MW	30
	SGT-100	5/6 MW	30 – 65
	SGT-A05	4 to 6 MW	2 – 15

DLE burner WLE burner Diffusion burner with unabated NOx emissions

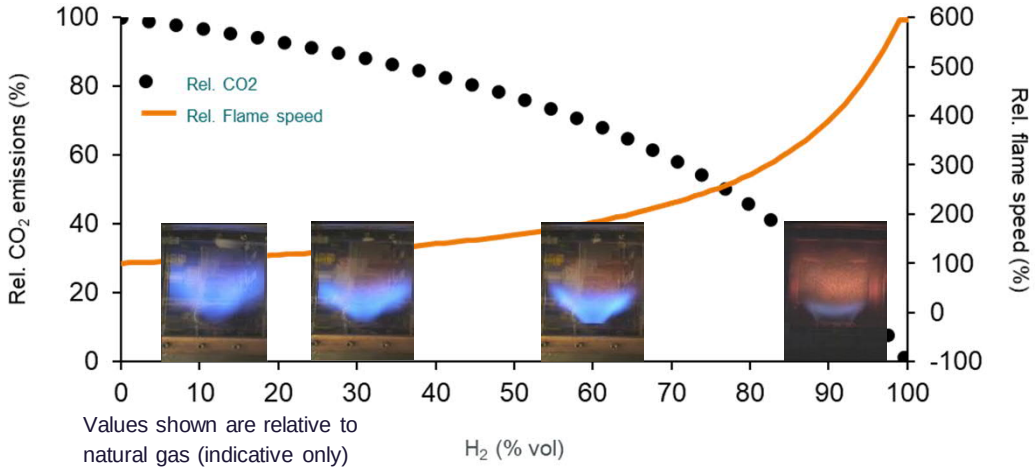
Heavy-duty gas turbines Industrial gas turbines Aeroderivative gas turbines

1) ISO, Base Load, Natural Gas; Version 3.4, July 2020

Values shown are indicative for new unit applications and depend on local conditions and requirements. Some operating restrictions/ special hardware and package modifications may apply.

Higher H_2 contents to be discussed on a project specific basis

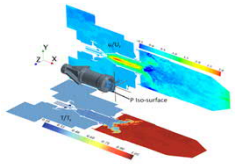
Hydrogen does not produce CO_2 emissions, but challenging physical properties require rapid design and testing cycles



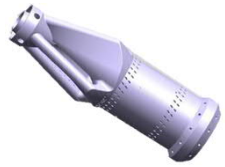
Challenges

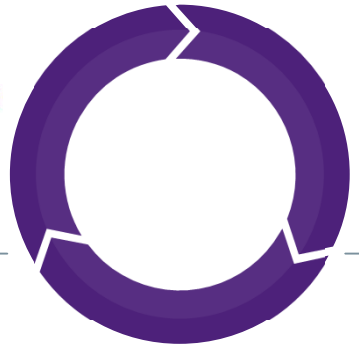
- **Higher diffusivity** requires re-certification of sealing, upgrade to stainless steel materials …
- **Lower volumetric energy content** requires larger flows to be handled byfuel system
- **Higher reactivity** pushes flame towards burner and increases risk of explosion or flashback
- **Higher flame temperature** can lead to local hotspots if imperfectly mixed and thus increased NOx emissions

1. High fidelity CFD
High fidelity CFD tools like LES can provide automated optimized designs



2 Rapid prototyping using AM
Additive manufacturing reduces lead time and enables better designs





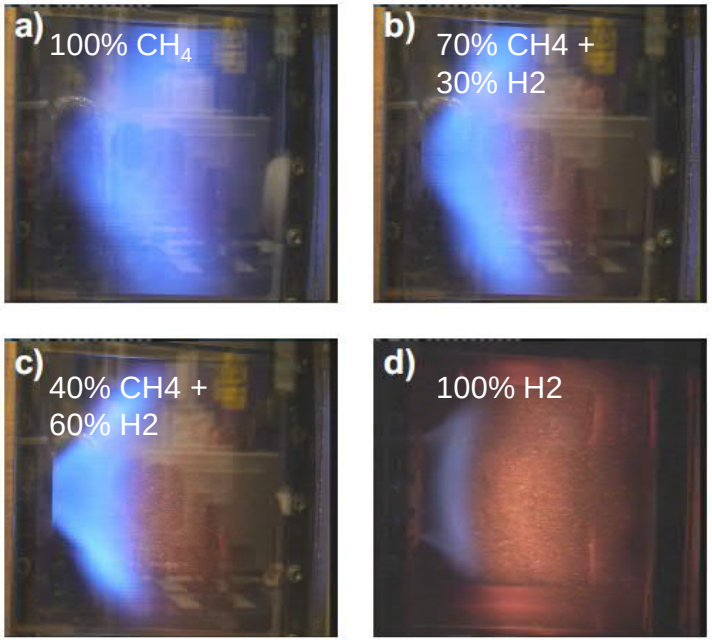
3. High-pressure testing at engine conditions
Facility in Berlin allows for high-pressure burner tests at engine conditions

Full engine test

Recent success in high-pressure test rig achieving 100% hydrogen operation on a SGT-600 burner

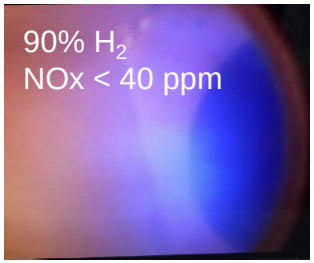
SIEMENS energy

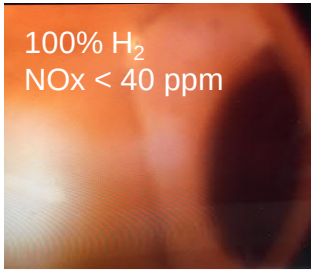
Atmospheric conditions
Flame position is moving upstream and shape more compact with increased amount of hydrogen



High pressure conditions
Burner concept tested at HPCR on 100% H2 to full load conditions.

Siemens Clean Energy Center Berlin 2019





Source: Siemens

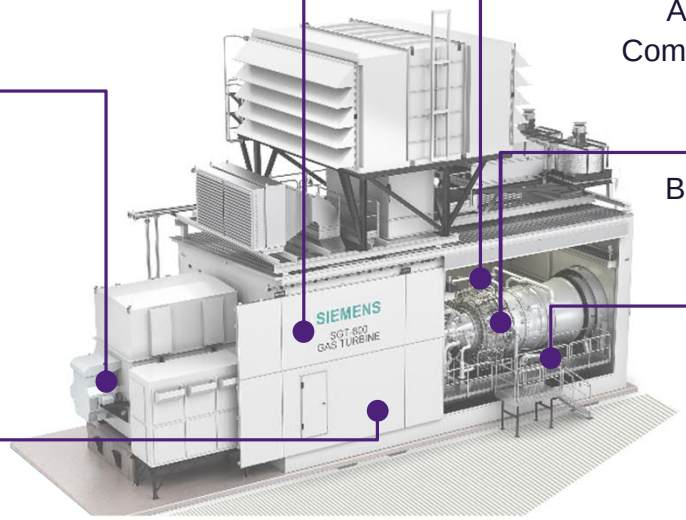
Burner Adjustment/Exchange for Industrial Gas Turbines

Main systems requiring modification when upgrading to higher H_2 content

Fire Protection System

Gas Group IIC
electrical equipment

H_2 compatibility of plant
auxiliary and peripheral systems



Additional Flame Control and
Combustion Monitoring Systems

Burner Adjustment/Exchange

Fuel Gas System
material and set-up

Consequences and solution

- Project specific evaluation and decision on required modifications
- Power output control to ensure compliant NOx emission levels
- Conventional/non-H_2 fuels may be required for start-up and shutdown
- Re-certification with respective authorities might be required

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Future of Energy is about Decarbonization through Sector Coupling and a new Market Design

Cornerstones of a Future Decarbonized Energy System

Decarbonization of Energy

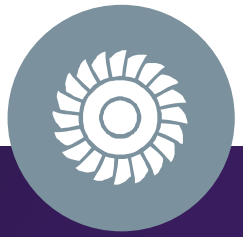
Transforming the conventional generation capacity into low-carbon assets

Sector Coupling

Leveraging renewables in power sector to decarbonize heat, mobility, industry

Power-to-X

Key technology for sector coupling and fuel for decarbonization of energy



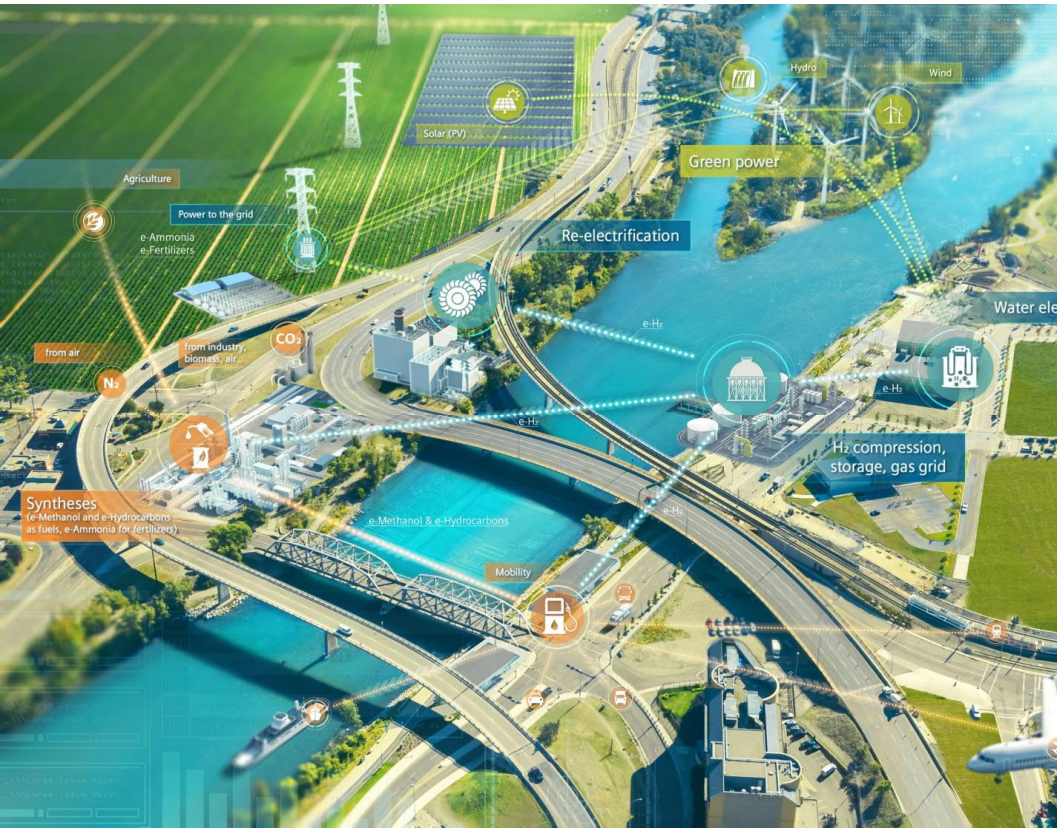
Gas turbines

Sustainable investment into security of supply – operating with natural gas and green gases such as hydrogen or synthetic fuels at lowest CAPEX Investment

Regulatory Framework

Set decarbonization targets, technology-open.

Contact page



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