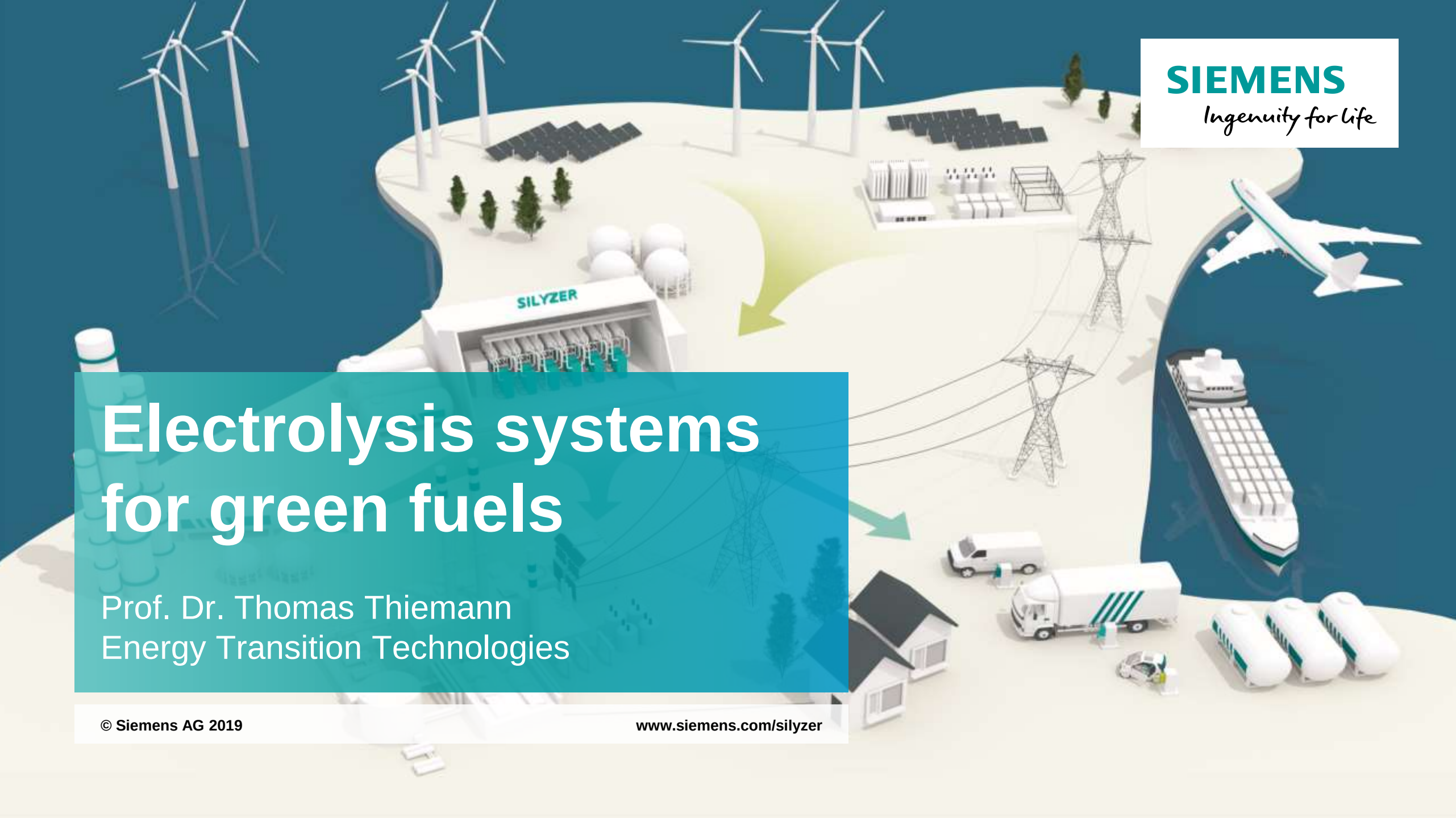

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Electrolysis systems for green fuels

Prof. Dr. Thomas Thiemann
Energy Transition Technologies

www.siemens.com/silyzer

Content

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- Who we are and our view on hydrogen
- Siemens electrolysis systems – status quo
- Green H2 in GT's - challenges and opportunities
- Some inspirations ....

Who we are ….

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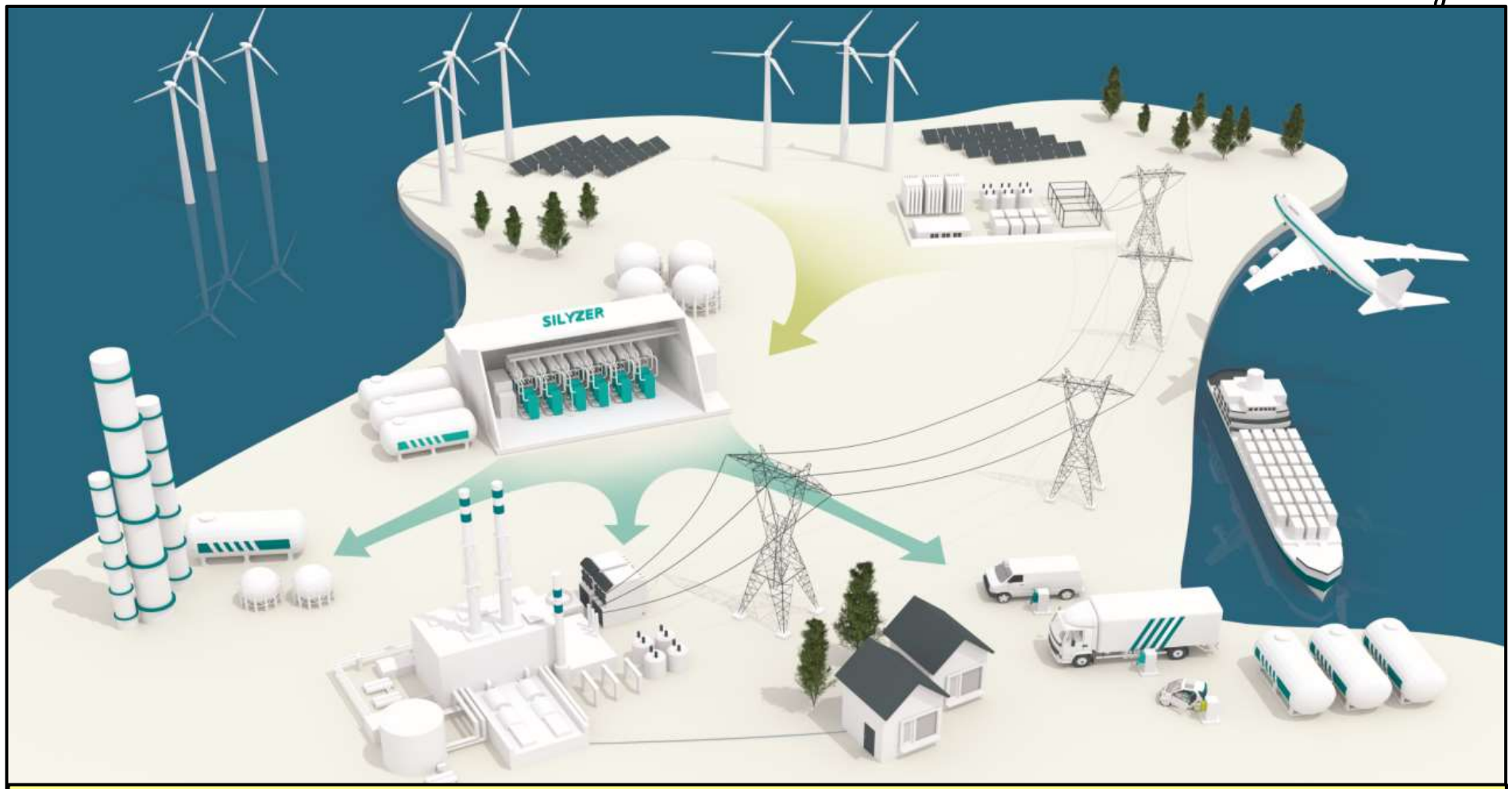

OEM - also for major components of green sector coupling solutions

(electrolysis systems, compressors, GT‘s, transmission, distribution, digitalization / Mindsphere, ….)

Our view on Hydrogen ….
H2 is multi-functional and applications can be combined tailored to customer demands

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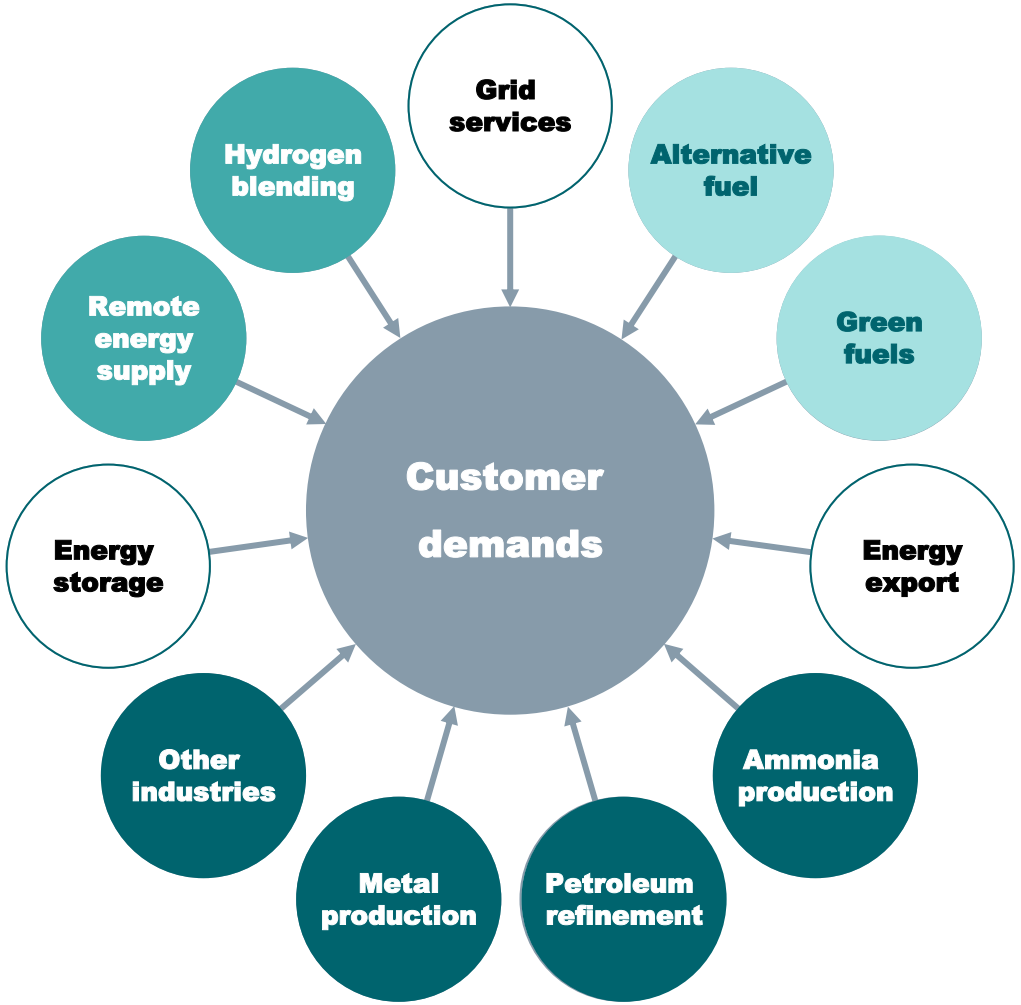

Our view on Hydrogen ….
Handling of hydrogen is safe, tried and tested in spite of negative headlines in the past

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Myth	Fact
Hydrogen is a **dangerous gas** and very **explosive**	**Hydrogen is shipped since decades in large amounts by trucks and ships without critical incidents**
Hydrogen is a very small molecule and material **diffusion / leaking is a critical issue**	**Steel pipes allow a proper handling of up to 1,000 bar without significant diffusion / leaking of hydrogen**
Fuel cell cars are **dangerous** because of the **explosion** potential of the compressed **hydrogen tank**	**Car manufactures undertake exhaustive crash and explosion tests of hydrogen tanks to ensure a top level of safety**

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Silyzer 300 – the next paradigm in PEM electrolysis

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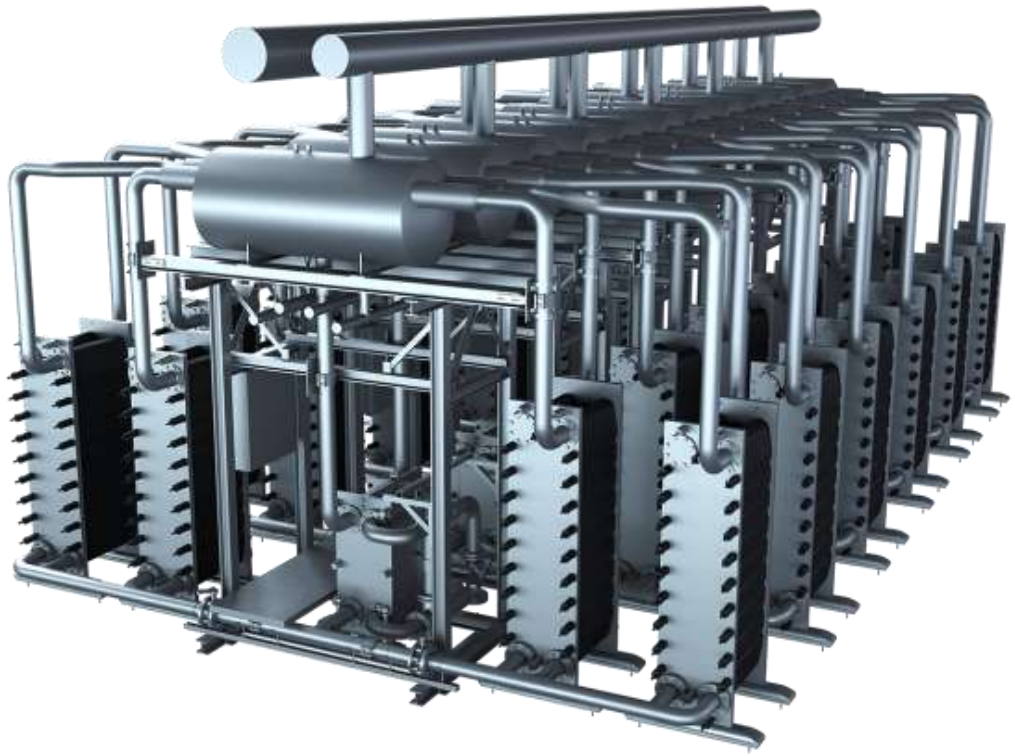
17.5 MW	per full Module Array (24 modules)
75 %	System efficiency (higher heating value)
24 modules	to build a full Module Array
340 kg	hydrogen per hour per full Module Array (24 modules)



Silyzer 300 – Module Array (24 modules)

Why a Proton Exchange Membrane (PEM) electrolyzer system?

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PEM is the natural choice for our future renewable energy system

- Incredibly fast start-up and shut-down
- Highest operational flexibility
- Cold start capability

PEM is clean by nature

- No CO_2 emissions, unlike SMR[1], which emits 8-10 kg CO_2 for each kg of hydrogen
- There is nothing except water, hydrogen and oxygen in the system
- Highest hydrogen purity >99.9%
- Oxygen as the only “contaminant”
- No aggressive chemical electrolyte (e.g. KOH  in Alkaline systems)

PEM is competitive

- Competitive hydrogen price per kg at green electricity prices below 3 ct/ kWh
- Small footprint compared to Alkaline systems
- Significantly lower OPEX[2] compared to Alkaline systems due to maintenance-free stack

1) SMR: Steam Methane Reforming; 2) OPEX: Operational Expenses

The Silyzer 300 enables primary reserve services with efficient hydrogen yield and maximum dynamics

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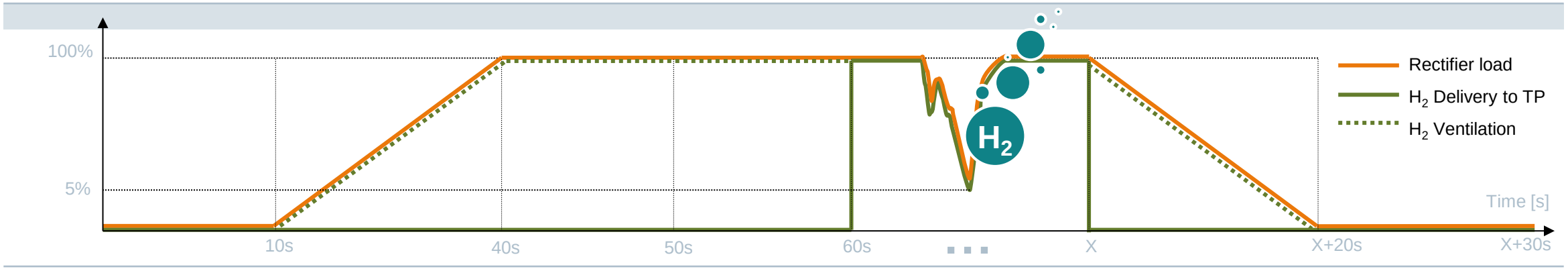
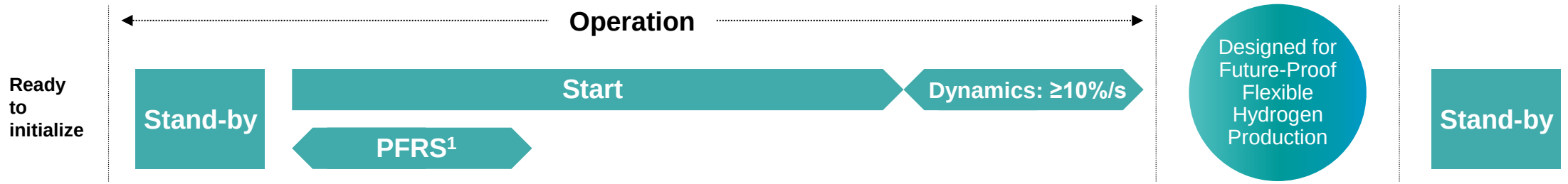
	Start 0-100% H2	**<1min, enabled for PFRS[1]**
	Dynamics in range	**≥ 10%/s in range 0-100%**





1) PFRS: Primary Frequency Reserve Service

We have references for our Silyzer portfolio in all applications

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Year	Country	Project	Customer	Power demand	Product offering
Silyzer 200 Reference					
2015	Germany	Energiepark Mainz	Municipality of Mainz	3.8 MW / 6 MW (peak)	Pilot Silyzer 200
2016	Germany	Wind Gas Haßfurt	Municipality of Haßfurt Greenpeace Energy	1.25 MW	Silyzer 200
2017	Germany	H&R	H&R Ölwerke Schindler GmbH	5 MW	Silyzer 200
2020	UAE	DEWA Expo 2020	Dubai Electricity and Water Authority (DEWA)	1.25 MW	Silyzer 200
2019	Australia	Hydrogen Park SA (HyP SA)	Australian Gas Infrastructure Group (AGIG)	1.25 MW	Silyzer 200
2019	Sweden	AAK	AAK AB Sweden	2.5 MW	Silyzer 200
Silyzer 300 Reference					
2019	Austria	H2Future[1]	voestalpine, Verbund, Austrian Power Grid (APG)	6 MW	Pilot Silyzer 300

[1] 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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Challenges?

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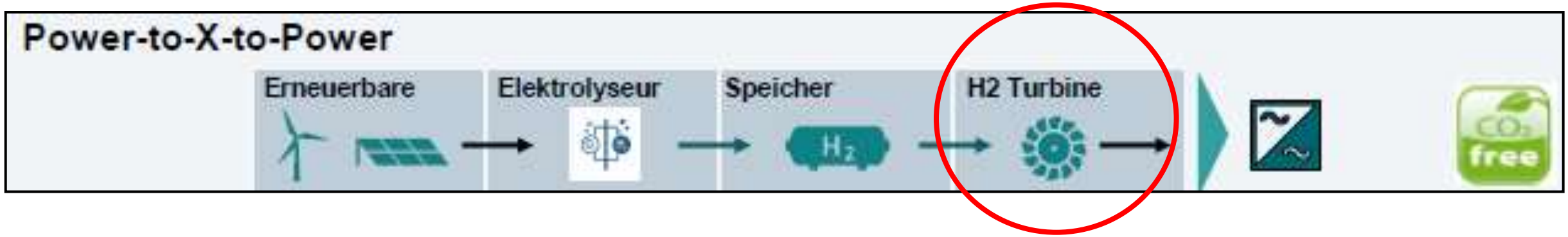
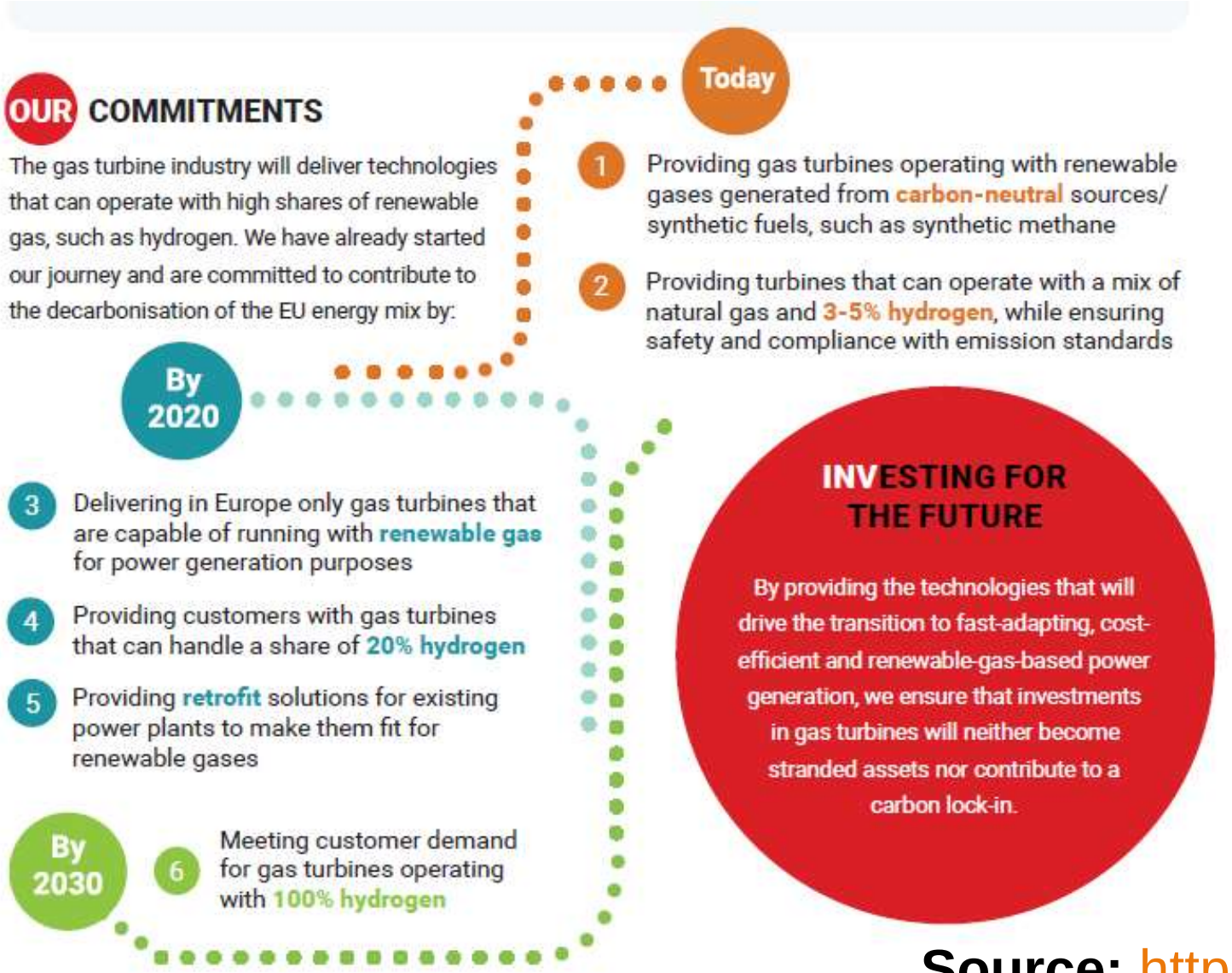


H2 commitment of European turbomachinery OEM's



Source: https://powertheeu.eu/

Siemens Hydrogen Gas Turbines for our sustainable future – The mission is to burn 100% hydrogen

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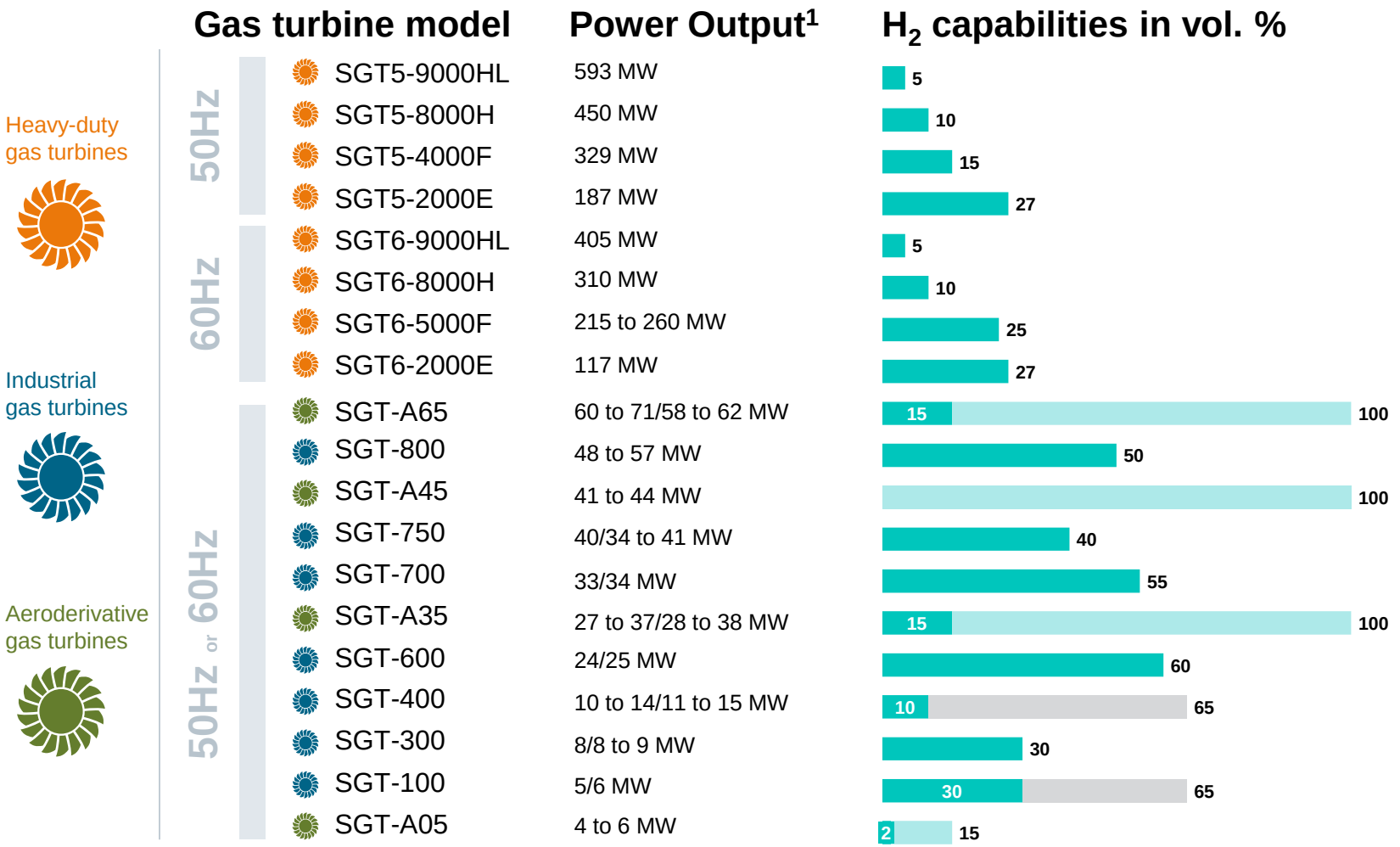

Values shown are indicative for new unit applications and depend on local conditions and requirements. Some operating restrictions/special hardware and package modifications may apply. Any project >25% requires dedicated engineering for package certification.

Higher H_2 contents to be discussed on a project specific basis

1 ISO, Base Load, Natural Gas
Version 2.0, March 2019

Challenges?

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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

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Silyzer portfolio roadmap

0,1 MW → 1 MW → 10 MW → 100 MW → 1000 MW

2011

Silyzer 100
Lab-scale demo
~4.500 op.h[1]
~150k Nm³ of H_2

2015

Silyzer 200
~43.000 op.h
~6.0 mio Nm³ of H_2

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

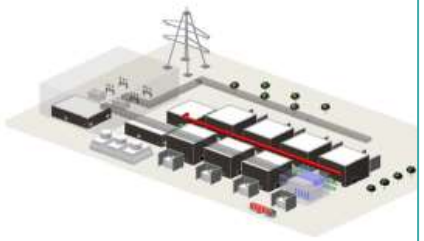
2018

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) op.h.: operating hours

Key: Availability of economical large scale electrolysis systems!

15.02.19

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Beschluss
des Bundesrates

6. Der Bundesrat ist der Auffassung, dass schon heute mit der Errichtung von großtechnischen Elektrolyseanlagen mit mehr als 50 Megawatt (MW) Leistung begonnen werden muss, damit bis 2030 die Skalierung, die Weiterentwicklung der Produktionstechnik für die Anlagen und deren Netzintegration gelingt.

7. Der Bundesrat stellt fest, dass derzeit die für das Gelingen der Energiewende unerlässliche Wasserstoffelektrolyse noch nicht wirtschaftlich ist. Er fordert die Bundesregierung auf, ein Markthochlaufprogramm aufzulegen, mit dem die Erstellung großtechnischer Anlagen zur elektrolytischen Wasserstofferzeugung ermöglicht wird.

→ **„…. Governmental stimulation of a market ramp-up program in Germany?“**

Green H2 for GT's - challenges

…. to stimulate our discussion ….

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Site specific drivers	**Depending on e.g.**
▪ Electricity price	sufficient availability of (excess) renewable energy, governmental regulations / tariff models for production & application of green hydrogen (e.g. RED II), ….
▪ Electrolyzer uptime	Operating hours → specific costs, ….

Technology specific drivers	**Depending on e.g.**
▪ CAPEX of electrolyzer solution	economies of scale, increased power density, ….
▪ Efficiency	technology development (membranes, coating, ….)
▪ GT specific	upgrade packages, high demand for: Mass flow, pressure, power, storage capacity, ….

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Green Hydrogen Fuel & Power

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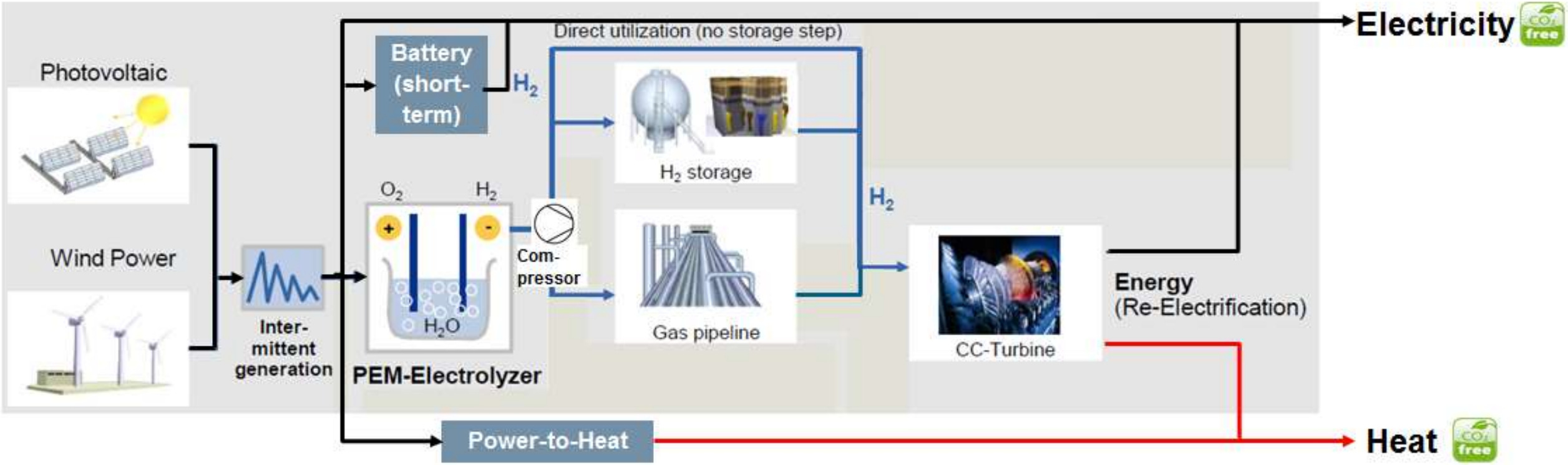

CO_2-free H_2-Energy Center Concept (Combined Heat & Power) (10 MW electrical / 10 MW thermal)

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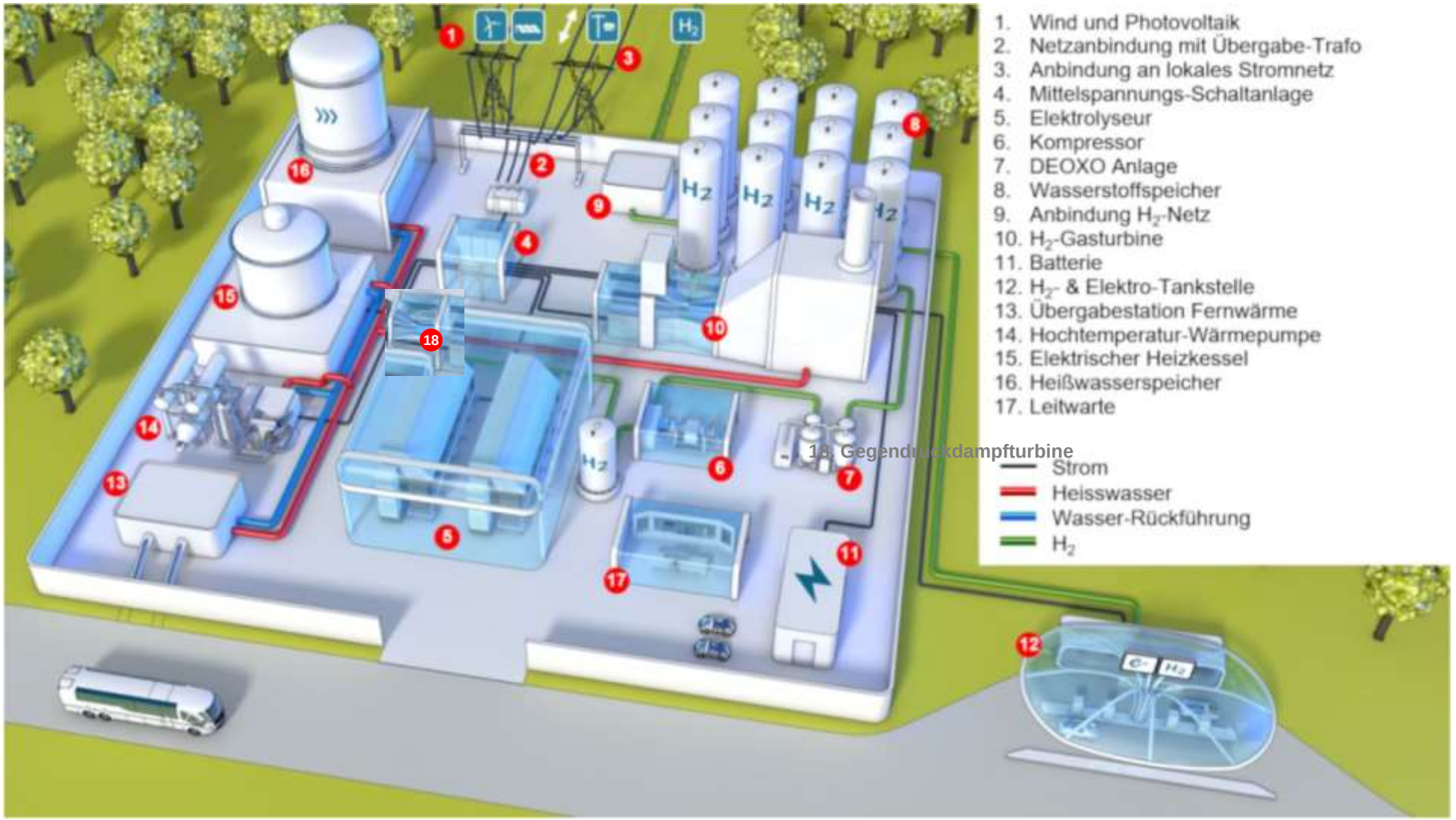

Thank you

To find a new way of business

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