Hydrogen and the Energy Sector

Africa webinar
25 February 2021

Host: Mark van Antwerp, VP Generation Sales, Southern & Eastern Africa
Presenter: Erik Zindel, Director/VP Global Hydrogen BD & Sales

Who we are
The leading pureplay energy company

SIEMENS energy

Our offering

Products
Solutions
Services

Along the value chain

Generation
Transmission
Storage

Broad technology portfolio

From
Conventional
to Renewables

Siemens Energy

Gas and Power (“GP”)

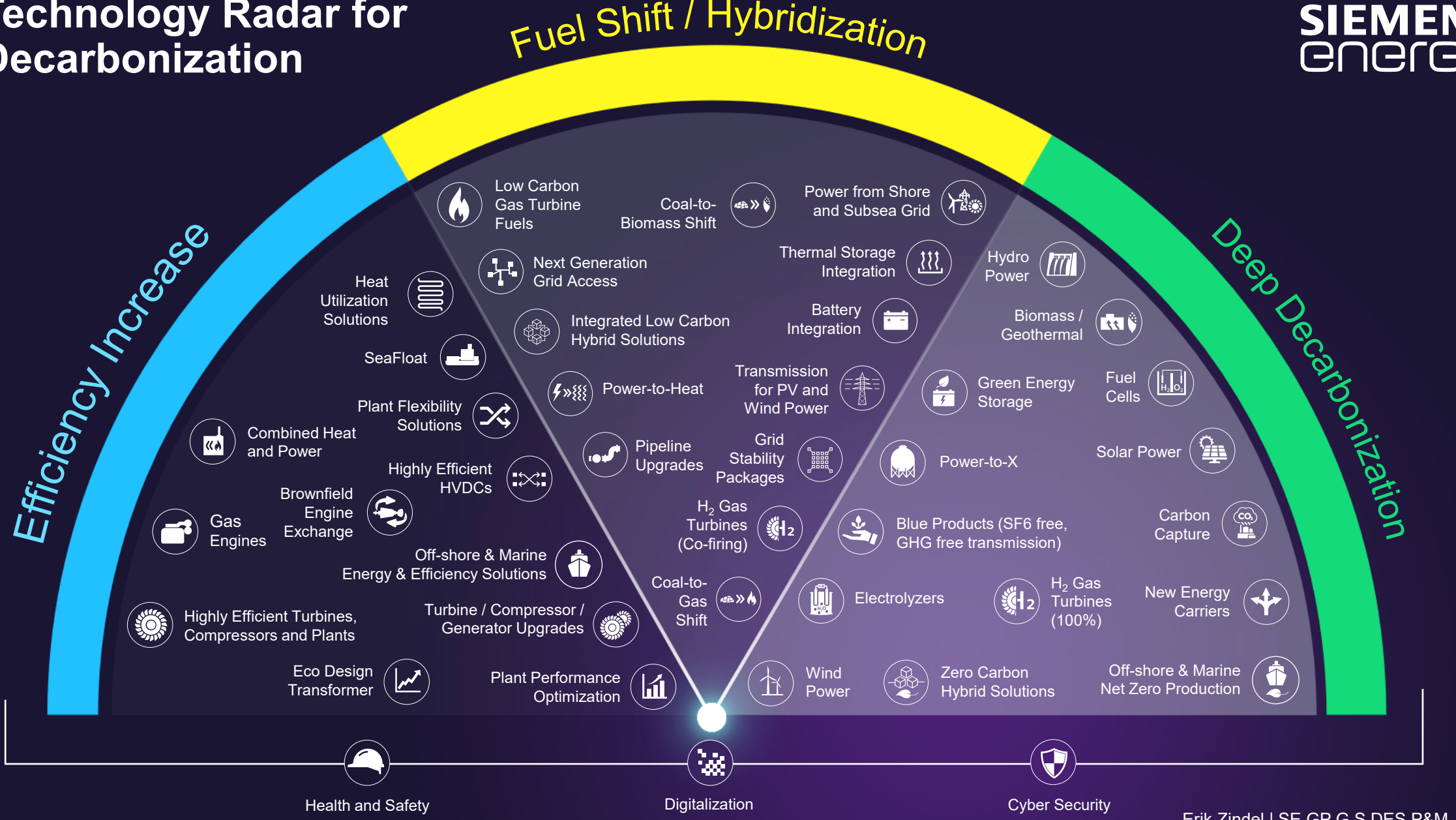
- **Generation**
  - Central
  - Distributed
- **Industrial Applications**
- **Transmission**
- **New Energy**

Siemens Gamesa Renewable Energy (“SGRE”)

67% owned

- **Onshore**
- **Offshore**

Technology Radar for Decarbonization



Agenda

01 The role of Hydrogen in the future Energy Landscape

02 Siemens Energy portfolio for the hydrogen economy

03 Hydrogen combustion in Siemens Energy gas turbines

04 Conclusion

01. The role of Hydrogen in the future Energy landscape

Reduction of CO_2 emissions is critical to limit global warming to below current commitments (considered unsustainable)

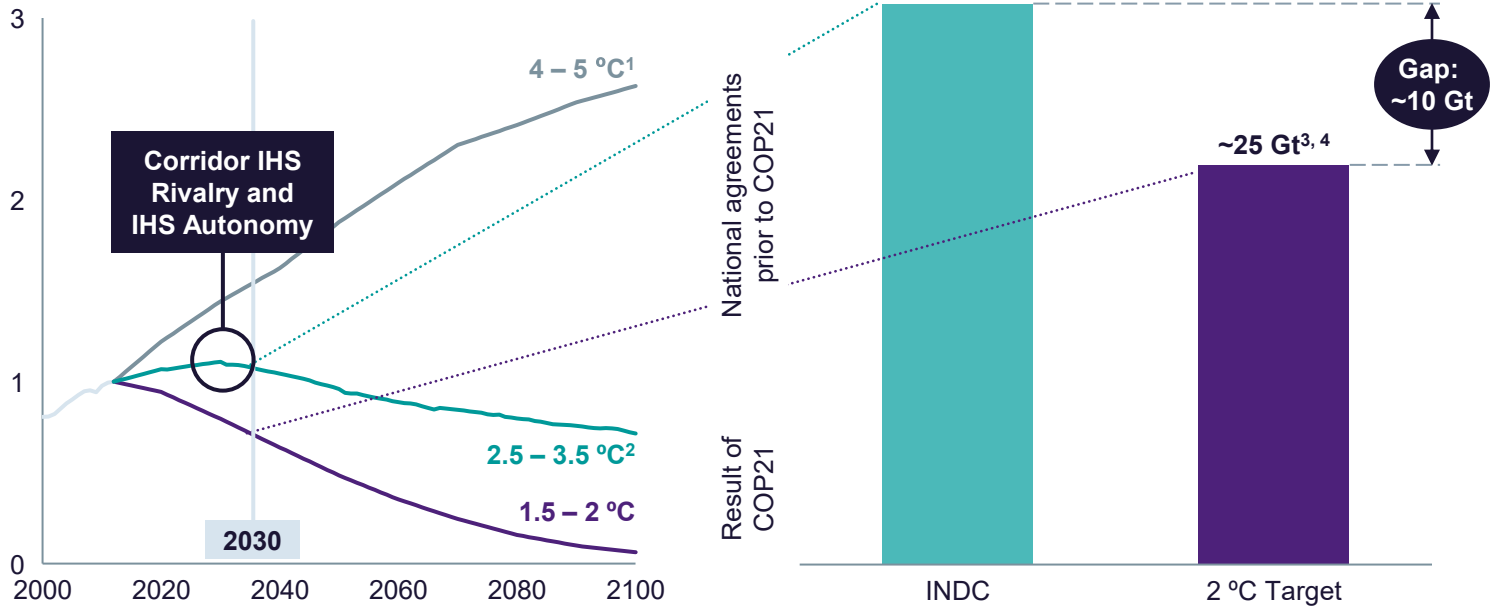
Increasingly ambitious targets from COP21 leave the world …

… with a significant CO_2 gap[3], already in 2030 …

… which needs to be closed to achieve 1.5 – 2° C target

Global warming scenarios

Index, 2012 = 1



Transition of power generation mix

- Coal to natural gas (short term)
- Aggressive renewable growth
- Natural gas to sustainable hydrogen (long term)

Efficient energy management

- Electricity storage for intermittent renewables
- Smart grid technology for demand response

Improved energy efficiency

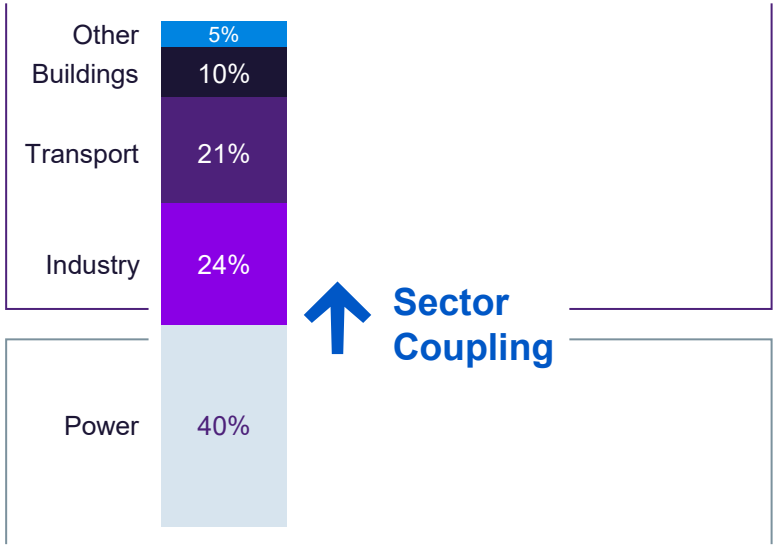
- Efficient use of energy
- Electrification of other sectors e.g. transportation/heat (sector coupling)

1 Business as usual (BAU), without any emission reduction effort | **2** Intended Nationally Determined Contributions (pre-COP21 commitments) |
3 BAU & INDC data based on CO_2 equiv., whereas scenarios only provide CO_2 emissions which are ~33% lower than total CO_2 equiv |
4 Following Climate Action Tracker (~38 Gt CO_2 equiv. in 2030) | **Source:** CD ST SU, PV/Energy Mix Project Team, IEA

“Sector Coupling” is the key lever for decarbonization of all end-user sectors

Shares in global CO_2 emissions by sectors

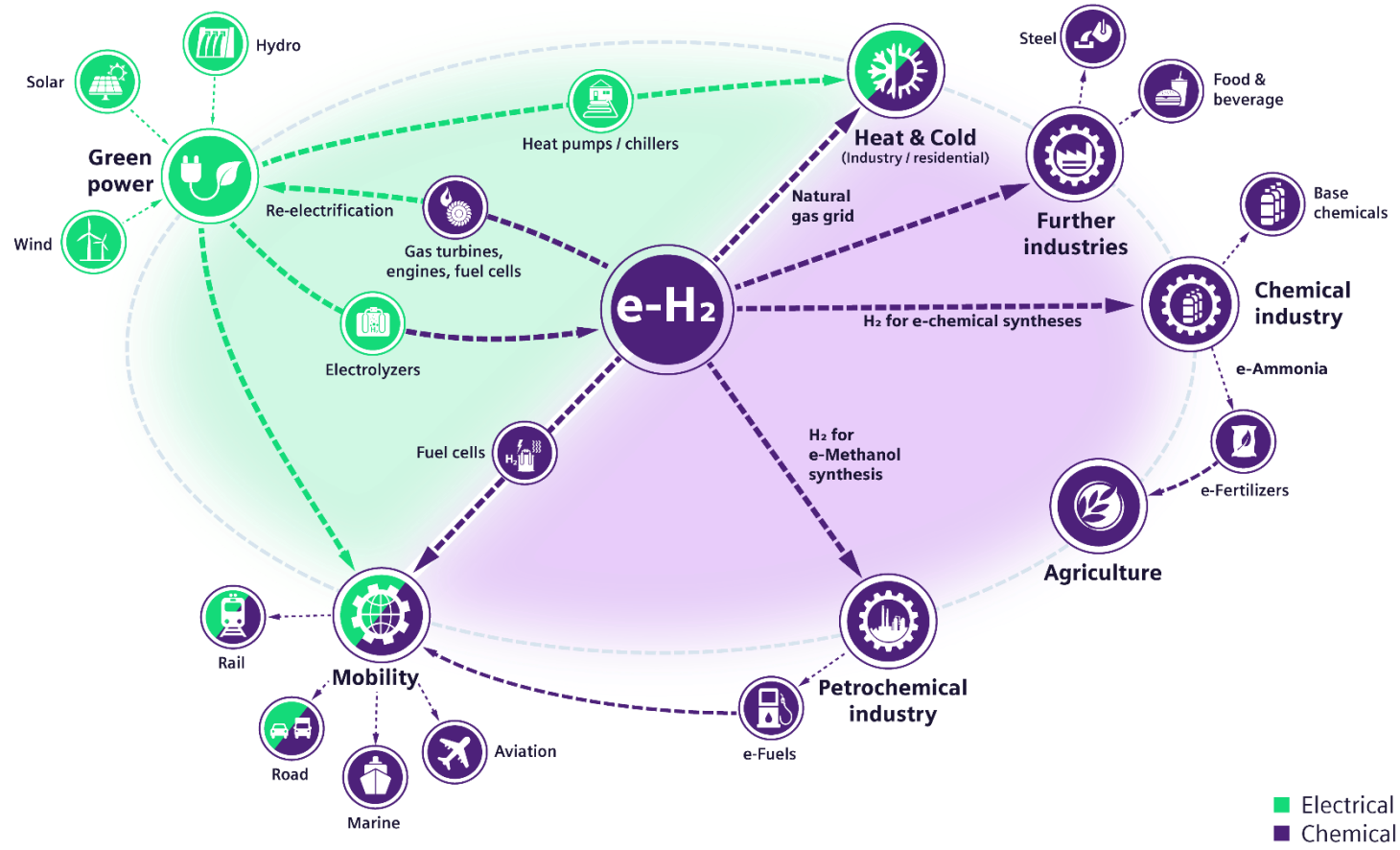
Increased future focus for emission reduction
Share on CO_2 emissions: 60%
Share of Renewables: 8%



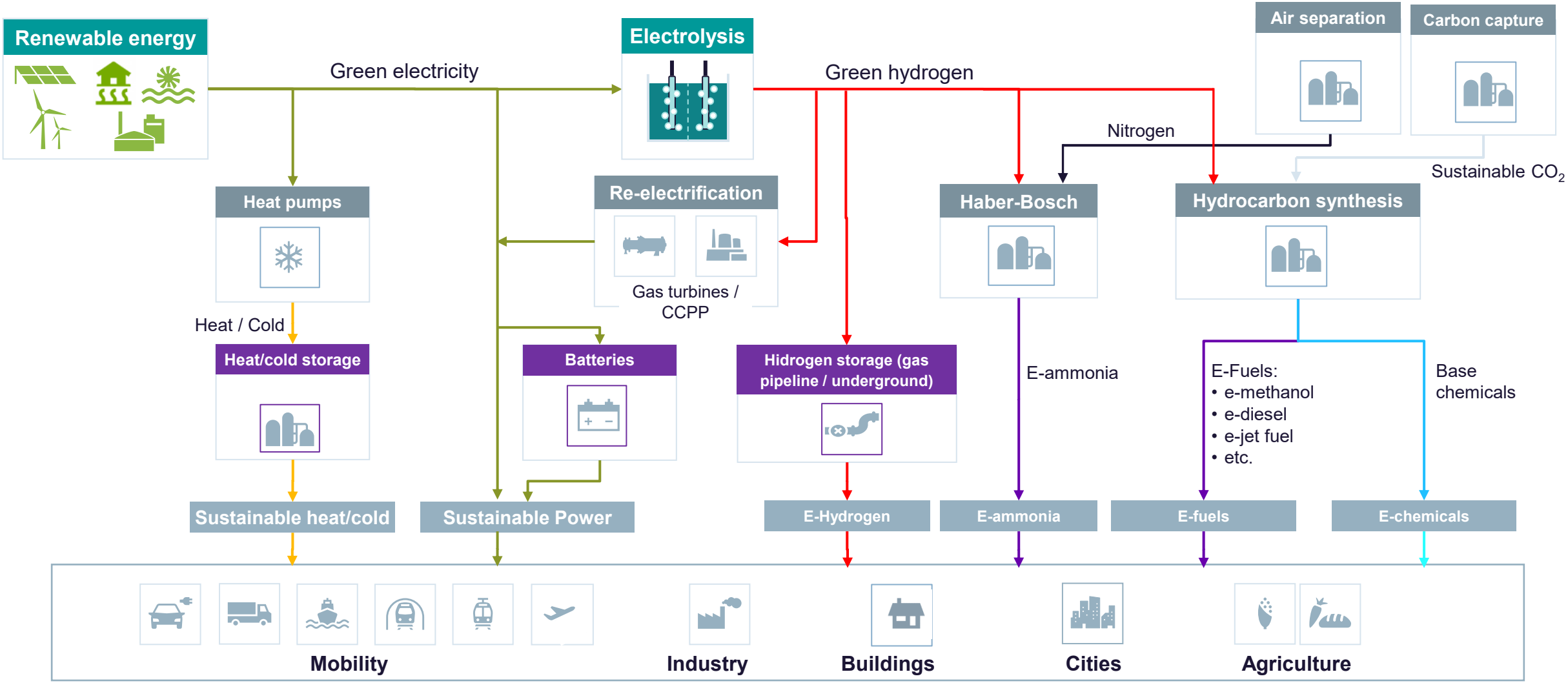
Continuous emission reduction required
Share on CO_2 emissions: 40%
Share of Renewables: 22%

Source: World Energy Balances 2018

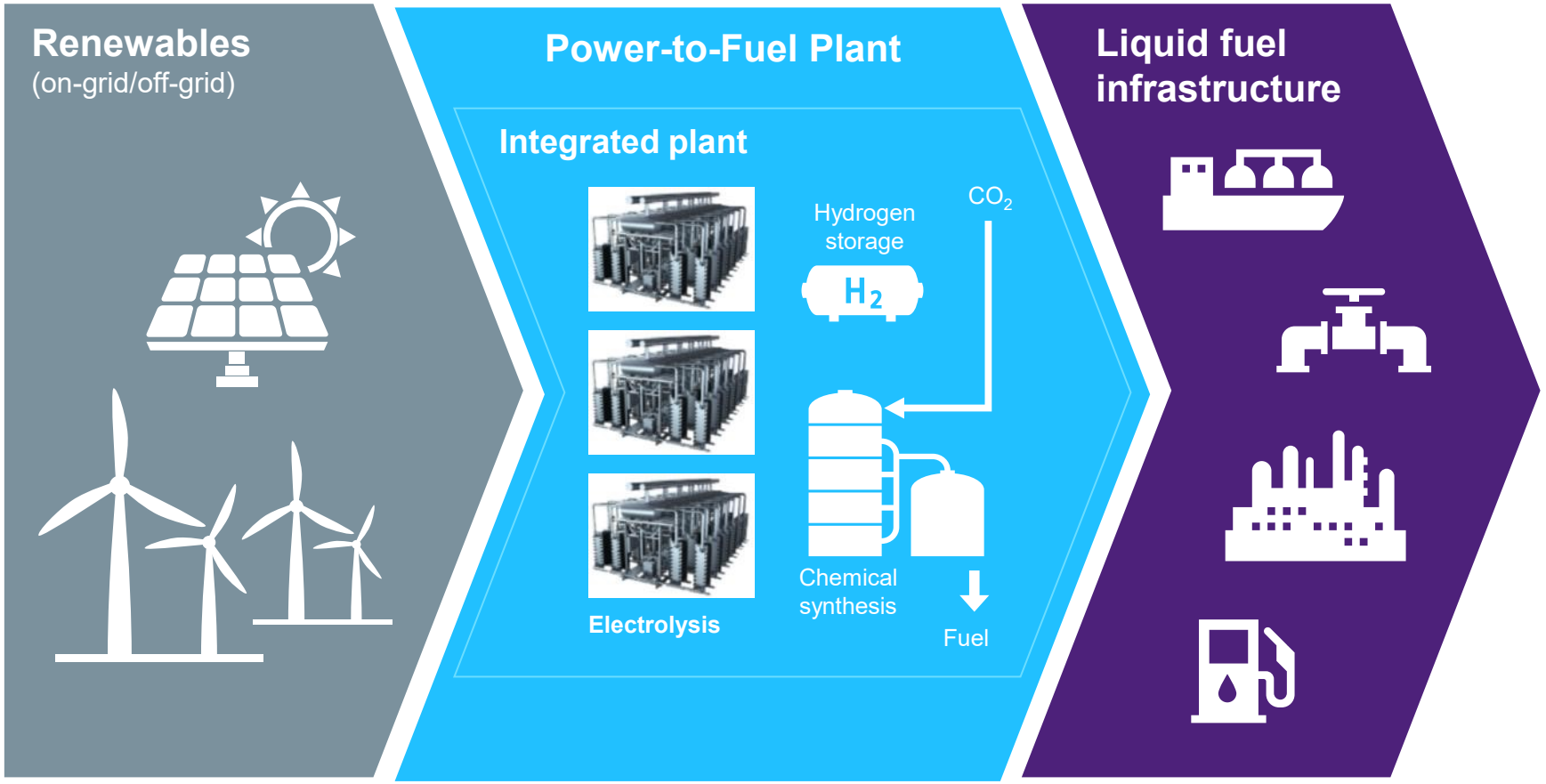
Sector Coupling – Links and Interactions



In a fully decarbonized scenario (beyond 2050), Power-to-X plays a major role in the energy landscape



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

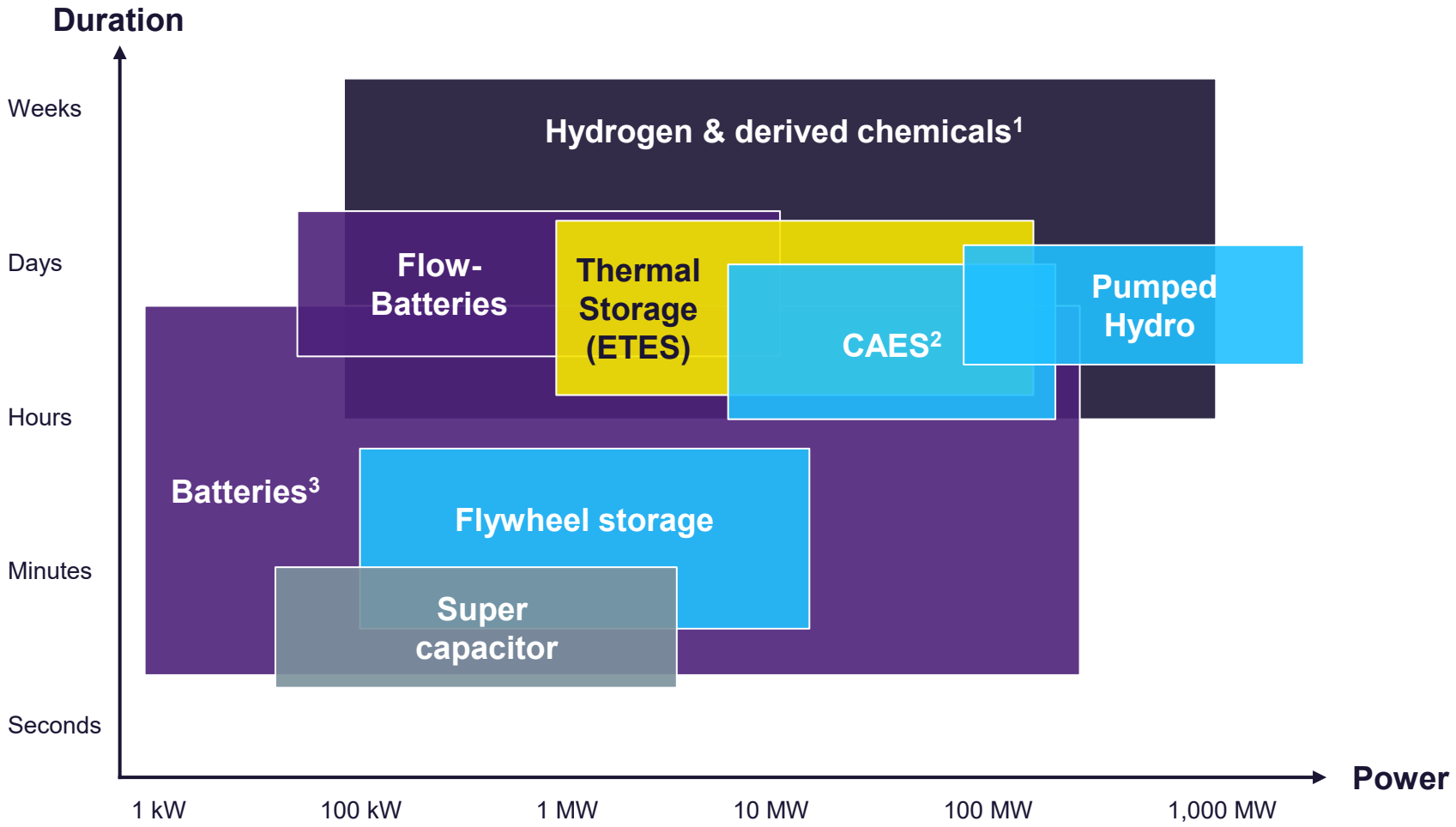
Road transport
App. 85 Mio. km road mileage = fleet with 2,000 trucks for one year

OR

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

Numbers derived from own assumptions

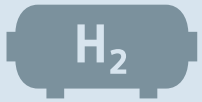
Different storage technologies for different applications –
Hydrogen for large scale and long term energy storage



Technology Chemical | Electrochemical | Mechanical | Electrical | Thermal

1 Such as Ammonia, Methanol or other hydrocarbons | **2** Compressed Air Energy Storage | **3** Li-Ion, NaS, Lead Acid, etc.

Hydrogen can be stored cost-effectively on a large scale.



There are solutions and challenges for storage and transportation of Hydrogen depending on the application

Hydrogen storage

Compressed hydrogen cylindrical tank (MWh range)
- 50-200bar, up to 700bar for mobility applications)
- 5-15% losses

Compressed hydrogen, spherical tank (GWh range)
- ≤ 100bar
- 5-10% losses

Compressed hydrogen, dedicated/blended pipelines and cavern storage (TWh range)
- ≤ 100bar
- 5-10% losses

Liquid hydrogen, spherical tank (GWh range)
- <4 bar, cryogenic (20-30K)
- 25-30% energy losses + additional boil-off losses

Hydrogen transport

Truck/train (cylindrical tanks)
- Only small quantities, local distribution
- Capacity: ~1 Ton / truck

Pipeline (dedicated/blended)
- Large quantities, up to 1000-2000km
- Integration of long term storage (caverns)

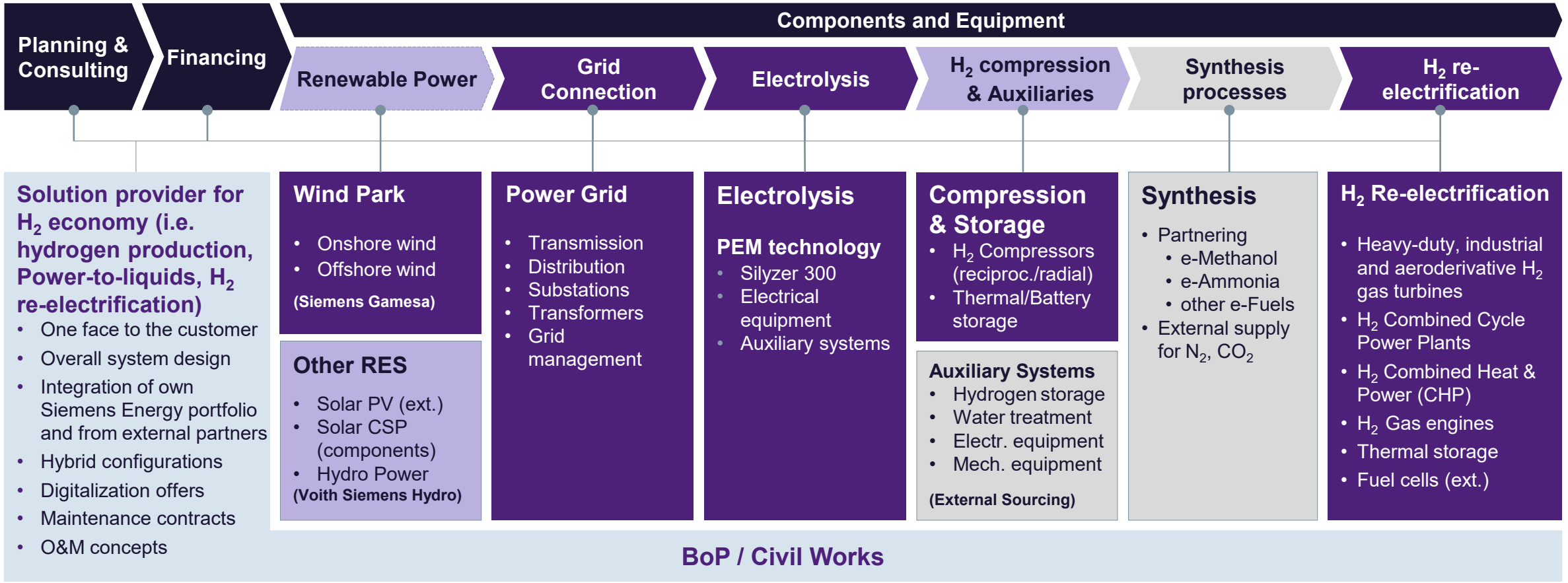
LH_2 carrier vessel (cryogenic)
- Long-haul transport of up to 15,000 Tons
- First ships under development in JP (Kawasaki)

H_2 derivates (e-ammonia/LOHC/e-synfuels)
- Easy state-of-the-art transport
- Additional efficiency losses if reconversion back to H_2 is required, otherwise preferred method (local production of e-ammonia/e-fuels and transport to destination)

02. Siemens Energy portfolio for the hydrogen economy

Siemens Energy can offer products, solutions and services across the whole hydrogen / P2X value chain

Siemens Energy covers most value chain parts to deliver Hydrogen/Power-to-X projects on a turnkey basis



Own/majority owned portfolio JV/minority owned portfolio Portfolio from external partners

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 → 1,000 MW

2011

Silyzer 100
Lab scale demo
~20 kOH[1],
~30 t of H_2

2015

Silyzer 200
~130 kOH[1]
~1700 t of H_2

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

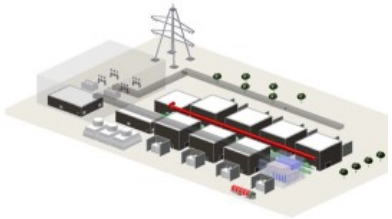
2018

Silyzer 300

Biggest PEM cell in the world built by Siemens!

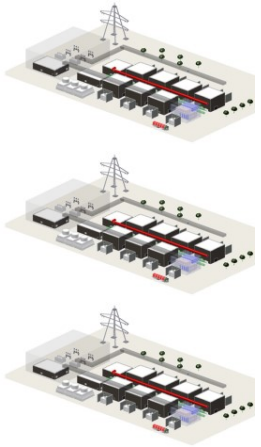
2023+

Next generation
Under development



2028+

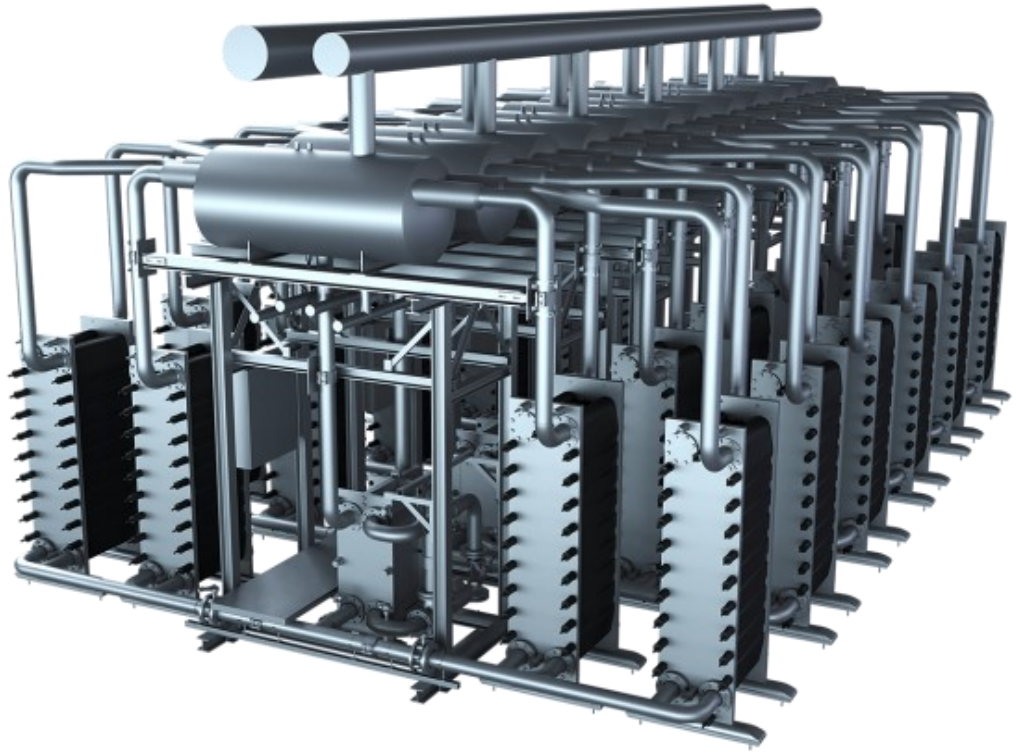
First investigations in cooperation with chemical industry



1 Operating Hours; Data OH & tons as of Oct 2020

Silyzer 300 – Full Module Array
The next paradigm in PEM electrolysis

Hydrogen production	335 kg/h
Plant efficiency (HHV[1])	>75.5%
Power demand	17.5 MW
Start-up time	<1 min, enabled for PFRS[2]
Dynamics in range	10%/s in 0 – 100%
Minimal load	20% single module
Dimension full Mod. Array	15.0 x 7.5 x 3.7 m
Module design lifetime	Optimized for up to 80 kOH[4]
Plant availability	~95%
Demin water consumption	10 l/kg H_2
Dry gas quality[3]	99,9999%
Delivery pressure	Customized

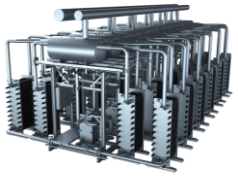


1 Plant efficiency includes rectifier, transformer, transformer cooling and gas cooling | **2** Primary Frequency Response Service | **3** With DeOxo | **4** Operating Hours

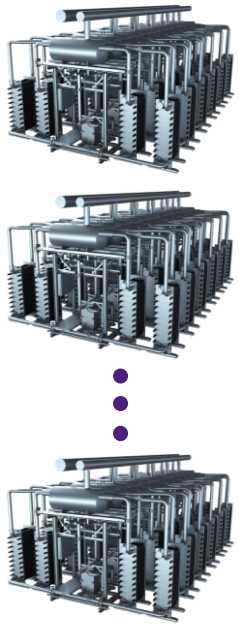
The modular design of Silyzer 300 can be easily scaled to your demands

SIEMENS energy

Module | **Module array** | **n+1** | **Customized solution** | **Plant**



Between 12 and 24 modules



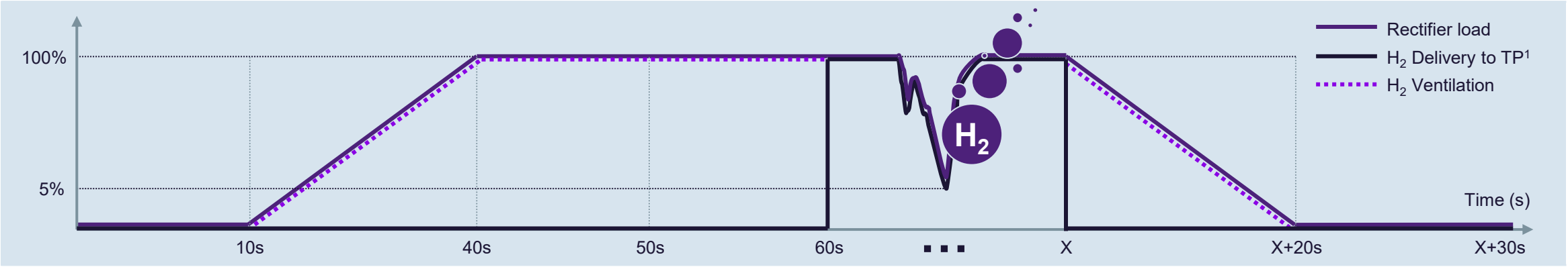
Scale up to the necessary demand

Control system | Water refinement | Transformer | Rectifier | LV supply

! Modular concept to cover wide production rate

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

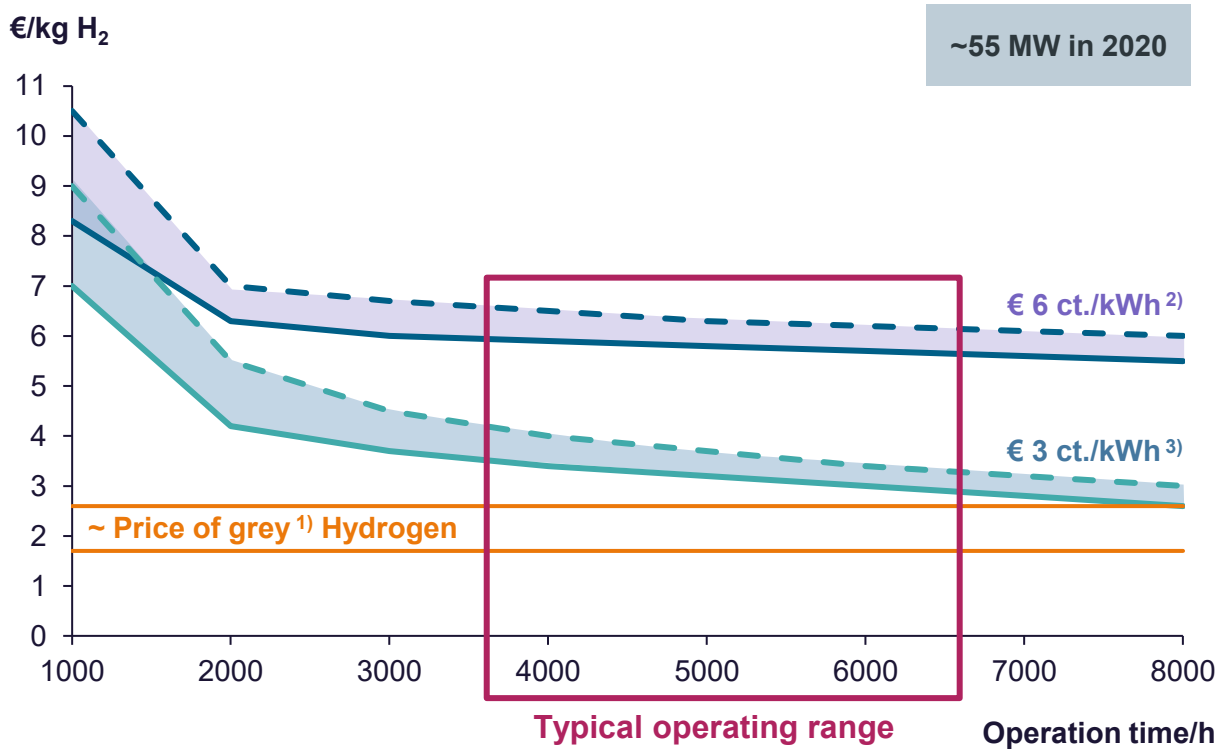
Hydrogen production cost depend on site and technology specific drivers

Site specific drivers

Electricity price

Operation time

H_2 production cost[1] per capacity factor



Technology specific drivers

Maintenance cost

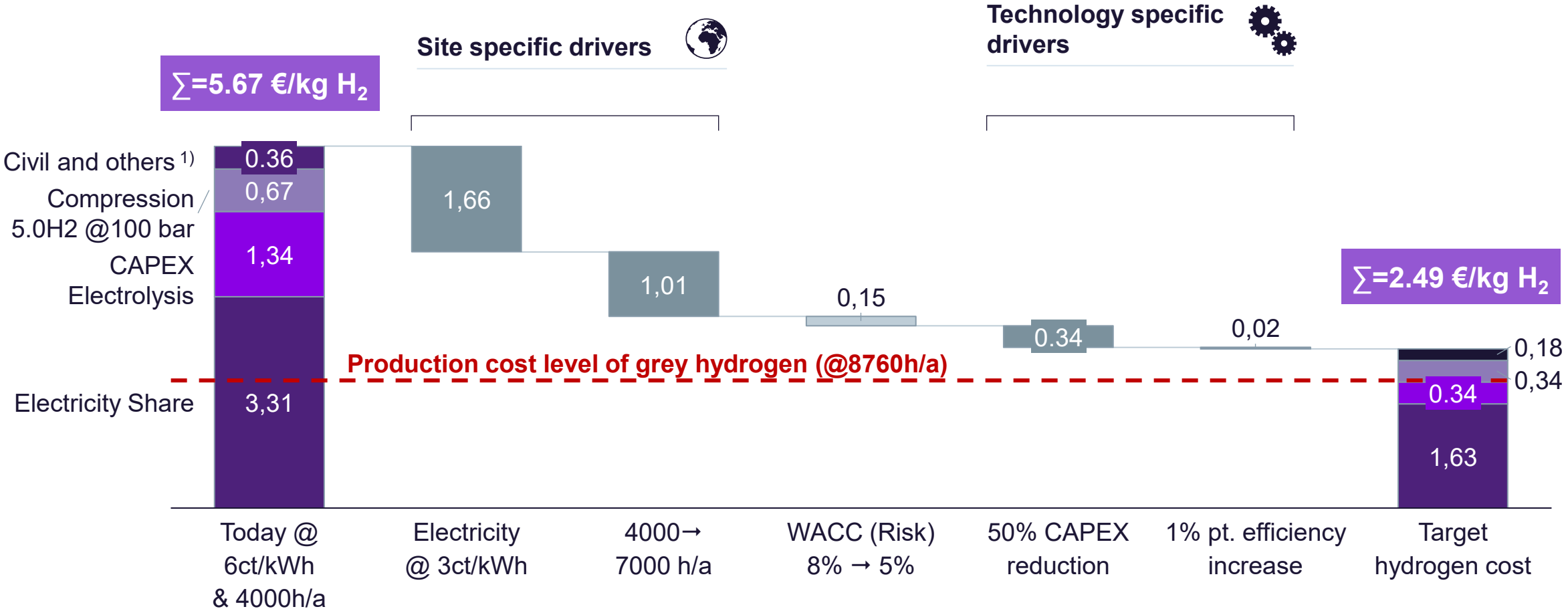
CAPEX

Efficiency

1) **Grey H2:** Hydrogen produced by conventional methods as steam methane reforming;
2) **€ 6 ct./kWh:** E.g., on shore wind (4-6ct./kWh) or PV in Germany; 3) **€ 3 ct./kWh:** Reachable in renewable intense regions like Nordics (Hydro Power), Patagonia (Wind), UAE (PV)
Source: NEB

Site specific operation conditions as main drivers to reach 2 €/kg H2 production cost

Production cost reduction drivers



Note: Electrolyzer power: 55 Mw_{el} (72 modules) ; Hydrogen production: 1005 kg/h (H5.0 @ 100 bar) with 99.999% purity
1) Siemens EPC internal estimation
Source: NEB

Haru Oni Pilot Project (Chile)

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Worldwide first integrated plant for the production of climate-neutral e-fuel from wind and water

750.000 liters

of e-methanol per year from 2022
(130.000 liters of e-gasoline)

>55m liters

e-fuel per year
planned from 2024

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

February 2021

Project

- Customer: HIF (Highly Innovative Fuels)
- Off-taker: Porsche AG
- Country: Chile, Patagonia
- Installation: 2021
- Product: Power-to-methanol solution based on Silyzer 200

Use cases

E-Fuel for Porsche cars

Potential for adding Kerosene or Diesel production in future phases

Methanol for ship motors

Opportunity

- Huge wind energy potential in Magallanes
- Existing industry and port infrastructure

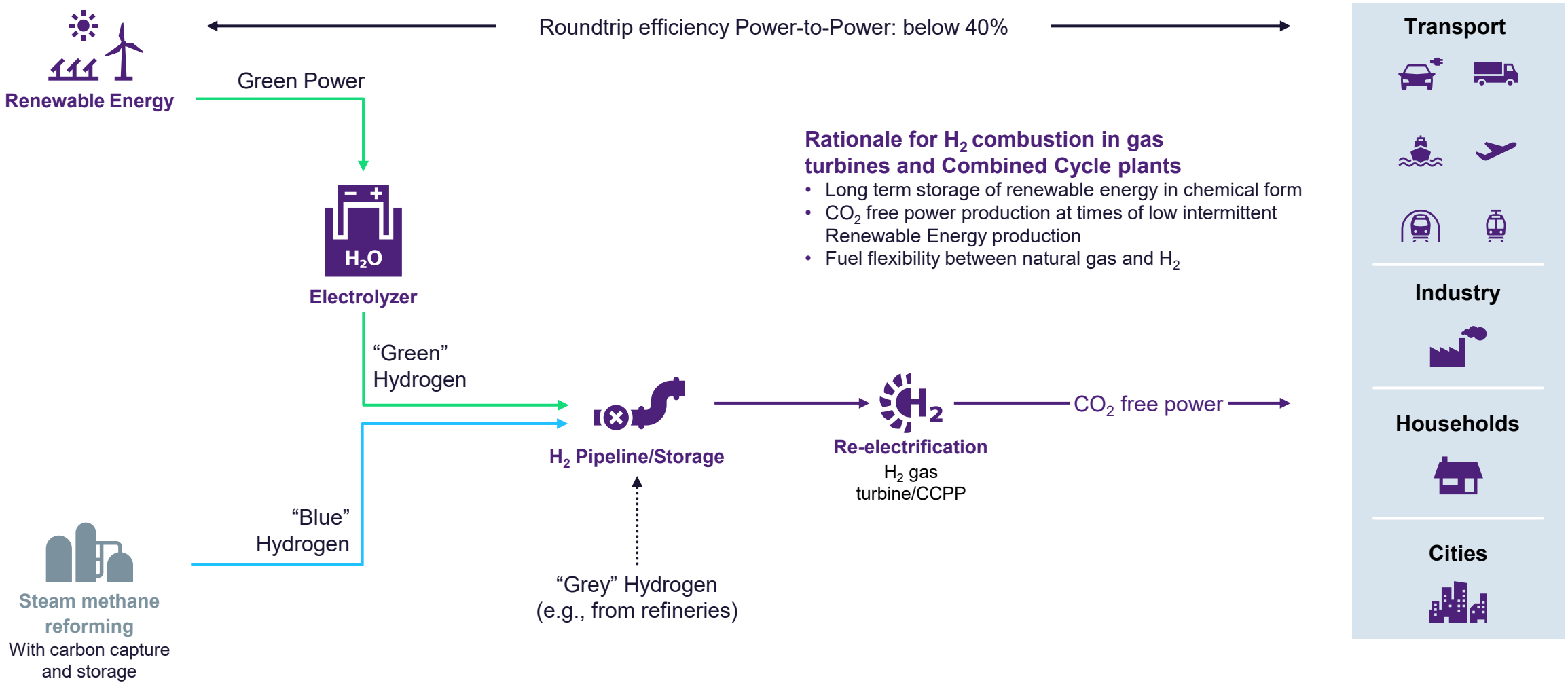
→ Perfect conditions to export green energy from Chile to the world

Solutions

- Production of e-gasoline and e-methanol at one of the best spots worldwide for wind energy
- Co-developer Siemens Energy realizing the system integration from wind energy to e-fuel production
- International Partners like Porsche and AME

03. Hydrogen combustion in Siemens Energy gas turbines

Hydrogen combustion in gas turbines enables CO_2 free power production to compensate volatility of renewable energy sources



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. %	CO_2 reduction$_{2)}$ [%]
50Hz	SGT5-9000HL	593 MW	30	11%
	SGT5-8000H	450 MW	30	11%
	SGT5-4000F	329 MW	30	11%
	SGT5-2000E	187 MW	30	11%
60Hz	SGT6-9000HL	405 MW	30	11%
	SGT6-8000H	310 MW	30	11%
	SGT6-5000F	215 to 260 MW	30	11%
	SGT6-2000E	117 MW	30	11%
50Hz or **60Hz**	SGT-800	48 to 62 MW	50	23%
	SGT-750	40/34 to 41 MW	40	17%
	SGT-700	33/34 MW	55	27%
	SGT-A35	27 to 37/28 to 38 MW	15 – 100	5 / 100%
	SGT-600	24/25 MW	60	31%
	SGT-400	10 to 14/11 to 15 MW	10 – 65	3 / 36%
	SGT-300	8/8 to 9 MW	30	11%
	SGT-100	5/6 MW	30 – 65	11 / 36%
	SGT-A05	4 to 6 MW	2 – 15	1 / 5%

Values shown are indicative for new unit applications and depend on local conditions and requirements. Capability to operate on 100% natural gas is maintained (full fuel flexibility). Some operating restrictions/special hardware and package modifications may apply.

Higher H_2 contents to be discussed on a project specific basis

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 4.5, November 2021 2) Compared with 100% natural gas operation

EU-Turbines Commitment to drive the transition towards a decarbonized Energy Mix

Hydrogen co-firing commitment from EU-Turbines

In January 2019, Siemens signed a **commitment on H_2 co-firing** in gas turbines at the #PowerTheEU summit

2019: Operation with **3 – 5% H_2** content
(→ already achieved for all new GT models)

2020: Operation with **20% H_2** content
(→ already achieved for most GT models)

2030: Commercial availability of turbines for **100% H_2**
(→ already achieved for AD-GTs, R&D and implementation plans in place to cover more GT models until 2030)

https://powertheeu.eu/

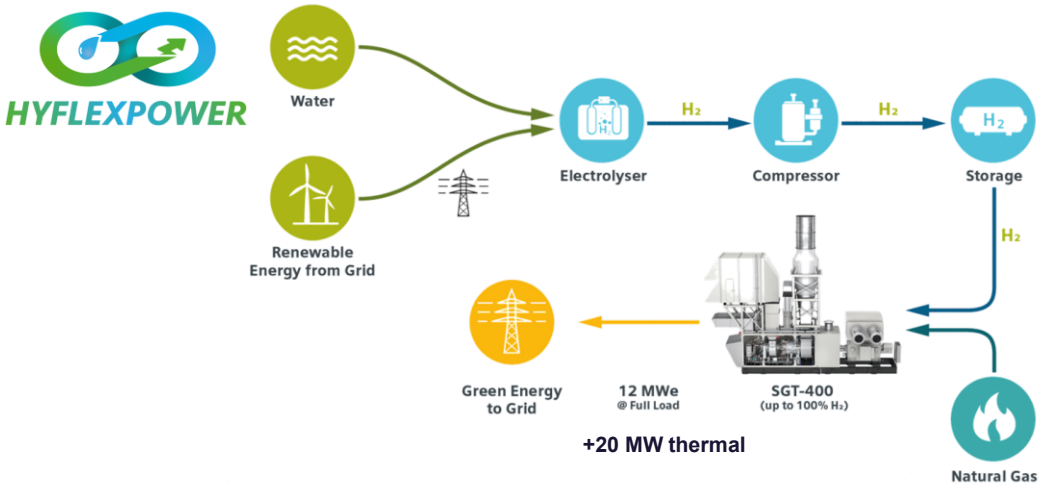
Siemens Energy R&D activities to increase hydrogen capabilities

Siemens Energy lately invested in in-house H_2 testing capabilities at Clean Energy Center in Berlin – Single burner tests at engine conditions

Engine Tests for SGT-600/700/800 running on H_2 in DLE (dry low emissions) combustion systems has resulted in sales release of 60/55/50 vol-H_2 respectively

Ongoing development to increase capabilities of our engines

EU-funded HYFLEXPOWER Project (France)
A CO_2 free power-to-power path using 100% H_2 in DLE combustion



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

Source: http://www.hyflexpower.eu/

Gas turbines built for natural gas combustion can be upgraded at later stages to hydrogen when required

Potential future developments

- **Hydrogen content in gas pipeline likely to increase** in future e.g., due to electrolyzers gaining wider acceptance and discharging hydrogen into the gas grid
- Opportunity to burn **hydrogen, e.g., from nearby refinery** willing to burn surplus hydrogen more efficiently
- Changes in legislation enforcing decarbonization of power sector, leading to a **requirement to co-burn increased content of sustainably-produced hydrogen**

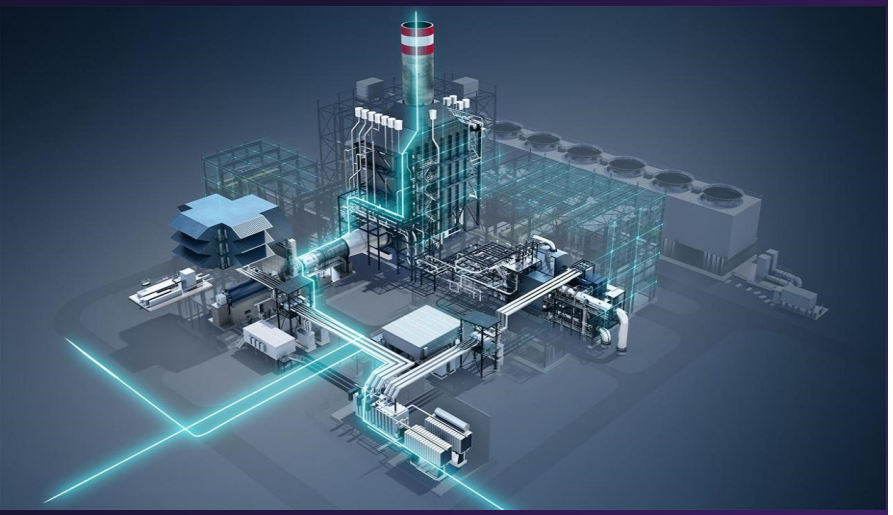
Upgrade requirement

- Requirement to modify existing gas turbines and combined cycle power plants to burn hydrogen in the future
- Minimization of risk of having future "stranded investments" when deciding today on new GT/CCPP power plant construction projects

Siemens Energy gas turbines

with ability to burn hydrogen (with full NOx emission compliance!) enabled to be upgraded for future hydrogen combustion as future-proof investment

"H_2 Ready" Plants can reduce future H_2 retrofit costs



- For new CCPPs not requiring immediate H_2 operation, an optimized configuration can be offered that takes future H_2 retrofit into account ("H_2 ready plants")
- While keeping front-end investments low, the plant can already be prepared to be retrofitted at a later stage with limited efforts
- Depending on H_2 co-firing time roadmap and requirements, optimized equipment configurations will be offered

Areas:	Equipment/Systems considered:
Fuel Supply:	Materials, sizing, aux. fuel, metering, additional systems...
Fire/Ex Protection:	Fire/Ex protection concepts, sizing of systems
HRSG:	Materials, temperatures, purging requirements
I&C & Electrical:	Design acc. to IIC
Safety:	Safety Integrity Levels definition and design
Certification:	Certification Requirements

04. Conclusion

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

Cornerstones of a Future Energy System

Decarbonization of Energy

Transforming the energy consumption in all economy sectors towards a full defossilization

Sector Coupling

Leveraging renewables in power sector to decarbonize heat, mobility, industry through electrification and use of hydrogen and its derivates

Power-to-X

Green Hydrogen as the key technology for sector coupling and decarbonized energy vectors

Hydrogen Turbines

Hydrogen-fueled gas turbines/CCPPs to provide decarbonized backup power for dark doldrum periods

Regulatory Framework

Required to drive the hydrogen economy by valuing CO_2 reduction in a technology-open way

Key takeaways for South African market

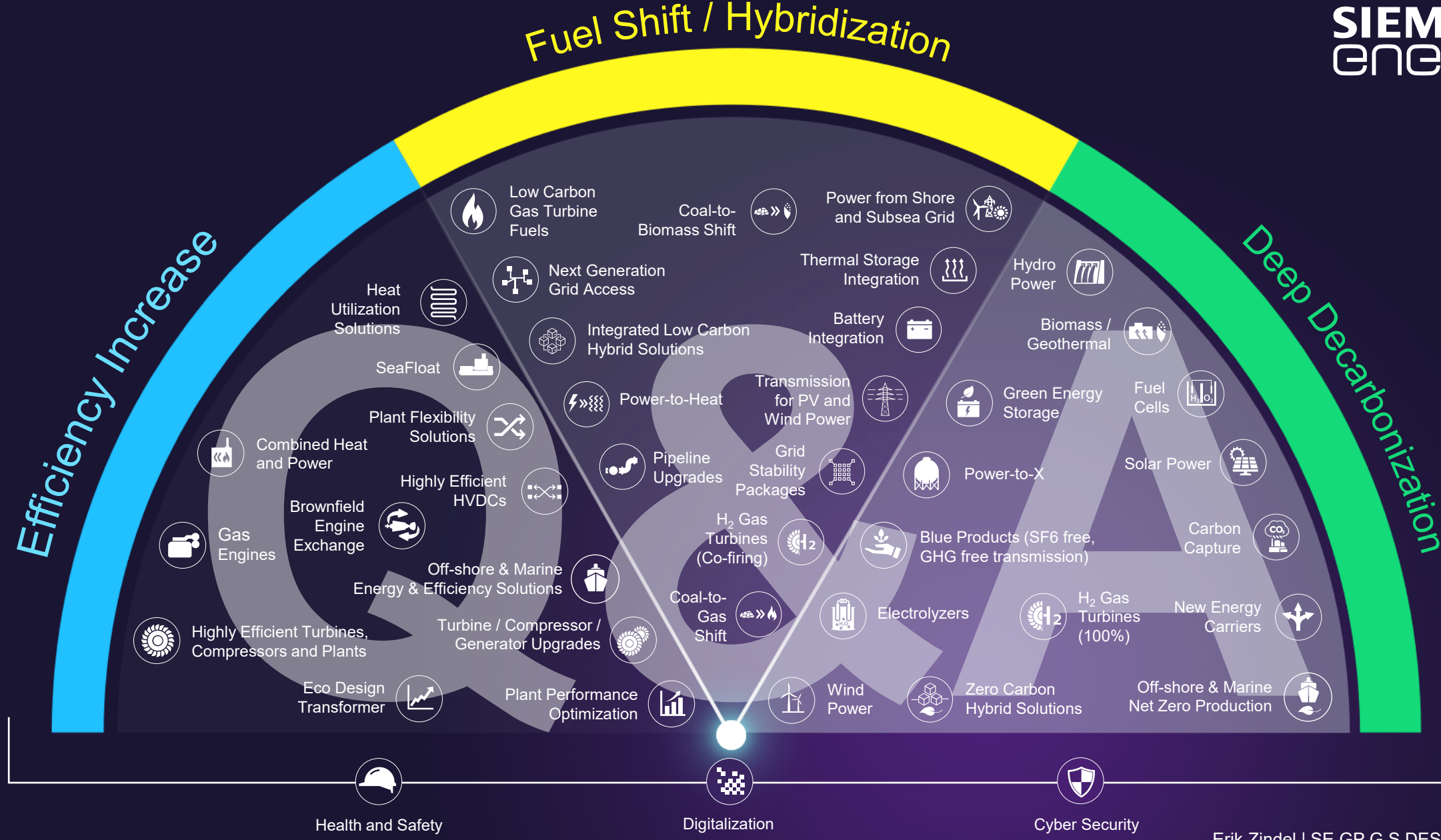
Africa is blessed with wonderful sunshine and wind that enables renewable energy and an abundance of land for world class production of green hydrogen – let's use it to drive the shift away from coal and decarbonisation in general

A Hydrogen Economy brings many benefits:

- ✓ **Sustainability** through decarbonisation of the economy in South Africa
- ✓ **Economic growth and job creation** through industrialisation - produce value added products from hydrogen like ammonia, e-synfuels, Liquid Organic Hydrogen Carriers (LOHC) for export
- ✓ **Foreign Direct Investment** in new and repurposed power plants

Renewable power and gas combined cycle plants (CCPP) harmonize very well (cheap, stable, flexible power supply) and is fully compatible with a fully decarbonized energy system (later fuel switch of CCPPs to hydrogen)

First hydrogen projects may be a good idea as a showcase for South Africa, which can also be implemented in a phased approach



Contact page

Published by Siemens Energy

Mark van Antwerp
Vice President
Generation Sales
Southern & Eastern Africa

Mobile: +27 82 521 0037
mark.vanantwerp@siemens-energy.com

siemens-energy.com

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