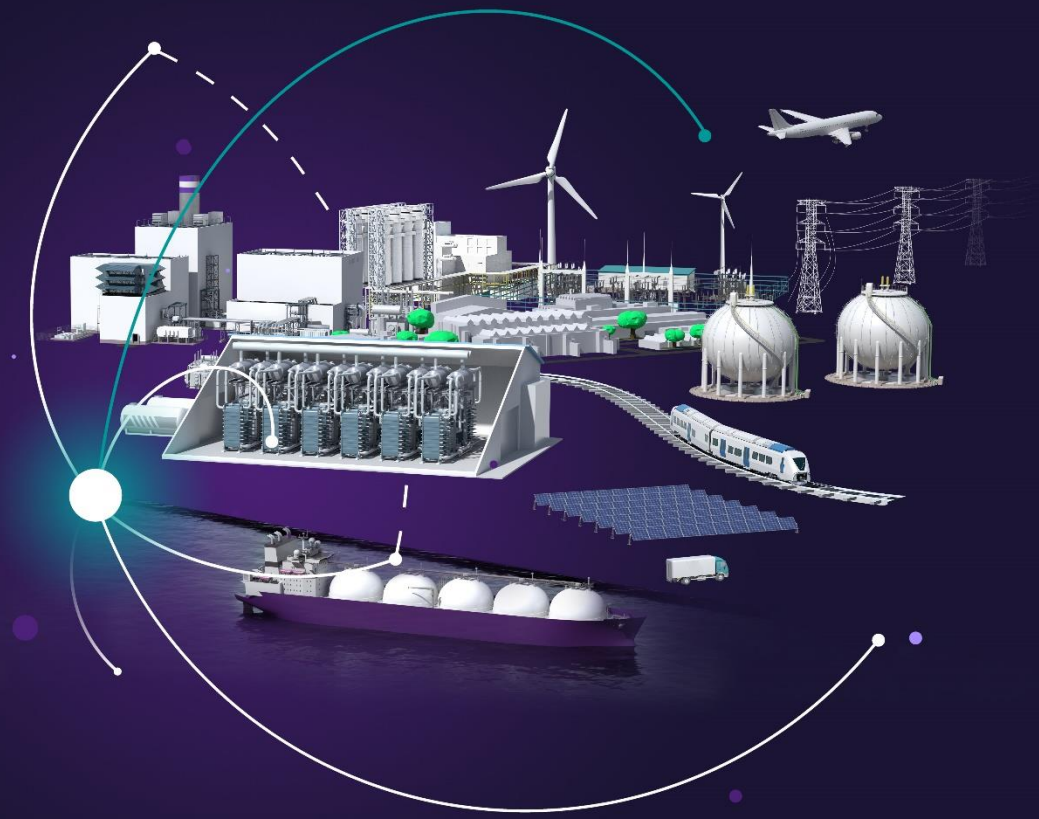
Green H_2 – Solutions
for Power Generation & Storage



ICCI 2023, Istanbul Expo Center
Christian Grenz / Market & Business Development

WHY

- Green hydrogen is the second stage of the energy transition
- Indispensable for decarbonization

WHAT

- In-house PEM electrolysis technology
- Large Power-to-X-solutions enabled by the full Siemens Energy competence
- Digital twin and service concepts

HOW

- Secure technology and cost leadership
- Implement Giga factory
- Strong international partner ecosystem

We know-how to industrialize technologies!

Boundary conditions are changing

Major green initiatives drive hydrogen related initiatives and investments

GLOBAL
Paris Agreement
Clean Hydrogen Ministerial (CN, US, EU, NL, NO, IN, JP, SK, NZ, KSA)

UNITED STATES
Biden Green Energy Plan
various initiatives

EUROPE
EU Green Deal
European Clean Hydrogen Alliance (ECH2A)

CHINA
14th 5-year plan
China Hydrogen Alliance

JAPAN
Japan Climate Initiative
Basic Hydrogen Strategy

SAUDI ARABIA
The 2030 Solar Plan und NEOM

UAE
UAE Energy Strategy 2050

SOUTH KOREA
Green New Deal

QATAR
Qatar Vision 2030

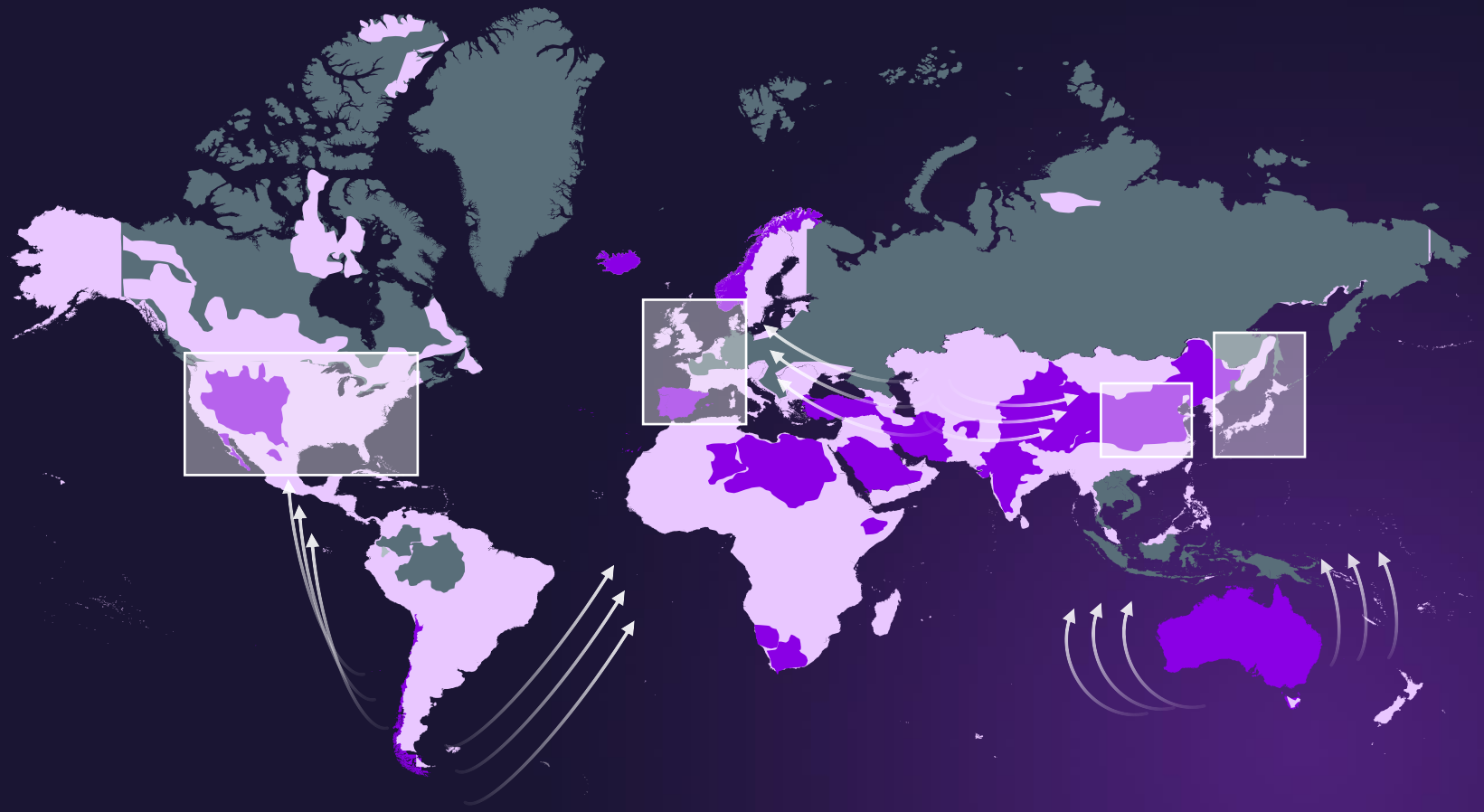
€300 bn
investment expected through 2030

€80 bn
thereof investment volume “mature”

228
announced projects

Source: Hydrogen Council, McKinsey “Hydrogen insights report 2021”

Today's challenge – Green energy needs to travel from lowest cost regions to decarbonize demand centers



36 Giga tons

total energy-related emissions in 2019

- **10.2** Giga tons
- **5.3** Giga tons
- **2.6** Giga tons
- **1.7** Giga tons
- **1.1** Giga tons
- **0.7** Giga tons

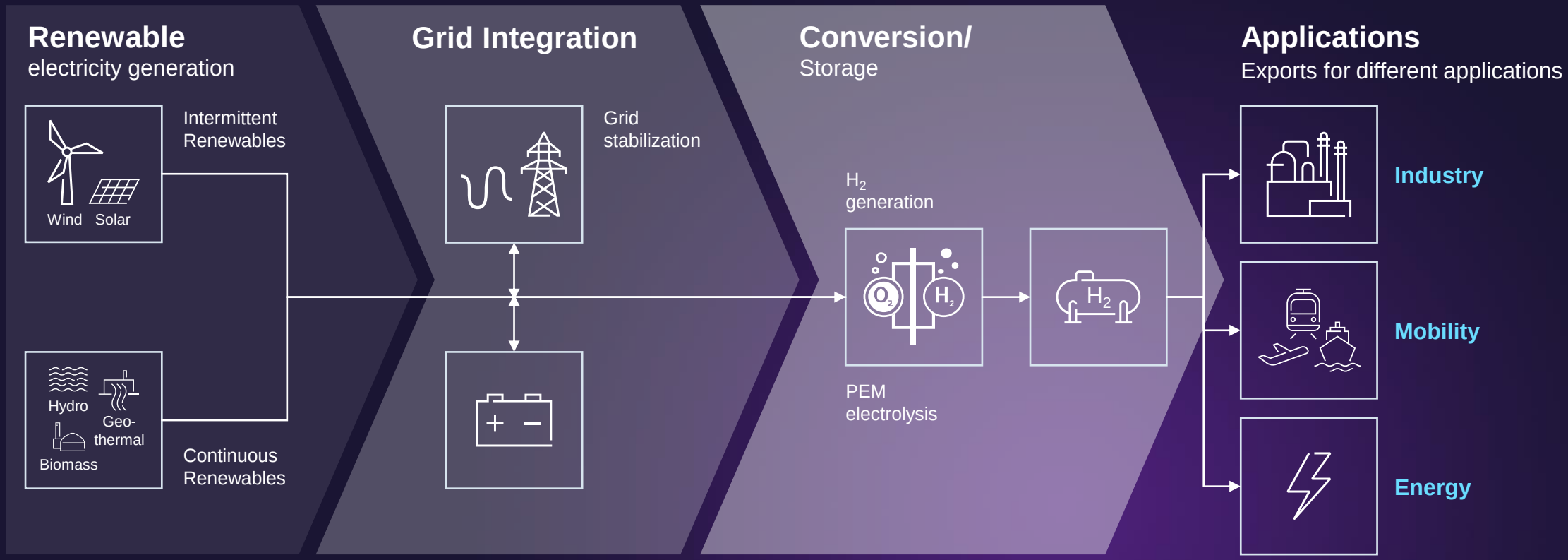
X.X – CO_2 Emissions Demand centers with high CO_2 emissions

Source: Hydrogen Council, McKinsey "Hydrogen insights report 2021", Global Carbon Atlas

Least Most

PV/wind resources for renewable hydrogen production

Hydrogen from renewables enables large scale, long term storage and sector coupling



Example applications for hydrogen and quantity required

Transport fuel
Toyota Mirai

- Onboard storage as pressurized gas 700 bar
- Range > 1,000 km
- **5 kg H_2 per refill**

Industrial power generation
SGT 400

- 13 MW open cycle 100% H_2 gas turbine
- **1,100 kg H_2 per hour**

Grid scale power generation
SGT 9000 HL

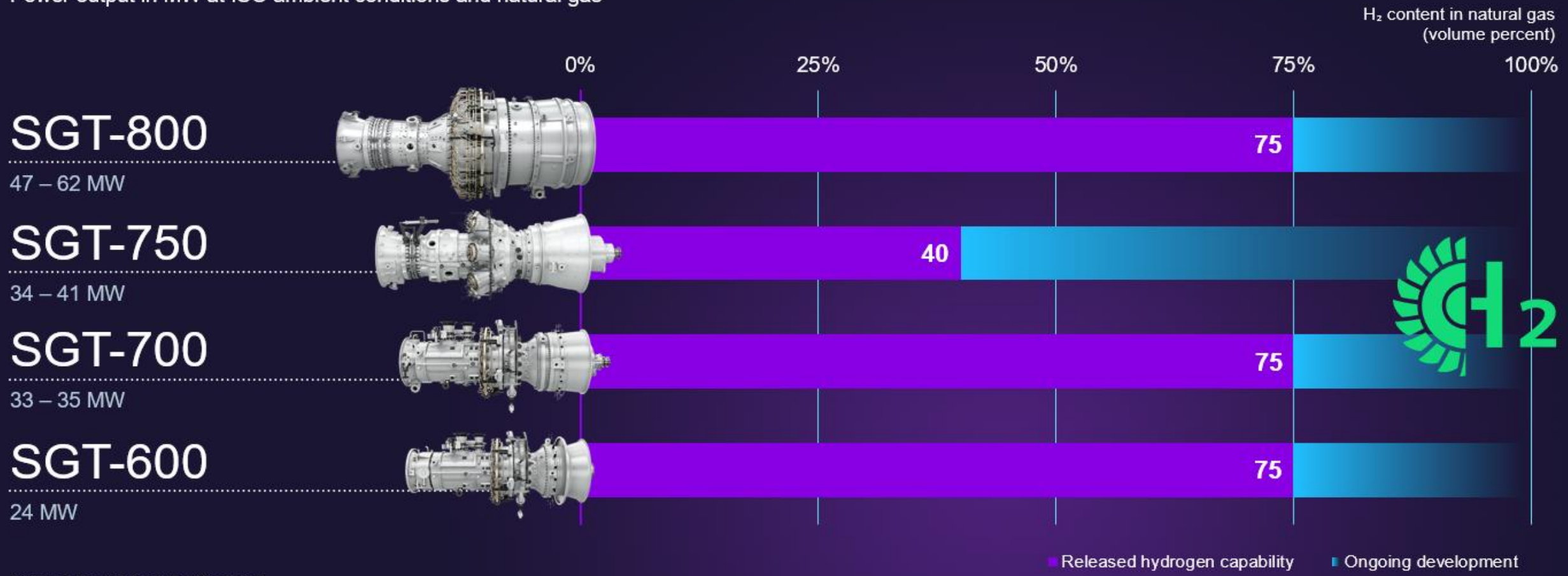
- 830 MW combined cycle 100% H_2 gas turbine
- **50,000 kg H_2 per hour**

Hydrogen capability in Siemens Energy medium size gas turbines

SIEMENS energy

All turbines equipped with DLE burner technology

Power output in MW at ISO ambient conditions and natural gas



Turbines can be used as MD as well.

Storage options for compressed hydrogen gas

= No option for re-electrification business models

						
	Tube	Manifold Cylinder Pack	Tube Trailer	Multi Element Gas Container	Cylinder Tank	Geological Storage
H_2	1 kg	17 kg	300 kg	300 kg	450 kg	Thousands of tonnes
Gross weight	80 kg	1,500 kg	30,000 kg	25,000 kg	50,000 kg	-
Pressure	200 bar	300 bar	300 bar	300 bar	25 bar	60-200 bar
Capital cost	€ <1 k	€ 8.5 k	€ 275 k	€ 260 k	Typical range € 500-700/ kg	Typical range € 500-700/ kg

Pressure Vessel Types

Type 1 A traditional all-metal bottle made of steel used for storing liquid and gases for industrial processes. Cheap to produce, but heavy

Type 2 An additional layer of carbon fibre reinforcement is added round a steel inner tank and shares the load with the metal. This gives it added strength and reduces weight, but makes it more expensive than Type 1

Type 3 A carbon-fibre composite vessel, with a steel or aluminium vessel inside. The carbon fibre outer vessel takes the load. With more carbon fibre involved, costs are higher than Type 2, but higher pressures can be achieved

Type 4 A vessel made of all carbon fibre, with an inner liner of polyamide or polyethylene plastic. Characteristics are a much lower weight and very high strength. Comparatively expensive, because of the volume of carbon fibre

Alternatives to compressed hydrogen gas storage

for large scale and long-term energy storage (e.g. for re-electrification)

Liquid (Cryogenic) H_2

- H_2 boiling point:
  ~ 20 Kelvin/ ~ -253°C

- Cooling and compression to liquefy takes energy equivalent to around 30 % of the energy content of the hydrogen
- Once liquid can be transported in highly insulated containers and easily re-gasified by using ambient heat

NASA uses liquid H_2 for space rockets

Material based

Special materials that pack hydrogen molecules tightly within another substance

- Adsorbent e.g. MOF-5
- Liquide organic e.g. BN Methyl cyclopentane

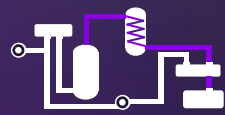
- Interstitial hybrid e.g. $LaNi_5H_6$

Requires heavy material to be transported back for refilling

Chemical

Use H_2 to synthesize other chemicals that are easier to store and transport

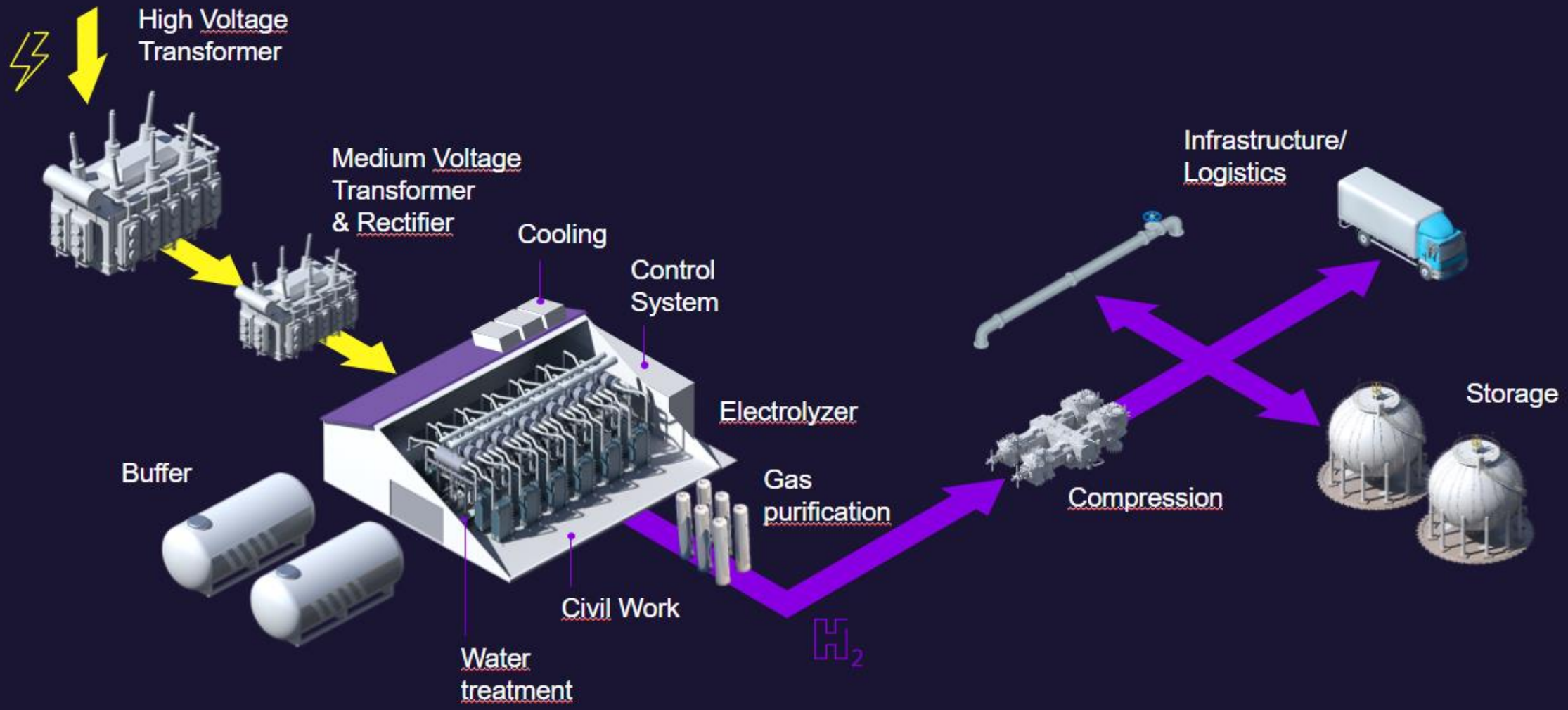
- **Methanol** CH_3OH: Fisher-Tropsch-Process
- **Ammonia** NH_3: Haber-Bosch-Process



- 5-10% Energy penalty to convert

These fuels can be used as they are or “cracked“ to release pure hydrogen

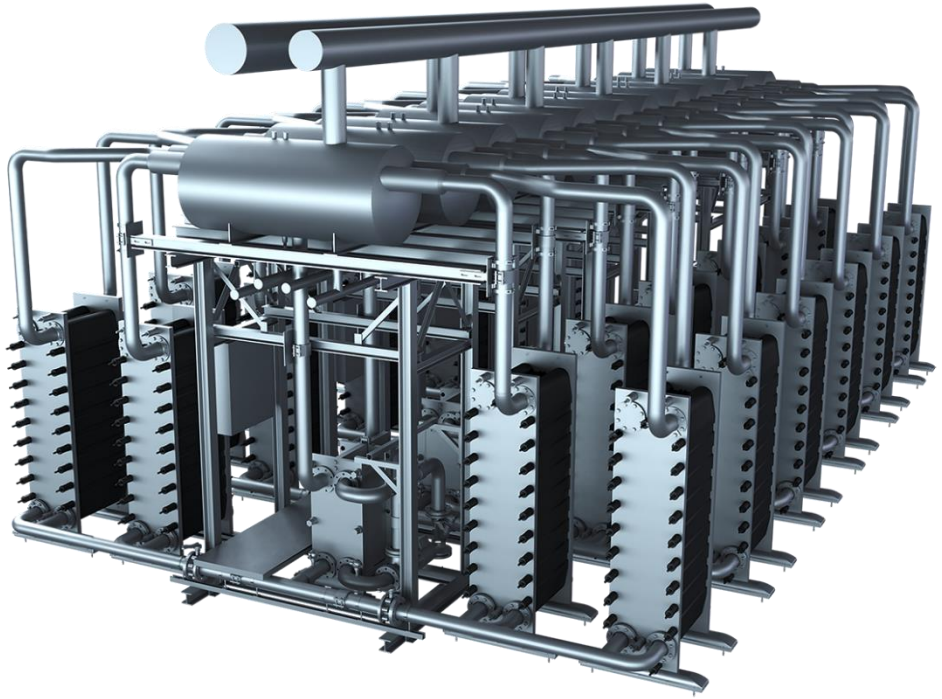
Hydrogen Generation



Silyzer 300
Fact Sheet

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	40% single stack
Dimension full stack array	15.0 x 7.5 x 3.7 m
Dimension system plant	35.5 x 15.5 x 9.0 m
Stack design lifetime	Optimized for 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



Projects completed or in implementation based on Silyzer 300
Scale-up is already happening

6 MW | **8.5 MW** | **17.5 MW** | **50 MW** | **50 MW** | **70 MW** | **200 MW**

H2Future Linz

- Green hydrogen for the steel making process
- Our partners: VERBUND, voestalpine, Austrian Power Grid (APG), TNO, K1-MET

Wunsiedel

- Green hydrogen for industry, grid services and mobility
- Our partners: Siemens AG, WUNH2, SWW Wunsiedel GmbH

Oberhausen

- Green hydrogen for Air Liquide pipeline infrastructure
- Our partner: Air Liquide

e-Methanol Kassø

- Green hydrogen for CO_2-neutral shipping at large-scale
- Our partner: European Energy

Chemical Company

- Hydrogen for chemical site

FlagshipONE

- Green hydrogen for CO_2-neutral shipping at large-scale
- Our partner: Ørsted

NormandHy

- Renewable electricity
- Engineering and Long Lead Started
- Our Partner: Air Liquide

Ready to deliver large-scale electrolysis systems
+ capacity increase in Germany is locked and loaded

2021 Erlangen

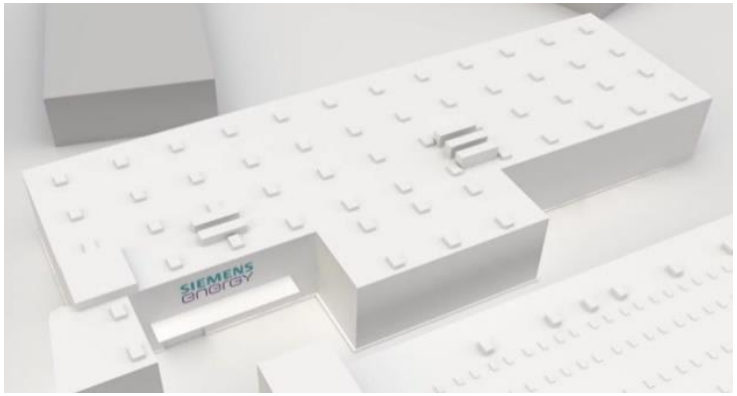
250 MW - 750 MW

- Implementation of **modern robots**
- **Fully automated** production line
- **Industry 4.0 Digitalization** implemented

2023 Berlin + Erlangen

1 GW

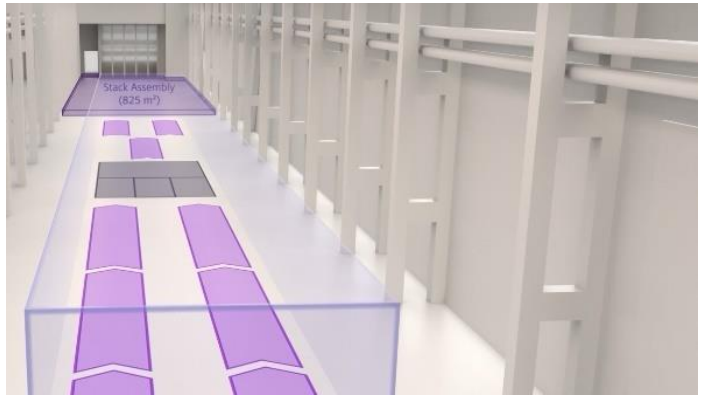
- **Inhouse design** allows for internal and external local packaging
- **Packaging** will be established depending on the development of the markets



2025 Berlin

3 GW + **1GW/ year**

- **Capacity growth plan locked-in** and layouts finalized
- **Additional 1 GW per year** depending on demand

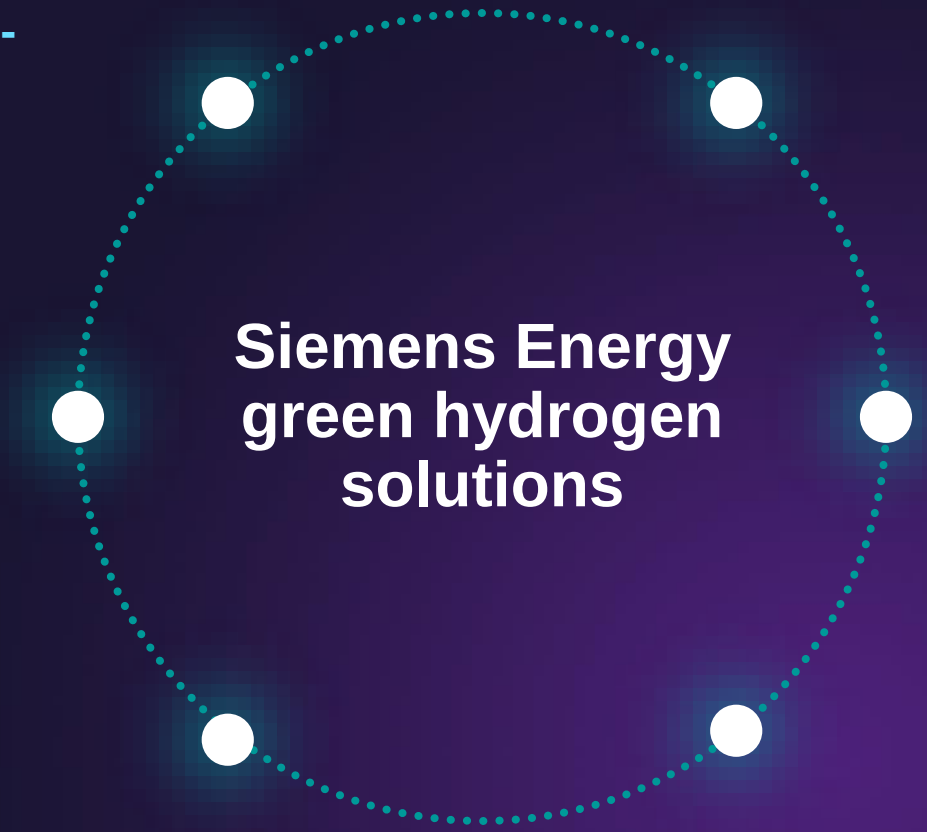


Siemens Energy
The right partner to lead green hydrogen solutions

Proven industrial-grade large-scale electrolyzer systems
>200,000 operating h in MW range

Scalable solutions
Pre-fabricated and pre-engineered packages

Energy Consulting & Digital Services
H_2 value chain design and optimization



Fully integrated solutions
from green electrons to green molecules with our strong partner ecosystem

Global G2M setup and customer domain know-how
configuration of industry-specific solutions

Reliable technology and reliable partner
with highest standards in safety and project excellence

Large scale electrolyzer partnership for sustainable hydrogen production

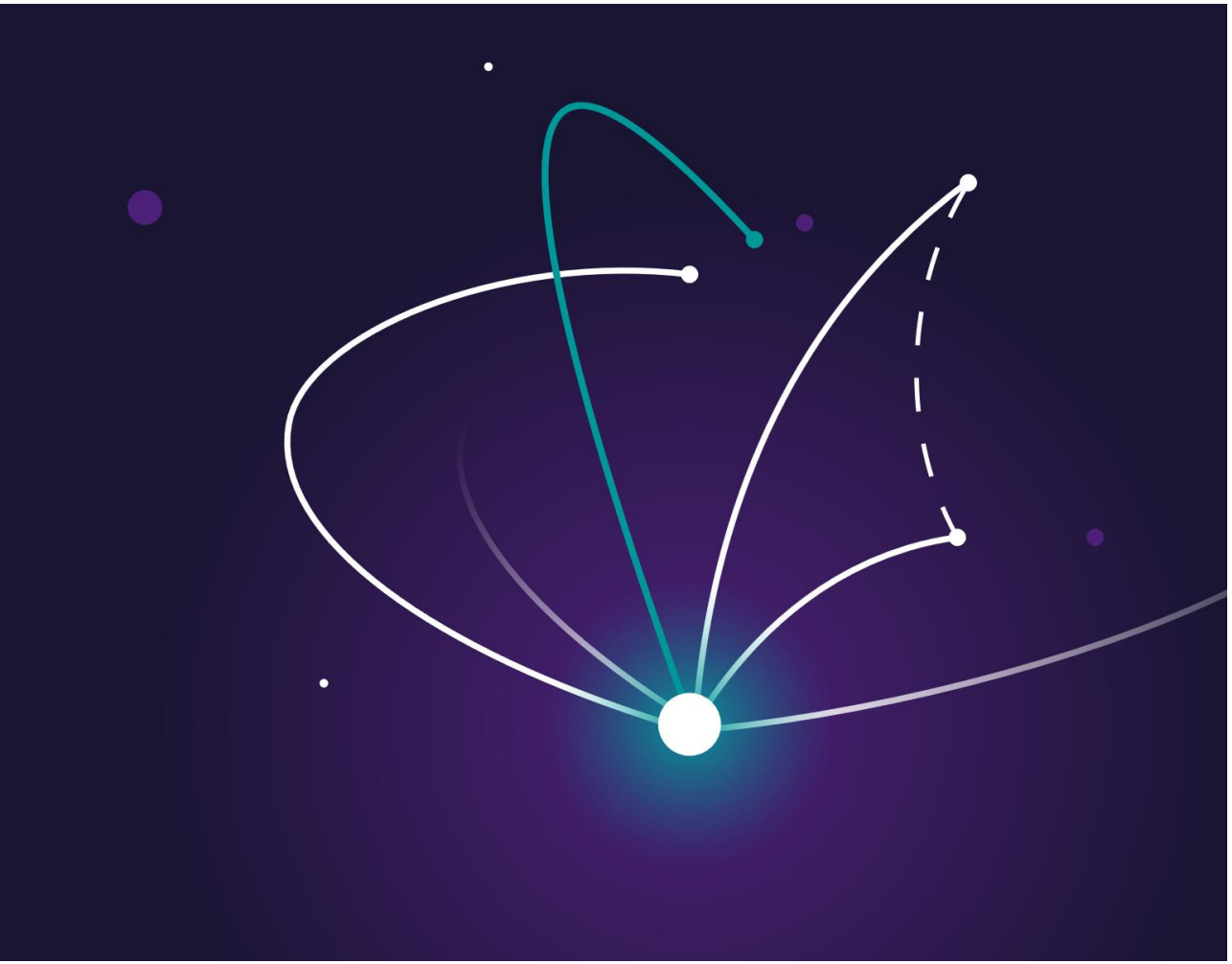
“We want to be a driving force in hydrogen technology. To make green hydrogen competitive, we need serially produced, low-cost, scalable electrolyzers. We also need strong partnerships and look forward to implementing innovative solutions and collaborating to shape this new hydrogen market.”

Christian Bruch, CEO, and President of Siemens Energy

Siemens Energy and Air Liquide to combine their expertise in hydrogen technology

- Creation of a joint venture (74.9% owned by Siemens Energy and 25.1% owned by Air Liquide) dedicated to the series production of industrial scale renewable hydrogen electrolyzers in Europe
- Multi-gigawatt factory that produces Silyzer electrolysis stacks located in the German capital Berlin
- The factory will supply stacks to both Groups for their respective broad range of customers and to serve the rapidly growing market
- The strategic partnership will benefit from a portfolio of hydrogen projects combining both Air Liquide and Siemens Energy’s pipelines
- Dedicate R&D capacities to the co-development of the next generation of electrolyzer technologies

Contact page



Christian Grenz

Director
Market & Business Development

Schuckertstr. 1
91058 Erlangen
Germany

Phone: +49 9131 94 25 61 3
Mobile: +49 152 22 97 29 44

Christian.Grenz@siemens-energy.com