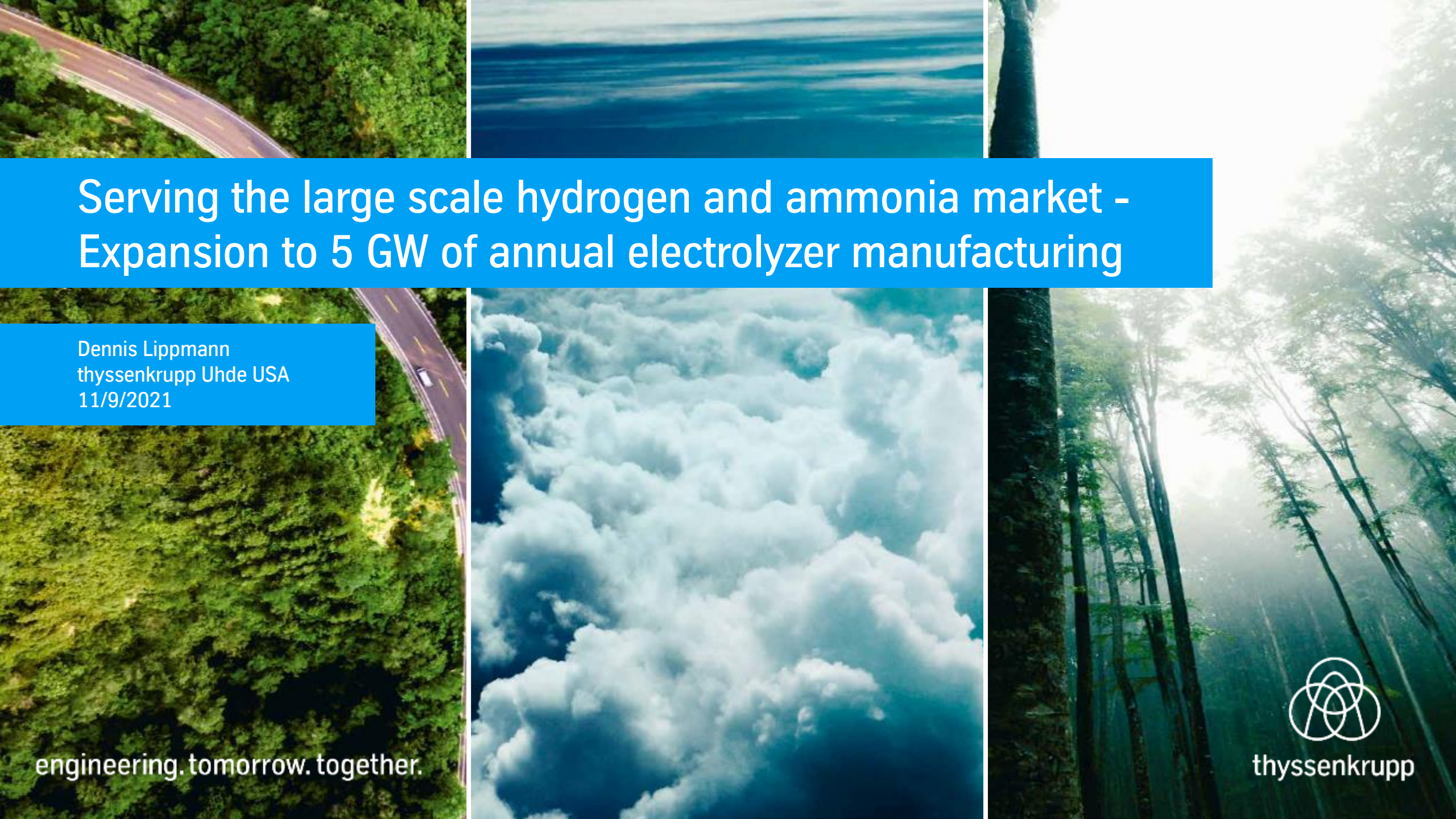


Serving the large scale hydrogen and ammonia market - Expansion to 5 GW of annual electrolyzer manufacturing

Dennis Lippmann
thyssenkrupp Uhde USA
11/9/2021

engineering.tomorrow.together.

thyssenkrupp

What happened during the past year…

Our technology portfolio enables a sustainable industry

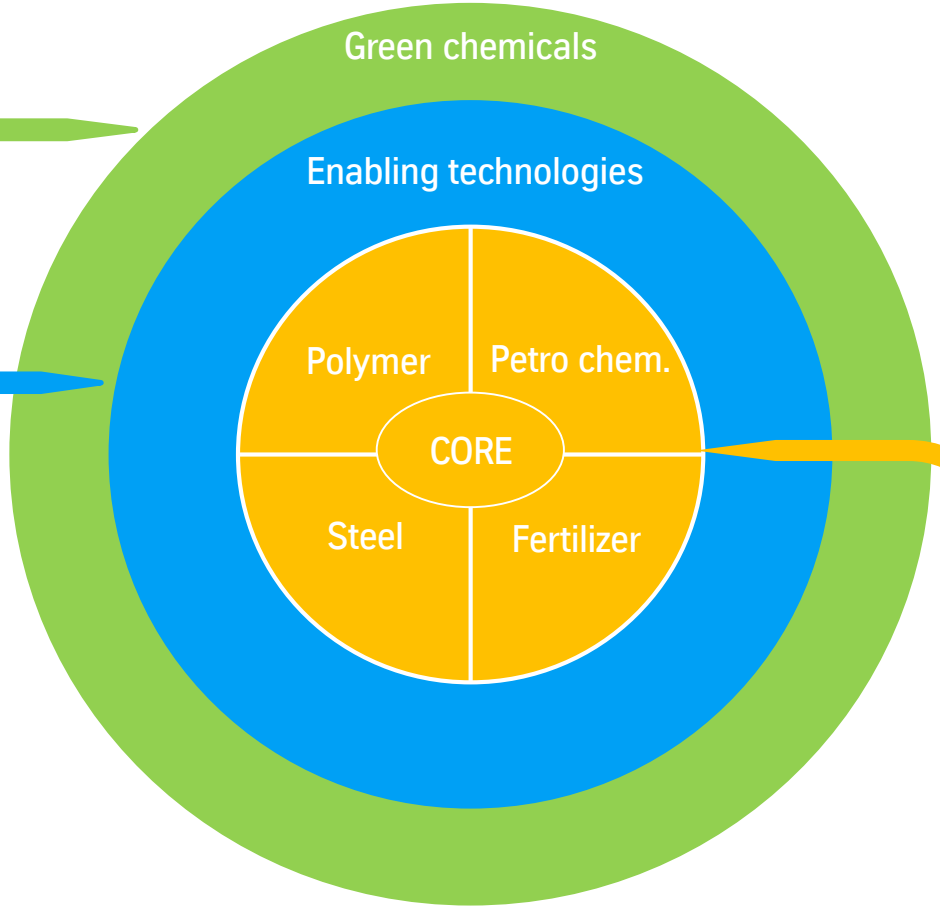
GREEN TECHNOLOGIES:

Green Chemicals

- Green hydrogen & oxygen
- Green ammonia
- Green methanol & DME
- Green synthetic natural gas
- Green fuels (BioTFueL, GtL)
- Green fertilizer

Enabling Technologies

- Revamps
- Blue hydrogen / CO_2 Capture
- EnviNOx
- Polymer recycling
- Oleochemicals
- Biobased Polymers (e.g. PLA)
- Energy recovery
- Water desalination



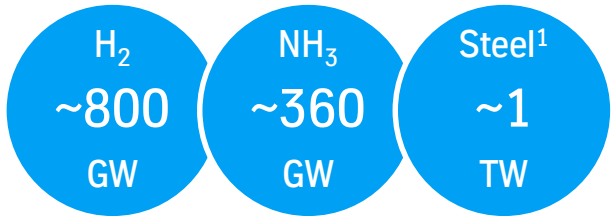
CORE TECHNOLOGIES:

- Fertilizers & Methanol
- Coke Plants (black & white side)
- Gas Cleaning Plants
- Refineries, Petrochemicals & Polymers
- Chlor-Alkali Electrolysis
- High Pressure Technologies

Drivers for green hydrogen and green chemicals: Scale up technology for efficient operations

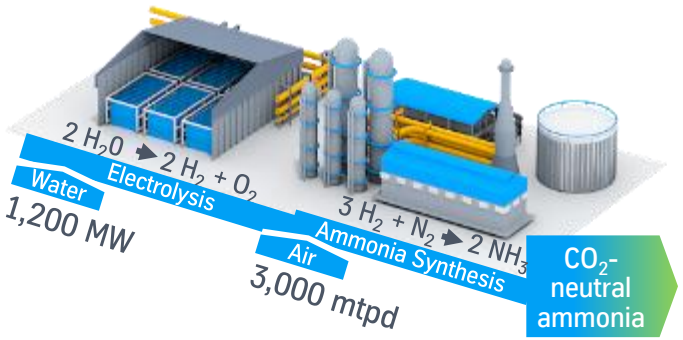
1

Substitution of grey hydrogen in existing value chains already requires gigawatt scale



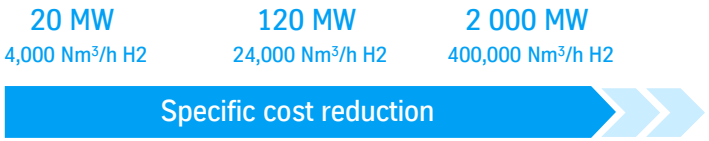
2

Power-to-X applications require scale to compete against gray commodity prices



3

Scaling up electrolysis plants shows significant cost reduction



4

Only at gigawatt scale global transport chains operate efficiently

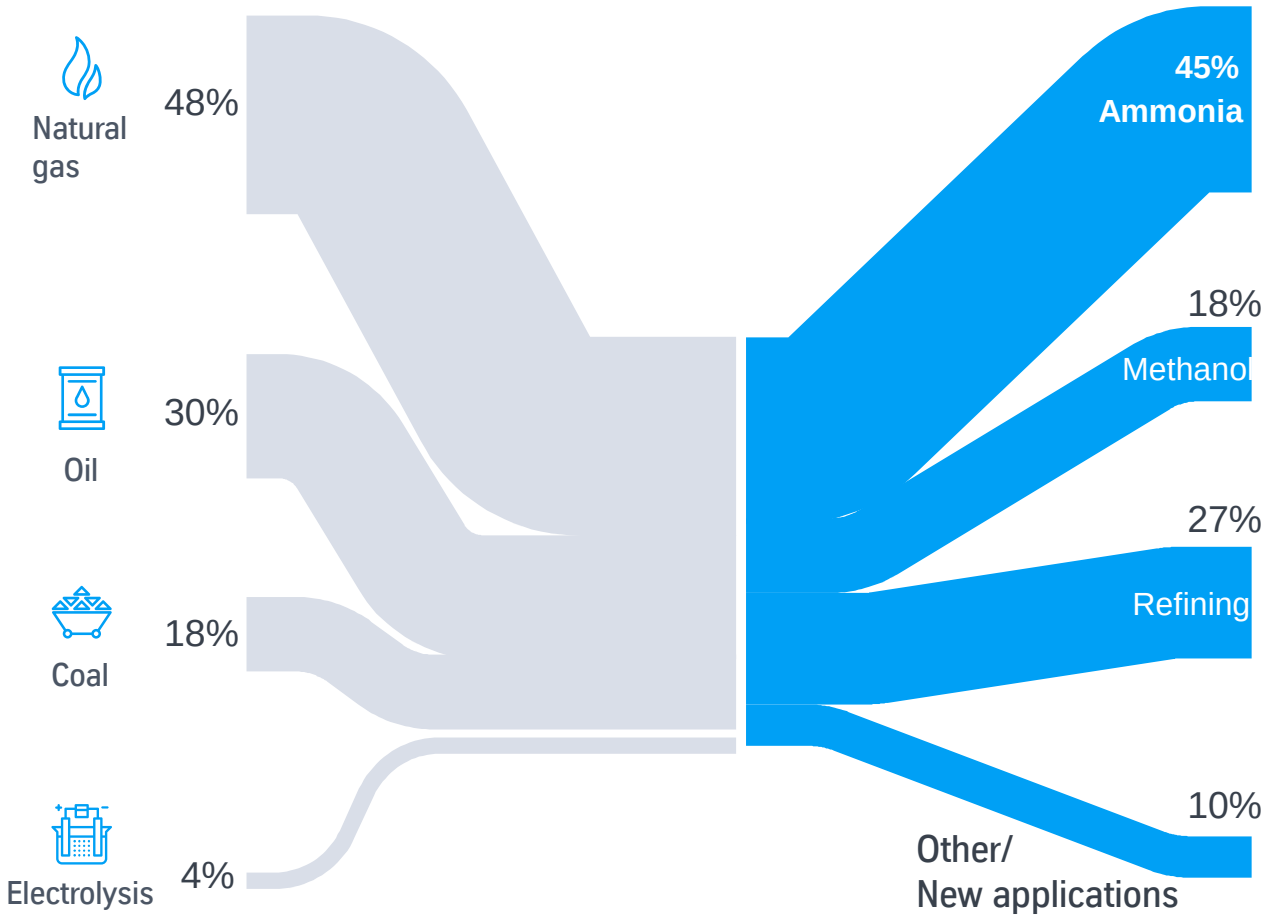
1 Direct reduction of iron ore.

Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

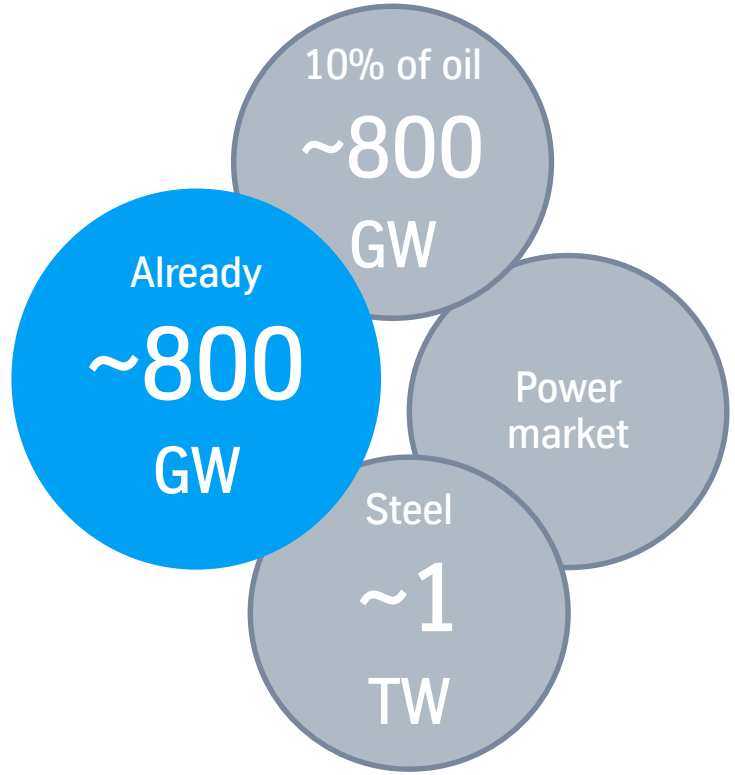
“Today’s hydrogen market already requires gigawatt scale”

Today’s hydrogen market is to a major extent gray

Market sizes 9.8 EJ = 2784 TWh



Substitution of fossil feed and fuel



By tk based on today’s market size; installed electrolysis capacity in a green scenario with 6000 full load hours per year and 75% efficiency. In the steel sector, hydrogen can be used for direct reduction of iron ore.

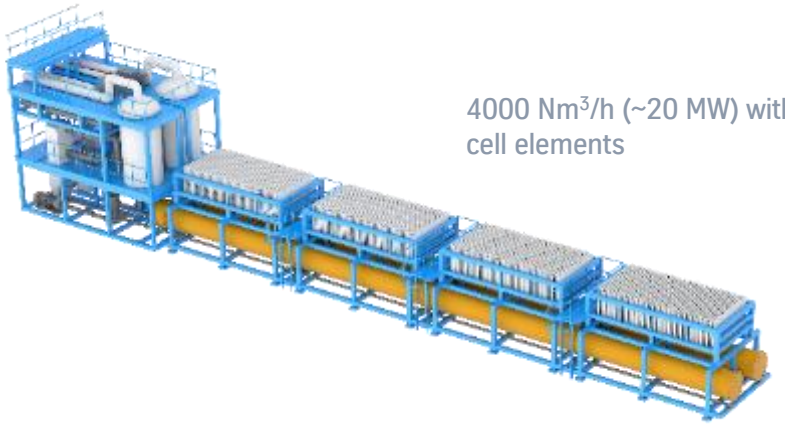
thyssenkrupp is one of the world leaders in industrial-scale electrolysis

10 Gigawatt
installed Power (Chlor-alkali electrolysis)

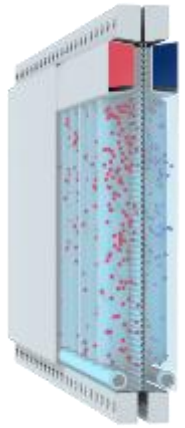
50 years
expertise in design, construction and operation

> 1 Gigawatt
of water electrolysis equipment capacity can be manufactured in Germany

> 600
installed capacity worldwide (chlor-alkali electrolysis)



4000 Nm^3/h (~20 MW) with cell elements

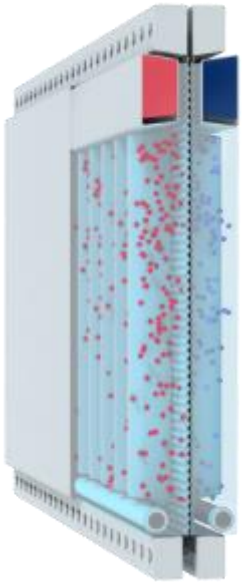


Cell element

- ✓ Reliable technology
- ✓ High efficiency
- ✓ Fast dynamics to join the power market
- ✓ Mass production, supply chain at scale
- ✓ Current production capacity of total 1 GW electrolysis cells per year

thyssenkrupp has a clear development path based on proven design

Process intensification



Proven cell design ✓

Scalable electrolyte and gas flow ✓

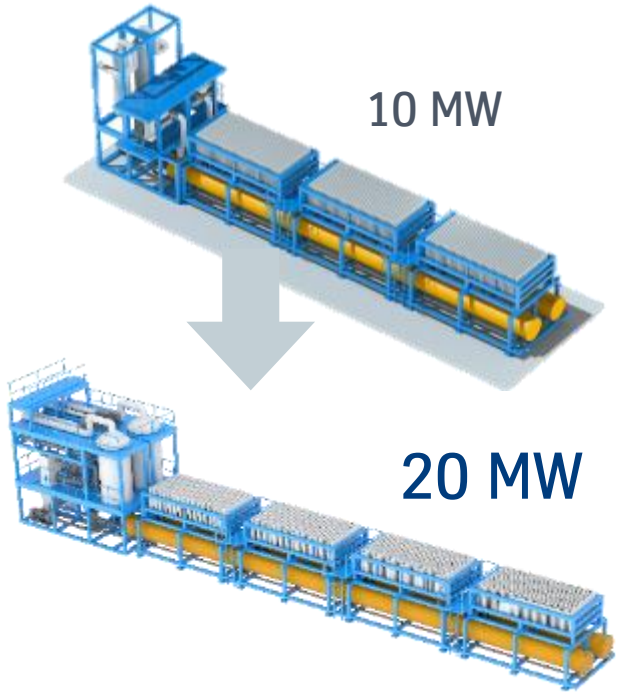
Very high utilization of material ✓

Cell size is already quite large (close to 3m² active area) and rectangular design

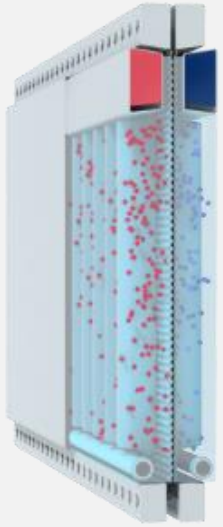
Module size increase

Increased current density without compromising on efficiency by:

- Evolved cell design
- Improved electrochemical active catalysts
- Improved separators



We prepare for an even more dynamic project market and aim for a 5 GW supply chain



1

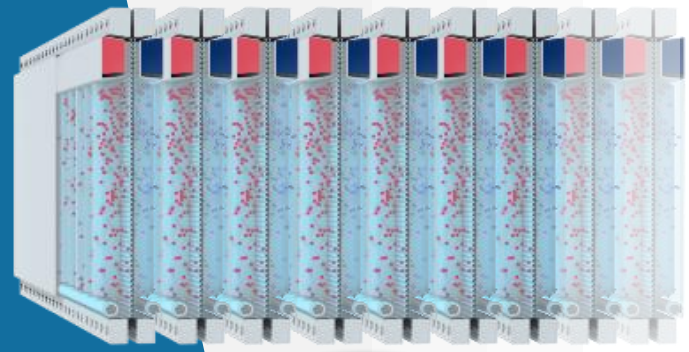
Stack and cell development

2

Optimization and scaling of manufacturing

3

Optimization and automation of assembly



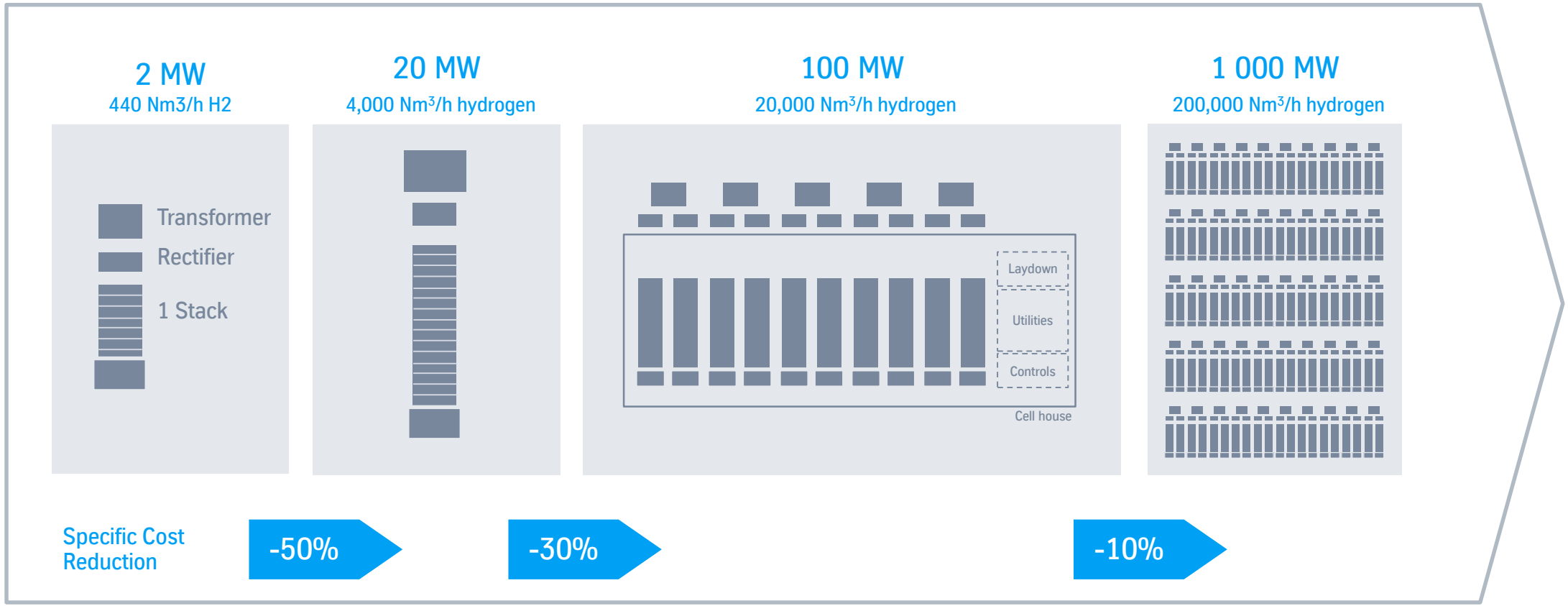
1 GW

5 GW

Pave the way to industrial series production with high volumes and strong partnerships

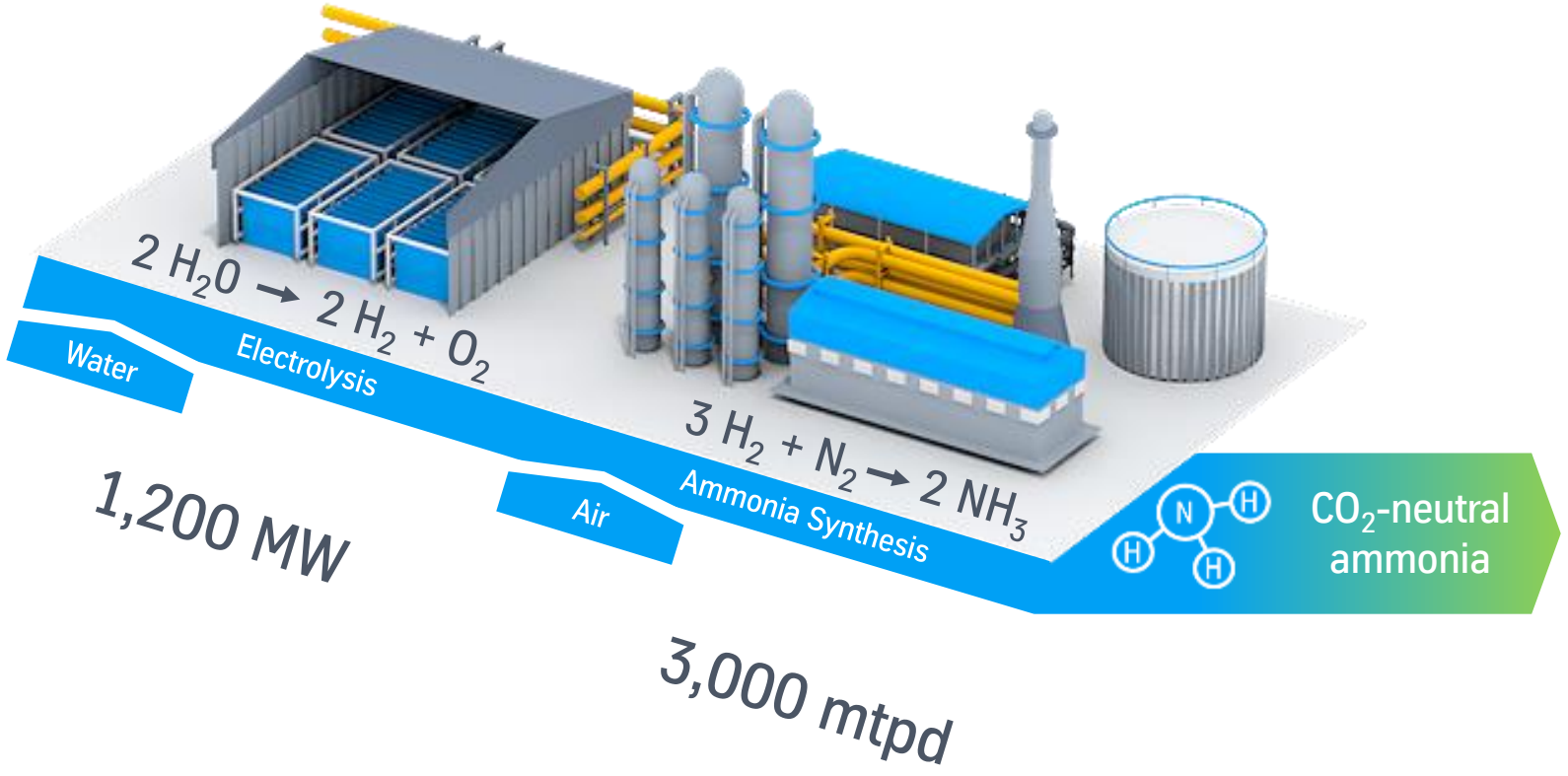
Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

Although being a highly modularized technology, scaling up electrolysis plants shows significant cost reduction



Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

Power to X applications, such as green ammonia, require scale to compete against gray commodity prices



Large scale commercial solution for green ammonia

Our experience goes back to 1921 with more than 130 plants built and about 50mln tpa ammonia capacity

50 mln tons p.a.
installed ammonia capacity

100 years
expertise in design, construction and operation

50 to 5,000 mtpd
ammonia capacity range

Market Leading
for large capacity, 5 plants ≥ 3,300 mtpd

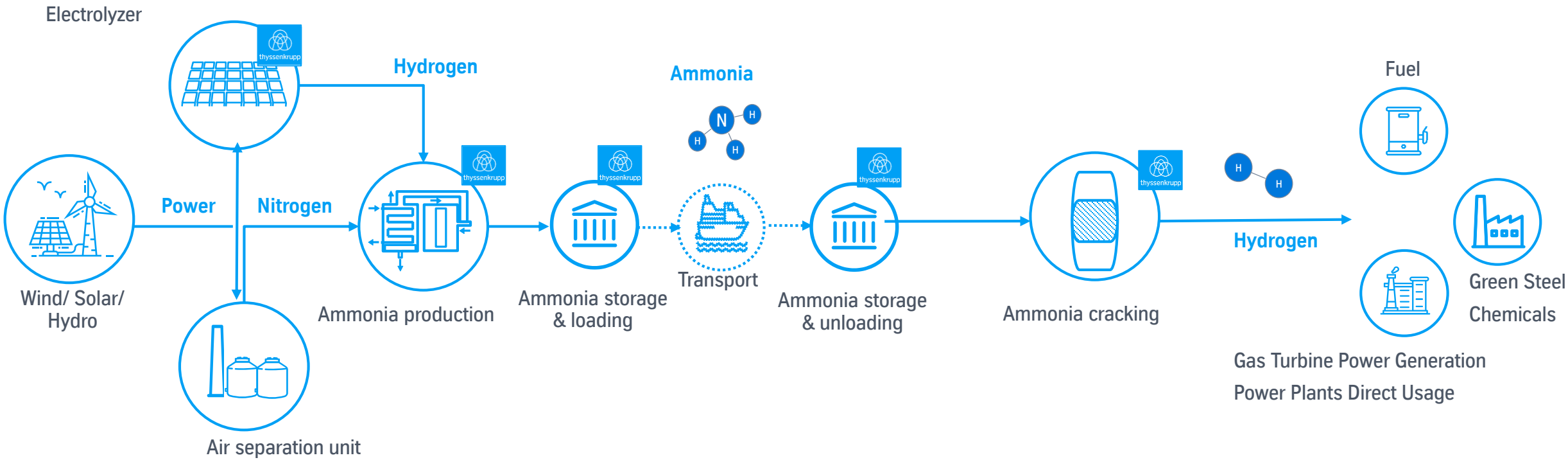
> 130
installed capacity worldwide

A Market Ready Solution:

- Modularized plant concept
- Pre-Configured plant concepts to maximize process modularization
- Integrated offering of green ammonia and electrolysis
- Worldwide supply chain with qualified and audited vendors
- One-stop-shop and EPC solutions provider
- World wide foot print and service

Green Ammonia as Energy carrier – Set up along the whole energy supply chain

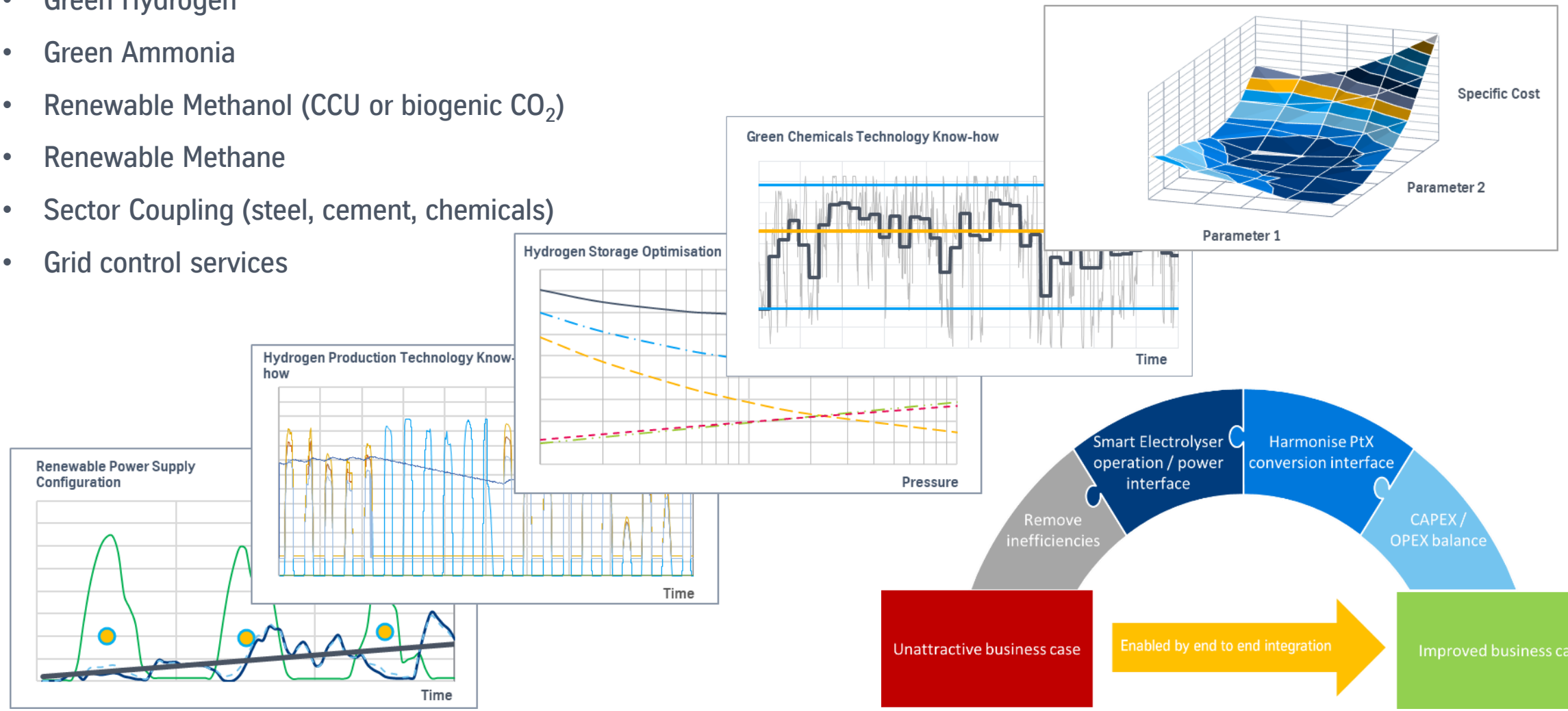
The complete solution from one source



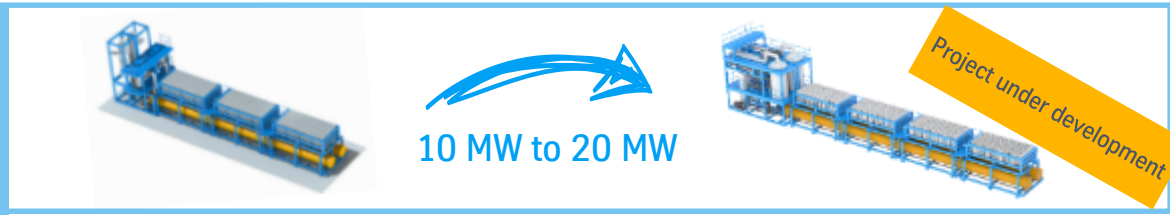
Ammonia usage for energy transport, utilization as energy carrier or re-conversion to hydrogen

RHAMFS © - Sustainable PtX solutions founded on technology know-how and further harmonized to master the unique challenges of renewable value chain

- Green Hydrogen
- Green Ammonia
- Renewable Methanol (CCU or biogenic CO_2)
- Renewable Methane
- Sector Coupling (steel, cement, chemicals)
- Grid control services



What we are working on for customers

ELAN	88 MW electrolysis in 2023 (expected) Located in Varennes, Canada Green hydrogen to green methanol, ethanol, DME as biofuels, power from hydroelectric plant	
CFI	20 MW electrolysis in 2023 (expected) Located in Donaldsonville, LA, USA Green hydrogen in existing ammonia plants to produce green ammonia (decarbonize production)	
Element 1	20 MW Module size Located in NEOM, KSA Operation from 2023 (expected)	
HYLIOS	650 t per day green hydrogen 2025 (expected) Located in NEOM, KSA Green hydrogen as feedstock for green ammonia (energy carrier)	
HydrOxy100	500 MW electrolysis in 2025 (expected) Co-located to steel plant in Duisburg, Germany Hydrogen use for DRI plant and Oxygen use in the converter	

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