thyssenkrupp

engineering. tomorrow. together.

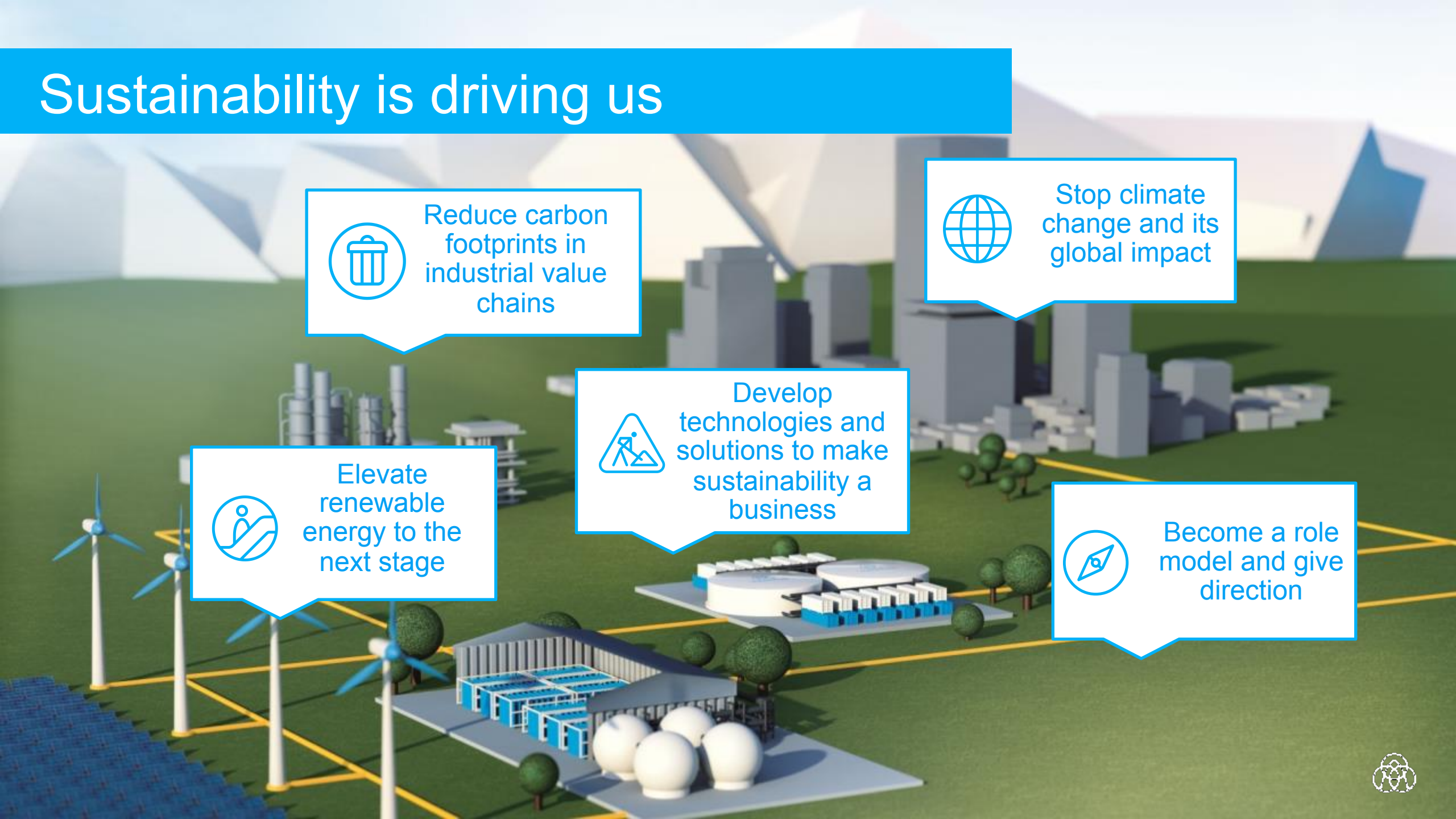
Realization of Large-Scale Green Ammonia Plants

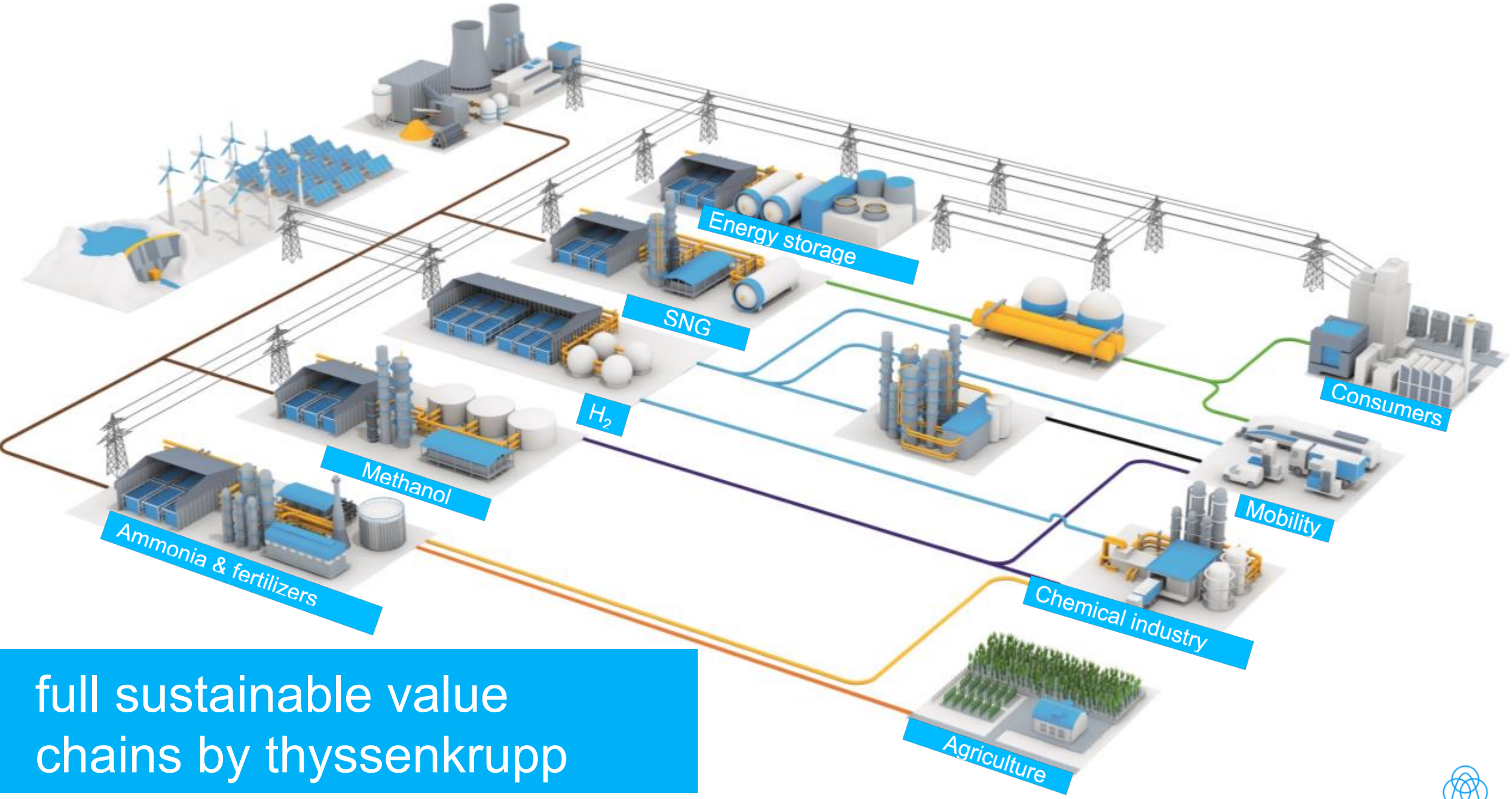
Solutions for sustainable NH_3 production

2018 AIChE Annual Meeting – NH3 Energy+ Topical Conference

October 2018 | Markus Will | thyssenkrupp Industrial Solutions

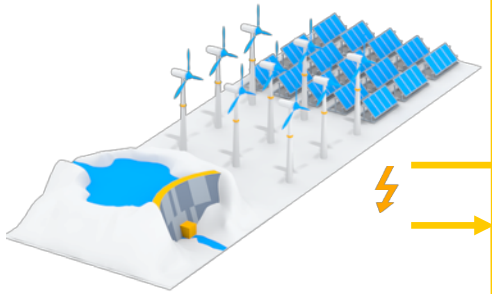
Sustainability is driving us





full sustainable value chains by thyssenkrupp

Our solutions: redox flow batteries (RFB) and alkaline water electrolysis (AWE)



Renewable energy

Electrochemical energy storage systems (RFB)
Short- to mid-term storage

Conventional energy production & heavy industry

Water electrolysis
Long-term storage
(AWE)

Power-to-Power

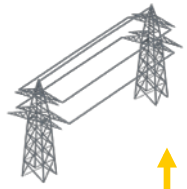
H_2

O_2

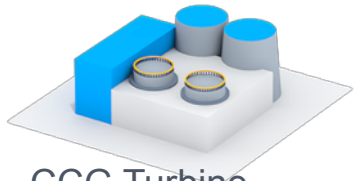
CO_2 (Carbon sequestration)

Power-to-Chemicals

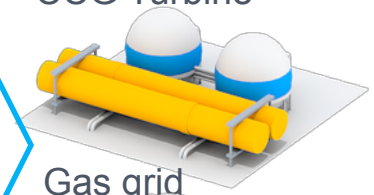
- Ammonia
- ~~Methanol~~
- Urea / DEF
- SNG (Power-to-gas)



Power grid



CCG Turbine



Gas grid

Mobility

Chemicals

thyssenkrupp's integrated portfolio for energy storage & chemicals

Cutting-edge ammonia technology since 1928

uhde® ammonia process

- One of the leading technology providers in ammonia field
- Improved energy efficiency and higher capacities
- Reassuring reliability
- Pioneers in critical plant equipment

Experience cannot be copied.

#1

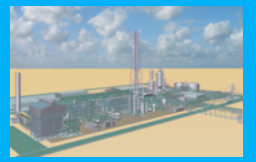
supplier in EPC business for ammonia plants

≈ 130

ammonia plants realized worldwide

> 90

years of turnkey EPC solutions

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Hydrogen at scale – large water electrolysis plants

Advanced Water Electrolysis

- Zero-gap technology
- Innovative electrode coatings by DeNora
- High efficiency atmospheric operation
- Fast response to fluctuating power input
- Post-compression optional
- Full turnkey EPC plants
- Large capacity supply chain
- Global service

Experience cannot be copied.

#1 49% market share
supplier for electrolytic hydrogen production

600
electrochemical plants realized worldwide

over **10 GW**
of power installed

Hydrochloric acid diaphragm electrolysis

Hydrochloric acid ODC[1] membrane electrolysis

Chlor-alkali membrane electrolysis

[1] ODC: Oxygen Depolarized Cathodes

Introducing renewable ammonia by thyssenkrupp

2 worldwide leading processes

1 wholistic solution

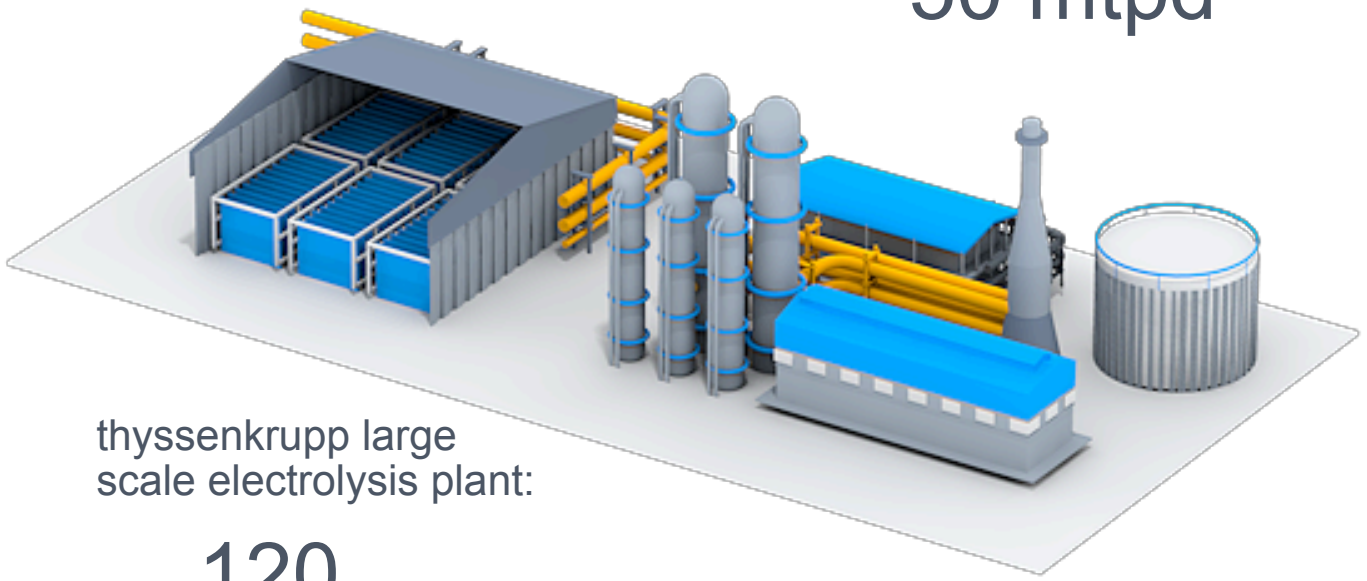
0 CO_2 emissions*

thyssenkrupp electrolysis plant:

20 MW

thyssenkrupp smallest scale ammonia plant:

50 mtpd



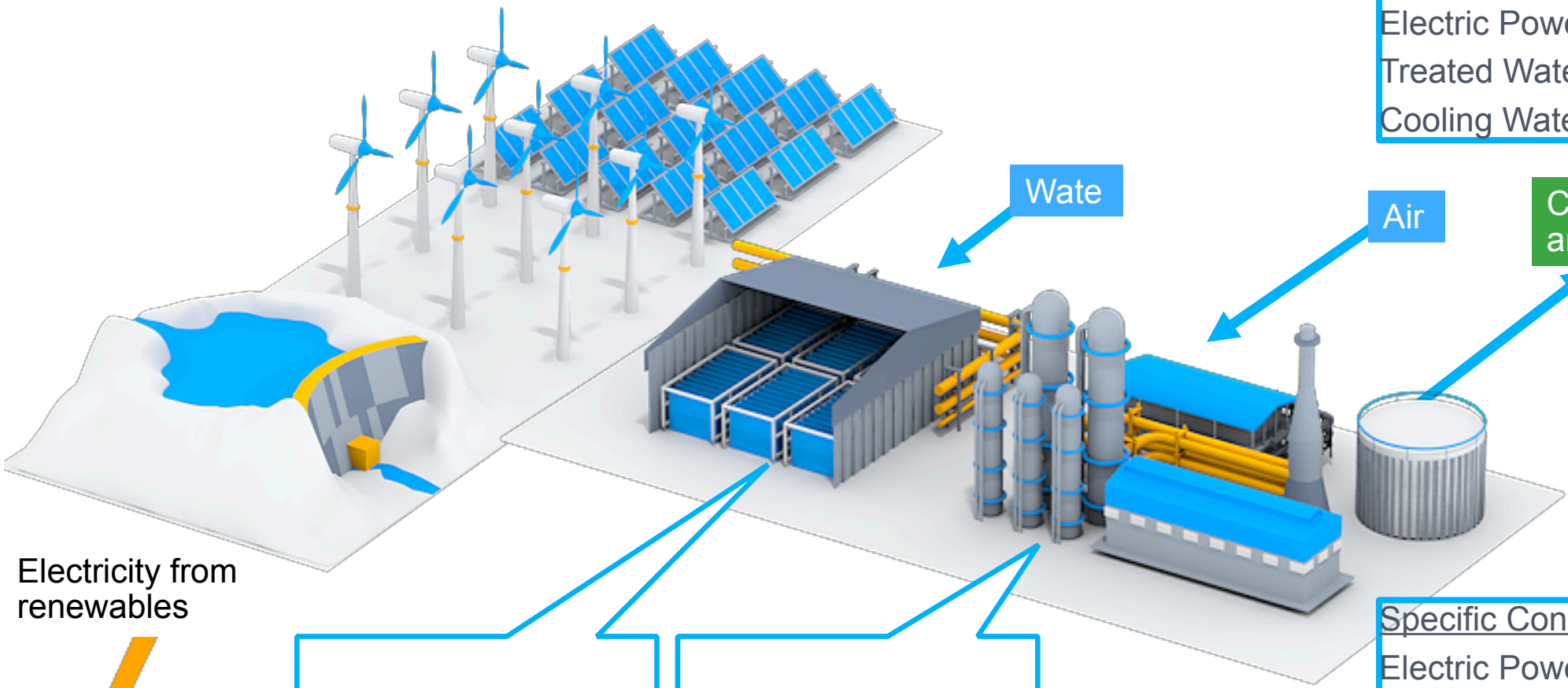
thyssenkrupp large scale electrolysis plant:

120 MW

thyssenkrupp small scale ammonia plant: **300 mtpd**

*depending on E-power source

Introducing renewable ammonia by thyssenkrupp

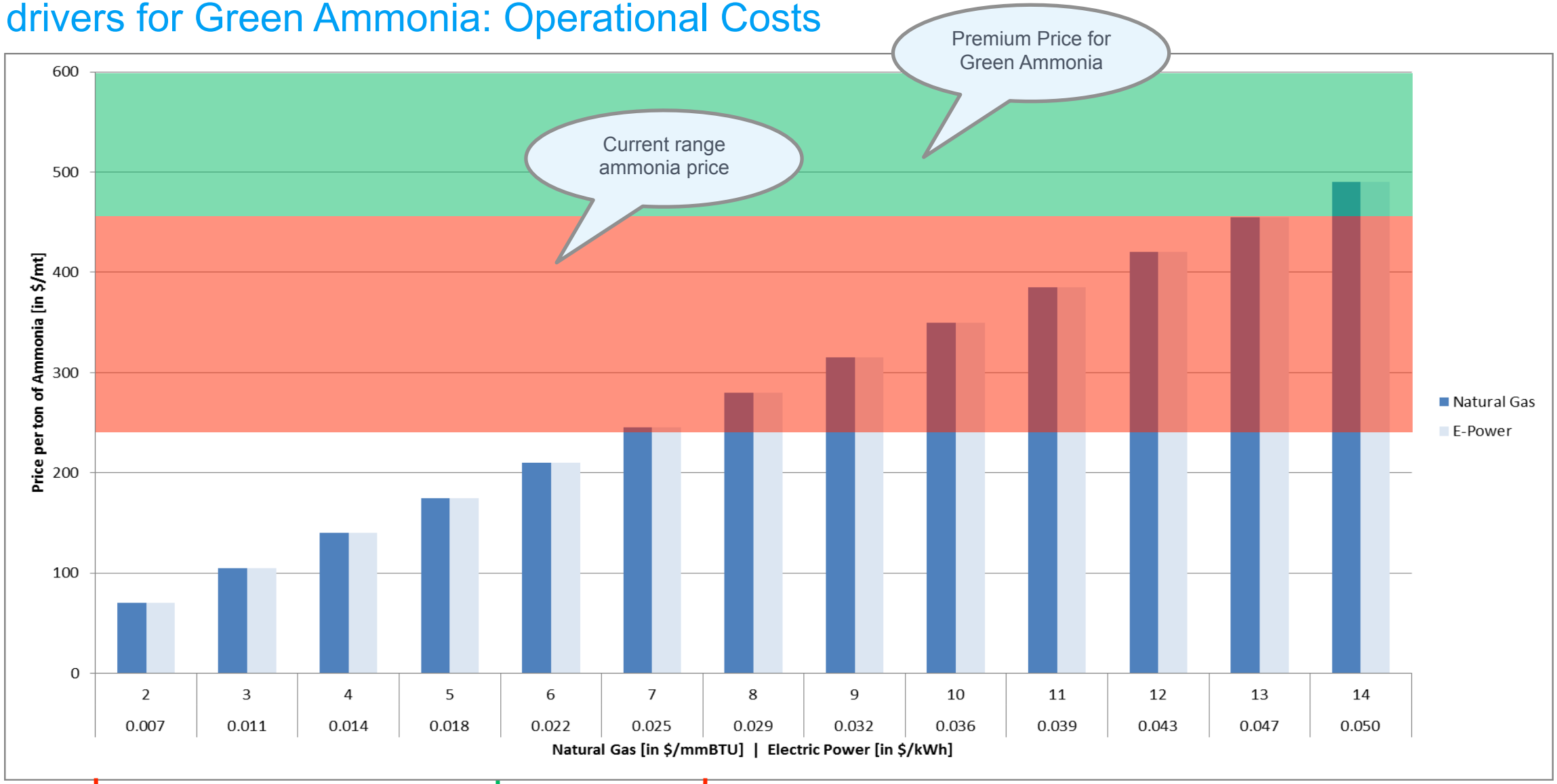


Specific Consumption 50 mtpd plant	
Electric Power:	~ 10 MWh/t_{NH3}
Treated Water:	~ 1.6 $tons/t_{NH3}$
Cooling Water*:	~ 240 $tons/t_{NH3}$

Specific Consumption 300 mtpd plant	
Electric Power:	~ 9.4 MWh/t_{NH3}
Treated Water**:	~ 1.62 $tons/t_{NH3}$
Cooling Water*:	~ 170 $tons/t_{NH3}$

*CW loop flowrate
** incl. steam generation

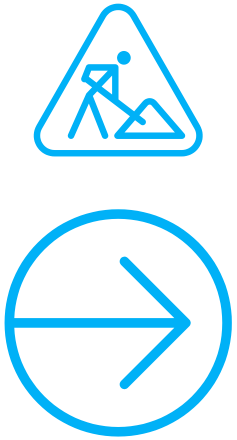
Key drivers for Green Ammonia: Operational Costs

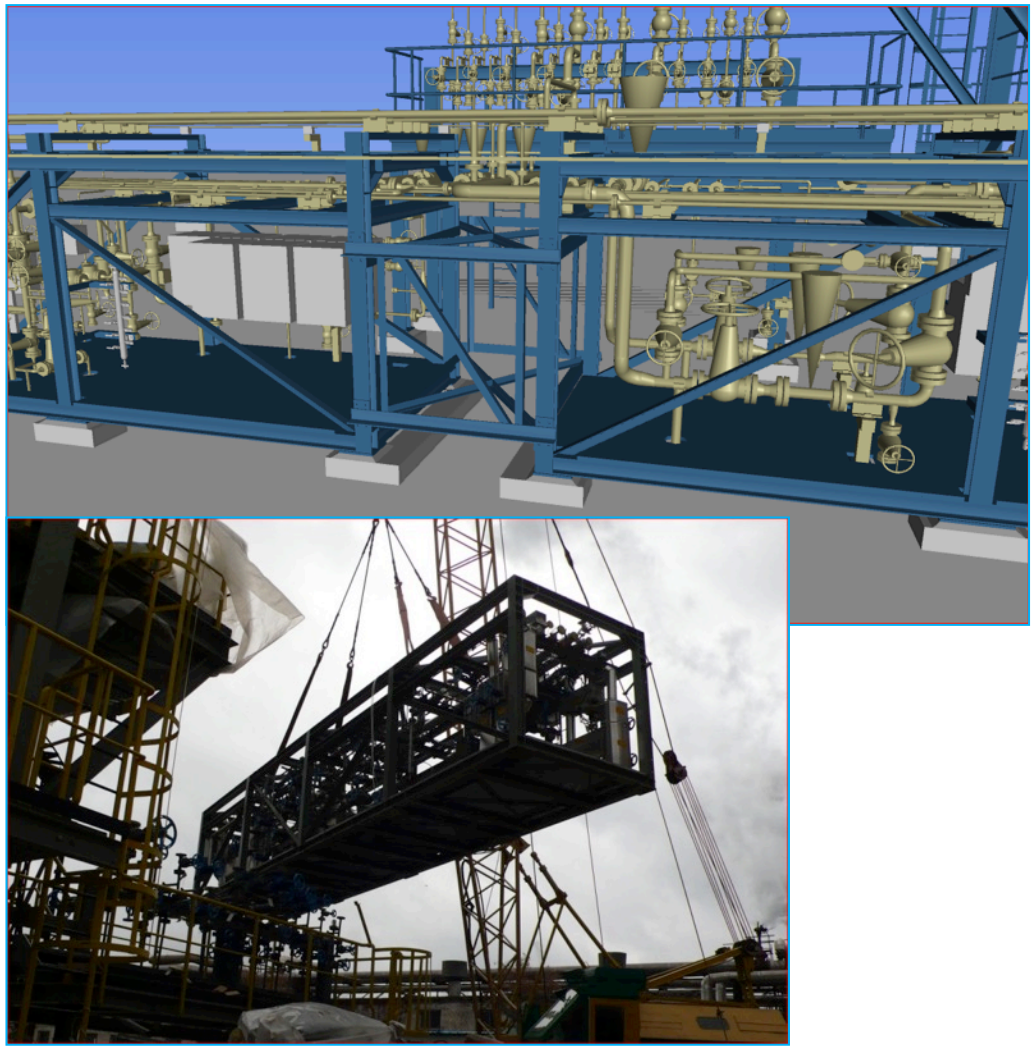


natural gas price

electric power price

AIM: Reduce Construction Costs



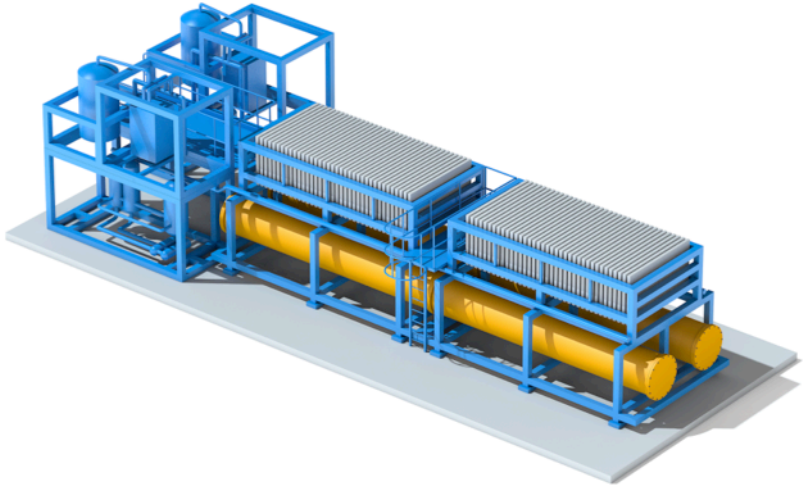


Stick-Built

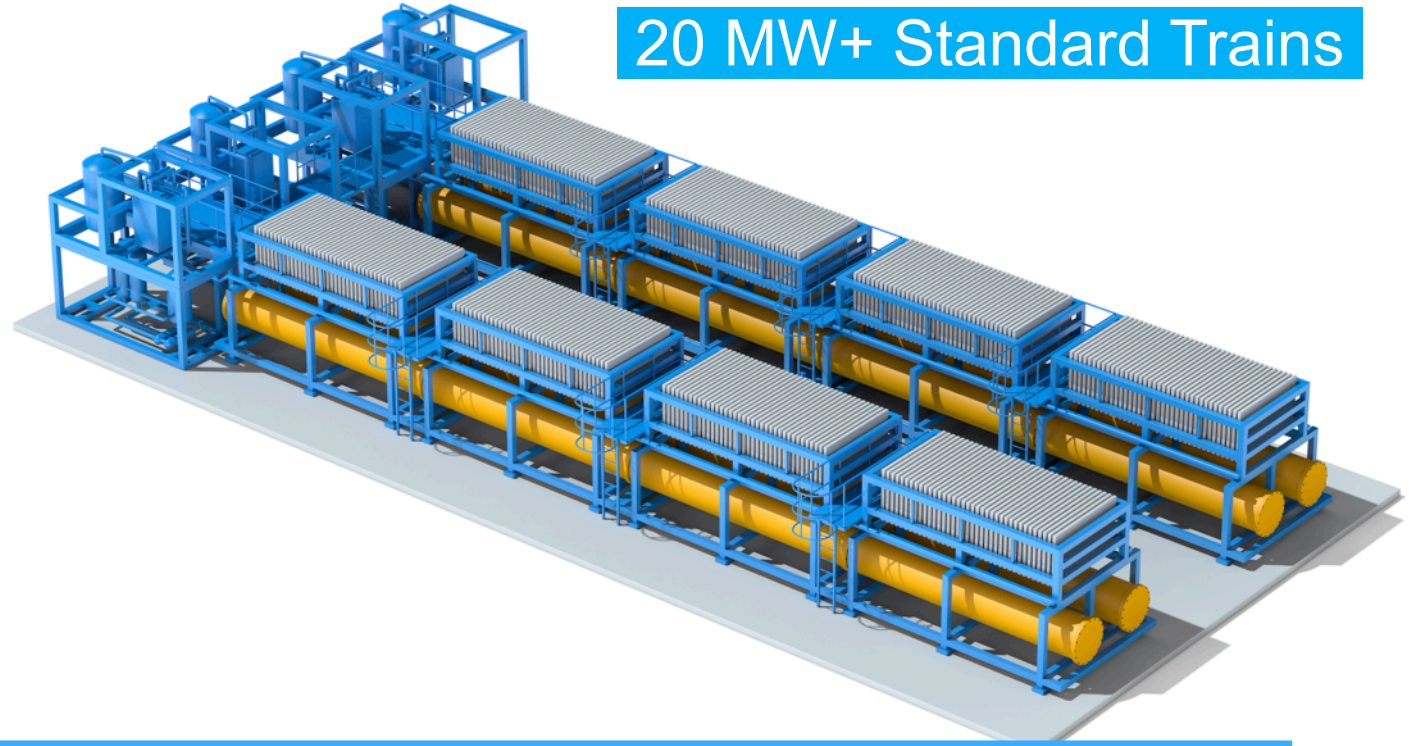
Modularized

Our design philosophy: highly modular and standardized on prefabricated skids

5 MW Standard Module

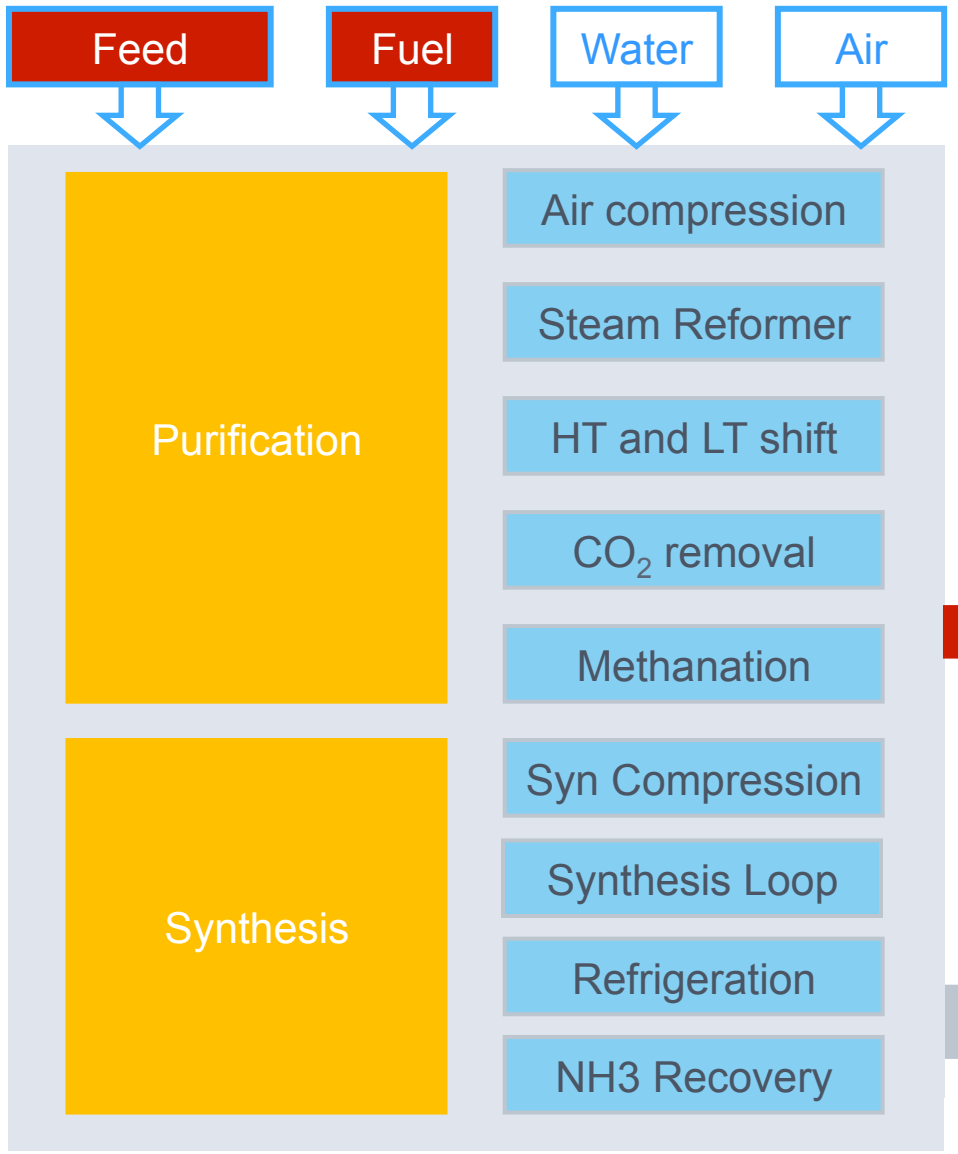


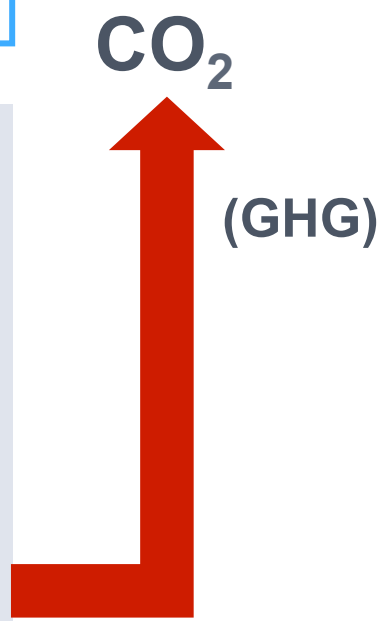
20 MW+ Standard Trains



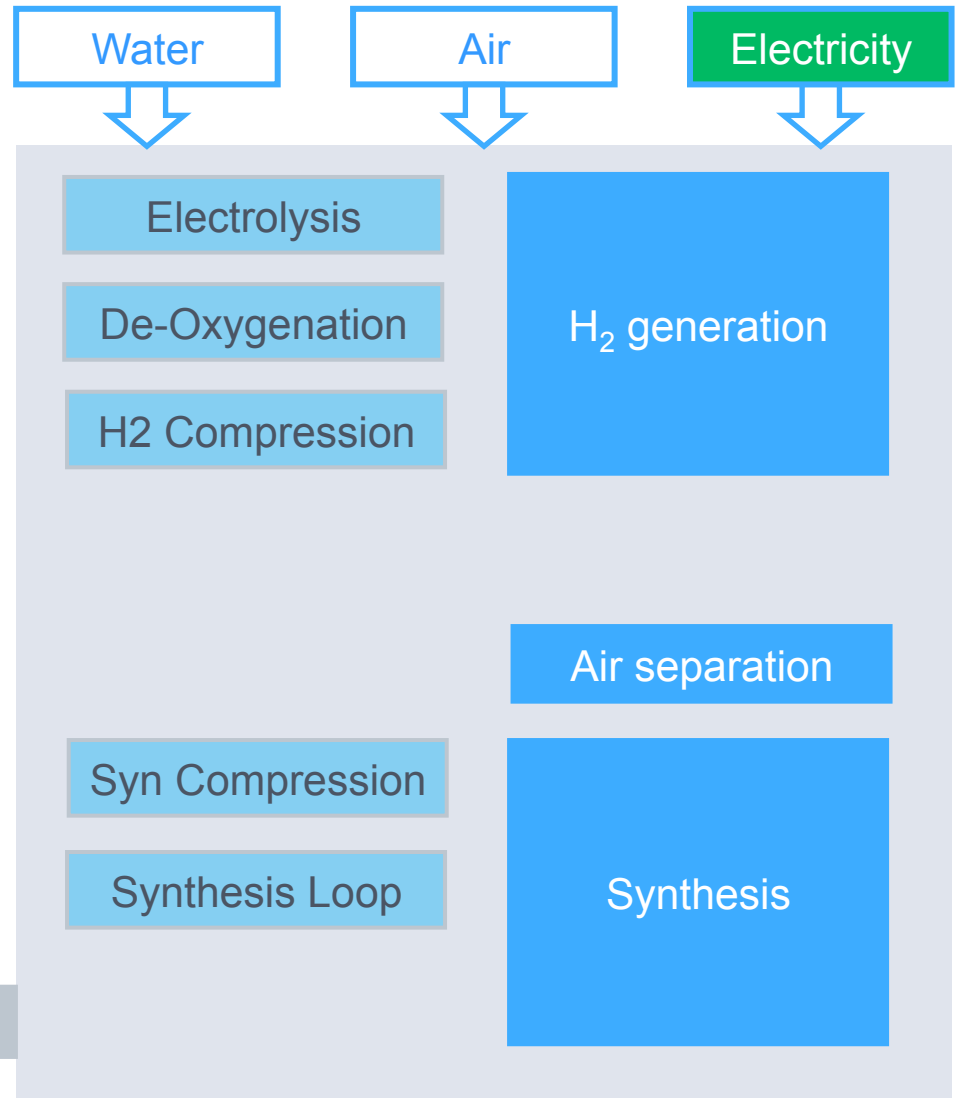
- Standardized, skid mounted electrolysis modules for cost efficient deployment at site.
- Area required for a 100 MW electrolysis plant is about 3000 m².
- Optional downstream processing equipment: compression, oxygen removal and drying

Conventional ammonia production

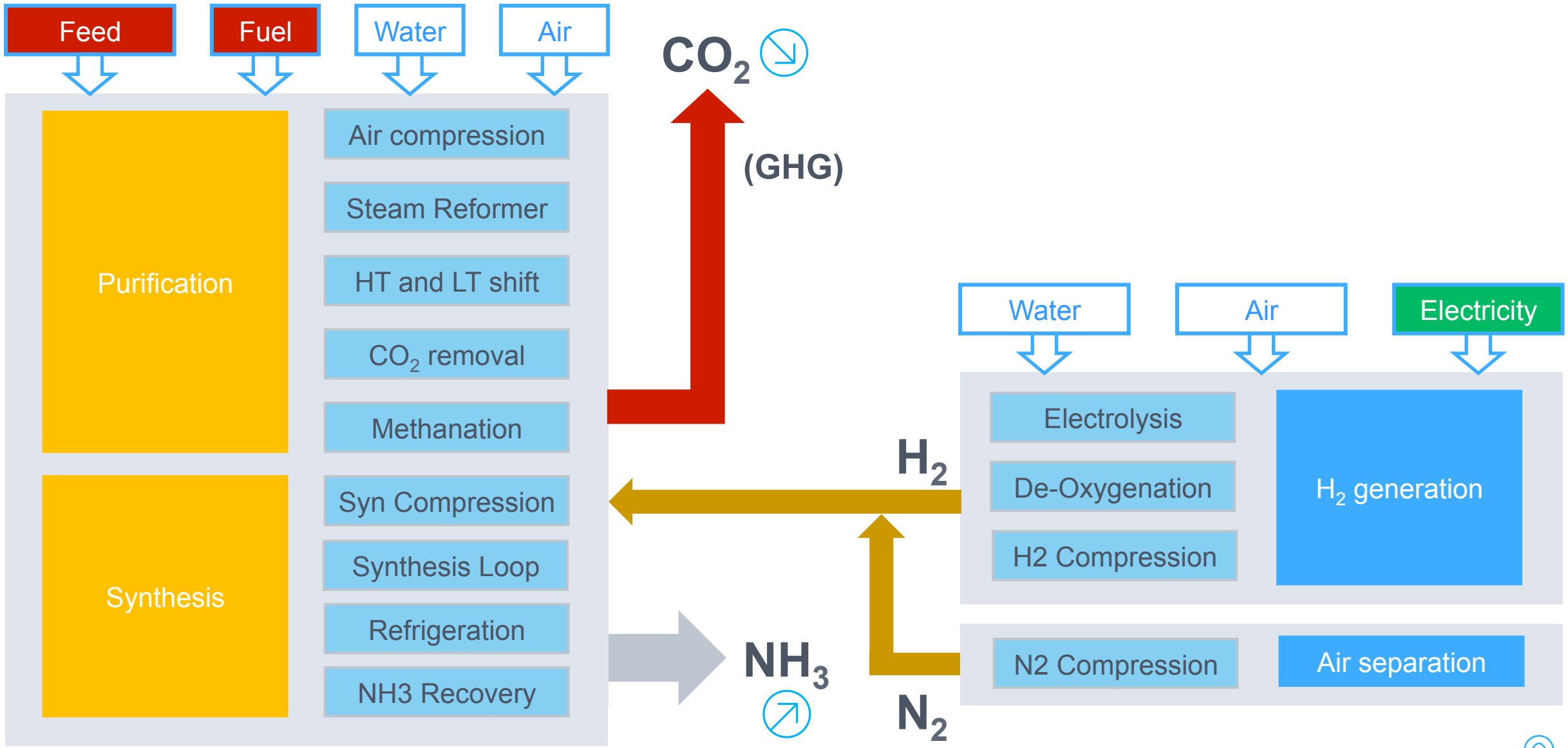


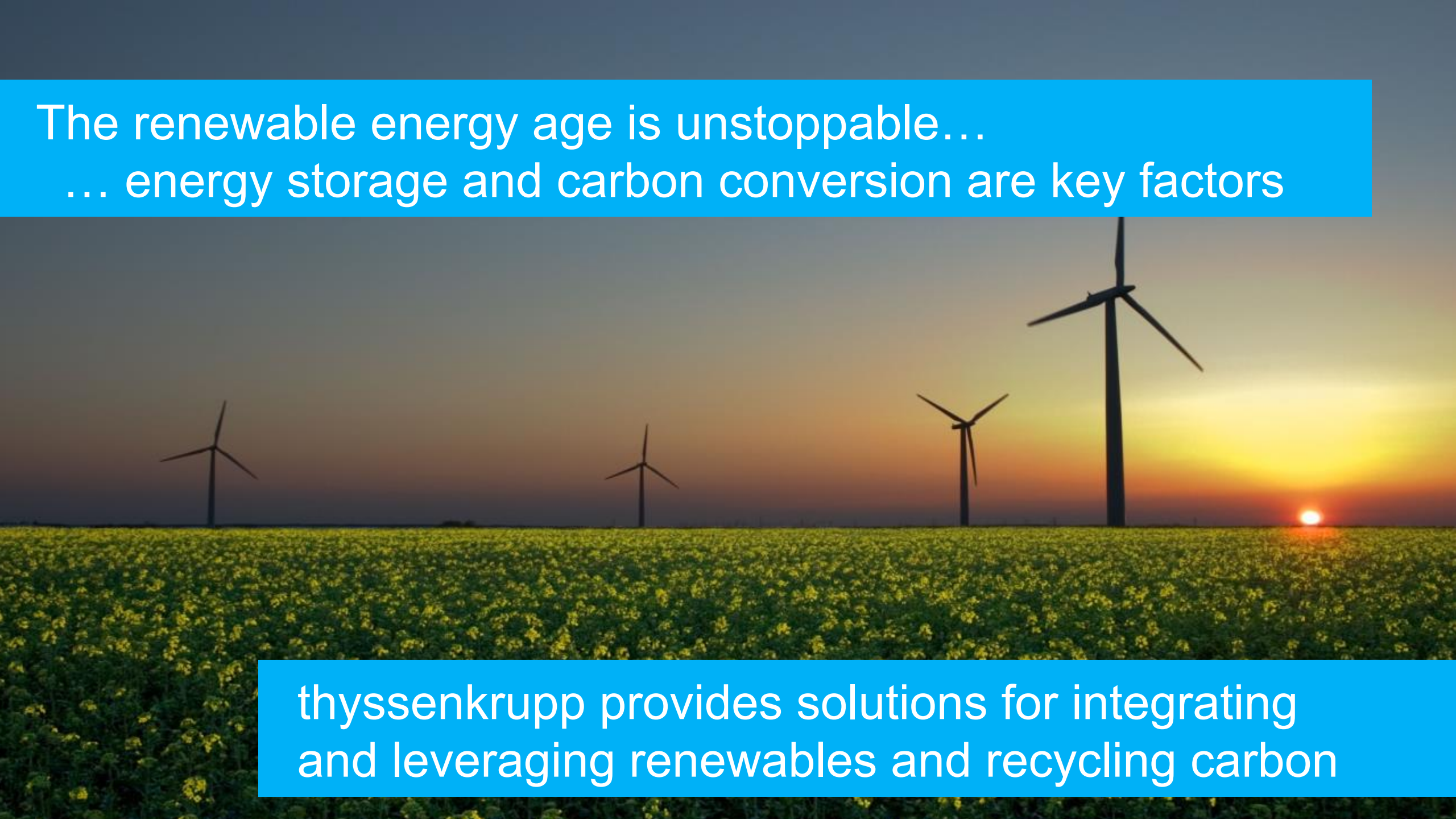


Electricity-based ammonia production



Intermediate Step: Green ammonia Revamp option




The renewable energy age is unstoppable…
… energy storage and carbon conversion are key factors
thyssenkrupp provides solutions for integrating
and leveraging renewables and recycling carbon