



thyssenkrupp engineering. tomorrow. together.

Green ammonia uhde® Green Ammonia - a holistic solution driving towards a more sustainable future

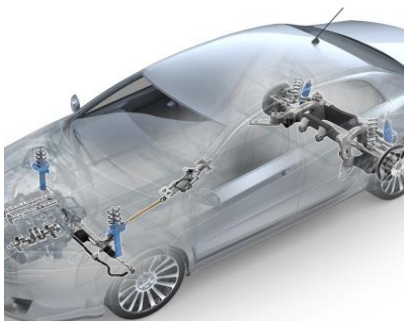
SNETP Forum 2021, February 2nd to 4th, 2021
Tobias Birwe | thyssenkrupp Industrial Solutions



Overview of our businesses

Automotive Technology

Automotive Components



Industrial Components

Forged Technologies



Plant Technology

Chemical & Process Technologies



Mining Technologies



Cement Technologies



Marine Systems

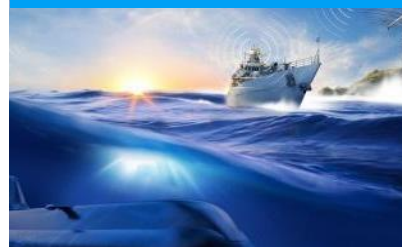
Submarines



Surface Vessels



Naval Electronic Systems



Materials Services

Raw Materials & Trading



Production



Distribution



Supply Chain Services



Steel Europe

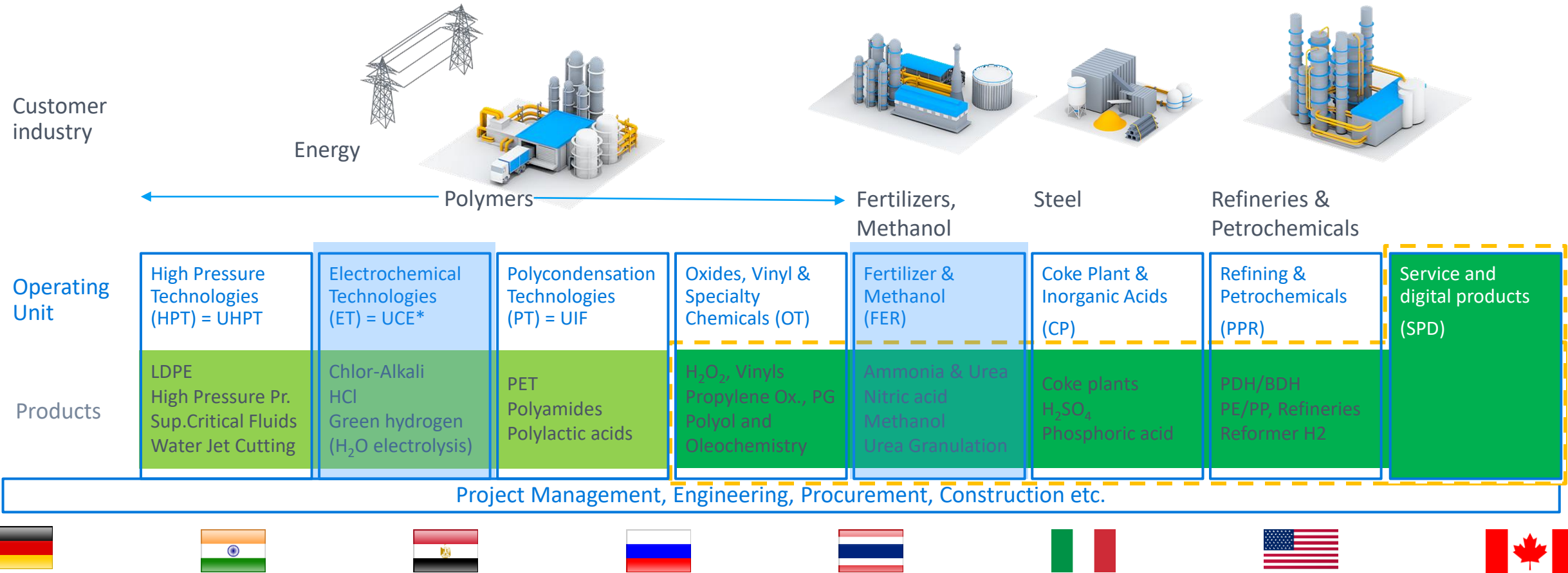
Production & Service



Business Unit Chemical & Process Technologies (formerly Uhde)

Technology Portfolio

Business Unit Chemical and Process Technologies (CPT)



* Joint venture with Denora S.p.A



Latest political and commercial drivers...

- EU and G8 leaders announced an **objective to reduce greenhouse gas (GHG) emissions by 80% below 1990 levels by 2050.**

Source: www.roadmap2050.eu

- **Cost of solar and wind power has seen an 80% decrease** over the past decade.
- Recent subsidy-free offshore wind bids in Europe close to or below \$20 per megawatt hour (MWh) have been seen.

Source: Path to hydrogen competitiveness, Hydrogen Council, 20.01.2020

- Since 2010, the **cost of electrolysis has fallen by 60%**, from between \$10-15 per kg hydrogen to as low as \$4-6 today.

Source: Path to hydrogen competitiveness, Hydrogen Council, 20.01.2020

- Dry seasons
- Severe weather events
- Loss of land
- Loss of food security



- President of the European Commission, Ursula von der Leyen has warned China and other large fossil fuel producers to find a way to price carbon at home or risk being hit by the EU with a **planned CO2 tax on imports.**

Source: Financial Times; <https://www.ft.com>

- “World Bank’s Carbon Pricing Leadership...not to be at least in the range of \$40-80/tCO2e by 2020 and \$50-100/tCO2e by 2030 to deliver on the **Paris Agreement targets...**”

Source: Nitrogen+Syngas 362

Economic and political conditions are more and more supportive for decarbonizing the industry



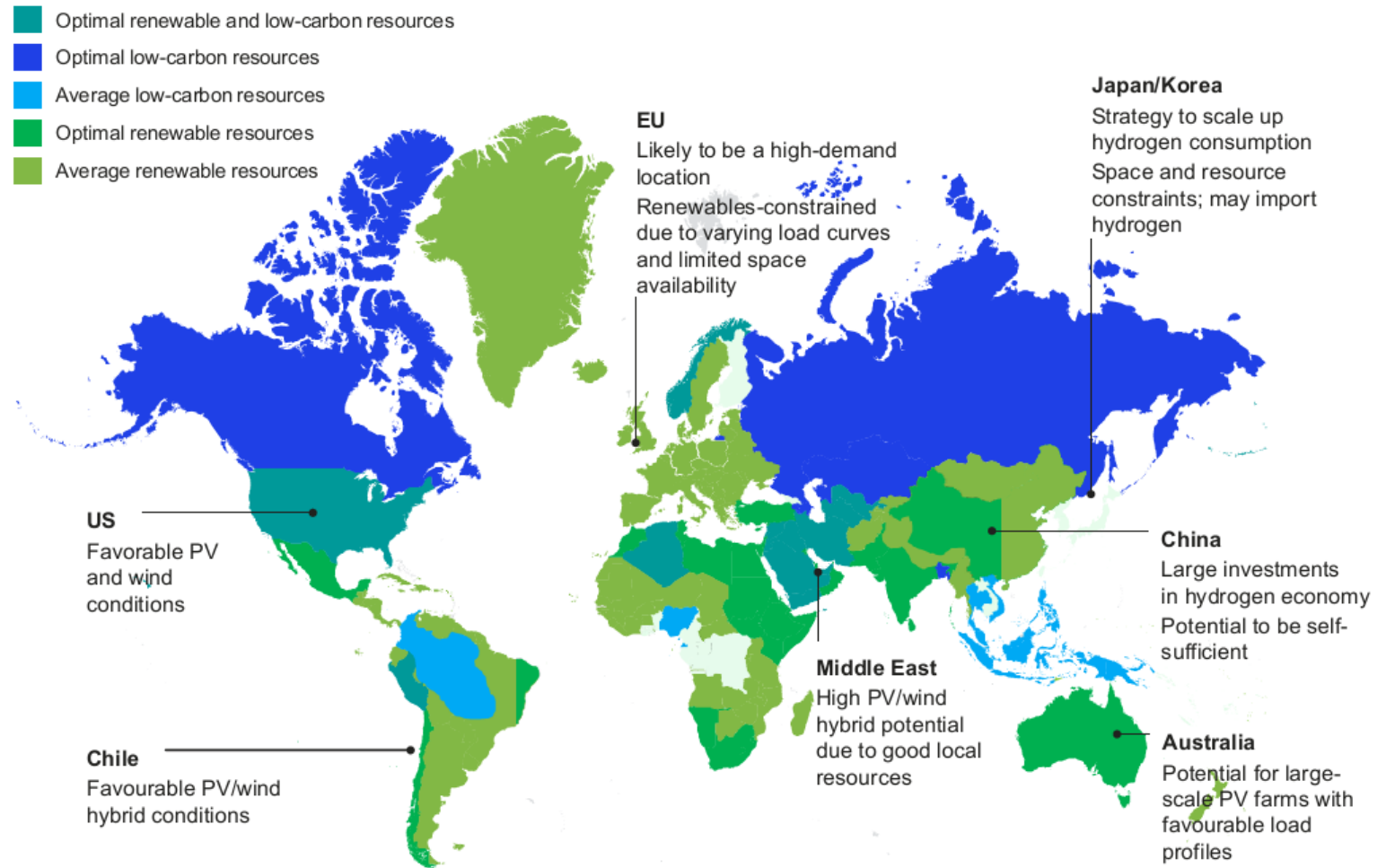
Regions with good conditions for renewable energy and CCS...

Key drivers...

- High availability of renewables
- Low E-power cost
- CO2 taxes
- Transportation restrictions
- CCS availability (for blue solutions)

resulting in potential for...

- New business in new regions
- New business in established regions
- Independence of gas prices
- Decentralized production
- Lowering transportation cost

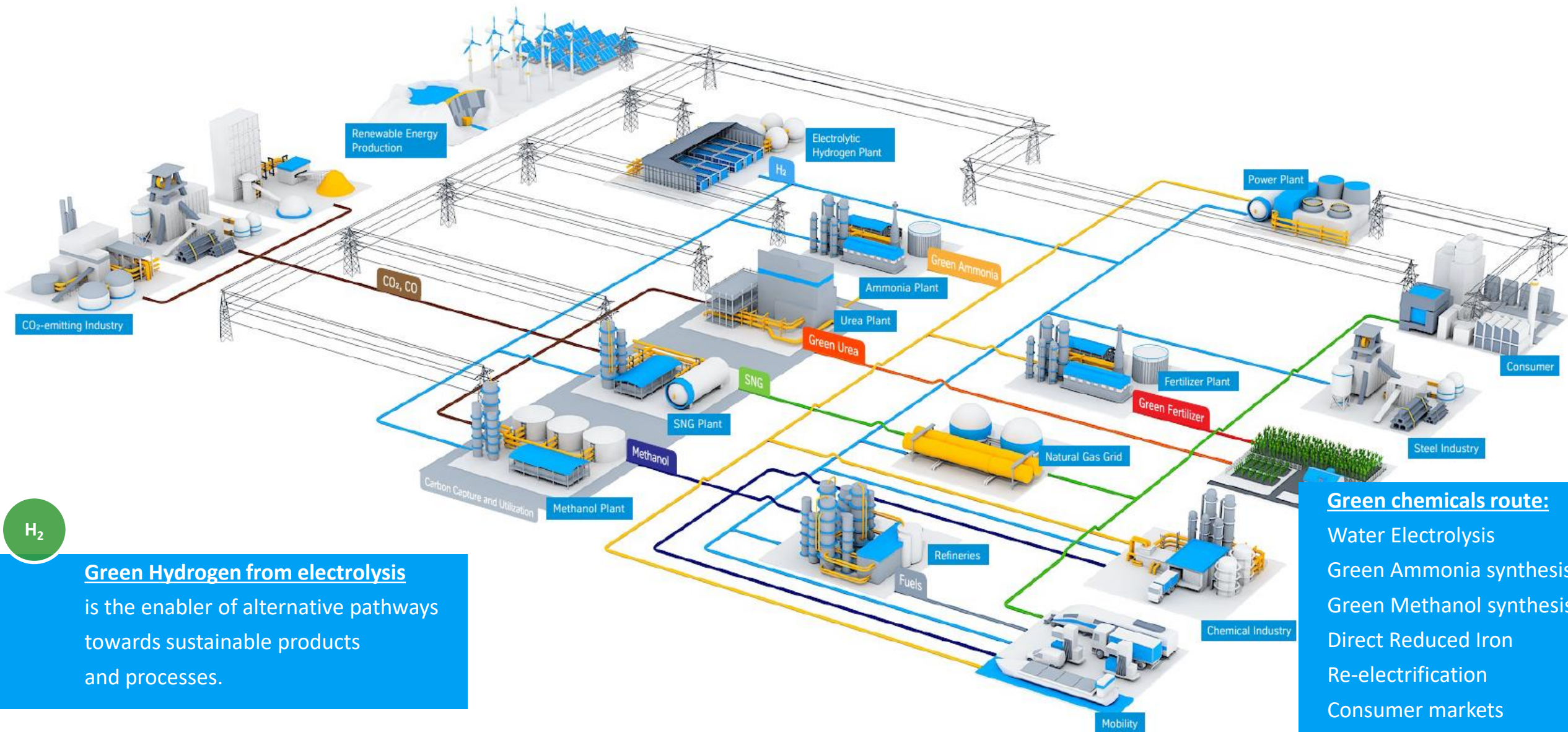


SOURCE: IEA; McKinsey

Several regions have huge potential for PtX business either for CCS solutions or renewable resource solutions



green chemicals value chains



Water Electrolysis

key technology for sustainable hydrogen value chains

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⁺
membrane
electrolysis



Chlor-alkali
membrane
electrolysis



⁺ ODC: Oxygen Depolarized Cathodes



Key features of a 10 MW Electrolyzer Unit

>82 % stack efficiency (HHV,
DC, 4.3 kWh/Nm³)

H₂ purity:
>99.95 % (from electrolyzer, dry basis)
to 99,999% (after purification/drying)

98% availability
lifetime >30 years

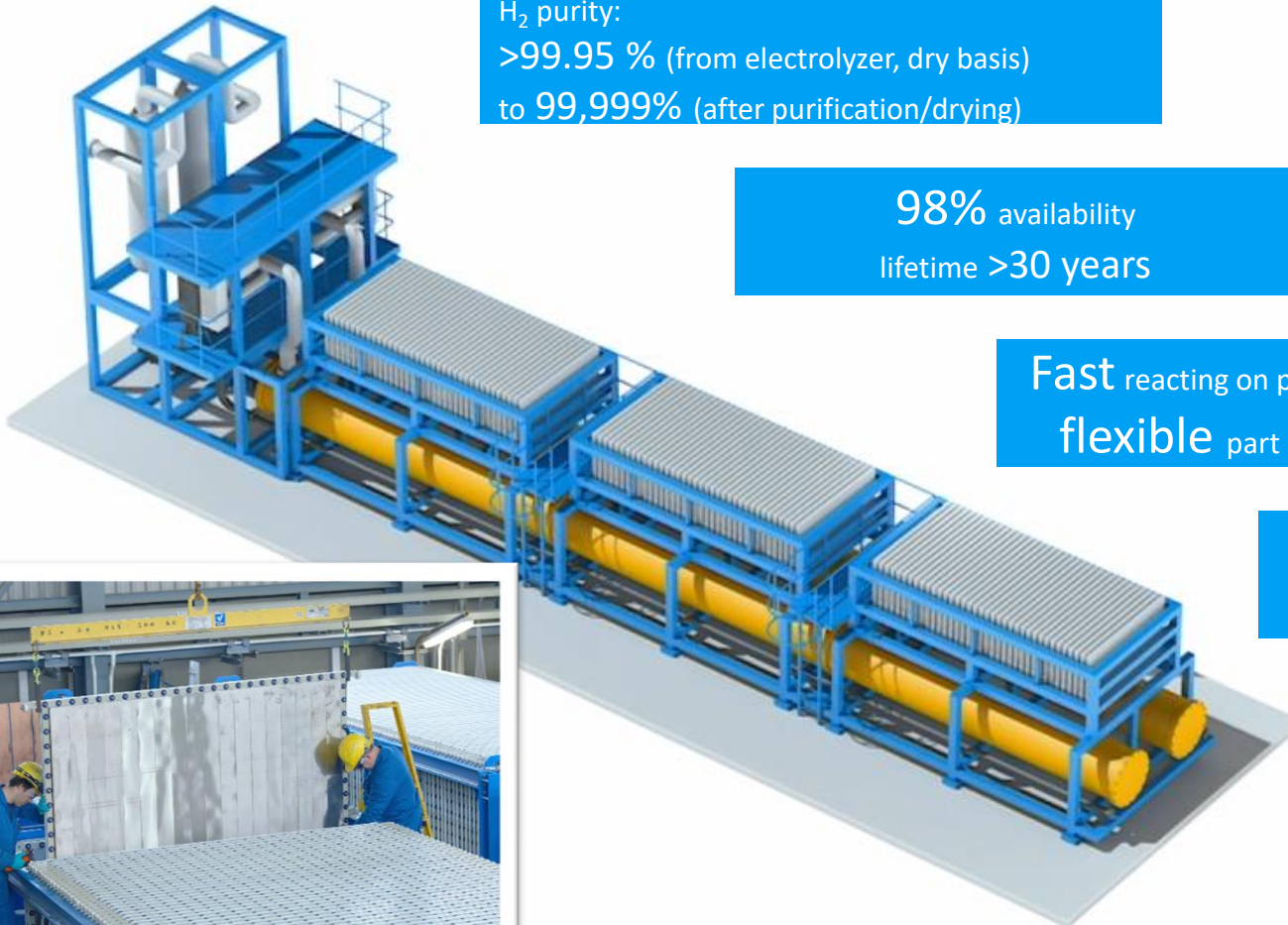
Fast reacting on power markets and
flexible part load operations.

Fully automated operation

skid mounted for cost efficient
installation on site

Digital Features:

- Upgradable dedicated control system
- Data acquisition system for performance evaluation
- Connectivity



Water Electrolysis by thyssenkrupp - proven technology with established supply chain

>300,000

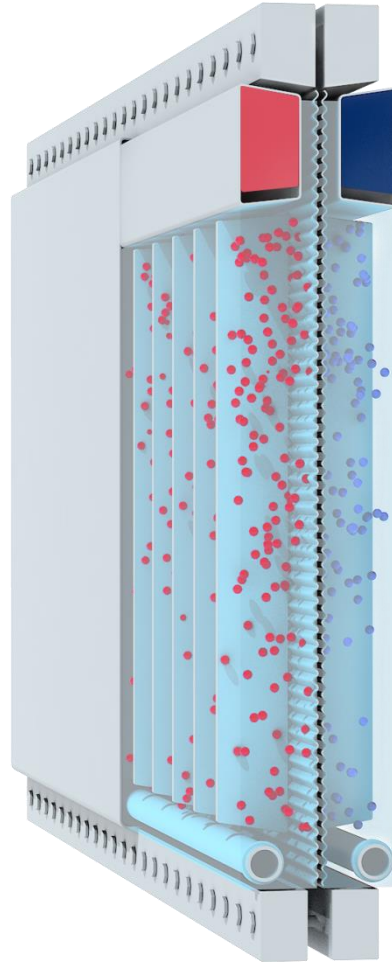
of elements manufactured¹

>1.6 million m²

of electrodes produced¹

>1,000 MW

can be installed each year²



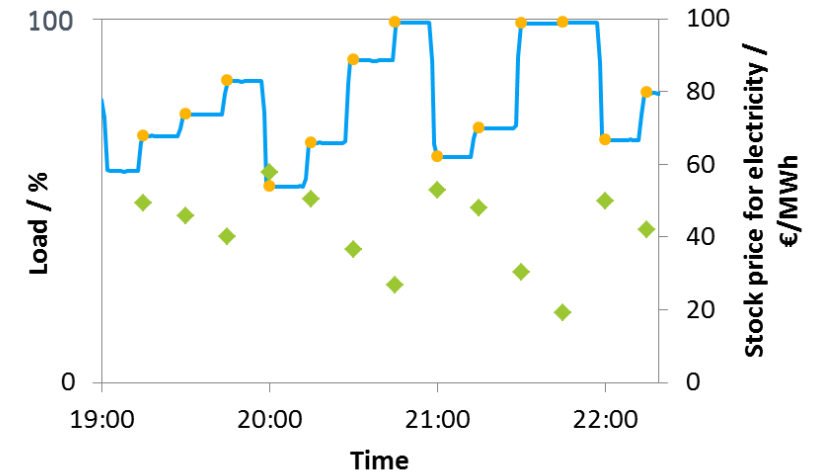
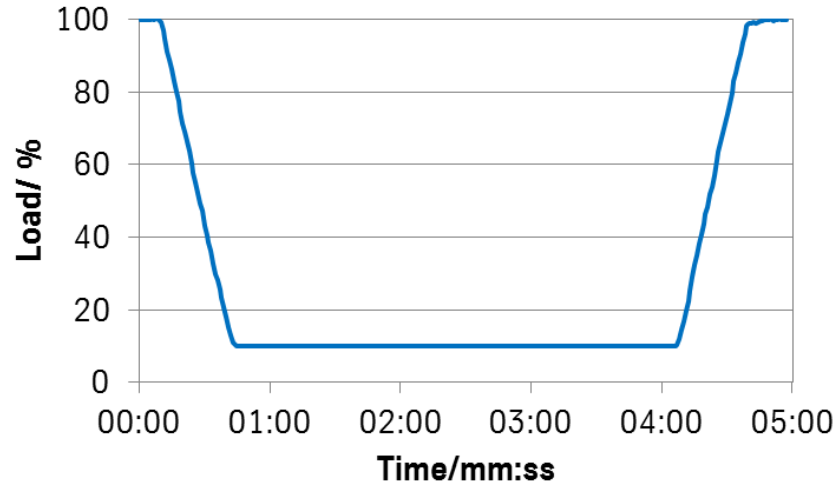
- Proven zero-gap technology
- Introduction of **high efficiency cathode design and coating** (with De Nora) for hydrogen evolution, proven in chlor-alkali technology
- Introduction of **high efficiency anode design and coating** (with De Nora) based on proven chlorine technology
- **Optimized high-performance separators and diaphragms** based on proven design

¹for chlor-alkali plants producing hydrogen as co-product, ²for electrolytic hydrogen production



tkUCE large scale Water Electrolysis

thyssenkrupp Water Electrolysis system is validated at industrial scale for dynamic operation



Operation of technical evaluation plant at Carbon2Chem, Duisburg

- Capacity: up to 2 MW
- H₂ production: 440 Nm³/h
- H₂ purity: > 99.95 % (dry basis)

Fast ramping capabilities proven

- Load changes between 10% and 100% in less than 30sec
- Enables utilization for primary control reserve

Power price optimized operation

- Power price based load management established
- Enables optimization of average power price

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



thyssenkrupp

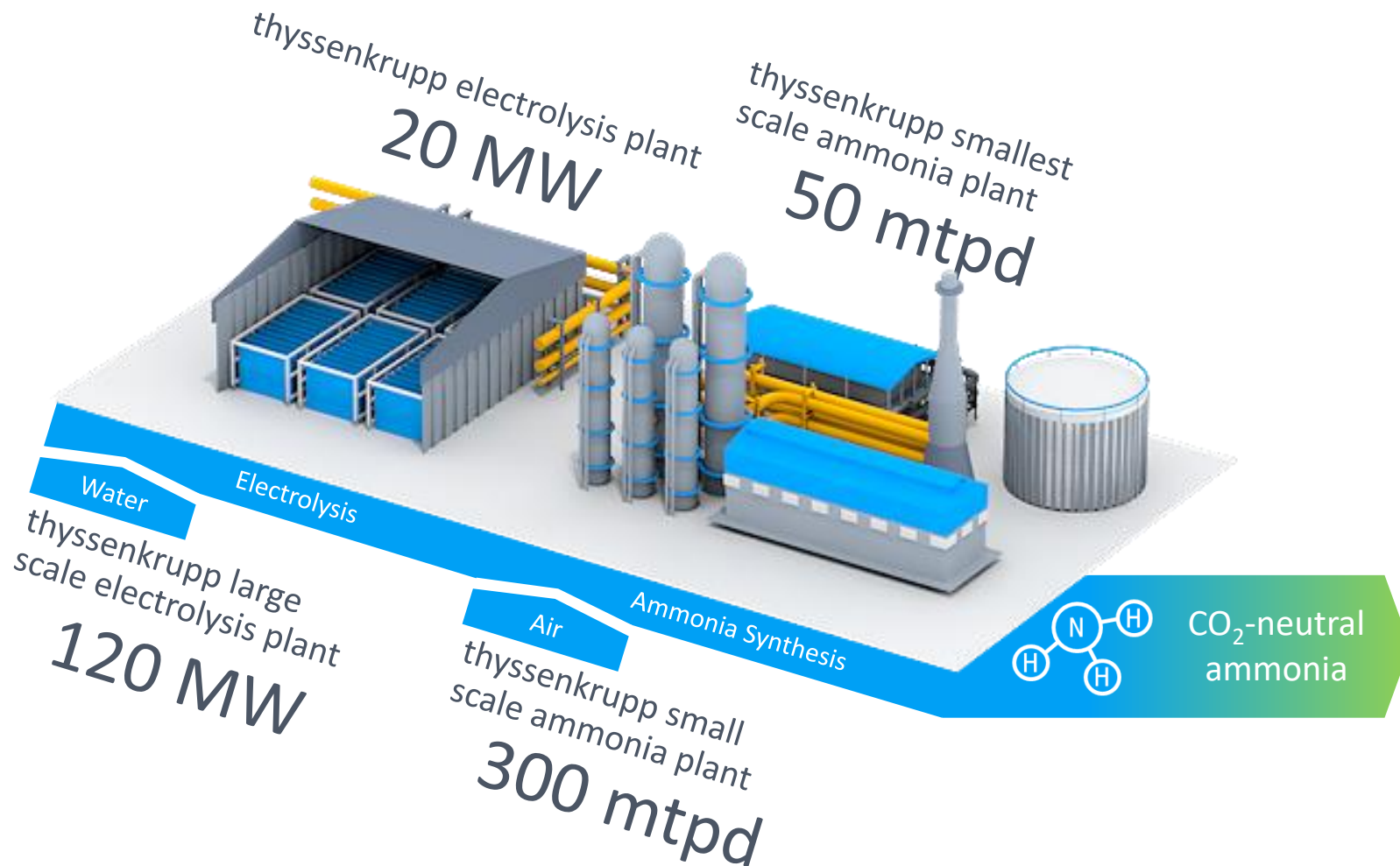
Introducing green ammonia by thyssenkrupp

2 worldwide leading processes

1 holistic solution

0 CO₂ emissions¹

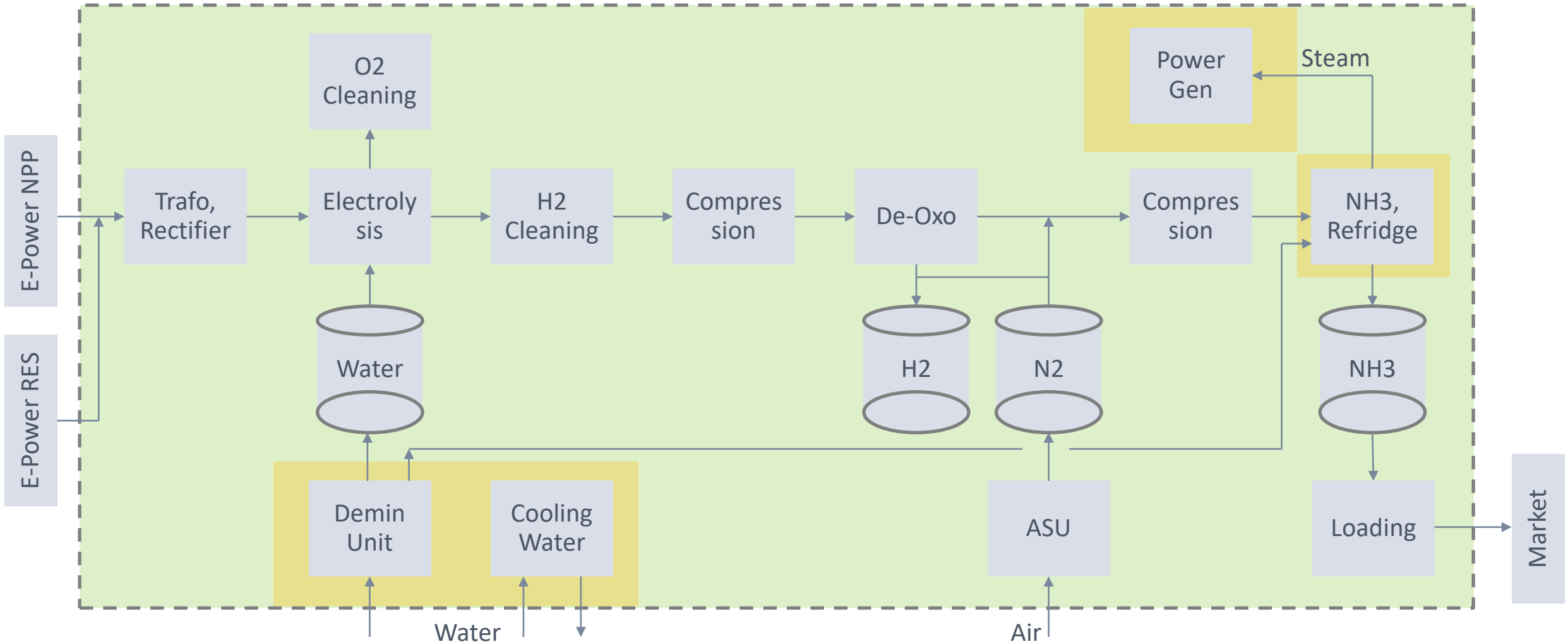
¹ depending on E-power source



20/50 and 120/300 being fully modularized and standardized ready for the market, tailor-made up to 5000mtpd

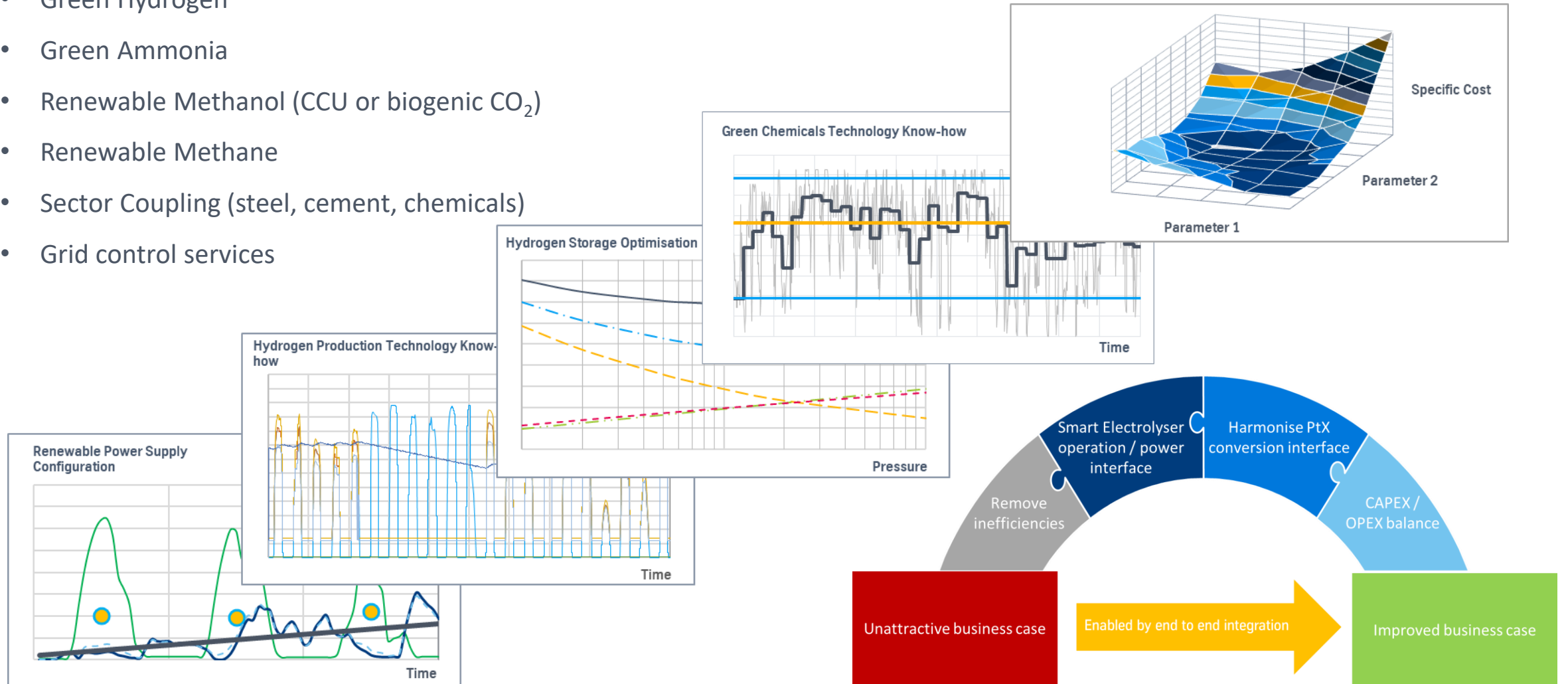


Integration is key



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 CO₂)
- Renewable Methane
- Sector Coupling (steel, cement, chemicals)
- Grid control services



Thank You for Your Attention.

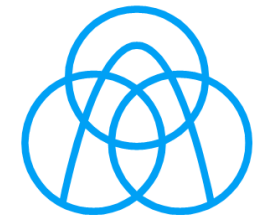


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engineering.tomorrow.together.