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
- System Engineering

Industrial Components
- Forged Technologies
- Bearings

Plant Technology
- Chemical & Process Technologies
- Mining Technologies
- Cement Technologies

Marine Systems
- Submarines
- Surface Vessels
- Naval Electronic Systems

Materials Services
- Raw Materials & Trading
- Distribution
- Supply Chain Services

Steel Europe
- Production & Service
## Business Unit Chemical & Process Technologies (formerly Uhde)

### Technology Portfolio

![Diagram of Business Unit Chemical and Process Technologies (CPT)](image)

#### Operating Unit

<table>
<thead>
<tr>
<th>Products</th>
<th>Operating Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>High Pressure Technologies (HPT) = UHPT</td>
</tr>
<tr>
<td>High Pressure Pr. Sup.Critical Fluids Water Jet Cutting</td>
<td>Electrochemical Technologies (ET) = UCE*</td>
</tr>
<tr>
<td>Chlor-Alkali HCl Green hydrogen (H₂O electrolysis)</td>
<td>Polycondensation Technologies (PT) = UIF</td>
</tr>
<tr>
<td>PET Polyamides Polyactic acids</td>
<td>Oxides, Vinyl &amp; Specialty Chemicals (OT)</td>
</tr>
<tr>
<td>H₂O₂ Vinyls Propylene Ox. PG Polyol and Oleochemistry</td>
<td>Fertilizer &amp; Methanol (FER)</td>
</tr>
<tr>
<td>Ammonia &amp; Urea Nitric acid Methanol Urea Granulation</td>
<td>Coke Plant &amp; Inorganic Acids (CP)</td>
</tr>
<tr>
<td>Coke plants H₂SO₄ Phosphoric acid</td>
<td>Refining &amp; Petrochemicals (PPR)</td>
</tr>
<tr>
<td>PDH/BDH PE/PP Refineries Reformer H₂</td>
<td>Service and digital products (SPD)</td>
</tr>
</tbody>
</table>

#### Customer Industry

- Polymers
- Energy
- Fertilizers, Methanol
- Steel
- Refineries & Petrochemicals

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* Joint venture with Denora S.p.A

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thysenkrupp Industrial Solutions – BU-CPT, OU-FER

3 | February 4th 2021 | Tobias Birwe
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
Several regions have huge potential for PtX business either for CCS solutions or renewable resource solutions.

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
Green Hydrogen from electrolysis is the enabler of alternative pathways towards sustainable products and processes.
Water Electrolysis

key technology for sustainable hydrogen value chains

Experience cannot be copied.

#1 supplier for electrolytic hydrogen production

600 electrochemical plants realized worldwide

over 10 GW of power installed
Key features of a 10 MW Electrolyzer Unit

- **>82 % stack efficiency (HHV, DC, 4.3 kWh/Nm³)**
- **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
- H₂ purity:
  - >99.95 % (from electrolyzer, dry basis)
  - to 99,999% (after purification/drying)
- **>99.95 % purity**

Digital Features:
- Upgradable dedicated control system
- Data acquisition system for performance evaluation
- Connectivity
Water Electrolysis by thyssenkrupp - proven technology with established supply chain

- 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

>300,000
of elements manufactured\textsuperscript{1}

>1.6 million m\textsuperscript{2}
of electrodes produced\textsuperscript{1}

>1,000 MW
can be installed each year\textsuperscript{2}

\textsuperscript{1}for chlor-alkali plants producing hydrogen as co-product, \textsuperscript{2}for 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 30 sec
- 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
Introducing green ammonia by thyssenkrupp

2 worldwide leading processes

1 holistic solution

0 CO₂ emissions

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

O2 Cleaning → Electrolysis → H2 Cleaning → Compression → De-Oxo

Water

Demin Unit → Cooling Water

Water

H2 Compression

NH3, Refrigeration

Steam

Power Generation

NH3 Loading → Market

Air

ASU

H2, N2

Steam

E-Power NPP

E-Power RES

E-Power NPP

Cooling Water

Potential NPP scope

tkIS Scope (EPC)
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.

Tobias Birwe
Sales Director
Operating Unit Fertilizer & Methanol
tobias.birwe@thyssenkrupp.com

engineering.tomorrow.together.