Building a sustainable industrial and energy infrastructure

AEA Conference, November 16th to 18th
thyssenkrupp Industrial Solutions, Tobias Birwe, November 17th
We are a global corporation with ~€34 bn sales and 109,000 employees & presence in 60 countries with ~1,090 locations
Overview of our businesses

Automotive Technology

Industrial Components

Solutions provider

Plant Technology

Marine Systems

Materials Services

Applicant Steel Europe

Automotive Components

Forged Technologies

Chemical & Process Technologies

Submarines

Raw Materials & Trading

Production & Service

System Engineering

Bearings

Mining Technologies

Surface Vessels

Production

Distribution

Steel Europe

Automotive Technology

Forged Technologies

Cement Technologies

Naval Electronic Systems

Distribution

Supply Chain Services

Raw Materials & Trading

Production

Surface Vessels

Naval Electronic Systems

Supply Chain Services
**Business Unit Chemical & Process Technologies (formerly Uhde)**

**Technology Portfolio**

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### Business Unit Chemical and Process Technologies (CPT)

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

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* Joint venture with Denora S.p.A

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**Customer industry**

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

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**Project Management, Engineering, Procurement, Construction etc.**

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4 Ammonia Energy Association Conference, Tobias Birwe
Carbon2Chem®
From idea to commercial implementation

Location of Carbon2Chem® Technical Center at thyssenkrupp Steel site in Duisburg
Water electrolysis

Gas cleaning

Ammonia

Methanol

1st production: 20th September 2018

1st production: 18th December 2018

Carbon2Chem®
First products

Supported by BMBF funding numbers 03EK3037 to 03EK3043
Carbon2Chem®: Pilot plant is in full operation since April 2018

<table>
<thead>
<tr>
<th>Water electrolysis</th>
<th>Gas cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Completion</strong></td>
<td>April 2018</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td></td>
</tr>
<tr>
<td>440 Nm³/h H₂</td>
<td>coke oven gas converter gas blast furnace gas</td>
</tr>
<tr>
<td></td>
<td>100 Nm³/h 70 Nm³/h 70 Nm³/h</td>
</tr>
<tr>
<td><strong>Manufacturer</strong></td>
<td>thyssenkrupp Uhde Chlorine Engineers</td>
</tr>
<tr>
<td></td>
<td>thyssenkrupp Plant Technology (BU-CPT)</td>
</tr>
</tbody>
</table>

2 MW water electrolysis

Gas cleaning
Smart Solutions for Climate Protection — Alkaline Water Electrolysis
Carbon2Chem in Duisburg
Water Electrolysis

key technology for sustainable hydrogen value chains

Experience cannot be copied.

#1 supplier for electrolytic hydrogen production

49% market share

600 electrochemical plants realized worldwide

over 10 GW of power installed
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

>1.6 million m² of electrodes produced

>1,000 MW can be installed each year

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1 for chlor-alkali plants producing hydrogen as co-product, 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 30sec
- Enables utilization for primary control reserve

**Power price optimized operation**

- Power price based load management established
- Enables optimization of average power price
Introduction to Carbon2Chem®
Production of syngas / chemicals from steel mill gases

Steel mill gases can be used for the production of purified syngas and for the production of chemicals.

COG = Coke oven gas
BFG = Blast furnace gas
BOFG = Basic oxygen furnace gas
PSA = Pressure swing adsorption

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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

1. Holistic solution

2. Worldwide leading processes

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
Introduction to Carbon2Chem®

Results from 1\textsuperscript{st} phase and main objectives for the 2\textsuperscript{nd} phase

**1\textsuperscript{st} phase**
- 2016 - 2020
- Production of methanol and ammonia from steel mill gases and hydrogen from alkaline water electrolysis
- Carbon2Chem\textsuperscript{®} can reduce the CO\textsubscript{2} emissions of the cross-industrial network if renewable hydrogen is available

**2\textsuperscript{nd} phase**
- 2020 - 2024
- Development of business cases
- Demonstration of long-term stability
- Implementation of the C2C technology into other industries (e.g. cement, lime, waste)
- Proof that industrial network is technical feasible
Thank You for Your Attention.

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Operating Unit Fertilizer & Methanol
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engineering.tomorrow.together.