Large scale Modular AWE Technology for Green Hydrogen plants

Jai Prakash Soni
Sr. Gen Manager Process
thyssenkrupp Ind. Sol. India Pvt. Ltd.

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thyssenkrupp - Overview of businesses

- Automotive Technology
- Industrial Components
- Plant Technology
- Marine Systems
- Materials Services
- Steel Europe

Automotive Components
Forged Technologies
System Engineering
Bearings

Chemical & Process Technologies - Uhde
Mining Technologies
Cement Technologies
Naval Electronic Systems
Submarines
Surface Vessels

Raw Materials & Trading
Production
Distribution
Supply Chain Services

€28.9 bn sales in '19/20
~ 104,000 employees
thyssenkrupp Industrial Solutions - a global footprint with world-scale plants (formerly Uhde)

- **Fertilisers**: 130 plants
- **Nitric acid**: 185 plants
- **Refineries**: 380 plants
- **Aromatics**: 75 plants
- **Hydrogen, ammonia, methanol**: 120 plants
- **Org. Chemicals/petrochemicals**: 375 plants
- **Plastics, synthetic fibres**: 115 plants
- **Polyester / polyamides**: 400 plants
- **Electrolysis / Electrochemical Technologies**: 600 plants
- **Coke Plant Technologies**: 500 plants
- **Tank storage facilities**: 105 plants
- **Industrial plants**: 150 plants
## thyssenkrupp Industrial Solutions (India) – At a glance

<table>
<thead>
<tr>
<th>Formation</th>
<th>Erection Office</th>
<th>1965</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Branch Office</td>
<td>1970</td>
</tr>
<tr>
<td></td>
<td>Indian Company</td>
<td>1977</td>
</tr>
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<table>
<thead>
<tr>
<th>Engineering Capacity</th>
<th>2.0 Million man-hours per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Engineering, Project Management, Procurement Services &amp; Construction Management)</td>
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</tbody>
</table>

<table>
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<tr>
<th>Office Space</th>
<th>Approx. 18,600 sq. m.</th>
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<tr>
<th>Projects Executed</th>
<th>Over 800 projects</th>
</tr>
</thead>
</table>

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<tr>
<th>Types of Contracts</th>
<th>EPC-LSTK / EPCM, PMC, Reimbursable Services, Open Book Estimates</th>
</tr>
</thead>
</table>

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<tr>
<th>Quality Assurance, Health Safety &amp; Environment</th>
<th>ISO 9001 : 2015</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>ISO 14001 : 2015, ISO 45000 : 2018</td>
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</tbody>
</table>
The joint venture setup of thyssenkrupp Industrial Solutions and Industrie De Nora

thyssenkrupp Uhde Chlorine Engineers

- Product development with IP
- Engineering
- Procurement
- Sales, Business Development
- Service
- EPC contracting

Supporting with Engineering, Procurement, Construction, Financing, etc.

Electrolysis Cell Components and Manufacturing as per tk design

...market lead in electrolysis....
tkUCE is No.1 electrolysis supplier for industrial scale Electrolysis solution

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)

Experience from Electrolysis plants used for AWE

- Chlor Alkali Membrane Electrolysis
- HCl Membrane Electrolysis

- High Reliability
- Atmospheric operation
- Large size cell- close to 3 m²
- Skid mounted for efficient site installation
- Mass production, supply chain at scale
- Digital Features: Upgradable dedicated control system, data acquisition system for performance evaluation, connectivity

Chlor Alkali Membrane Electrolysis
HCl Membrane Electrolysis
AWE
**Alkaline Water Electrolysis (AWE)** with a liquid, alkaline electrolyte at temperatures between 40 °C and 90 °C

- **Overall reaction:** \(2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2\)
- **Electrolyte:** 20 – 40 % KOH

- Single element based on Zero gap tkUCE C/A design
- Nickel is base material for both half shells
### Key features of tkUCE electrolyser unit

- **High stack efficiency 82%, Power 4.5 kWh/Nm³ HHV, DC**

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

- **98% availability, Longer cell lifetime**

- **~300mbar pressure at module outlet**

- **Fast reacting on power markets and flexible part load operations**

- **Reliable technology**

- **Fully automated operation**

- **Turn down ratio 10%**

- **Ramp-speed (up & down) from Hot system 30 seconds from 10% to 100% and 100% to 10%**
thyssenkrupp Uhde Chlorine Engineers – AWE 20 MW Module

- Standardized 20 MW Power Module
- Hydrogen production: 4000 Nm³/h
- Easily Scalable
- Easy construction at site
The benefits of economy of scale

Upstream & Downstream units: Classic Scale-up advantages

Electrolysis modules: mix of scale-up and numbering up

Compression & purification
Green Chemicals – Sustainable Value chain accruing from Green Hydrogen
Technology for Green Methanol

Electricity from renewables

Electrolysis

\[ 2H_2O \rightarrow 2H_2 + O_2 \]

Methanol synthesis

\[ CO_2 + 3H_2 \rightarrow CH_3OH + H_2O \]

To Fuel

CO₂

Water

Methanol
Technology for Green Ammonia

Electricity from renewables

Electrolysis

$\text{2H}_2\text{O} \rightarrow \text{2H}_2 + \text{O}_2$

Ammonia synthesis

$\text{3H}_2 + \text{N}_2 \rightarrow 2\text{NH}_3$

Water

Air

CO$_2$ “neutral” Ammonia

To Green Fertilizer
Location of Carbon2Chem® Technical Center at thyssenkrupp Steel site in Duisburg
Carbon2Chem®
From the idea to commercial implementation

2 MW Module

Water Electrolysis with Renewable Energy

Treated Gas from Steel Mill

H₂

Syngas

Methanol

Ammonia

1st production: 2018

BMBF funding numbers 03EK3037 to 03EK3043
Green hydrogen plant Plant A, Canada
Electricity with a strong green footprint

<table>
<thead>
<tr>
<th>Capacity:</th>
<th>88 MW electrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Varennes, Canada</td>
</tr>
<tr>
<td>Energy:</td>
<td>Hydroelectricity</td>
</tr>
</tbody>
</table>
| Concept:  | Green hydrogen to green methanol, ethanol, DME as bio fuels  
|           | Green oxygen as waste incineration aid |
| Status:   | Phase I Engineering |
Green hydrogen plant B, USA
Decarbonizing Ammonia production

<table>
<thead>
<tr>
<th>Capacity:</th>
<th>20 MW electrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Donaldsonville, Louisiana, USA</td>
</tr>
<tr>
<td>Energy:</td>
<td>Renewable from grid</td>
</tr>
<tr>
<td>Concept:</td>
<td>Use of hydrogen in existing ammonia plants to produce green ammonia</td>
</tr>
<tr>
<td>Status:</td>
<td>Basic Engineering</td>
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</tbody>
</table>
Green hydrogen plant C, KSA
Scaling up to 20 MW standard module as test pilot for HyLIOS project

<table>
<thead>
<tr>
<th>Capacity:</th>
<th>20 MW</th>
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<tbody>
<tr>
<td>Location:</td>
<td>NEOM, KSA</td>
</tr>
<tr>
<td>Energy:</td>
<td>Wind and PV</td>
</tr>
<tr>
<td>Concept:</td>
<td>Green hydrogen, partially green methanol Qualification of 20 MW module in three year test operation for direct use in the modular plant in the HyLIOS project</td>
</tr>
<tr>
<td>Status:</td>
<td>Under development</td>
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Green hydrogen plant D, KSA
Pioneering innovation lab – Major step for entering the global hydrogen market

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<tr>
<th>Capacity:</th>
<th>650 t per day green hydrogen (multi GW electrolysis)</th>
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<td>NEOM, KSA</td>
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<tr>
<td>Energy:</td>
<td>Wind and PV</td>
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<tr>
<td>Concept:</td>
<td>Green hydrogen feedstock to green ammonia</td>
</tr>
<tr>
<td></td>
<td>Green ammonia as energy carrier</td>
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<tr>
<td>Status:</td>
<td>Under development</td>
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Summary

• Hydrogen which has traditionally been associated with high carbon emissions, but production using renewable energy sources - Water electrolysis, it can be completely de-carbonized.

• Hydrogen can make energy Storable and easily Transportable and can play big role in mitigation of from CO₂ Industries for making useful Chemicals and help to achieve Carbon Neutral status.

• thyssenkrupp tkUCE is a front runner for technologies for production of Green Hydrogen via Alkaline Water Electrolysis (AWE) based on vast experience of Electrolysis technologies.

• AWE technology is Reliable, High efficient and being large Module makes it easy to scale for Mega-Complexes.

• thyssenkrupp can offer technology and large scale plants for downstream Chemical value chain completely integrated with Green Hydrogen.
Thank You for Your Attention.

Questions?