thyssenkrupp Industrial Solutions

Why the Industrial Sector is No1 Driver to Scale-up of Green Hydrogen Today

Dr Christoph Noeres, Head of Green Hydrogen @ thyssenkrupp
Value propositions and driver

**Climate Protection/ Sustainability**

\[ \text{CO}_2 \]

**Evolution of the energy system**

**Diversification of Energy Supply**

**Limits for Local Emissions**

**Use Gas Infrastructure Legacy**

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**EU**

Reduction of greenhouse gas emissions
- 2030 by 40 %
- 2040 by 60 %
- 2050 by 80 %
(base year 1990)

**Germany**

Reduction of greenhouse gas emissions
- 2020 by 40 %
- 2030 by 55 %
- 2040 by 70 %
- 2050 by 80 to 95 %
(base year 1990)
Big Picture of Green Hydrogen

- **Renewable Power**
  - Renewable electricity will be the primary energy source for all market segments
  - Cost decline of renewable will continue decreasing

- **Power Grid**
  - Demand of power transport will increase 5 to 10 times

- **Green Hydrogen**
  - Renewable integration
  - Energy transport
  - Balancing power generation (storage)
  - Power grid optimization
  - Power grid services

- **Transport & Storage**
  - H₂ infrastructure to enable decentralized solutions

- **Hydrogen Markets**
  - Hydrogen for clean and sustainable gases, fuels, chemicals, steel/feedstocks, etc.

**Green hydrogen driver & enabler**
- Climate & environmental protection
- Growing share of renewable energies
- Appropriate legal frameworks
Why is green hydrogen not yet big business?

Until now – decentral small units only

- most green hydrogen projects are decentral with small (max single MW) electrolysis units
- green hydrogen pilots focused mainly on supply of hydrogen for mobility
- but, mobility will take time to pick up and relevant markets have not been addressed yet

→ small scale electrolyzer equipment without equipment scale effect
→ no feasible business cases available → no scale up of supply chain

Hydrogen cost are still too high!

But, We need green hydrogen < 2€/kg

To reduce cost of green hydrogen we need:
- large scale equipment
- high efficiency equipment
- large scale supply chains

We need central / industrial applications!
Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

1. Substitution of Grey Hydrogen in Existing Industrial Complexes

Today's existing hydrogen applications are to a major extent grey

100% H2 = 9.8 EJ = 2784 TWh → 600 GW electrolysis

- Natural gas: 48%
- Oil: 30%
- Coal: 18%
- Electrolysis: 4%

- Ammonia: 45%
- Methanol: 18%
- Refining: 27%
- Other/New applications: 10%
Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

2. Backend Applications such as Ammonia Need Scale
Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

3. Electrolysis Technology is a Modular System, Scale Matters and Reduces Cost

Specific Cost Reduction

-30%

-10%
Why is the Industrial Sector No1 Driver for Scale-up of Green Hydrogen?

4. Global Transport Chains Operate Only Efficiently at Gigawatt Scale

**Transport Options**

- **LH₂**
  - For international distribution
  - Requires technical development

- **H₂ / CH₄**
  - For medium distances
  - Leverages NG infrastructure

- **CH₃OH**
  - For methanol end-uses
  - Leverages existing infrastructure

- **NH₃**
  - For ammonia end-uses
  - Leverages existing infrastructure

- **LOHC**
  - Binds hydrogen in liquids
  - Binding/unbinding requires energy

- **LNG**
  - H₂ reforming in target country
  - CO₂ return to CCS via shipping
Driver for Green Hydrogen: Massive Renewable Energy is Coming Onstream - Every Year 150 GW_{el} capacity

1.35 USD CENT / kWh PPA by Abu Dhabi Power for a 2GW PV based project
Driver for Green Hydrogen:
National Strategies in Roll-out Process Including Funding in bn EUR Scale.

The European Green Deal

#EUGreenDeal
Sustainable green value chain by thyssenkrupp
WE ARE READY: thyssenkrupp is No.1 in Electrolysis Technology in Industrial Scale

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)

- Reliable technology
- High efficiency
- Fast dynamics to join the power market
- Mass production, supply chain at scale
Smart Solutions for Climate Protection — Carbon2Chem®
From idea to commercial implementation

Location of Carbon2Chem® Technical Center at thyssenkrupp Steel site in Duisburg
<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Pilot plant space</td>
<td>3,700 m²</td>
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<tr>
<td>Laboratory space</td>
<td>520 m²</td>
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<tr>
<td>Number of laboratories</td>
<td>6</td>
</tr>
<tr>
<td>Number of offices</td>
<td>12</td>
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</tbody>
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Smart Solutions for Climate Protection — Alkaline Water Electrolysis
Demo unit in Duisburg
Green Hydrogen @ Industrial Sector: Reallabor Westküste 100 in Heide, Germany

Phase 1: 30 MW electrolysis,
Phase 2: 700 MW electrolysis, green methanol and fuel for aviation

Location: Heide, Germany
Funding: by BMWi
RE Feed: Offshore wind
Idea: - green hydrogen feedstock to refinery of Heide,
     - green methanol / fuel production by refinery
     - green hydrogen for fuelling stations

Startup: 2023
Green Hydrogen @ Industrial Sector: HELIOS Project, KSA

Capacity: 650 t per day green hydrogen (multi GW electrolysis)

Location: NEOM, KSA
RE Feed: Wind and PV
Idea: - green hydrogen feedstock to green ammonia,
      - green ammonia for energy carrier

Startup: 2025
THANK YOU FOR YOUR ATTENTION