Realization of Large-Scale Green Ammonia Plants

Solutions for sustainable NH$_3$ production

2018 AIChE Annual Meeting – NH3 Energy+ Topical Conference

October 2018 | Markus Will | thyssenkrupp Industrial Solutions
Sustainability is driving us

Reduce carbon footprints in industrial value chains

Stop climate change and its global impact

Develop technologies and solutions to make sustainability a business

Elevate renewable energy to the next stage

Become a role model and give direction
full sustainable value chains by thyssenkrupp
Our solutions: redox flow batteries (RFB) and alkaline water electrolysis (AWE)

- **Power-to-Power**
  - Power grid
  - CCG Turbine
  - Gas grid
  - Mobility
  - Chemicals

- **Power-to-Chemicals**
  - Ammonia
    - Methanol
    - Urea / DEF
    - SNG (Power-to-gas)

- **Electrochemical energy storage systems (RFB)**
  - Short- to mid-term storage

- **Water electrolysis (AWE)**
  - Long-term storage

Renewable energy

Conventional energy production & heavy industry

thyssenkrupp's integrated portfolio for energy storage & chemicals

Renewable energy

Conventional energy production & heavy industry

thyssenkrupp Industrial Solutions – BU-FER

August 2018 | Tobias Birwe & Markus Will
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
Hydrogen at scale – large water electrolysis plants

Advanced Water Electrolysis
- Zero-gap technology
- Innovative electrode coatings by DeNora
- High efficiency atmospheric operation
- Fast response to fluctuating power input
- Post-compression optional
- Full turnkey EPC plants
- Large capacity supply chain
- Global service

Experience cannot be copied.

#1 over
supervisor for electrolytic
hydrogen production

49% market share

600
600 over

electrochemical
plants realized
worldwide

of power installed

400 GW

10 GW of power installed

\[ \text{Hydrochloric acid diaphragm electrolysis} \]

\[ \text{Hydrochloric acid OIC membrane electrolysis} \]

\[ \text{Chlor-alkali membrane electrolysis} \]
Introducing renewable ammonia by thyssenkrupp

1. Wholistic solution
2. Worldwide leading processes
0. CO2 emissions*

*depending on E-power source

thyssenkrupp large scale electrolysis plant:
120 MW
thyssenkrupp smallest scale ammonia plant:
50 mtpd

thyssenkrupp small scale ammonia plant:
20 MW
thyssenkrupp electrolysis plant:
300 mtpd
Introducing renewable ammonia by thyssenkrupp

Electricity from renewables

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

Ammonia synthesis
\[ 3H_2 + N_2 \rightarrow 2NH_3 \]

CO\(_2\)-neutral ammonia

Specific Consumption 50 mtpd plant
- Electric Power: \( \sim 10 \text{ MWh}/\text{t}_{\text{NH}_3} \)
- Treated Water: \( \sim 1.6 \text{ tons/t}_{\text{NH}_3} \)
- Cooling Water*: \( \sim 240 \text{ tons/t}_{\text{NH}_3} \)

Specific Consumption 300 mtpd plant
- Electric Power: \( \sim 9.4 \text{ MWh}/\text{t}_{\text{NH}_3} \)
- Treated Water**: \( \sim 1.62 \text{ tons/t}_{\text{NH}_3} \)
- Cooling Water*: \( \sim 170 \text{ tons/t}_{\text{NH}_3} \)

*CW loop flowrate  
** incl. steam generation
Key drivers for Green Ammonia: Operational Costs

Current range ammonia price

Premium Price for Green Ammonia

natural gas price

electric power price
Key drivers for Green Ammonia: Investment Costs

AIM: Reduce Construction Costs

Stick-Built

Modularized
Our design philosophy: highly modular and standardized on prefabricated skids

- Standardized, skid mounted electrolysis modules for cost efficient deployment at site.
- Area required for a 100 MW electrolysis plant is about 3000 m².
- Optional downstream processing equipment: compression, oxygen removal and drying
Conventional ammonia production

- Feed
- Fuel
- Water
- Air

Purification
- Air compression
- Steam Reformer
- HT and LT shift
- CO₂ removal
- Methanation

Synthesis
- Syn Compression
- Synthesis Loop
- Refrigeration
- NH₃ Recovery

Electricity-based ammonia production

- Water
- Air
- Electricity

Synthesis Loop

Electrolysis
- De-Oxygenation
- H₂ generation
- H₂ Compression

Air separation
- Syn Compression
- Synthesis Loop

Synthesis

NH₃ Recovery

(GHG) CO₂
Intermediate Step: Green ammonia Revamp option

- **Feed**: Water, Air, CO₂ removal, Methanation, Syn Compression, Synthesis Loop, Refrigeration, NH3 Recovery
- **Fuel**: Air compression, Steam Reformer, HT and LT shift, CO₂ removal, Methanation, Syn Compression, Synthesis Loop, Refrigeration, NH3 Recovery
- **Water**: Electrolysis, De-Oxygenation, H₂ Compression, N2 Compression, NH3 Recovery
- **Air**: Electricity, H₂ generation, Air separation
- **Electricity**: Water, Air, Electricity
- **CO₂**: (GHG)
The renewable energy age is unstoppable…
… energy storage and carbon conversion are key factors

thyssenkrupp provides solutions for integrating and leveraging renewables and recycling carbon