Innovations in Ammonia

Trevor Brown NH3 Fuel Association (Ammonia Energy Association)

US Department of Energy, H2@Scale R&D Consortium Kick-Off Meeting Chicago, August 1, 2018



Ammonia: >Half Today's Hydrogen Market

- Ammonia production, 2017: 183 million metric tons
- Hydrogen-to-ammonia, 2017: 32.6 billion kg
- Hydrogen is captive: SMR / POX from gas, coal, etc
- Ammonia is captive: Urea, nitric acid, AN, UAN, etc
- 80% fertilizer, ~2% CAGR
 <10% traded: 16-17 million tons

19 GLOBAL USAGE OF HYDROGEN



Zakkour/Cook 2010; own diagram



Ammonia History: Energy Efficiency



Ammonia Technology Evolution, 1910-2015

Various sources, AmmoniaIndustry.com, March 2018



Ammonia Future : Diminishing Returns

- Potential 25% improvement: in energy efficiency: Asset turnover, old→new Feedstocks, coal→gas
- At best, 2050 global average could be similar to 2015 BAT
- Haber-Bosch is optimized for energy efficiency already
- 25% improvement fails to meet industry targets





Energy Efficiency is not Sufficient

- Best <u>Available</u> Technology (BAT) is not good enough: we need new technologies
- But new technologies do not improve energy efficiency ...
- Therefore "energy efficiency" cannot be the only driver of innovation and investment
- A diverse technology portfolio also rewards carbon efficiency



Ammonia Technology Evolution, 2000-2050

Green Ammonia Technology Portfolio

 Low carbon technologies become competitive when carbon efficiency is rewarded Ammonia Technology Evolution, 2000-2050 IFA Benchmarks / CEFIC, AmmoniaIndustry.com, March 2018





Showa Denko: Low-Carbon Ammonia (2003)

- Kawasaki, Japan
- 65% hydrogen is from recycled plastic (i.e., 100% feedstock but no fuel)
- Commercial: Ecoann[™] ammonia sold as premium green deNOx product

"Approved and rated high as 'eco-friendly goods for procurement' by major electric power companies."





U.Minnesota: Wind-to-Ammonia Pilot (2013)

- Morris, MN, USA
- R&D innovation:
 Scaling down
 Haber-Bosch
 to match wind





U.Minnesota: Low-pressure H-B (2018)

Absorption (staged) Replaces Condensation (mixed)



Reaction-Absorption





FREA: Renewable Ammonia Pilot (Q2 2018)

- Fukushima, Japan
- R&D innovation:
 Catalyst development for lowpressure electrolytic hydrogen





Siemens: Green Ammonia Pilot (Q2 2018)

- Oxford, UK
- R&D innovation:
 Business Models:
 ancillary grid
 services (DSM),
 energy storage,
 electrofuels,
 electricity markets





Siemens: Green Ammonia Pilot (Q2 2018)

The Green Ammonia Demonstrator will show the complete cycle of renewable power, storage as ammonia, and conversion back to electricity

SIEMENS



Haldor Topsoe: SOEC+HB Pilot (2025)

- Denmark
- R&D innovation: Electrification of industry, SMR asset revamp

Green Ammonia by SOEC Synergy between SOEC and Synthesis



- · Ammonia synthesis waste heat for steam production.
- SOEC more efficient than present electrolysis. Internal waste heat used to split water.
- SOEC is steam electrolysis. This is new and more efficient!

(presented by John B. Hansen in AIChE 2017)

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NH3 FUEL

ThyssenKrupp: Hydrogen Utility Pilot (2020)

- Port Lincoln, South Australia
- R&D innovation: Market development for ammonia exports as energy commodity





ThyssenKrupp: Modular Ammonia (2018)

Introducing renewable ammonia by thyssenkrupp



ThyssenKrupp: Offshore Ammonia (concept)



Yara / BASF: Freeport Ammonia (Q2 2018)

- Freeport, TX
- R&D innovation:
 Byproduct hydrogen from
 Dow's 2017 ethylene cracker
- 170 million scf per day, H₂
 750,000 tons per year, NH₃
- \$600 million plant capex
 25% reduction v SMR

Low GHG emissions of byproduct hydrogen



Source: Amgad Elgowainy presentation, H2@Scale Workshop (May 2017) https://www.energy.gov/sites/prod/files/2017/05/f34/fcto may 2017 h2 scale wkshp elgowainy.pdf



Innovations in Ammonia

- Nitrogen Commodity \rightarrow Hydrogen Commodity
- Homogenous Commodity → Heterogeneous Commodity \$ Price Premium = \$ Local Function[Carbon Footprint]
- Green Ammonia (Energy Markets) → Green Ammonia (Ag Markets) Low-Carbon Leakage: supply creates demand
- Green Hydrogen demand:

32.6 billion kg / year, installed base 2017 (feedstock only) 0.65 billion kg / year, annual additions (BAU @ 2% CAGR)

Questions?

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https://ammoniaindustry.com https://nh3fuelassociation.org



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