

Ammonia Energy

AURI, MN Renewable Energy Roundtable
Agriculture's Opportunity in the Emerging Hydrogen Economy

September 10, 2020

Trevor Brown, Ammonia Energy Association



AMMONIA ENERGY
ASSOCIATION

Ammonia Energy Association

A global trade association that advocates for the responsible use of ammonia in a sustainable energy economy.

ammoniaenergy.org

Ammonia Energy Association

Supply: decarbonize ammonia production.
Demand: adopt ammonia in energy markets.

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AMMONIA ENERGY ASSOCIATION



MEMBER LIST - September 2020

* indicates representation on Board of Directors

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Low-Carbon Ammonia – Supply

Pilot plants, Revamps, Industrial Feasibility



Enaex – Cusco, PE (1962)

Capacity: 10,000 tpy ammonia (estimate). Feedstock: hydro power.

Note: Only remaining commercial electrolysis-ammonia plant (Uhde).

Nutrien – Joffre, AB (1987)

Capacity: 490,000 tpy ammonia. Feedstock: byproduct hydrogen.

Note: 25% reduction in carbon footprint, offsets company carbon tax liability.

Showa Denko – Kawasaki, JP (2003)

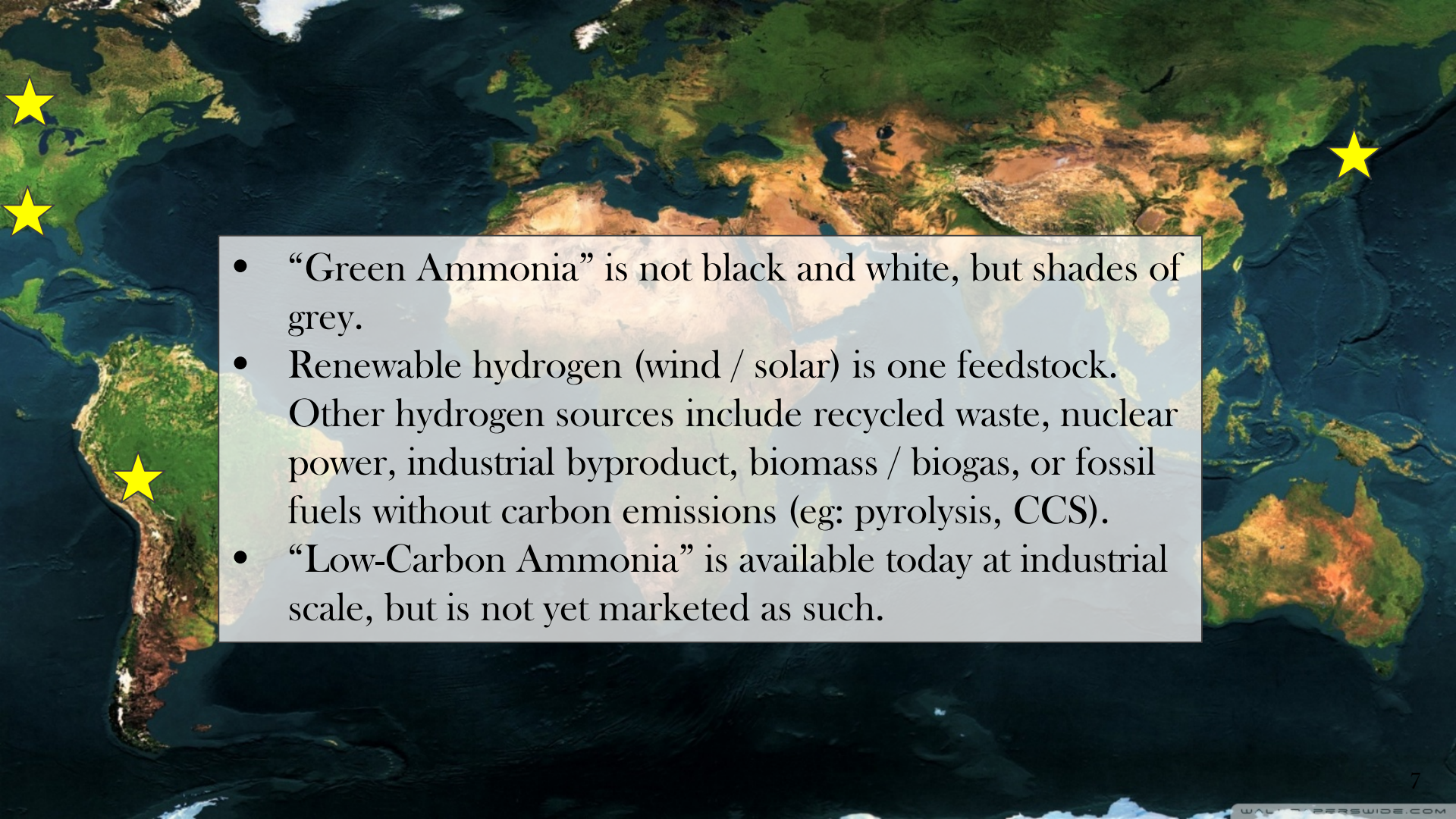
Capacity: 60,000 tpy ammonia. Feedstock: waste plastic / natural gas.

Note: 65% of hydrogen comes from plastic; sells low-carbon deNOx fluid (Ecoann™) in protected market (“eco-friendly goods for procurement”).

Yara / BASF – Freeport, TX (2018)

Capacity: 800,000 tpy ammonia. Feedstock: byproduct hydrogen.

Note: 25% reduction in carbon footprint.

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- “Green Ammonia” is not black and white, but shades of grey.
 - Renewable hydrogen (wind / solar) is one feedstock. Other hydrogen sources include recycled waste, nuclear power, industrial byproduct, biomass / biogas, or fossil fuels without carbon emissions (eg: pyrolysis, CCS).
 - “Low-Carbon Ammonia” is available today at industrial scale, but is not yet marketed as such.



University of Minnesota – Morris, MN (2014)

Capacity: 25 tpy ammonia. Feedstock: wind power.

Note: Small-scale, distributed model, driving chemical engineering / economics research.

Siemens – Harwell, UK (2018)

Capacity: 10 tpy ammonia. Feedstock: wind power

Note: Haber-Bosch + intermittent power, informs electricity business cases.

FREA / JGC Corporation – Koriyama, JP (2018)

Capacity: 7 tpy ammonia. Feedstock: wind / solar power.

Note: Catalysts optimized for low pressure Haber-Bosch. Also: ammonia combustion (gas turbine).

OCP – Jorf Lasfar, MA (date TBD)

Capacity: TBD. Feedstock: solar power.

Note: Collaboration with Fraunhofer IMWS (Germany).



Enaex – Antofagasta, CL (date TBD)

Capacity: 20,000 tpy ammonia. Feedstock: solar power.

Note: Pilot plant, 62 MWp solar / 47 MW electrolyzer. Engie: feasibility study.

Proton Ventures / Siemens / Yara – Goeree-Overflakkee, NL (date TBD)

Capacity: 20,000 tpy ammonia. Feedstock: wind / tidal power.

Note: Regional "green hydrogen" economy.

SiemensGamesa – Skive, DK (date TBD)


Capacity: TBD. Feedstock: wind power.

Note: Upstream industry, developing downstream markets.

Ballance Agri-Nutrients – Kapuni, NZ (date TBD)

Capacity: 5,000 tpy ammonia (estimate). Feedstock: wind power.

Note: 16 MW wind turbines, NZ\$50 million budget.



Queensland Nitrates – Moura, AU (date TBD)

Capacity: 20,000 tpy ammonia. Feedstock: solar power.

Note: Feasibility; partners include Incitec Pivot / Wesfarmers JV; partners Neoen, Worley.

Dyno Nobel – Moranbah, AU (date TBD)

Capacity: 60,000 tpy ammonia (estimate). Feedstock: solar power.

Note: Feasibility; proposal is for 210 MW solar / 160 MW electrolyzer.

Yara – Pilbara, AU (2006 / TBD)

Capacity: 25,000 tpy ammonia. Feedstock: natural gas / solar power.

Note: 850,000 tpy current capacity. Addition of 100 MW solar, 50-60 MW electrolyzer; future hydrogen tie-in already completed during 2018 turnaround. Engie feasibility.

H2U / thyssenkrupp – Port Lincoln, AU (TBD)

Capacity: 20,000 tpy ammonia. Feedstock: wind / solar power.

Note: Business case demonstration for renewable energy exports (“Hydrogen Hubs”), with two under development in South Australia and Queensland (up to 3 GW).



Enaex – Antofagasta, CL (date TBD)

Capacity: 350,000 tpy ammonia. Feedstock: solar power.

Note: Full scale at 1,030 MWp solar / 778 MW electrolyzer. Engie: feasibility study.

Fertiberia – Puertollano, SP (2021)

Capacity: 4,000 tpy ammonia (estimate). Feedstock: solar.

Note: 100 MW solar, 20 MW electrolyzer, EUR 150 million investment by Iberdrola.

Decarbonizes about 2% of total ammonia plant capacity of 200,000 tpy.

Haldor Topsøe – Foulum, DK (2025)

Capacity: 300 tpy ammonia (estimate). Feedstock: wind power.

Note: Solid oxide electrolyzer, no ASU, modular. Energy efficiency estimated at 7.2 MWh (26 GJ), equal to best available technology (world-scale SMR-Haber Bosch).

Yara – Porsgrunn, NO (2022)

Capacity: 2,500 tpy ammonia (estimate). Feedstock: hydro power (grid).

Note: 5 MW electrolyzer drives manufacturing scale-up, reduces unit capex. Electrifies 1% of plant capacity, so existing Haber-Bosch plant will produce 500,000 tpy of 99% fossil ammonia but, with certification, can market 5,000 tpy of 100% green ammonia.



Wabash Valley Resources – Terre Haute, IN, United States (date TBD)

Capacity: 550,000 tpy ammonia. Feedstock: pet coke.

Note: US Dept of Energy funding for CCS. 45Q tax credits (carbon sequestration), and LCFS credits (reduction in ethanol fuel carbon intensity).

NEOM / Air Products – Neom, Saudi Arabia (2025)


Capacity: 1.2 million tpy ammonia. Feedstock: wind & solar power.

Note: 4 GW scale, \$5 billion investment from NEOM, Air Products, ACWA Power. Additional \$2 billion investment by Air Products to distribute 100% of offtake ammonia into hydrogen transportation markets (fuel cell trucks and buses).

Asian RE Hub– Pilbara, Australia (2028)

Capacity: 3-4 million tpy ammonia (estimate). Feedstock: wind & solar power.

Note: 15 GW, AU\$ 22 billion investment (US\$ 16 billion), 6,500 square kilometer site, export oriented for international fuel markets.

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- A world map with a satellite-style background. Yellow stars are placed on the following regions: the West and East coasts of North America, the British Isles, Scandinavia, Central Europe, the Mediterranean coast of Europe, the Middle East, East Asia, the West and East coasts of South America, and Australia.
- “Green Ammonia” is happening
 - This transition is not driven by fertilizer economics.

Low-Carbon Ammonia – Markets

Low-Carbon Fertilizer, Hydrogen Carrier, Maritime Fuel

Low-Carbon fertilizer demand

Back of an envelope illustration #1:

- GREET (Argonne National Lab) model update: low-carbon fertilizer.
- Gasification with CCS: emits 0.18 tons CO₂ per ton ammonia (GHG index 8.9 v 100 SMR baseline).
- Carbon Intensity of ethanol (fertilizer impact): ~ 10 down to ~ 4 g/MJ
- LCFS credits equate to ~ \$450 premium per ton low-carbon ammonia

Low-Carbon ammonia demand

Back of an envelope illustration #2:

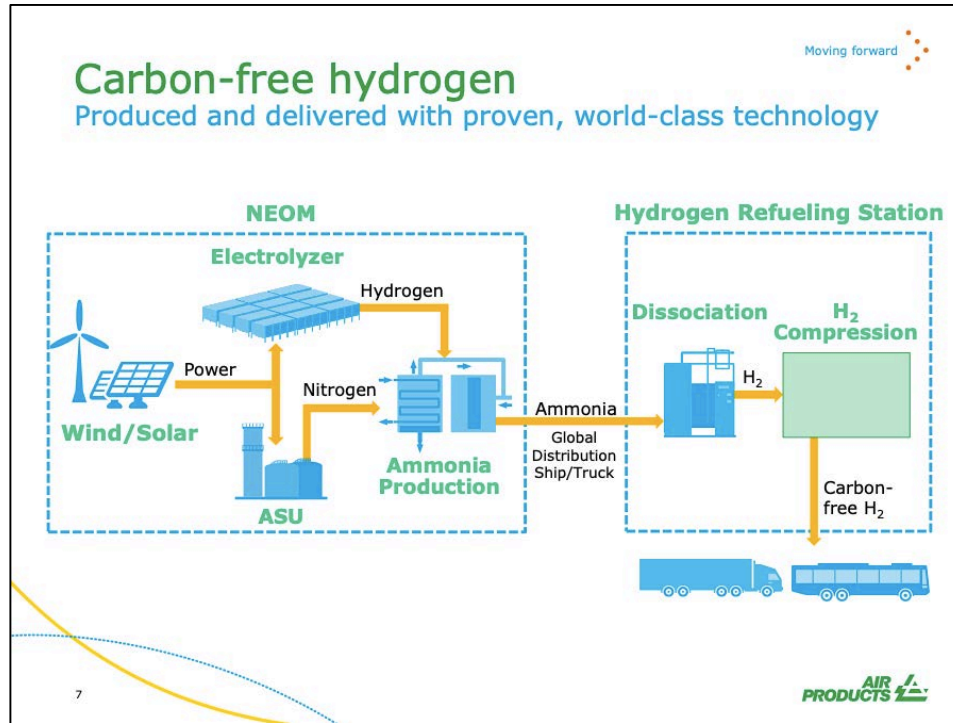
- CA hydrogen fuel retail @ \sim \$14 / kg H₂
- CA ammonia fertilizer retail @ \sim \$500 / metric ton NH₃
- Switch value from N to H ...
- CA hydrogen fuel retail @ \$1,891 / metric ton NH₃

Assumes 24.1% loss during cracking and purification, thus 135 kg H₂ per ton NH₃.

See Giddey et al, "Ammonia as a Renewable Energy Transportation Media." ACS Sustainable Chem. Eng., 2017:

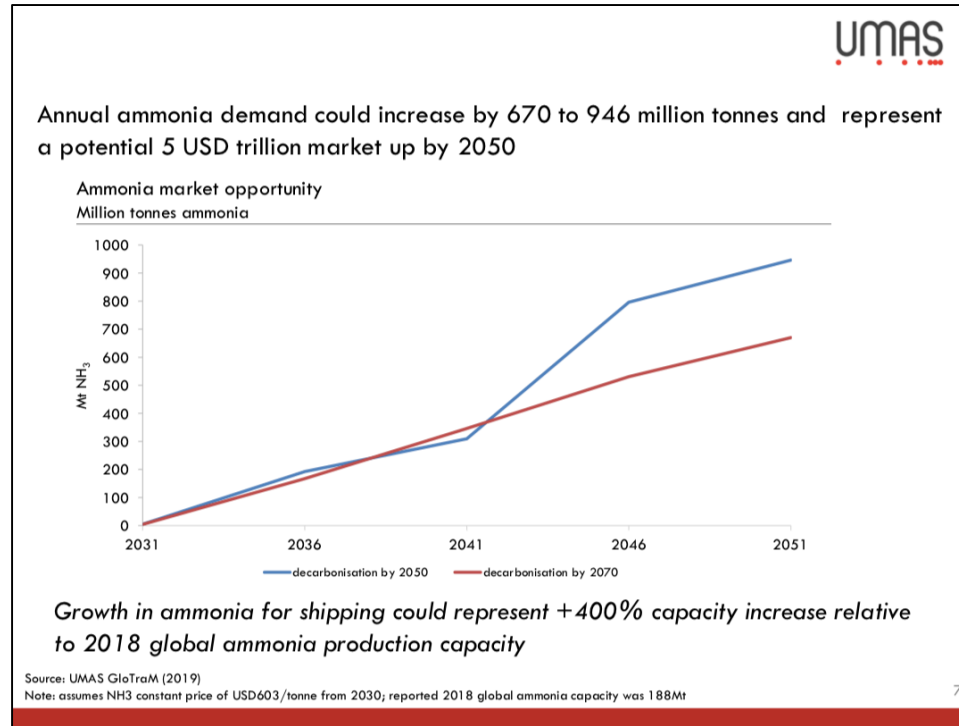
<https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.7b02219>

Hydrogen fuel demand



Air Products investor presentation, “Carbon-Free Hydrogen: The Energy Source of the Future,” July 07, 2020
<http://investors.airproducts.com/static-files/b0595961-b2ac-45ff-89c5-7d9d8837a363>

Maritime fuel demand



Tristan Smith et al, UMAS / Global Maritime Forum, “Aggregate investment for the decarbonisation of the shipping industry,” January 19, 2020

<https://www.globalmaritimeforum.org/news/the-scale-of-investment-needed-to-decarbonize-international-shipping>

Ammonia Energy – what's next?

Demand certainty will drive production scale-up.

Ammonia Energy Association spearheading Low-Carbon Certification initiative to support market premium.

Will the Mid-West export renewable energy using molecules?

What role for Ag-producers in bio-ammonia?

Thank you

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