

The Role of Ammonia in Decarbonization

KAUST Research Conference:
Near Zero-Carbon Combustion Technology

Trevor Brown, Executive Director, Ammonia Energy Association
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Ammonia Energy Association

A global, cross-sectoral industry association that advocates for the responsible use of ammonia in a sustainable energy economy.

Supply: decarbonize ammonia production.

Demand: adopt ammonia in energy markets.



AMMONIA ENERGY
ASSOCIATION

Ammonia Energy Association



MEMBER LIST — June 2021

* indicates representation on Board of Directors

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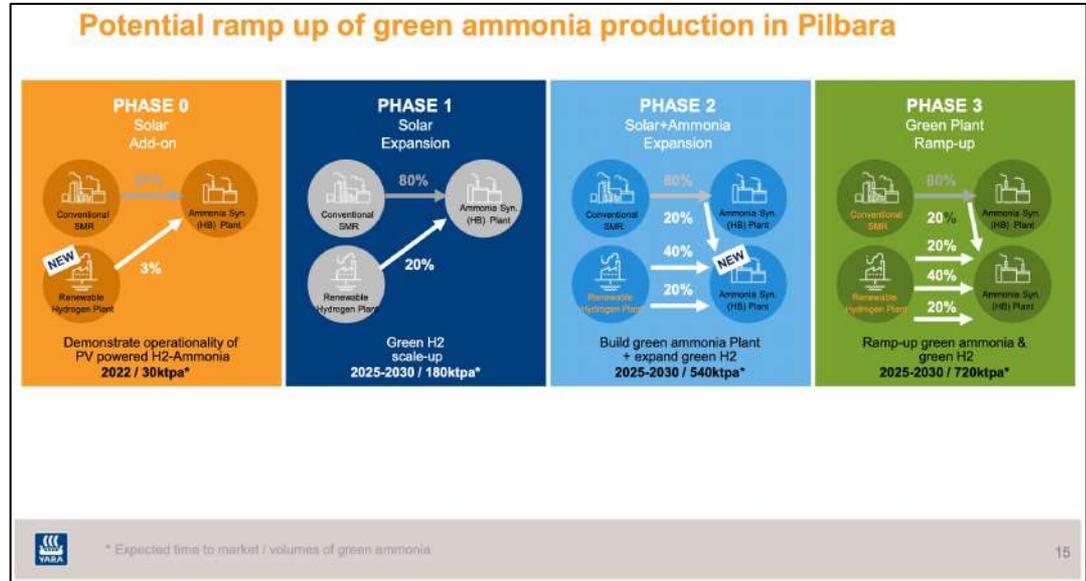


Roles for Clean Ammonia

Fertilizer, Hydrogen Carrier,
Fuel for Maritime & Electric Power Generation

Ammonia for Fertilizers

- Global market: 180 million tons per year (2nd most-produced chemical).
- International trade: 18 million tons per year.
- 1% global GHG emissions.
- >150 years of knowhow.
- For decarbonization, ~1,000 existing plants to revamp or replace within 30 years.



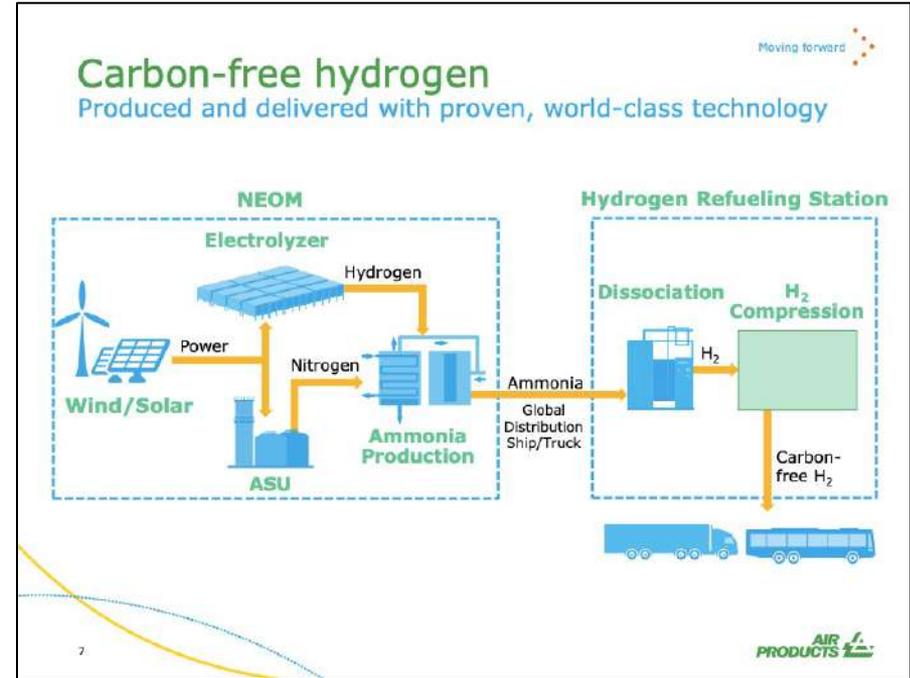
Chris Rijksen (Plant Manager, Yara Pilbara), “Green hydrogen feed for Haber Bosch ammonia synthesis,” AEA Australia Conference, August 2019.

<https://www.ammoniaenergy.org/paper/green-hydrogen-feed-for-haber-bosch-ammonia-synthesis/>

Ammonia as a Hydrogen Carrier

- Ammonia is 17.8% Hydrogen
- Liquid at -33°C (vs. -253°C)
- 50% more H_2 than H_2

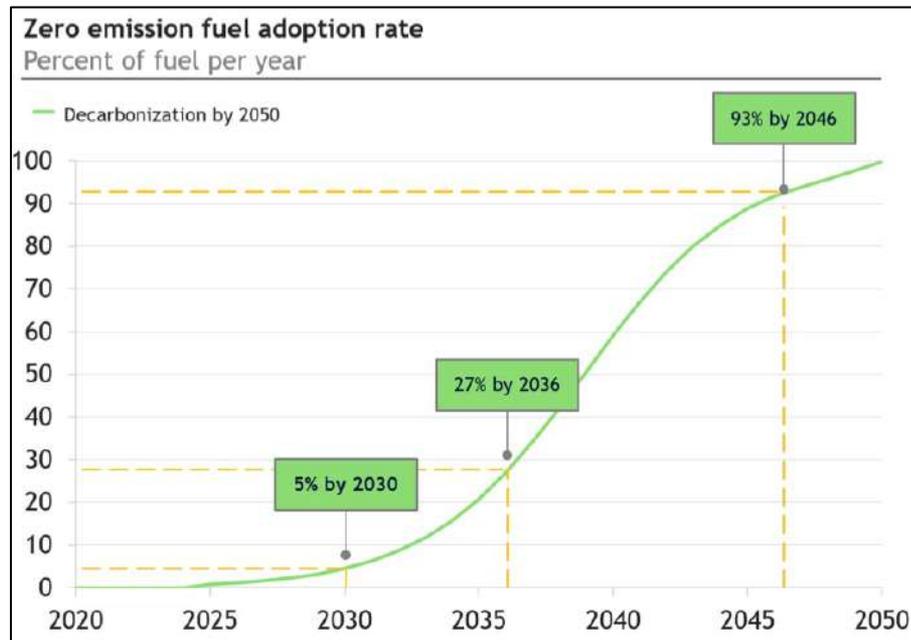
- Ammonia pipelines:
 - 0.5x cost of natural gas pipelines
 - 0.25x cost of hydrogen pipelines (because ammonia is denser)
- Ammonia tanks:
 - 60,000 ton tank holds 90 GWh
- Ammonia cracking: energy penalty, but competitive vs hydrogen transport



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>

Ammonia for Maritime Fuel

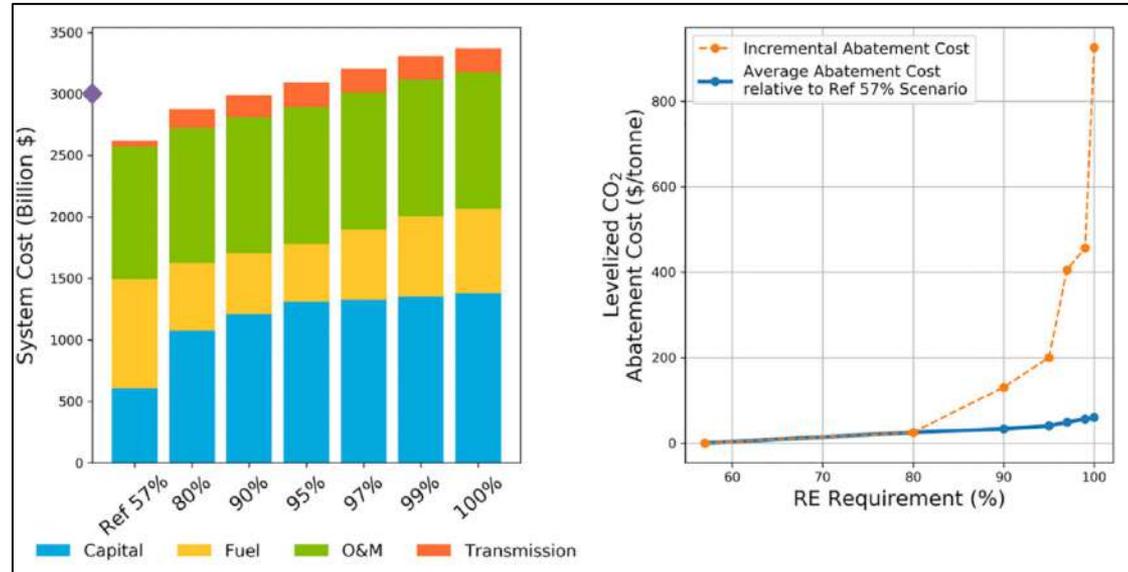
- April 2018, IMO Initial GHG Strategy: 50% reduction by 2050.
- 5% zero-carbon fuels by 2030, implies 60GW electrolyzers to produce 30 million tons ammonia (0.64 EJ / 15.8mt HFOe)
- 93% zero-carbon by 2046
>1TW electrolyzers
~300 million tons ammonia



COP26 Climate Champions / UMAS: Getting to Zero Coalition: “Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization,” March 2021 https://www.globalmaritimeforum.org/content/2021/03/Getting-to-Zero-Coalition_Five-percent-zero-emission-fuels-by-2030.pdf

Ammonia for Electric Power

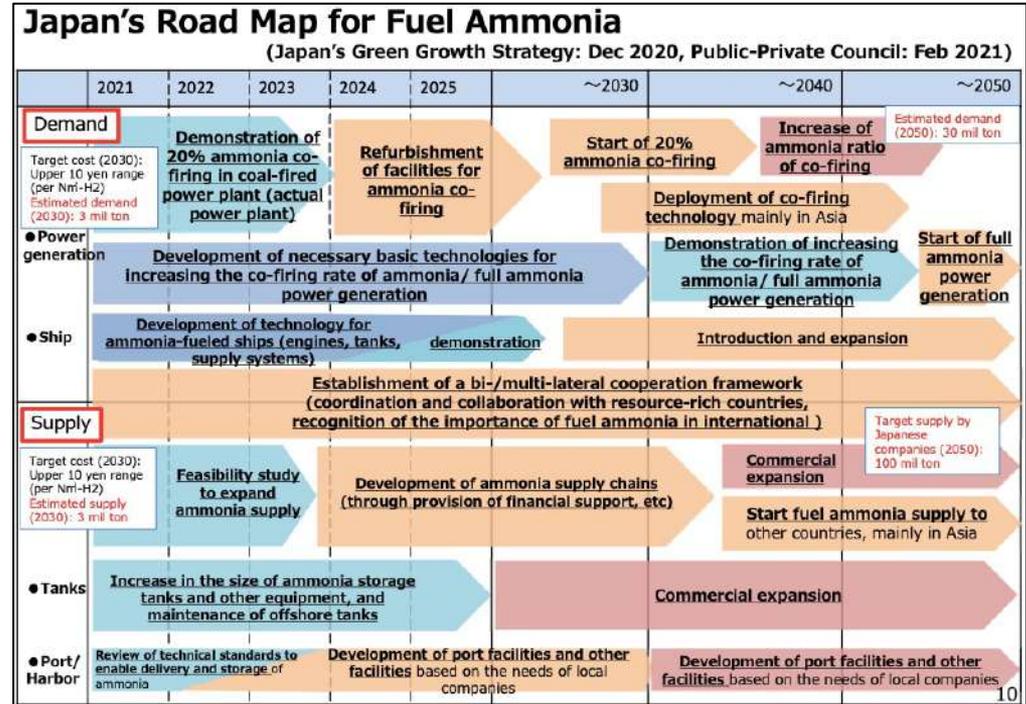
- Watch this space!
Ammonia not considered in analysis / policy (yet).
- Sector coupling ignored.
- Lowest-cost carbon-free grid includes high-cost carbon-free molecules.
- High capital cost (low capacity factor)
- Highest incremental abatement cost (lowest systemic levelized cost)



Cole et al., Quantifying the challenge of reaching a 100% renewable energy power system for the United States, Joule (2021), <https://doi.org/10.1016/j.joule.2021.05.011>

Ammonia for Electric Power

- For energy importer nation, “electrify everything” is inefficient: direct use of imported molecules preferable.
- In Japan:
- Ammonia-Coal co-firing: 20% by energy content, 1GW plant consumes 0.5 mtpy; 3mt demand by 2030
- 100% Ammonia gas turbine, 30mt domestic demand by 2050, 100mt regional demand by 2050



METI, Fuel Ammonia Road Map, February 2021,

<https://www.ammoniaenergy.org/articles/japans-road-map-for-fuel-ammonia/>

Thank you

tbrown@ammoniaenergy.org

Join us for our 18th Annual Ammonia Energy Conference

Boston, November 9-11

Call for Abstracts closes July 15

<https://www.ammoniaenergy.org/conferences-events/>



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