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Renewable Energy Storage and Utilization Using Hydrogen and Anhydrous Ammonia

MN House Energy and Climate Committee

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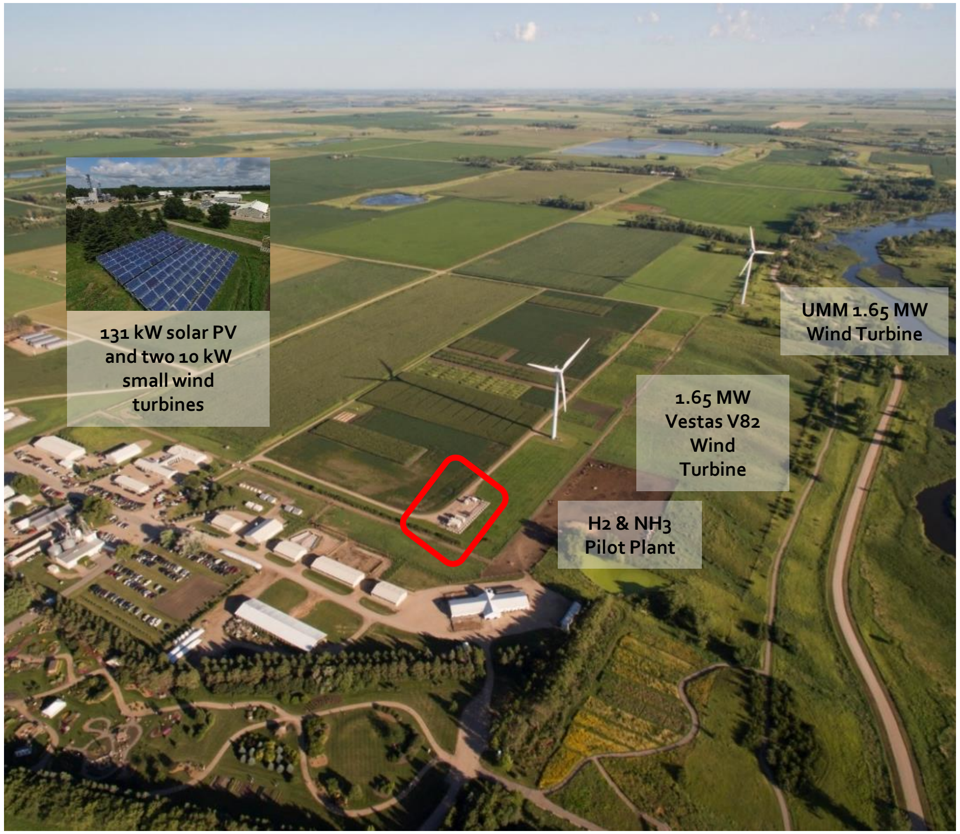
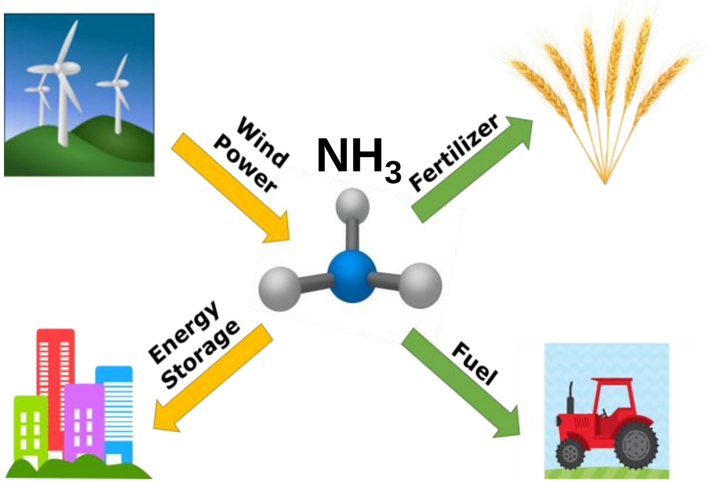
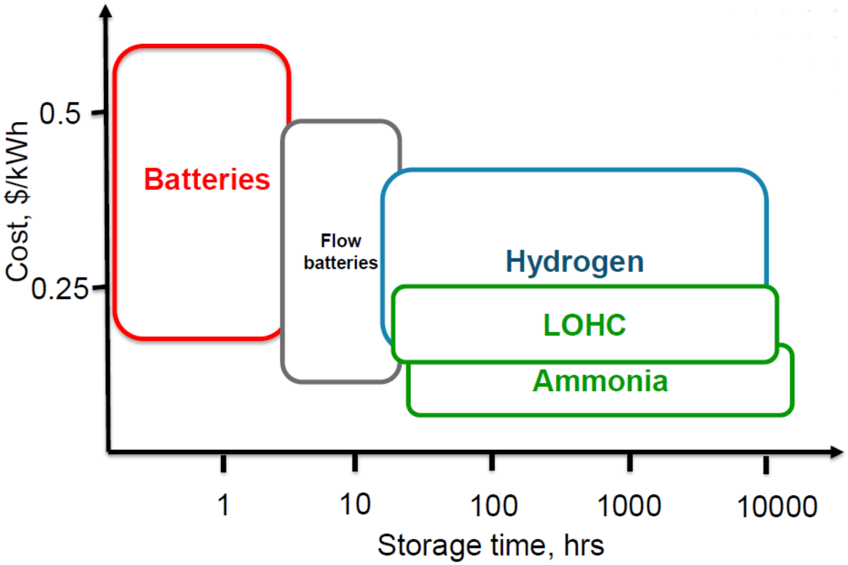
Renewable Ammonia for Energy Storage

University of Minnesota is a global research leader in this field.



Existing Wind-to-Ammonia Pilot Plant at the UMN WCROC, Morris, MN



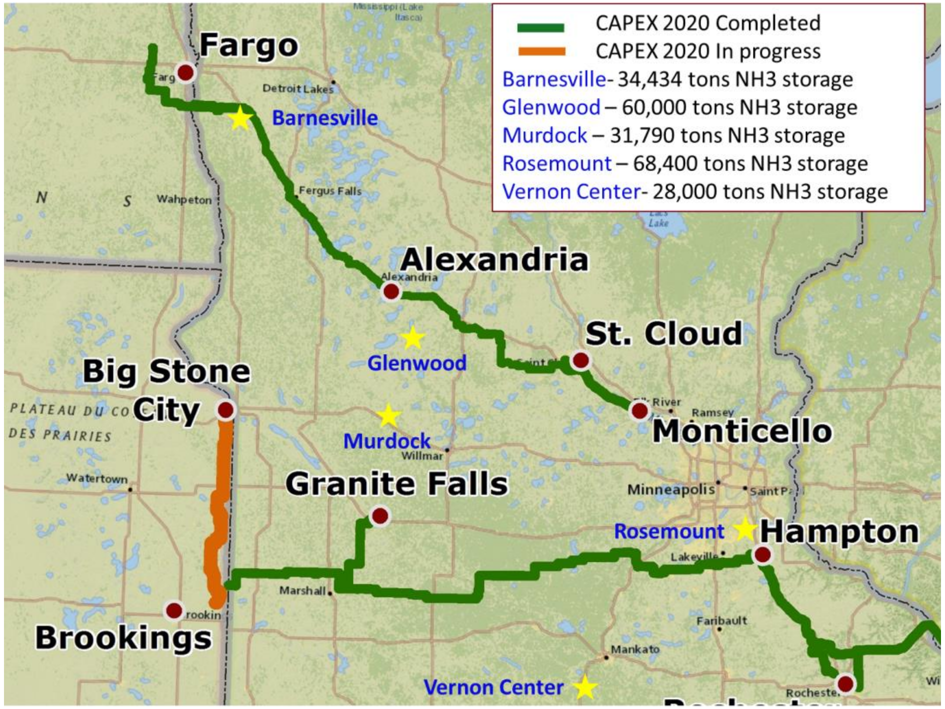


G. Soloveichik, US Dept. of Energy, 2016

Benefits for using ammonia as regional-scale energy storage

- Provides both distribution and transmission-scale energy storage,
- Wide range of fuel uses (ICE genset, turbine, fuel cell, and thermal energy)
- Seasonal storage capability,
- Grid stabilization,
- Readily dispatchable generation capacity (Peak load and peak fertilizer months are complementary. High N fertilizer demand is during utility shoulder seasons.),
- Enables utilization of excess generation of wind, solar, and nuclear (low and negatively priced power within the Regional Transmission Organization / Independent System Operator),
- Provides emergency backup outside of traditional energy sources
- Flexibility between renewable and non-renewable generation (allows choice of carbon intensity of fuel between green and brown ammonia)
- Significant levels of ammonia storage already in the Midwest (and usually near significant distribution and transmission lines as well as industrial load), and
- Multiple avenues of synthesis (electricity, methane from manure, gasification, etc)

Large-scale ammonia storage is already in place:



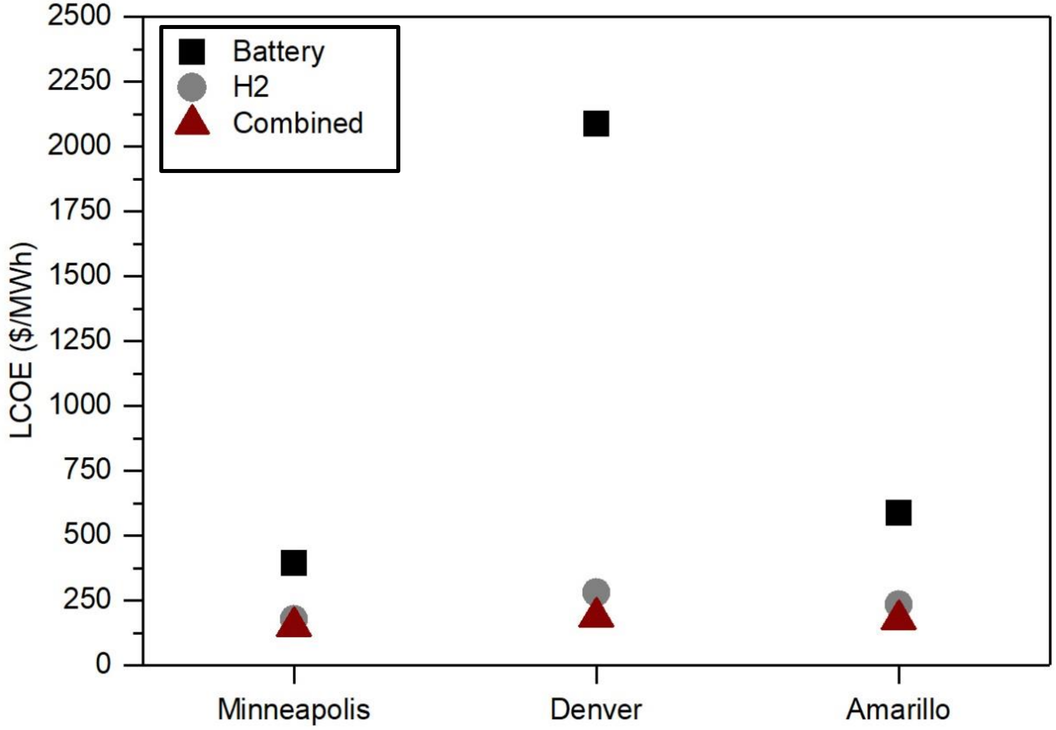
CF Industries Glenwood Ammonia Terminal

- Capacity of 60,000 tons of NH_3
- Equivalent to an estimated 111,000 MWh of electricity
- Wind and solar PV in close proximity
- Capex 500 kV line in close proximity
- Hub for wind energy transmission

Hydrogen and Ammonia Renewable Energy Storage Systems

Palys & Daoutidis. (2020). *Comput. Chem. Eng., 136*, 106875.

Optimal economics: Levelized cost of energy

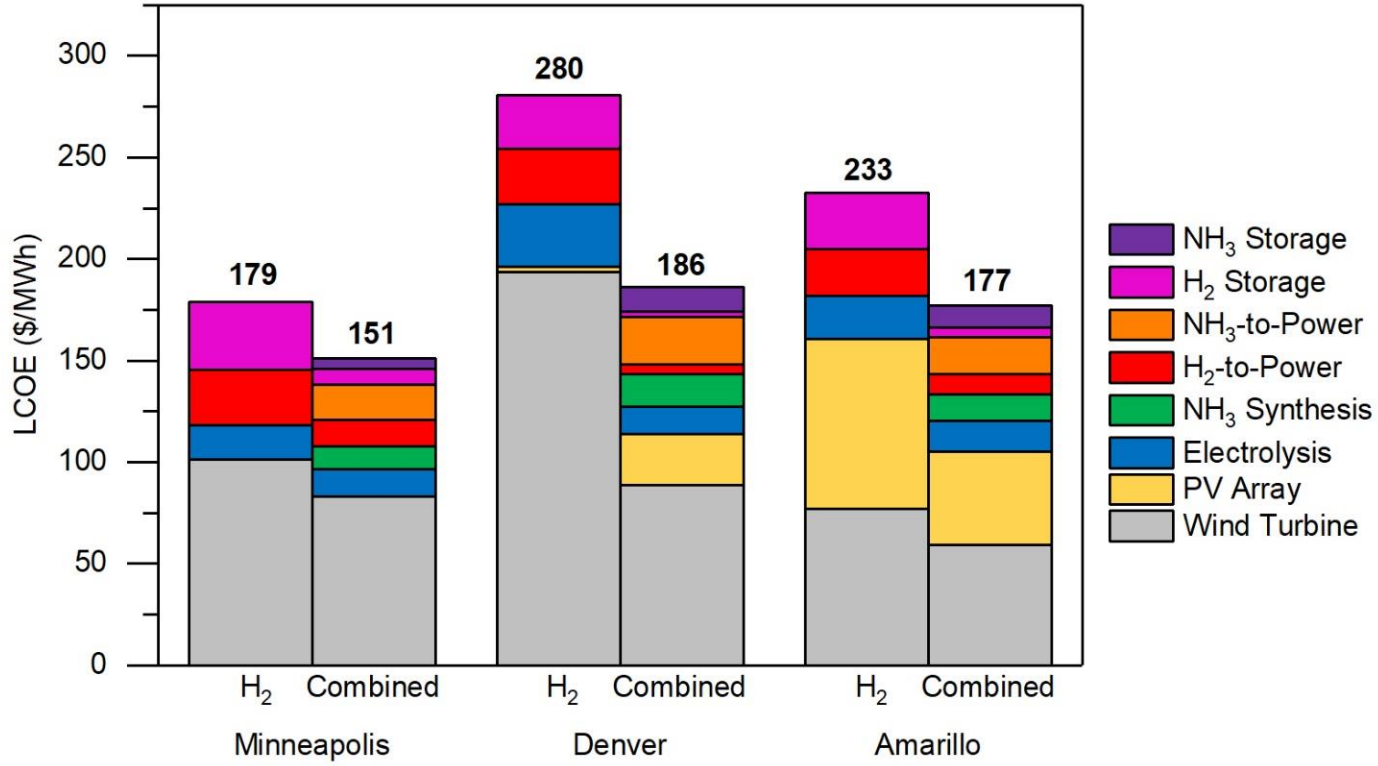


- Batteries alone are expensive (especially for significant long-term storage)
- Hydrogen provides improvement
- Hydrogen *and* ammonia is optimal

Hydrogen and Ammonia Renewable Energy Storage Systems

Palys & Daoutidis. (2020). *Comput. Chem. Eng., 136*, 106875.

Optimal economics: LCOE cost breakdown for H_2 and combined systems



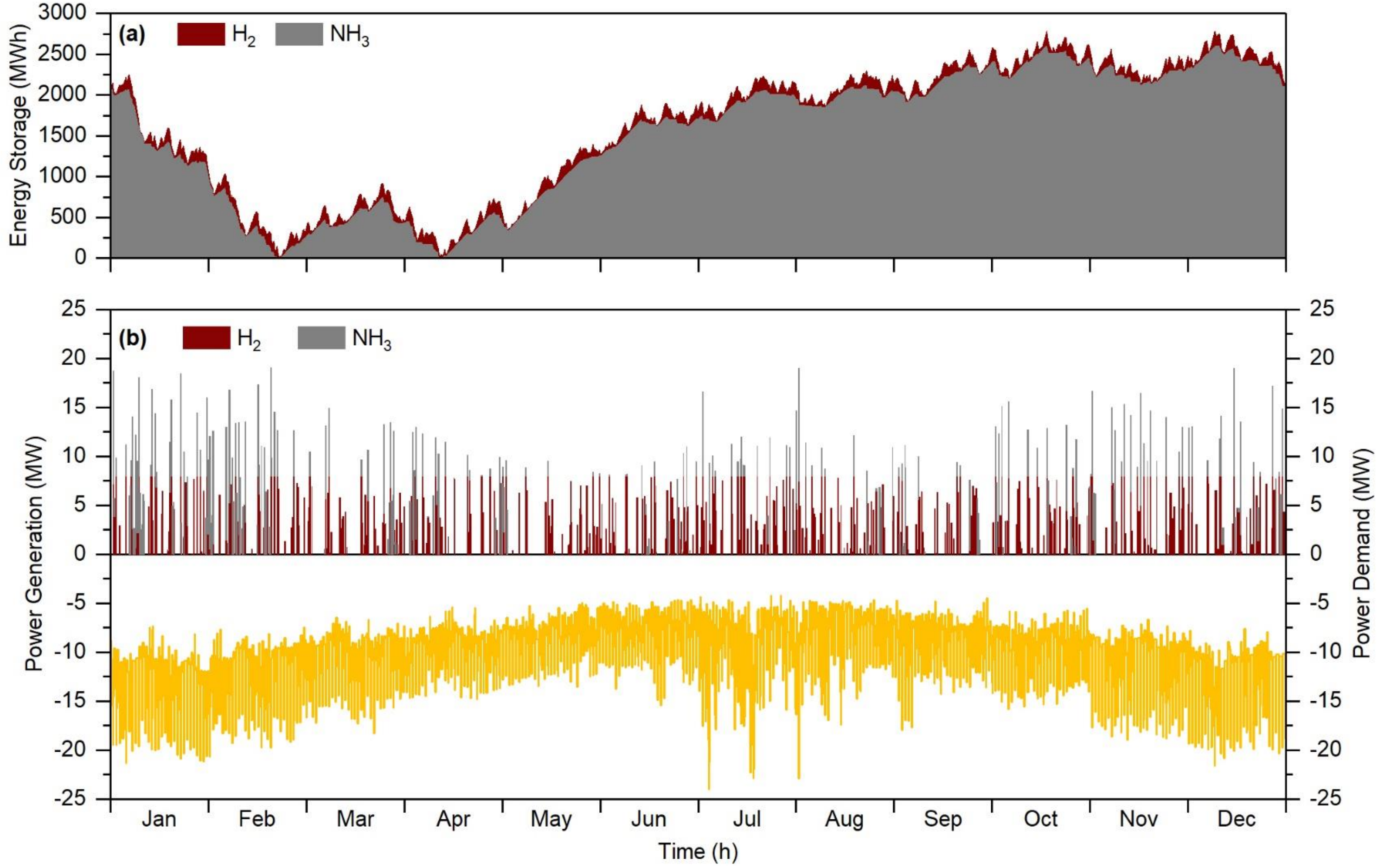
- Renewable generation infrastructure costs dominate: 55-75%
- Ammonia production costs not significant: 11-16$/MWh

Why do we need ammonia?

Hydrogen and Ammonia Renewable Energy Storage Systems

Palys & Daoutidis. (2020). *Comput. Chem. Eng., 136*, 106875.

Optimal Schedules: Minneapolis, MN

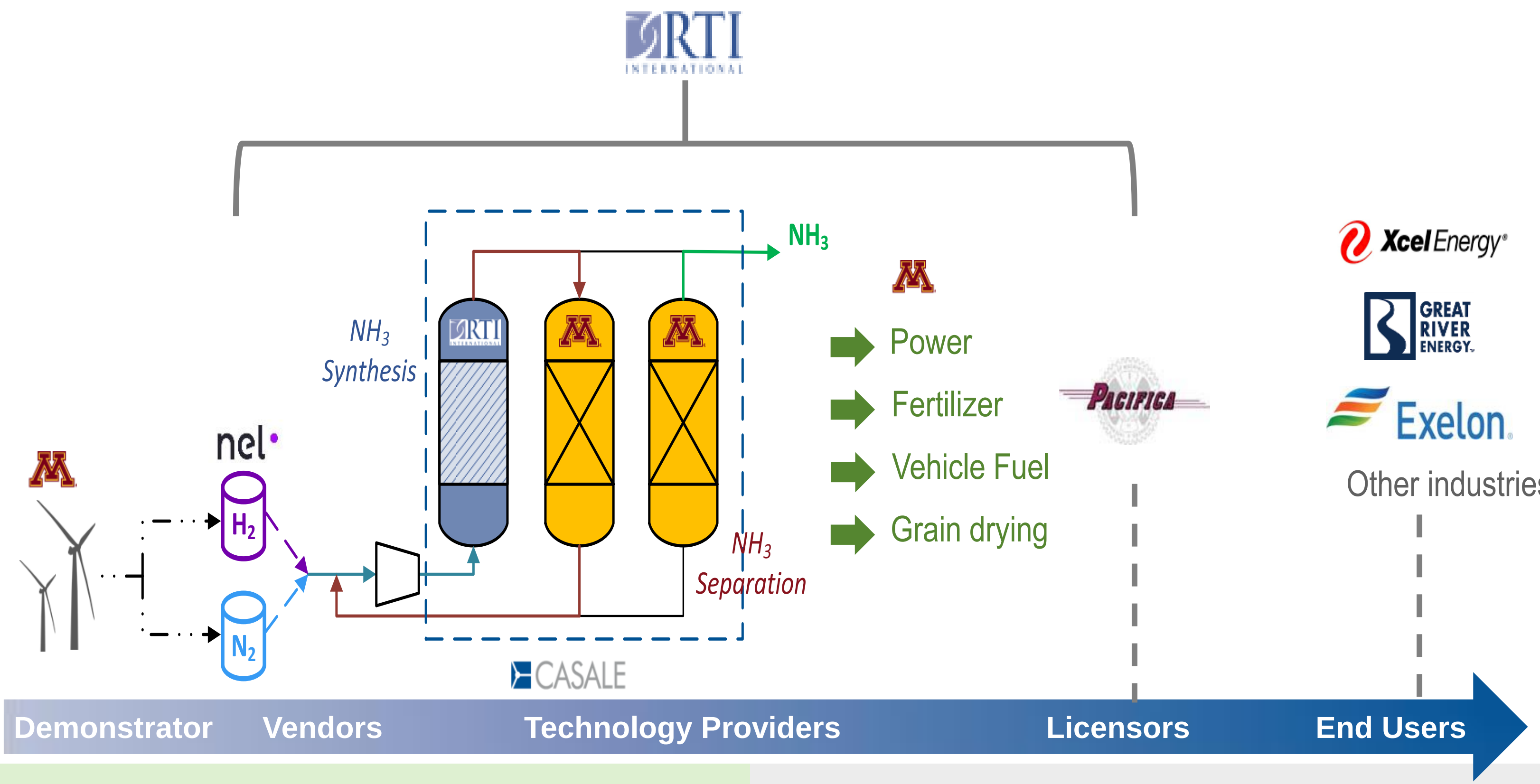


Hydrogen : fast / ammonia : slow (seasonal) → efficiency vs. storage cost

Request Matching Funds for a 1000 kg / d Ammonia Production Pilot Plant

- Federal funding is anticipated to construct an integrated ammonia technology production plant which uses electricity to power production.
- The production plant will be a globally-unique asset which will showcase leading edge ammonia production and energy storage technologies – technologies that will be important for Xcel Energy and other utilities across the State.
- Due to our past leadership, the University of Minnesota is considered a top candidate although there is significant competition.
- The total project is anticipated to cost $18.4 million with over $10 million provided by the US Dept of Energy ARPA-E REFUEL Program.
- Up to 50% matching funds are required. If successful, we anticipate the University of Minnesota’s share will be up to $5.2 million.
- A contribution from the Xcel RDA fund will provide a huge boost in attracting this important energy storage project to the State!

Proposed 1 MT/day Ammonia Technology Integration



Renewables-based Market

- Midwestern market ideally located with access to renewables
- Well-developed market for fertilizers; potential for storage

Integration with existing NH_3 plants

- Drop-in opportunity for greenfield plant designs
- Debottleneck existing plants

Modular Process Design	Low temperature ammonia synthesis	Low-cost separation to minimize refrigeration	Integration with state-of-the-art feed supply	Operational flexibility for load following

Acknowledgements

ARPA-E Refuel Program

- Grant USDOE / DE-AR0000804

Legislative-Citizen Commission on Minnesota Resources

- Environmental and Natural Resources Trust Fund