



S.F. 2017

“Green Ammonia-Fueled Power Production”

Michael Reese, Director of Operations, and
Renewable Hydrogen and Ammonia Research Lead
UMN West Central Research & Outreach Center (WCROC)

CFANS
Center for Food and Agriculture
Systems

West Central Research & Outreach Center
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World Leader in Green Ammonia Research



Green Hydrogen and Ammonia Production and Utilization – First in-the-world pilot plant

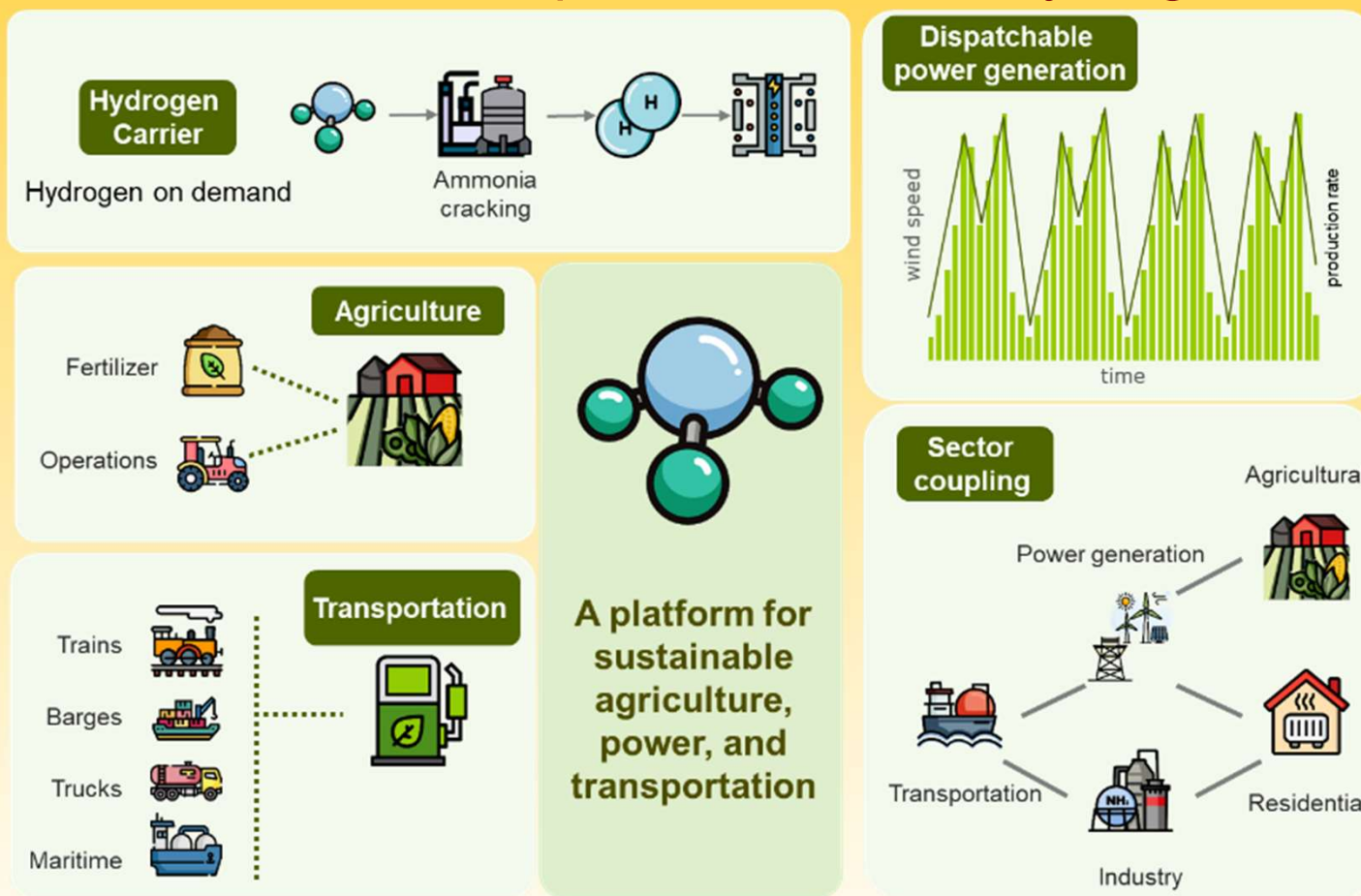


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Ammonia: Transformative impact – enables a hydrogen economy



US DOE ARPA-E REFUEL – Next Generation Ammonia Production Using Wind and Solar Power – Construction in 2025



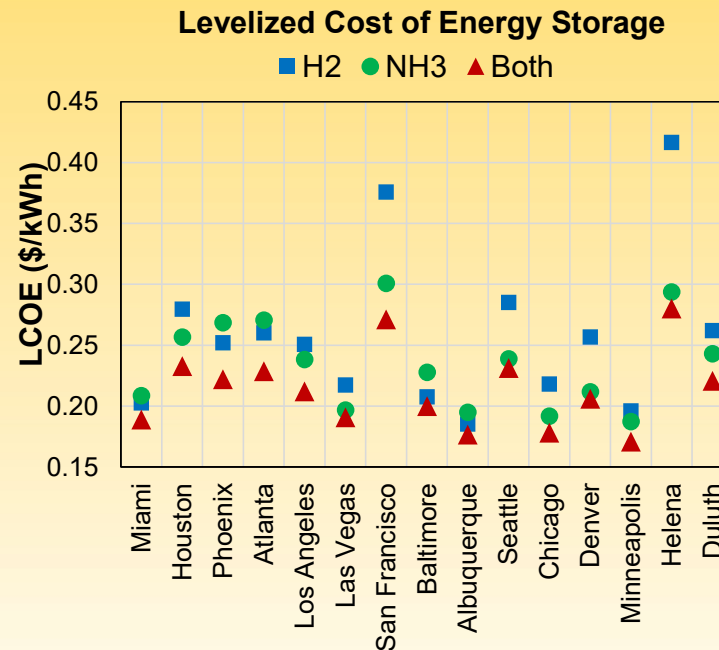
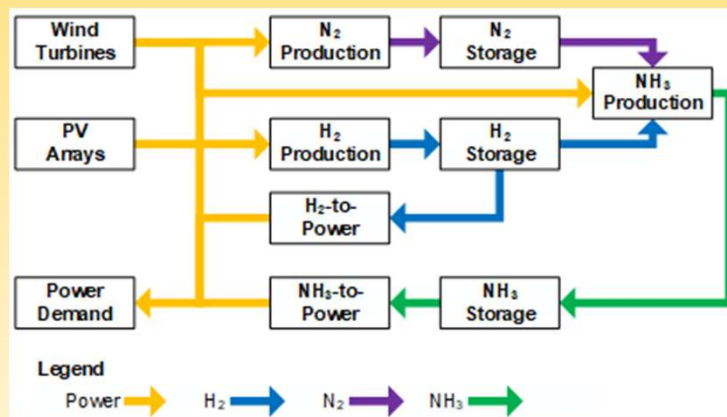
~18x scale-up of existing wind-to-NH₃ pilot plant

Hydrogen and Ammonia Renewable Energy Storage Systems

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

Economics of hydrogen and ammonia energy storage

- Islanded renewable energy systems with 1000 kW annual average demand
- Combined optimal sizing and scheduling to minimize LCOE



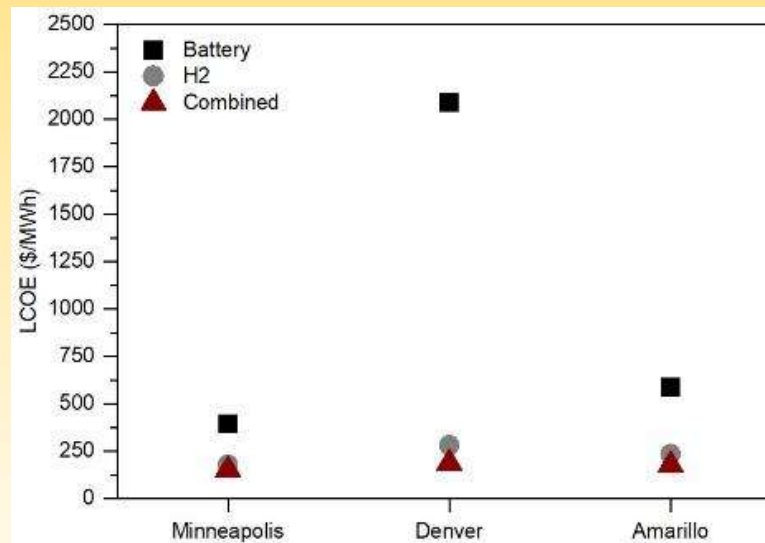
Combining ammonia and hydrogen gives lowest cost in all locations

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 is better short-term storage but, ammonia is better long-term storage as it is significantly less costly to store



Large-scale ammonia storage is already in place:



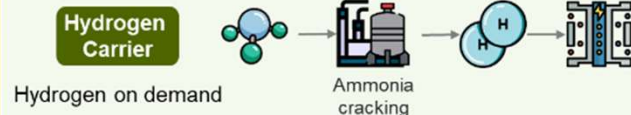
CF Industries Glenwood Ammonia Terminal

- 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

Green Ammonia Research: University of Minnesota is a world leader



West Central Research and Outreach Center at Morris (CFANS) First-in-the-world green ammonia pilot plant (2013). Developing next-gen plant in 2025. Test-bed for ammonia-fueled tractor, grain dryer, and generators. **Michael Reese, Eric Buchanan, Dr. Joel Tallaksen, and Cory Marquart.**

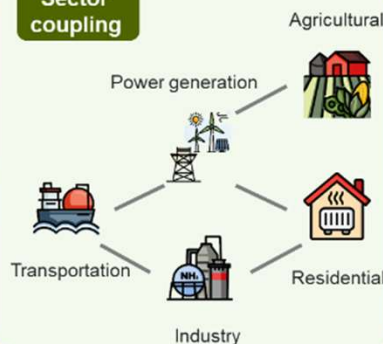


A platform for sustainable agriculture, power, and transportation

Dispatchable power generation



Sector coupling



Department of Chemical Engineering and Material Science (CSE) Award-winning publication (co-authored by Ph.D. student) *"Using hydrogen and ammonia for renewable energy storage: A geographically comprehensive techno-economic study."* **Dr. Matt Palys and Professor Prodromos Daoutidis**



Absorbent-enhanced ammonia production and ultra safe storage, **Professor Alon McCormick**. Non-wire solutions using green ammonia, **Professor Qi Zhang**. Novel catalysis for ammonia production and cracking, **Distinguished McKnight Professor Paul Dauenhauer**.



Department of Mechanical Engineering (CSE) Ammonia-fueled tractor (2019), ammonia-fueled grain dryer (2022), ammonia-fueled engine generator (2025). **Professor Will Northrop and Dr. Seamus Kane**

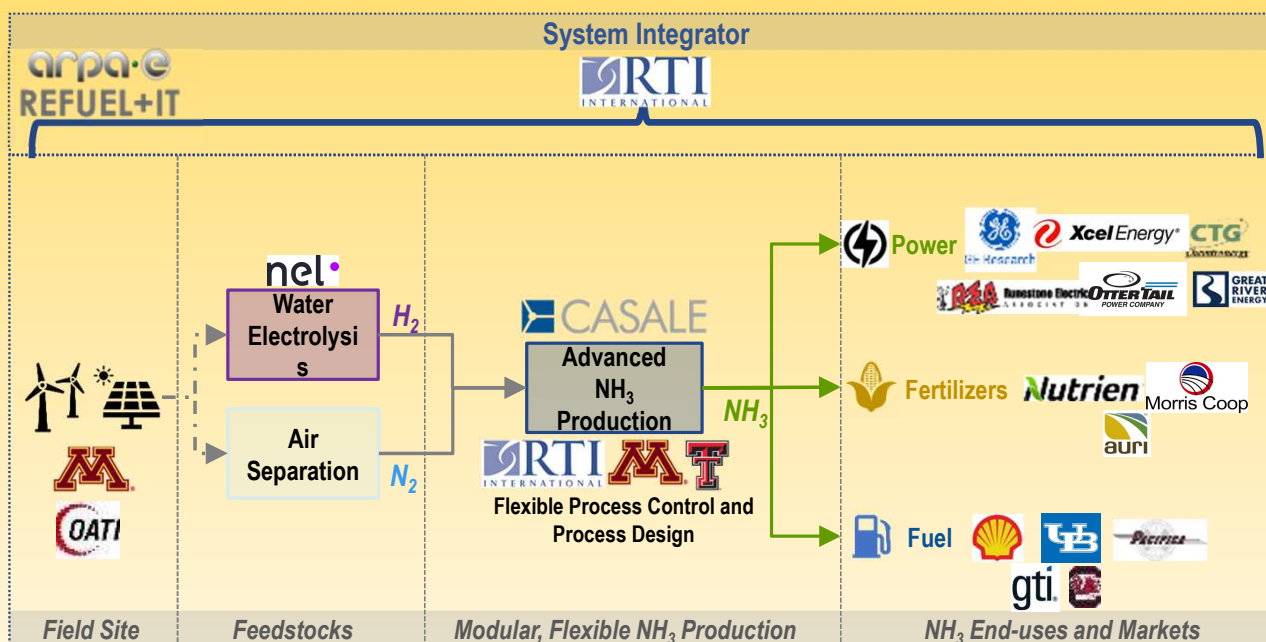


Humphrey School of Public Affairs Green ammonia policy, education, and acceptance. **Professor Elise Harrington**



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Next Generation Ammonia Production from Wind and Solar



Next-gen NH₃ production and utilization technologies

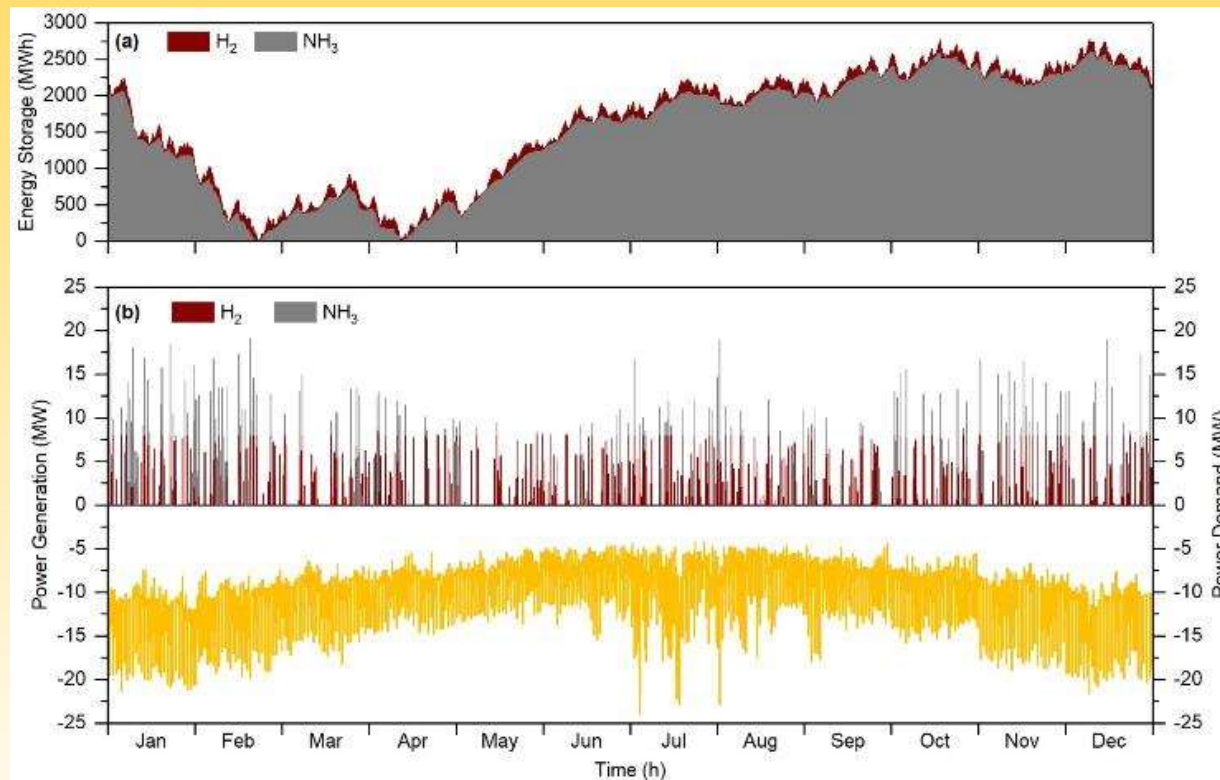
Demonstrate under real-world conditions

Connect with end-users and markets to accelerate commercialization

Hydrogen and Ammonia Renewable Energy Storage Systems

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Optimal Schedules: Minneapolis, MN



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



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