West Central Research & Outreach Center
Renewable Energy Program

Renewable Hydrogen

Hydrogen in the most abundant element in the world. Since 1890 when Danish scientist Poul La Cour produced hydrogen with wind energy, the use of hydrogen for transportation fuel and electrical generation has intrigued scientists, policy makers, and industry. Hydrogen is difficult to store and transport but can be a clean fuel. Hydrogen may be the future energy carrier of choice, but an intermediate step is needed. Hydrogen is currently used to produce nitrogen fertilizer. Hydrogen and nitrogen gas can be produced using wind energy, water, and air. When combined, the elements form anhydrous ammonia which is a vital nutrient for crops grown in the Midwest.

Wind to Hydrogen to Ammonia Pilot Plant

In March of 2005, a utility scale wind turbine was constructed at the WCROC. Through this process, several barriers became evident that limited the development of wind energy in the Midwest. The two main barriers were the inherent intermittency of wind energy and the lack of transmission grid capacity necessary to move the resource to load centers. To address these barriers, in 2005 the WCROC sought and received an $800,000 grant from the Legislative Citizens Commission on Minnesota Resources (LCCMR) to demonstrate the process in which wind energy is used to electrolyze water to create hydrogen thereby "storing" wind energy. The hydrogen is then used in an internal combustion generator set to provide peak or base load power. Staff at the WCROC also began exploring alternatives to create value-added products from wind energy and hydrogen. Because of its utilization as a primary agricultural nitrogen fertilizer product in the Midwest, anhydrous ammonia (NH_3) came to the top as a viable candidate for further study. *An elegant model was envisioned in which farmers could utilize wind energy that blows across their land to create a value-added nitrogen fertilizer source which can then be applied back to fields to nourish their crops.* The wind-to-hydrogen-to-anhydrous ammonia pilot plant provides a flexible model capable of energy storage through the production and utilization of hydrogen for transportation fuel and electrical generation. In addition, anhydrous ammonia can be produced for fuel, electrical generation, and as nitrogen fertilizer.

This facility is important to the University of Minnesota because it:

- Provides a globally unique research facility to address the critical barriers in storing and adding value to wind energy and other renewable electrical energy systems
- Assists in addressing key issues within agriculture, energy, rural economies, and the environment
- Helps reduce agriculture's reliance on fossil fuels and can dramatically lower the carbon footprint
- Creates a format for public and private collaborations in several emerging sectors
- Addresses an opportunity for impoverished countries to produce their own source of nitrogen fertilizer, of which next to water, is the most critical nutrient for plant growth and food production

University of Minnesota
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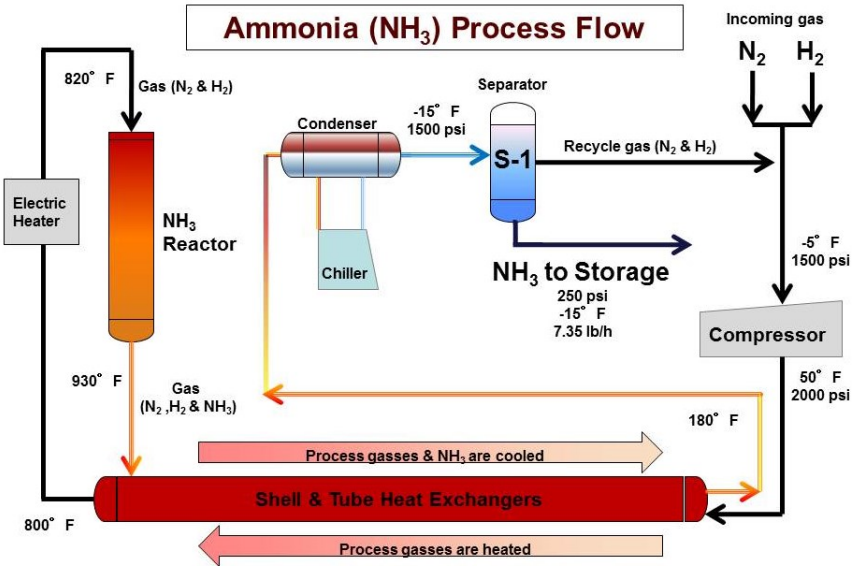
Renewable Hydrogen and Ammonia Production Pilot Plant

Quick Facts:

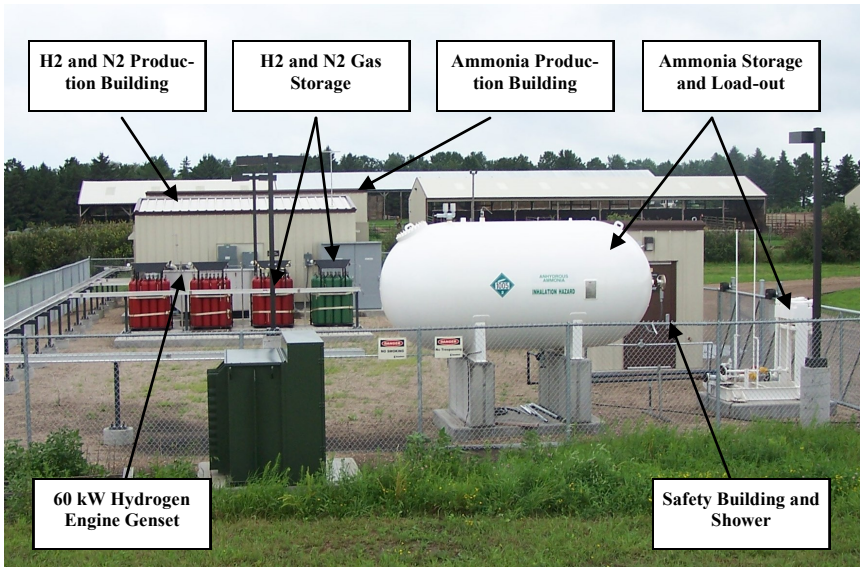
- Utilizes energy from the 1.65 MW Vestas wind turbine
- 10% of total wind energy generation for anhydrous ammonia (NH_3) production
- 25 tons /yr NH_3 production capacity
- Electrolysis of water generates hydrogen gas (H_2)
- Nitrogen generator separates nitrogen gas (N_2) from ambient air
- H_2 and N_2 gases are combined in a reactor and passed through a catalyst bed
- Haber Bosch Process
- The NH_3 yield ranges from 10 to 20 %
- Remaining gases are re-circulated
- NH_3 will be condensed and moved to storage vessels
- Approximately 7 kilowatt hours of electricity is used to produce 1 lb of NH_3
- Electricity can be generated with H_2 gas using a 60 kilowatt engine generator
- Project Cost = $3.75 million (not including the wind turbine)



- Construction Cost = $2.95 million (equipment and installation)
- Capital funding from the State, Minnesota Environmental Trust Fund through the Legislative Citizens Commission on Minnesota Resources, and the College of Food, Agricultural, and Natural Resource Sciences (CFANS).
- Research funding from the University of Minnesota Initiative for Renewable Energy and the Environment (IREE), Minnesota Corn Research and Promotion Council, and the Swedish Energy Agency.

The research goals of the facility include:

- Establishment of baseline operating parameters and resulting efficiencies
- Development of alternative and more efficient production processes
- Utilization of the pilot facility as a means to scale-up the most promising lab-scale processes and technologies
- Economics of storing wind energy and the production of value-added products
- Scalability and portability of the system for utilization in underdeveloped countries
- Development of business models for local-ownership
- Life cycle analysis and environmental impact of renewable hydrogen and anhydrous ammonia versus the current method utilizing fossil fuels
- Development of a flexible renewable refinery providing on-demand electrical energy, transportation fuel, and value-added products
- Reduction of fossil fuel consumption in agricultural production systems



WCROC Renewable Hydrogen and Ammonia Pilot Plant

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