2005 Project Abstract
For the Period Ending June 30, 2010
I. PROJECT TITLE: Wind to Hydrogen Demonstration
Project Manager: Michael Reese
Affiliation: University of Minnesota West Central Research & Outreach Center
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FAX Number: (320) 589-4870
Web Page address: http://renewables.morris.umn.edu/
Funding Source: Environmental and Natural Resources Trust Fund
Legal Citation: ML 2005, First Special Session, Chp. 1, Art. 2, Sec. 11, Subd. 10(e) and ML 2009, Regular Session Chp. 143, Sec. 1, Subd. 16(3)
Appropriation Amount: $ 800,000

Overall Project Outcome and Results
The Wind to Hydrogen Demonstration project was funded by the Environment and Natural Resources Trust Fund in July 2005 with the goal of demonstrating the use of wind energy to store hydrogen for use as base load or peak power.

After a lengthy development process, in March 2010 the University granted final approvals necessary to proceed with construction of the facility. An electrolyzer capable of producing 1.2 lbs of hydrogen per hour was purchased from Proton Energy Systems and a 60 kilowatt engine generator was purchased from the Hydrogen Engine Center. The electrolyzer uses electricity to separate hydrogen and oxygen from water. The engine generator produces electrical energy by combusting hydrogen gas. The systems were installed at the West Central Research and Outreach Center in June 2010. Following installation, Proton Energy Systems and Hydrogen Engine Center commissioned the equipment and trained University staff. All commissioning steps were completed. The electrolyzer produced 3.5 cubic feet or 2.6 lbs of hydrogen. The hydrogen engine generator was brought up to full power generation.

The goal of the project to use wind energy to store hydrogen for use as base load or peak power has been successfully demonstrated. The University will continue to operate the pilot facility to determine the feasibility of using hydrogen to store wind energy and to create value-added products such as nitrogen fertilizer. Successful demonstration of the system can address main barriers for wind energy. Storage processes such as the production of hydrogen may be an opportunity to overcome the 'intermittency' barrier. The second barrier is the lack of transmission capacity. The production of hydrogen can impact this barrier by using excess wind energy to produce hydrogen and other value added components thereby diminishing the need for additional transmission to move power to load centers. Energy intense industries may then be created in rural areas with high wind resources. The benefits are three-fold: the grid is better managed, the environment benefits from increased use of renewable energy, and the state economy is enhanced. Wind to Hydrogen Demonstration - Abstract Page 2

Project Results Use and Dissemination:
The intent is for the results to lead to commercial wind to hydrogen production facilities. Initial funding for the Wind to Hydrogen Demonstration was provided by the Environment and Natural Resources Trust Fund. Additional funding from the State and the University for a second phase will be used to demonstrate using hydrogen to produce nitrogen fertilizer. It is anticipated that the combination of hydrogen storage for electrical energy generation and use for nitrogen fertilizer production could be a viable economic model in the near future. The information has been disseminated to a wide group of stakeholders and students through presentations, print materials, media articles, tours, and the web including seven national presentations, twenty-two regional presentations, and over fifty local presentations. Since its installation in June 2010, over 1,000 people have toured the facility. There have been several news articles primarily in agriculture magazines. The project has also been mentioned in hydrogen-related stories in the New York Times and the Washington Post. As a University of Minnesota

Research and Outreach Center – inherent in the name and mission – information regarding the project will continue to be disseminated to a broad audience in multiple formats.

TRUST FUND LCCMR 2005 FINAL REPORT

Date of Report: August 16, 2010
Final Report
Date of Work Program Approval: June 24, 2005
Project Completion Date: June 30, 2010

I. PROJECT TITLE: Wind to Hydrogen Demonstration

Project Manager: Michael Reese
Affiliation: University of Minnesota West Central Research & Outreach Center
Mailing Address: 46352 State Hwy 329
City / State / Zip : Morris, MN 56267
Telephone Number: (320) 589-1711
E-mail Address: reesem@morris.umn.edu
FAX Number: (320) 589-4870
Web Page address: http://renewables.morris.umn.edu/

Location: The work will be conducted in Stevens County and impacts the entire state.

Total Biennial LCCMR Project Budget:	**LCCMR Appropriation:**	**$** 800,000
	Minus Amount Spent:	**$** 800,000
	Equal Balance:	**$** 0

Legal Citation: ML 2005, First Special Session, Chp. 1, Art. 2, Sec. 11, Subd. 10(e) and ML 2009, Regular Session Chp. 143, Sec. 1, Subd. 16(3)

Appropriation Language:

$400,000 the first year and $400,000 the second year are from the trust fund to the commissioner of natural resources for an agreement (with) the University of Minnesota, West Central Research and Outreach to develop a model, community-scale wind to hydrogen facility.

The availability of the appropriations for the following projects is extended to June 30, 2010:
(3) Laws 2005, First Special Session chapter 1, article 2, section 11, subdivision 10, paragraph (e), wind to hydrogen demonstration, as extended by Laws 2007, chapter 30, section 2, subdivision 16;

II. and III. FINAL PROJECT SUMMARY

The Wind to Hydrogen Demonstration project was funded by the Environmental Trust Fund in July 2005. A lengthy development process ensued. In March 2010, the University granted final approvals necessary to proceed with construction of a the facility.

An electrolyzer capable of producing 1.2 lbs of hydrogen per hour was purchased from Proton Energy Systems and a 60 kilowatt engine genset was purchased from the Hydrogen Engine Center. The electrolyzer used electricity to separate hydrogen and oxygen from water. The engine genset produced electrical energy by combusting hydrogen gas.

The systems were installed at the West Central Research and Outreach Center in June 2010. Following installation, Proton Energy Systems and Hydrogen Engine Center commissioned the equipment and trained University staff. All commissioning steps were completed. The electrolyzer produced 3.5 cubic feet or 2.6 lbs of hydrogen. The hydrogen engine genset was brought up to full power generation.

The goal of the project to use wind energy to store hydrogen for use as base load or peak power has been successfully demonstrated. The University will continue to operate the pilot facility to determine the feasibility of using hydrogen to store wind energy and to create value-added products such as nitrogen fertilizer. The successful demonstration of the system addressed barriers for wind energy development. Storage processes such as the production of hydrogen was an opportunity to overcome the 'intermittency' barrier. The second barrier was the lack of transmission capacity. The production of hydrogen impacted this barrier by using excess wind energy to produce hydrogen and other value added components. The resulting implication is the diminishing need for additional transmission to move power to load centers. Results indicated energy intense industries may be created in rural areas with high wind resources. The future benefits are three-fold: the grid is better managed, the environment is protected with decreasing use of fossil fuels, and the state economy is enhanced.

IV. OUTLINE OF PROJECT RESULTS*:*

Result 1: Wind to Hydrogen Demonstration**–** Phase 1 **Budget: $** 800,000

Description:

A wind to hydrogen system design will be completed and approved by the University of Minnesota. Equipment specified in the design will be purchased and installed. System operation will be monitored and outreach activities will occur throughout the project duration with funds outside of this budget.

Development *:* $ **92,945** as amended September 2006

Design. These funds will be used to ensure that this system is safe, expandable, and suitable for research and demonstration. The National Renewable Energy Lab,

the premier renewable energy research lab in the nation, will assist in this effort and may require a portion of these funds. The remainder will be for a private design team.

Equipment: $ 707,055 as amended September 2006

Generation System (Electrolyzer, Storage Tanks, Reciprocating Engine Generator, and Interconnection Equipment)

The equipment purchased by this appropriation will be used beyond the 2 year scope of this project. The equipment will be used for the same purpose of wind to hydrogen demonstration and research in phases 2 and 3 of this project. If the equipment is used for a different purpose, the Environmental & Natural Resource Trust Fund will be payed back an amount approved by the director of the LCCMR.

Summary Budget Information for Result 1:	**LCCMR Budget**	**$ 800,000**
	Amount Spent:	
	Professional/ technical	92,945
	Equipment / installation	707,055
	Balance	**$ 0**

Completion Date: The equipment was delivered and installed by June 30, 2010. Testing, outreach, and dissemination will be on-going.

Final Report Summary

Following a long duration of planning and approval processes, in March 2010 the University of Minnesota granted final approvals necessary to proceed with constructing the wind to hydrogen pilot facility. Final designs were completed and approved, bids received, and Hazardous Operations (HazOp) reviews completed.

A 10 kilowatt electrolyzer system capable of producing approximately 1.2 lbs of hydrogen per hour was ordered from Proton Energy Systems (Connecticut) and a 60 kilowatt hydrogen engine genset was ordered from the Hydrogen Engine Center (Iowa). The hydrogen electrolyzer system ordered from Proton required ancillary equipment including a water deionization unit (necessary for clean water entering the hydrogen electrolyzer), a hydrogen compressor (necessary to bring the hydrogen product to appropriate pressure for storage), a chiller (necessary to cool the electrolyzer and compressor), and a modular building with required piping, controls, alarms, safety, and HVAC systems to house the sensitive equipment. Hydrogen storage vessels were also ordered from Proton Energy. Additional items were ordered for electrical interconnection including a transformer and switchgear. The transformer 'transforms' the power from the wind turbine from 12.5 kilovolt down to 480 volt and the switchgear allows for the hydrogen engine generator set to ramp up to full power prior to being "switched" on to the electrical grid.

Beginning in May, the hydrogen electrolyzer system and ancillary equipment were installed into the modular building off-site at Trachte Building Systems near Madison, Wisconsin. Prior to the hydrogen system arrival and in early June, civil work began on site, concrete pads were poured, and utilities including electrical, water,

communication / data lines were installed. The hydrogen storage tanks arrived on site and piping was installed the week of June 21st. On June 29th, the modular building with the hydrogen electrolyzer system was delivered to the University of Minnesota West Central Research and Outreach Center at Morris and installed on site. On June 30th, the hydrogen engine genset was delivered and installed. June 30th marked the final completion of LCCMR funded activities.

All funds provided by LCCMR were spent on design and equipment prior to June 30, 2010. With the use of other funds provided by the University and the State of Minnesota, security fencing was installed around the pilot facility the week of July 6th. The site and installations were inspected by the University of Minnesota Codes Department. Once inspection approvals were granted, Proton Energy Systems and Hydrogen Engine Center staff commissioned the equipment the week of August 9th. Commissioning also included training of four University staff in the operation of the systems. Even though not funded by the LCCMR, commissioning activities are an important aspect of the results.

The commissioning steps included:

1. Start the production of deionized water
2. Use nitrogen gas to purge the hydrogen electrolyzer, piping, and storage tanks of air
3. Start the chiller to cool the electrolyzer and the hydrogen compressor
4. Start the hydrogen electrolyzer
5. Start the hydrogen compressor and open lines to fill storage
6. Check safety systems including hydrogen sensors and emergency shutdown systems
7. Training of staff for operation, startup, shutdown, and maintenance procedures
8. Start, operate, and shutdown the hydrogen engine genset

All commissioning steps were completed. During commissioning the electrolyzer produced 3.5 cubic feet or 2.6 lbs of hydrogen. The hydrogen was then stored for later use. The hydrogen engine genset was brought up to full power generation. Although approved, the Interconnection Agreement with the local utility has yet to be formally signed so a local load was used to absorb the electrical energy generated from the hydrogen engine. The Interconnection Agreement is expected to be fully executed by the end of August. Once completed, hydrogen engine genset will be ran again with the power going first to the UMM campus and then to Ottertail Power Company's distribution grid. The hydrogen electrolyzer and engine genset were operated multiple times and durations throughout the week.

A second phase of the project (not a LCCMR deliverable or funded activity) is to produce anhydrous ammonia from hydrogen. The anhydrous ammonia production skid will arrive in October and installation and commissioning will occur through November. The entire facility will be fully operational in December.

The goal of the project to use wind energy to store hydrogen for use as base load or peak power has been successfully demonstrated. Even though the deliverable for the LCCMR funding has been completed, the University will continue to operate the pilot facility to determine the feasibility of using hydrogen to store wind energy and to create value-added products. There are two main barriers for the increased deployment and utilization of wind energy in the state. The first is the intermittent nature of wind energy and the inherent need for backup and base load power. Storage processes such as the production of hydrogen may be an opportunity to overcome the 'intermittency' barrier. The second main barrier is the lack of transmission capacity. The production of hydrogen can impact this barrier by using excess wind energy to produce hydrogen and other value added components thereby diminishing the need for additional transmission to move power to load centers. Energy intense industries are then essentially created in rural areas with high wind resources. The benefits are two-fold: the grid is better managed and rural economies are enhanced.

The delivery of the Wind to Hydrogen Demonstration project proved to be very complex and took much longer than originally anticipated. A summary and timeline of the development process is below:

Cecil Massie, a professional chemical engineer with Sebasta Blomberg completed the wind to hydrogen system predesign in September 2005 (Funded by the U of MN). Prior to the predesign completion in July 2005, representatives of the West Central Research and Outreach Center (WCROC), Xcel Energy, Electric Power Research Institute (EPRI), and the National Renewable Energy Lab (NREL) met at the NREL facility in Golden, Colorado to discuss wind to hydrogen demonstration efforts. The WCROC wind to hydrogen project, predesign draft, and economic models were discussed and evaluated. The group determined that it would be in our best interests to jointly develop safety guidelines and to provide design input and assistance for wind to hydrogen demonstrations.

In 2006, initial design and equipment order documents were developed. A contract was signed with Sebesta Blomberg in January 2006 to perform the final design of Phase One of the Wind to Hydrogen System. The contract amount was $92, 945. The increased budget for design was due in part to University requirements which caused an increase in the amount of services and time required by the contracted engineering firm. Additional contracted time was also required to participate in safety and design meetings with the National Renewable Energy Lab.

Four meetings (two in Minnesota and two conference calls) were held with the potential electrolyzer supplier, Norsk Hydro Electrolysers. Dag Ovebro, Chief Engineer at Norsk Hydro, delivered a wind to hydrogen presentation to over 200 people at the University of Minnesota Homegrown Energy Conference in Morris on February 28th. Norsk Hydro Electrolysers is based in Oslo, Norway and has over 75 years of experience in manufacture and supply of electrolyzers and production of hydrogen.

Following the Norsk Hydro meetings, Sebesta Blomberg engineers prepared specification for the electrolysis systems and a request for quotes was issued to Norsk Hydro Electrolyser for the purchase of a 200 kW 40 Nm3 electrolyzer with the add alternative cost to expand to a 400 kW 80 Nm3 electrolyzer.

Quotes were received from Norsk Hydro and were reviewed. As a result of the review there was further dialogue with the potential supplier and the quotes and specs were modified accordingly.

In May 2006 a design sharing meeting was held in Golden, Colorado with the National Renewable Energy Lab and Xcel Energy in order to share information and individual approaches in design. Xcel and NREL are collaborating on a small scale system. On May 24th a Hazard Operation Review meeting was held at the Nation Renewable Energy Lab. Every potential hazard was evaluated for the Xcel / NREL system along with safety design features for each potential hazard. A Sebesta Blomberg engineer and Mike Reese participated in this meeting to learn the process and to apply it to the University of Minnesota Wind to Hydrogen Demonstration.

Several design and equipment purchasing meetings were held from May through Septebmer 2006 including a visit with the potential supplier of the hydrogen genset system (Hydrogen Engine Center, Algona, Iowa). Specifications have been developed and a quote has been received from this potential supplier. The quote from HEC for a 60 kW hydrogen genset was $63,200 not including delivery and installation.

The MN legislature as part of the 2006 Bonding Bill approved funding for phase two of the Wind to Hydrogen System. The second phase is the production of value added products more specifically anhydrous ammonia. This has broadened the engineering and equipment scope without changing Phase One results and deliverables. It was necessary to consider both projects in the design in order to make a smooth transition between the two phases. All costs associated with Phase Two were charged to non-LCCMR funds. The addition of Phase Two caused a delay in the completion of Phase One but both phases ultimately benefited.

In order to complete the combined projects, in 2007 the University requested a two-year extension of the funding for the University of Minnesota West Central Research and Outreach Center's Wind to Hydrogen Project. The reason for the extension was to finish design on Phase 2 of the project which was the production of anhydrous ammonia. Construction for both phases was intended to occur simultaneously. The project was delayed further by holds placed on by the University and MN Department of Finance. Even though funding had been provided for Phase 2 through the 2006 bonding bill, the MN Department of Finance decided not release funds until the project was determined as bondable according to the state constitution. In March 2007, the Department of Finance agreed with the University that the project was bondable and the combined project was allowed to proceed.

During the delay a collaboration with Norsk Hydro was developed to provide technical assistance to the project. Norsk Hydro is a Norwegian company that has

over 80 years of experience in electrolysis, hydrogen, and ammonia production. There were several conference call meetings to discuss the design and a face to face meeting was held on January 31 through February 1st, 2007.

In March 2007, the University hired Knutson Construction Services as the general contractor. A schematic design meeting was held March 1st with several project partners within and outside the University. Norsk Hydro and Yara representatives from Norway traveled to Minnesota and provided valuable feedback on system design. In August 2007, the engineering team traveled to Norway (non-LCCMR funds) to visit with key equipment suppliers and to develop critical information for final design. Throughout Fall 2007, the engineering team developed equipment and design specifications.

In October 2007, two University representatives traveled to Allentown, PA to participate in a two-day hydrogen safety course (non-LCCMR funds) with Airproducts, Inc. Airproducts is an industry leader in hydrogen production and safety training. In addition to this training, University building code and environmental health and safety officials reviewed the system design and recommendations were incorporated into the design.

In 2008, design and development continued on the University of Minnesota Wind to Hydrogen Demonstration. The project scope and design was modified in Spring 2008 to accommodate the budget and a determination was made to bid the project as Design Build. Again, the project was put on hold and a determination was requested from the MN Department of Finance if the changes were still bondable. Following approval in August 2008, the University issued a Request for Proposals for a Design Build contract. In September, the University received and reviewed the Design Build proposals. In the Fall of 2008, a Letter of Intent was signed with a Minnesota company. In addition to the design-build contract, the University began negotiating a royalty agreement with design build firm for ammonia production. The funding for the ammonia production research facility is being provided by the State through capital finance bonds and University funds. According to the royalty agreement draft, the design build firm was to pay the University a commercialization fee for each commercial ammonia production facility constructed and the University would share the funds with the LCCMR at a pro-rated level.

In December 2009, the Wind to Hydrogen project experienced several complexities that slowed the development schedule. November through January 2010 brought considerable progress as well as some disappointments. On November 30th, 2009 the project team met with LCCMR Staff to update the project and to discuss an opportunity to partner with a Minnesota design build firm. A design build and royalty contract had been under development for 1.5 years and was finally nearing final form. Later on November 30th, the project team met with University of Minnesota Vice President of Research, Dr. Tim Mulcahy, who affirmed the project was a research priority of the University. On December 2nd, the project team presented the project to upper leadership of the University for approval. During this time frame, it was learned that the Minnesota design build firm was considering pulling out from the project citing economic and business concerns for the company as a whole.

Consequently, upper leadership requested the project team develop a new strategy for project delivery. The change in project delivery removed several of the intellectual property issues the University was balancing. Consequently, the project team renewed design services with Sebesta Blomberg and Associates and the original general contractor (Knutson Construction Services) to acquire updated pricing and scheduling from vendors and subcontractors. On January 19, the project team presented the results to upper leadership at the University. Results of the pricing and scheduling exercise have met target budget and completion dates. The project team was allowed to move forward into final design, equipment procurement upon approval at the University Regents meeting on February 11, 2010.
The original engineering firm, Sebesta Blomberg, completed design documents and worked with Knutsen Contruction Services on the pricing and scheduling. The design included a 10 kilowatt Proton Energy electrolyzer with all of the supporting equipment housed in a modular building. Hydrogen storage tanks were to be placed outside at the proper distance from the building. A Hydrogen Engine Center 60 kilowatt engine generator was to be placed outside of the building as well. In addition to these items, a portion of the project not funded by LCCMR was designed and priced including the anhydrous ammonia reactor skid, nitrogen separator, compressors, a second modular building to house the equipment, and nitrogen and ammonia storage. The final design also included necessary grid interconnection and other utility supply (water and communication). Vendors supplying the hydrogen skid including the electrolyzer and the hydrogen engine genset pledged a delivery prior to June 30, 2010 (as required by LCCMR). Again, the project delivery dates were met and the system has been successfully demonstrated.

Due in part to the extended period required to deliver this project, outreach efforts have been extensive. In 2005, the Wind to Hydrogen Demonstration project was presented at a wide variety of meetings including the 2005 MN Power Systems Conference in St. Paul, the 2005 Hydrogen Summit in Grand Forks, North Dakota, the 2005 University of Minnesota Renewable Energy Workshop, 2005 IREE Symposium, and many CERTS and smaller meetings. Newspaper and magazine articles were published detailing the project. In 2006 and 2007, presentations were made by WCROC staff across the state to audiences ranging from 10 – 300 people. Radio, television, and print media also were used to promote and describe the project. The project was also presented at the 2006 Hydrogen Economy Conference in Portland, Oregon, the 2006 Renewable Ammonia Conference in Denver, the 2007 National Hydrogen Association Conference in San Antonio, MN DEEDS Conference, Wautawan County Corn and Soybean Growers Meeting, Manitoba Renewable Energy Tour, CURE Renewable Energy Tour, the Annual CERTS Conference, Stevens County Soil and Water Conservation Board, Stevens County Economic Development Improvement Commission, Renville Renewable Energy Conference, Minnesota Corn Growers, 2007 Minnesota Soil and Water Conservation Society Annual Meeting, 2007 Ammonia as a Fuel Conference (San Francisco), 2007 Advanced Wind Workshop II (Morris), 2007 E3 Conference (Minneapolis), and the South Dakota Corn Utilization Council. Also, posters detailing the project were presented at the Energy Transition 2050 Conference (September 2006 in Madison, WI) and the Initiative for Renewable Energy and the Environment Annual Conference (November 2006 in Minneapolis). The Wind to

Hydrogen project was featured in several news paper articles and in the Corn and Soybean Digest magazine.

In 2008 several presentations on wind to hydrogen were made on a regional and national level including the following:

- U of MN Alumni Association -Invited speaker – Willmar, MN (Oct 2008)
- Ammonia as a Fuel Conference -Invited speaker – Minneapolis (Sep 2008)
- Kandiyohi County Economic Development -Invited speaker – Willmar, MN (Aug 2008)
- Kansas Community Wind Energy Workshop -Invited speaker – Kolby, KS (April 2008)
- Renewable Energy Guest Lecture Program -Invited speaker – Auburn Univ. (Jan 2008)
- SDSU Producer Winter Meetings -Invited speaker - Sioux Falls, SD (Jan2008)
- Manitoba Agriculture -Invited speaker – Winnipeg, MB (Jan 2008)
- Morden Renewable Energy Conference -Invited speaker – Morden, MB (Jan 2008)

In September 2008, the WCROC organized, sponsored, and co-hosted a national *Ammonia as a Fuel* Conference in Minneapolis. The Wind to Hydrogen project was highlighted as part of the conference. Over 140 people attended the conference with attendees coming from Australia, Denmark, Japan, Netherlands, and South Korea.

Again in 2009, several invited presentations on wind to hydrogen were made on a regional and national level. Most notable presentations include Manitoba Ag Days in Brandon, MB on January 21st and *Ammonia as a Fuel* Conference held October 12-13th in Kansas City. In addition, the West Central Research and Outreach Center hosted several tour groups from around the state, region, and world. The Wind to Hydrogen project was a favorite discussion topic for visitors.

Finally in 2010, outreach and education efforts continued with presentations to the Keystone Ag Producers in Winnipeg, Manitoba on January 27th, the University of Minnesota Department of Bioproducts and Biosystems Engineering, MinDakota Agriculture Builders, Northwest Technical College Electrical Program, and the Master Naturalist Conference. Following installation in June, tours have been provided to over 1,000 people including the MN State Cattlemen's Tour, West Central Initiative Foundation Board, WCROC Summer Station Day, AURI, and the West Central Minnesota Renewable Energy Road Tour. Individual tours have also been provided to gubernatorial and legislative candidates.

See Attachments for pictures of the Wind to Hydrogen facility.

Final Report Summary:

V. TOTAL LCCMR PROJECT BUDGET:

All Results: Personnel: $ 0
All Results: Equipment: $ 707,055
All Results: Development: $ 92,945
All Results: Acquisition: $ 0

All Results: Other: $ 0

TOTAL LCCMR PROJECT BUDGET: $ 800,000

TOTAL LCCMR PROJECT BALANCE: $ 0

Explanation of Capital Expenditures Greater Than $3,500:

All budget items are above expenditures greater than $3,500 including the purchase of the hydrogen generation package including the electrolyzer, compressor, modular building, and chiller ($485,449), Storage Tanks ($58,239), Reciprocating Engine Generator ($48,200), Electrical Interconnection Equipment, Controls, and Pads ($115,167), and System Design ($92,945). The amounts listed above may include a portion of the design, delivery, and installation costs. The University purchased the equipment as a package through the general contractor, Knutson Construction Services, rather than directly through individual suppliers. The University contributed $450,000 of which $20,000 was used for pre-design while the remaining funds were used for installation and civil work. This equipment and facility will continue to function as a wind to hydrogen demonstration and research system past the end of this LCCMR project and will be a key component of the University of Minnesota Renewable Energy Research and Demonstration Center.

TOTAL BUDGET: $ 800,000

VI. OTHER FUNDS & PARTNERS:

A. Project Partners:

University of Minnesota College of Food, Agricultural, and Natural Resource Sciences ($430,000), University of Minnesota, Morris ($ 0); University of Minnesota Initiative for Renewable Energy and the Environment ($ 20,000); Upper Midwest Hydrogen Initiative ($ 0), Windustry ($ 0), and the National Renewable Energy Laboratory ($0)

B. Other Funds being Spent during the Project Period:

Half of the net income from energy sales generated by the wind turbines is dedicated to the overall Renewable Energy Center. From these funds, an assistant scientist was hired and is responsible for the day-to-day operation of the system. Additional funds developed in the duration of this project will be reported.

The 2006 Minnesota State Legislature approved $2.5 million in bonding funds to develop an ammonia production facility utilizing a portion of the hydrogen generated from this facility. The University of Minnesota provided $450,000 and $800,000 from the LCCMR brings the total project to $3.75 million.

Other funds were sought from the US Department of Energy, Initiative for Renewable Energy and the Environment, MN Corn Research and Promotion Council, and the Xcel Renewable Development Fund. The MN Corn Research and Promotion Council provided $74,000 to study the feasibility of producing nitrogen fertilizer from wind energy (Phase two). Additional funds will continue to be sought.

C. Required Match (if applicable): NA

D. Past Spending:

Approximately $ 2,000,000 provided through the Initiative for Renewable Energy and the Environment and $150,000 from the LCCMR 2003 oil overcharge through the MN Department of Commerce was used to construct one 1.65 MW wind turbine and the necessary interconnection (Completed March 8, 2005). An additional $110,000 has been obtained for a Renewable Energy Center Coordinator and $190,000 for U of MN faculty and graduate student research. The Initiative for Renewable Energy and the Environment contributed an additional $20,000 for the wind to hydrogen predesign.

E. Time:

The project began in July 2005 and was extended through June 30, 2010. The project experience several delays in project delivery. The unique nature of this project made it difficult to deliver within a very process oriented University and State environment. However, the end result is a very refined Wind to Hydrogen Demonstration / Pilot Facility. Although not funded, University staff will continue to evaluate the operation and feasibility of the Wind to Hydrogen system well beyond the duration of this project scope.

VII. DISSEMINATION:

The WCROC Renewable Energy Director (Michael Reese) and other WCROC faculty and staff have disseminated the information through presentations (meetings, conferences, tours, and field days), written articles (news papers and magazines), the annual Renewable Energy Conference, and information has been placed on the WCROC renewable energy web site. All outreach activities have been reported in the updated work plans and in the final report.

VIII. REPORTING REQUIREMENTS:

Periodic work program progress reports were submitted in December 2005, July 2006, December 2006, July 2007, December 2007, July 2008, and December 2009. This final report and associated products will be submitted by COB August 16, 2010.

IX. RESEARCH PROJECTS: NA

X. Attachments – Pictures of Hydrogen Production Facility in Morris

Attachment A: Budget Detail for 2005 Projects -

Proposal Title: Wind to Hydrogen Demonstration (E-02) **Date: August 16, 2010**

Project Manager Name: Mike Reese

LCMR Requested Dollars: $ *800,000*

2005 LCMR Proposal Budget	Result 1 Budget:	Approved Budget Dec 05	Amended Budget Approved	Amount Spent JUN 10	Balance JUL 10
	Wind to Hydrogen Demonstration- Phase 1				
BUDGET ITEM					
Contracts					
Professional/technical	**System Design** (National Renewable Energy Lab and Private Design Team that will be contracted to appropriately configure the wind to hydrogen system for: 1. Safety. 2. Expandable. 3. Highly capable research and demonstration system.)	**71,000**	**92,945**	**92,945**	**0**
Equipment / Tools		**729,000**	**707,055**	**707,055**	**0**
	Electrolyzer Unit (Equipment necessary to split water to hydrogen.)	480,000		485,449	0
	Hydrogen Storage Tank(s) (Provides storage mechanism for wind energy and fuel for a genset.)	150,000		58,239	0
	Reciprocating Engine Generator (Engine genset modified to run on hydrogen and is used to produce on-demand electricity.)	65,000		48,200	0
	Compressor (Necessary to compress hydrogen in storage tank(s).)	4,000		0*	0
	Interconnection (Electrical devices including a bus bar, transformer, wire, and a control system necessary to connect and effectively manage the system.)	30,000		115,167	0
COLUMN TOTAL		**$800,000**		**$800,000**	**$0**

NOTES:

*****Cost of the compressor was included in the hydrogen production system.

1. Freight charges to Morris, MN are included in the equipment costs.

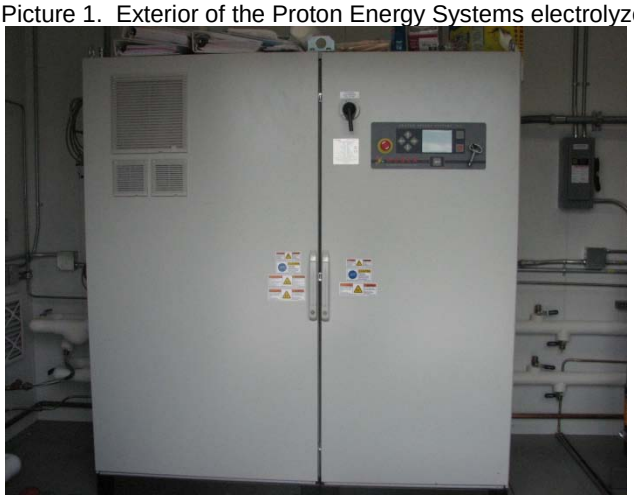
2. Additional funds were received for Phase 2 of the overall project which includes the production of nitrogen fertilizer from wind energy

3. Equipment will be used beyond the time frame of this proposal and will be used for wind to hydrogen demonstration.

4. The equipment was purchased by the University through the general contractor. The total amount of $707,055 was paid to Knutson Construction Services to procure, deliver, and install the equipment.

X. **Attachments** – Pictures of Hydrogen Production Facility in Morris

Picture 1. Exterior of the Proton Energy Systems electrolyzer.



Picture 2. Interior of the electrolyzer.

Picture 3. 60 kW hydrogen engine generator set

Picture 4. Hydrogen storage tanks

Picture 5. 12.5 kV to 480 volt transformer

Picture 4. Switchgear to place power on the grid

Picture 7. Chiller for cooling electrolyzer and compressor

Picture 8. Hydrogen compressor

Picture 9. Modular building housing the equipment

Picture 10. Water deionization system

Picture 11. Overall view of the hydrogen production facility located near Morris