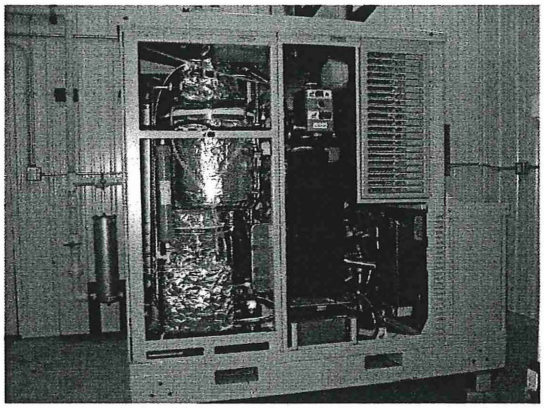
FINAL REPORT

2003 LCMR Project: *Advancing Utilization of Manure Methane Digester Electrical Generation*

Final Report to the Legislative Commission of Minnesota Resources (LCMR)



Proton Electron Membrane Fuel Cell

2003
10(6)

Submitted by:
Minnesota Department of Agriculture
Agricultural Resources Management and Development Division

MINNESOTA DEPARTMENT OF AGRICULTURE
FROM THE FARM TO YOUR FAMILY

2003 LCMR Project Abstract: ***Advancing Utilization of Manure Methane Digester Electrical Generation***

A commercial 5kW proton exchange membrane (PEM) fuel cell was successfully operated in February 2005 on anaerobic digester biogas produced on a Minnesota dairy.

An engineering team from the Department of Biosystems and Agricultural Engineering, University of Minnesota and a cooperating farmer purchased and commissioned a production model PEM fuel cell on the 800-cow Haubenschild dairy farm in Princeton MN.

A water-scrubbing tower removed soluble carbon dioxide and hydrogen sulfide while retaining insoluble methane in biogas stream. A final iron sponge scrub removed residual hydrogen sulfide. This simple pressure and flow control system was satisfactory to clean up the biogas. Optimization will reduce the energy used for gas cleanup.

Caterpillar engine generator emissions were compared to Plug Power™ (PEM) fuel cell using biogas in both technologies. The greenhouse emissions from the fuel cell are minimal compared with the internal combustion engine. Emissions of nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide ($SO_{2)}$ were less than detection limits. Total hydrocarbons (THC) were 1,790 ppmv or 14.5 g/kWh$_e$. Average genset emissions at 103 kW were NOx = 2,963 ppmv or 25.5 g/kWh$_e$, CO = 799 ppmv or 4.18 g/kWh$_e$, THC = 20460 ppmv or 53 g/kWh$_e$, SO_2 = 277 ppmv or 3.34g/kWh$_e$.

With assistance from the Minnesota Project and Minnesota Department of Agriculture, outreach efforts for the project consisted of 2 field days, 35 small tours, 10 formal presentations, and 2 papers presented at international conferences.

The primary recommendation to farm operators considering a fuel cell is to wait until the cost of fuel cells (currently greater than $10,000/ kW) is economically viable. The current pricing structure for electrical energy purchase by energy companies and co-ops does not provide enough income to farmers to make most operations economically viable. The value of renewable energy and incentives for making renewable must increase.

November 23, 2005

2003 LCMR Final Work Program Report

Date of First Status Report: December 31, 2003 (Revised January 28, 2004)
Date of Second Status Report: June 30, 2004 (Revised July 22, 2004)
Date of Third Status Report: December 31, 2004 (Revised April 15, 2005)
Date of Final Report: September 30, 2005
Date of Work program Approval: June 25, 2003
Project Completion Date: June 30, 2005

I. PROJECT TITLE: Advancing Utilization of Manure Methane Digester Electrical Generation

Project Manager: Paul Burns, Assistant Director, Agricultural Resources Management and Development Division
Affiliation: Minnesota Department of Agriculture
Mailing Address: 90 West Plato Blvd., Room 211
City / State / Zip: St. Paul, MN 55107-2094
Telephone Number: 651-296-1488
E-mail Address: Paul.Burns@state.mn.us
FAX Number: 651-297-7678
Web Page address: www.mda.state.mn.us

Total Biennial LCMR Project Budget:
LCMR Appropriation: $ 221,000.00
Minus Amount Spent: $220,965.34
Equal Balance: $34.66

***See Attachment A for Additional Budget Details**

Legal Citation: ML 2003, Chap. 128, Art. 1, Sec. 9, Subd. 10(b).

Appropriation Language: 10(b) Advancing Utilization of Manure Methane Digester Electrical Generation

$111,000 the first year and $110,000 the second year are from the trust fund to the commissioner of agriculture to maximize the uses of manure methane digesters by identifying compatible waste streams and the feasibility of micro turbine and fuel cell technologies.

II. and III. FINAL PROJECT SUMMARY

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IV. OUTLINE OF PROJECT RESULTS:

Result 1: Evaluating the Feasibility of Fuel Cell/Micro turbine Technology

A. Final Report Summary for Result 1, June 30, 2005:

The University of Minnesota Engineering team, led by Dr. Phil Goodrich, and farmer/cooperator Dennis Haubenschild successfully commissioned a proton electron membrane fuel cell (PEM) using biogas from anaerobically digested cow manure. To the best knowledge of the project participants, this is the first demonstration of a fuel cell running on biogas from livestock in the world. This project was made possible through the funds from this LCMR grant, the project cooperators (Minnesota Dept. of Ag, U of M, Dennis Haubenschild, and the MN Project), and private organizations that contributed

cash, equipment, and time to make this project a success.

There is a significant amount of background and supporting material that was developed for this project. In order to best organize this information effectively, a large proportion of the information for the final report is broken down into a series of appendices. These appendices are listed below and are attached to this final reporting document:

- Appendix A: Final Budget
- Appendix B: Report to MDA from the U of M Biosystems and Ag Engineering (BAE) Department.
- Appendix C: Powerpoints on the LCMR project developed by the U of M BAE
- Appendix D: MN Project final report to MDA
- Appendix E: MN Project fact sheets developed and submitted to MDA
- Appendix F: MN Project Web site information on the LCMR Project
- Appendix G: MDA Manure Digester Web site materials
- Appendix H: Digital photos for the project
- Appendix I: Poster displays developed for this project
- Appendix J: Schematic of energy flow at the Haubenschild Dairy
- Appendix K: Articles about the fuel cell project in the press
- Appendix L: Dataset example from fuel cell data acquisition system

B. Site Preparation

The site for the fuel cell project was the Dennis Haubenschild Dairy farm located 1 hour north of the Twin Cities Metropolitan area near Princeton, MN. Haubenschild farm was an ideal location for the project of a number of reasons: 1) Working manure digester on site with a proven track record of successful operation, 2) Related research already being undertaken on the farm related to manure digesters, 3) Surplus gas production at the site so the economic impact to the electrical production of the existing engine generator set would be minimal, 4) and the relative close proximity of the farm to the U of M campus.

The U of M received a gift of $40,000 from John Deere Inc. to construct a research building on the Haubenschild farm to assist with this LCMR project and future research projects. The research building was very important for the success of this project and for the ability of the all parties involved to secure future research funding. Once the building was constructed, gas piping and other infrastructure needed to prepare the research facility for the fuel cell was installed. Dennis Haubenschild and U of M staff worked cooperatively in designing and constructing the research facility. Haubenschild also provided in-kind infrastructure and tools to assist the U of M and the contractors in preparing the site.

C. Fuel Cell Selection

One of the most crucial steps in the project was finding a fuel cell that was suitable for the project. A number of criteria needed to be considered when developing the strategy for purchasing a fuel cell for the project: 1) cost, 2) fuel cell type, 3) technical support, 4)

easy of use, and 5) commercial availability. The U of M collected background information on fuel cell types and developed a request for proposal (RFF) based on that information. Plug Power Inc. responded to the RFP and was awarded the bid for the project. Plug Power Inc. produces proton electron membrane (PEM) fuel cells that are commercially available and had been used in various commercial and residential situations. This type of fuel cell is a lower temperature, lower cost fuel than other types of fuel cells being developed, but required a great deal of treatment of the biogas for impurities before the gas enters the fuel cell. Other types of fuel cells that run at a much higher temperature (molten carbonate and solid oxide) that have the potential to use biogas with less involved gas clean up, but there were no commercially available units ready for use in this type of application that met the budgetary limits of the project.

D. Data Acquisition System Installation

Numerous computer and monitoring systems needed to be installed in the research building before the fuel cell could be installed. Biogas monitoring and other data systems were installed and tested before the fuel cell was installed. Also, computer systems were installed so U of M staff and Dennis Haubenschild could receive and send electronic information from the research site. For more details on the data acquisition system, see Appendix B. The software programs that ran the Plug Power PEM fuel cell and the data acquisition system were able to collect a wide range of data. Because of the large amounts of data collected by the fuel cell software, an example data set is provided in Appendix L.

E. Fuel Cell Installation

The fuel cell arrived at the Haubenschild farm in September of 2005. Before the fuel cell could be installed, one U of M staff person went through a week of intensive training on how the use the fuel cell. Later in 2005, a second U of M staff was trained by Plug Power Inc. at their training center. U of M staff worked on completing the installation of the data acquisition system, electrical hook ups, and gas piping in the research building before the fuel cell was fully installed. U of M staff also installed a computer in the research building that would run the fuel cell software programs, collect data for the project, and allow data to be transferred from the Haubenschild farm back to the U of M.

F. Biogas Clean Up

Biogas, which is the gas produced from anaerobic digester of manure, is approximately 50-60% methane (CH4), 30-40% carbon dioxide (CO2), and a small percentage of impurities such as hydrogen sulfide (H2S) and water vapor. Natural gas, by comparison, is approximately 99% methane. The PEM fuel requires pure hydrogen as fuel, so hydrogen must be derived from the methane, and CO2 (carbon) and other impurities must be separated out. The first step was to monitor the biogas composition coming from the manure digester and after the biogas clean up process before the gas enters the fuel cell reformer. The methane content of the biogas from the Haubenschild manure digester was approximately 55%. The methane content of biogas is variable because of a number of

factors including: the season of the year, health of the cows, and the management of the feed. Carbon dioxide clean up was very important as it acted in diluting the hydrogen content of the biogas. Hydrogen sulfide, although a very small constituent of biogas, is very caustic to the internal systems of the fuel cell. Hydrogen sulfide levels of 3,000 to 5,000 ppm were observed in the raw biogas and reductions of 2 orders of magnitude were needed in order to safely use the biogas.

Three different systems were used to clean up the biogas: 1) water tower system, 2) pressure swing absorber, and 3) lime solution system. Ultimately, the water tower system, which was very effective at scrubbing CO2, was the most effective biogas clean up system tested. For more details on these systems, see Appendix B.

G. Running the fuel cell on natural gas

The fuel cell was first tested and commissioned on pure natural gas in January xx, 2005. This allowed the U of M researchers to become familiar with the operations of the fuel cell and to make sure it was functioning properly before it was run on biogas from the Haubenschild anaerobic manure digester. The Plug Power Inc. PEM fuel cell has a reformer that converts the methane (CH4) in the natural gas into pure hydrogen (H2) that ultimately fuels the electrochemical reactions in the fuel cell. Natural gas is almost composted almost entirely of methane and has very few impurities. Because of the experimental nature of this project, it was important that a natural gas source was available to start the fuel cell up initially and gradually add biogas to the fuel cell and reformer. This was very important in extending the life of the fuel cell stack for multiple experiments.

H. Running the fuel cell on biogas

The fuel cell was run on natural gas and was thoroughly tested before being run on biogas. Aforementioned, clean up of the biogas was essential and needed to occur before the biogas entered the fuel cell and its reformer. Once the first biogas cleaning system was in place, the fuel cell was first run on biogas on February xx, 2005. From February to June 2005, the fuel cell was run on biogas intermittently for a few hours to a day at a time. In order to preserve the integrity of the fuel cell and extend the life of the fuel cell stack, the fuel cell was only run on biogas for relatively short periods of time. In addition, the various biogas clean up systems needed to be monitored closely and a researcher from the U of M was needed on site to do ensure that those systems were operational. U of M researchers were able to study the following parameters when running the fuel cell on biogas: 1) biogas quality before and after clean up, 2) biogas clean up technology feasibility, 3) fuel cell start up and shut down procedures, 4) fuel cell stack emissions, 5) electrical output, and 6) reliability of the entire system.

I. Success running a fuel cell from digested dairy manure

This project was successful in being the first fuel cell to ever run from biogas from digested animal manure. This fact was groundbreaking and very exciting for all parties

involved. A lot of hard work and effort was involved in getting the stage where the fuel cell was operational and using biogas to produce electricity. There was a great deal of positive press and reports that came out of this effort, which helped showcase LCMR's involvement in this project and renewable energy. Read further in Appendix K for specific articles written by the media about the project. Also, staffs from the U of M and the MN Project were able to speak about this project to national and international audiences at conferences and meetings.

J. Pros and Cons of Fuel Cells vs. Conventional Engine Generators

Below is a brief summary of the differences, both positive and negative, between using a fuel cell vs. a conventional internal combustion generator to produce electricity from biogas derived from a manure digester.

Attribute	**Fuel Cell**	**Conventional Internal Combustion Engine Generator Set**
Capital Cost per Kilowatt	High ($10,000-12,000)	Low ($50-100)
Biogas Cleanup	Biogas needs to be cleaned to strict specifications	Little or none needed
Maturity of Technology	Rapidly emerging	Mature
Greenhouse Emissions	Minimal	Carbon dioxide, carbon monoxide, sulfur oxides, particulates
Noise Level of Equipment	Minimal	Very high and sound mitigation necessary
Moving Parts to Fail	Very few and most at ambient temperature	Many moving parts in a hot, challenging environment needing oil and cooling
Changes Occurring	Changing rapidly with extensive development	Mature and changing slowly
Maintenance Cost	Very high because of limited life of the fuel cell stack material	Variable given the maintenance and reliability of the unit

At the present time, fuel cell technology is not an economically viable option for livestock producers looking at producing electricity from biogas. The environmental benefits of the fuel cell are promising, but until the price comes down, this technology will have limited applicability on current farms with manure digestion.

K. Emission Reductions and Environmental Benefits

Emissions from Haubenschild Caterpillar™ engine generator were compared to Plug Power™ Proton Exchange Membrane (PEM) Fuel Cell (see table below) on March 11, 2005 using biogas in both technologies.

	Engine Generator	Fuel Cell
CO	(800ppmv) 4.18 g/kWh	(<1 ppmv) 0.014 g/kWh
NOx	(2960ppmv) 25.5 g/kWh	(<1 ppmv) <.0023 g/kWh
SO_X	(277ppmv) 3.34 g/kWh	(<1 ppmv) <0.030 g/kWh
$C_X H_Y$	(20460ppmv) 53 g/kWh	(1790 ppmv) 14.5 g/kWh

The data was shown in grams of pollutant emitted per kWh of electricity produced by a specific generator to better compare the emission from the 5kW fuel cell that produces less electricity than the 130kW internal combustion engine. These results show that emissions of carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and hydrocarbons (CxHy) are minimal in the fuel cell compared to the internal combustion engine. In the fuel cell, many of the pollutants are filtered out in the gas clean up process.

L. Education and Outreach

The MN Project, the U of M, Dennis Haubenschild, and the MDA worked cooperatively together on the education and outreach component of the project. The MN Project worked on developing educational materials, constructing a website with information on this project, and coordinating a field day to showcase the fuel cell technology. The MN Project also worked with the U of M on giving presentations on the LCMR at various meetings and conferences (see Attachment D for more detail). The U of M presented papers at national conferences, assisted with numerous field days, and worked with the media to provide information on the LCMR project (see Attachment B for more detail). Farmer Dennis Haubenschild gave many tours of his farm where he explained the LCMR project to captive audiences on his farm. Haubenschild also worked with the media in providing information on the success of the project and his future vision for renewable energy as it relates to anaerobic manure digesters. The MDA assisted in coordinating outreach efforts, developed a press release on the success of the project, and worked with media on disseminating information about the LCMR project.

M. Public/Private Partnership Development

This project was very successful in developing partnerships between the public and private sector. The funds awarded by LCMR for this project were very important in leveraging additional private and public funds (cash and technical assistance) that helped enhance this project. Here is a listing of outside contributors to the project:

- John Deere Inc.
- First District Dairy
- East Central Energy
- Great River Energy
- Energy and Power Research Institute (EPRI)

This project was enhanced by cooperation with other agencies, private sector funds, donated equipment, and additional U of M funds. This project has a great potential to bring in additional Federal, State, and private funds for future research on anaerobic manure digestion and renewable energy technologies.

N. Budget

The $221,000 in funds for this project (except for $34) was expended through work completed by the U of M Biosystems and Agricultural Engineering Department, the MN Project, and Dennis Haubenschild. The MDA worked with LCMR staff to amend the budget on a few separate occasions in order to reflect the amount of work U of M staff were undertaking and the additional staff time needed. Because of the unique nature of the project, it was difficult to find contractors with the proper knowledge to install some of the equipment and set up the fuel cell so it was more practical for U of M staff to do the work themselves.

O. Research Needs

This project covered new ground in understanding animal agricultures role with renewable energy and the hydrogen economy in Minnesota. This project proves that there is a great potential for the use of fuel cells and hydrogen on working farms in Minnesota once current technology and economic barriers have been hurdled. The following are potential research areas that could help accelerate the knowledge base and adoption of fuel cell and renewable energy technology on farms with anaerobic manure digesters:

- The feasibility of other fuel cell types needs to be researched (solid oxide and molten carbonate fuel cells). It is important to identify fuel cells that may be able to run on biogas that requires less pretreatment and will be able to provide heat for keeping the manure digester warm and operational during the winter months.
- The feasibility of producing hydrogen gas from biogas on-site, storing the hydrogen fuel, and ultimately transporting the hydrogen is a very realistic possibility and needs to be researched.
- In the future, as economics change for fuel cells, it is important that the U of M work to update economic feasibility data for manure digesters with this information.

P. Current Economics, Future Considerations, and Potential Outcomes for Fuel Cells

P(1). Is the PEM fuel cell an economically viable alternative to the conventional internal combustion engine?

At the current moment, the fuel cell technology including PEM fuel cells are not a viable alternative to the conventional internal combustion engine in Minnesota. If the emissions from the internal combustion engine are restricted as they are being restricted in

California, then they become a better candidate. The cost per kW installed is still too high to match the old and established technology.

Table 1: Cost per kWh to Purchase Electrical Generation Systems that can burn Biogas

Electrical Generation System	**Cost per kWh**	**Size of Individual Electrical Genset**
Internal Combustion Engine	$500-$1000	20 kW-500kW
PEM Fuel Cell	$2,000-$15,000	3kW-10kW
Solid Oxide Fuel Cell	$3,000-$25,000	1kW- 20kW
Molten Carbonate Fuel Cell	$1500-$2000	100kW- 1,500 kW
Micro turbine	$700-$1,100	30kW-80kW
Sterling Engine	$1000-$2000	30kW-55kW

Micro turbine Cost Capital Cost $700-$1,100/kW O&M Cost $0.005-0.016/kW Maintenance Interval 5,000-8,000 hrs (Courtesy of California Distributed Energy Resources Guide on Micro turbines)

Table 2: Energy Production Costs per kW to by Different Energy Generation Processes

Energy Source	**Production Costs per kW in U.S. Dollars ($)**
Coal	.02
Natural Gas	.04-.06
Nuclear	.01-.10
Solar	.20-.25
Geothermal	.10-.20
Wind	.03-.16
Biomass Incineration	.03-.10
Biogas from Manure Digestion (Internal Combustion Engine)	.04-.10
Biogas from Manure Digestion (PEM Fuel Cell)	.20-.30

*Average Retail Price for electricity in MN is 6-8 cents/kW

Table 3: Cost of Fuel Cell and Internal Combustion Engine at Haubenschild Dairy

Genset Type	Genset Capital Cost	Operation and Maintenance Costs	Life Span
Caterpillar Internal Combustion Engine (130 kW)	$110,000 or $846/kW	$15,000-$25,000/year	5 years (second engine in place)
Plug Power Fuel Cell (5 kW)	$80,000 or $16,000/kW	Unknown (will be high until technology is mature)	Unknown (will be shorter than internal combustion engine)

P(2). What is the value of demonstrating the use of a fuel cell for alternative electrical generation from biogas?

The best value of the demonstration is that fuel cells can be mated to the renewable resource that is expanding at a rapid rate in most dairy states. Dairy production uses large quantities of electricity in the production of low cost food for Americans. Independence is valuable. Also the emissions from the fuel cell conversion to electricity are very low compared to the engine generator.

P(3). What are the next critical steps and issues to be resolved for fuel cells to be adopted on livestock operations using manure digesters?

The suppliers of fuel cells are lowering the cost of the fuel cell per unit of energy generated. This is the most important step. The second most important step is to develop lower cost reliable and environmentally friendly methods to prepare the biogas for use in the fuel cell.

P(4). What will be the role of the U of M on future fuel cell research?

Research is underway at the U of M to lower the cost of cleaning up the impurities in biogas so that the biogas can be used as a renewable fuel for making hydrogen that can be marketed for use in fuel cells or for other uses. There are researchers approaching the problem of getting fuel cells much smaller and more compliant with small devices such as phones.

P(5). What will be the potential future role of the MDA in fuel cell and hydrogen research involving manure and other biomass sources?

MDA needs to continue to support research that assists farmers to develop alternative income streams from products produced. Fuel cells and hydrogen are promising technologies that may be harnessed to add value to crops and livestock farms. Additional employment opportunities and new business will be generated that will assist the state. MDA needs to continue to foster support for development of renewable energy and new products through incentives, loans and support for legislation, which fosters development and adoption of the new technologies.

P(6). What is the fate of the fuel cell purchased through the LCMR project?

The fuel cell will be used to test digester biogas mixtures that have been treated in various ways to remove impurities. This research will be carried out at the Haubenschild

farm for the next 1-2 years. The ability to withstand different levels of impurities will enhance the knowledge of bringing renewable energy to rural communities and enhancing income to the rural communities supported by agriculture.

Q. Project Description: This project will undertake a small-scale pilot project using fuel cell technology and will also evaluate micro-turbines as possible alternatives. The majority of manure digesters designated for electrical generation in the U.S. use internal combustion engine technology to power generators that produce electricity. Alternatives for farmers are needed to increase the use of this technology in Minnesota. Fuel cells are an emerging technology and this project would evaluate future technical feasibility of their use through the operation of a fuel cell in conjunction with a manure digester.

Micro-turbines are coming into the mainstream for alternatives for electrical generation and have potential advantages for reduced maintenance compared to internal combustion engines when fueled with biogas. The advantages are: 1) fewer moving parts and less maintenance 2) reduced NO_x and CO emissions 3) less sensitivity to H_2S corrosion than internal combustion engines. This technology will be researched through the literature, published data, and site visits to operational micro turbines. Total funds to the University of Minnesota for researching both technologies are $202,500.

The Minnesota Project will assist the Minnesota Department of Agriculture and the University of Minnesota in disseminating data and information collected in Result 1. The Minnesota Project will assist with work shops, facilitation, education, stakeholder involvement, and web site development for this project. Total funds to the Minnesota Project are $7,500.

Dennis Haubenschild, a farmer with an operational manure digester, or another farmer with an operational manure digester, will work with this project by hosting the fuel cell on-farm. Mr. Haubenschild will assist in the maintenance and operation of the fuel cell during the duration of the project. Mr. Haubenschild will assist with field days and dissemination of information on the project. Total funds to the Dennis Haubenschild farm are $9,125.

Amendment to Budget Description (September 1, 2004):
Upon the completion of the site preparation for the fuel cell, configuration of the biogas collection system, and portions of the data management systems, the University of Minnesota budget needs to be modified to reflect changes in the anticipated costs. No additional funds are being requested, but changes in the line item budgets are needed to effectively complete the objectives of the project. The cost of the fuel cell and the communications link were slightly less than anticipated. The line item for "Monitoring Equipment and Service Contracts" can also be reduced because of warranties for the fuel cell and other equipment covers these costs. For the cost of site preparation, the University undertook a larger portion of this, because qualified individuals for accomplishing some of the task involved (ex. biogas plumbing) were not available. This resulted in additional costs being applied to the "Personnel" line item, but less costs being applied to the "Site Preparation for Fuel Cell" line item.

Amendment to Budget Description (January 28, 2005)

Upon installation of the fuel cell, initial configuration of the biogas cleaning system, and most of the data management systems, the University of Minnesota budget needs to be modified to reflect changes in costs. No additional funds are being requested, but changes in the line item budgets are needed to effectively complete the objectives of the project.

Capital equipment (instruments/gas cleanup) will be leased instead of being purchased because of the specialized nature of the devices and the short-term use of the devices. This is more cost effective. Thus a short term leasing item is new and some money from capital equipment is reallocated to that item.

Another department at the University of Minnesota is conducting the tests for emissions and this cost needs to be classified differently than anticipated. The cost was planned but is being accounted for with a different category. Money from capital equipment is reallocated to the new laboratory services item.

Maintenance contracts will not be needed since instruments are not purchased. This money is reallocated to travel, which has increased due to inflation and additional trips needed to complete work at the farm.

Personnel developed and installed the gas systems and did more preparation that was originally budgeted in site preparation category. So site preparation funds are being reallocated to personnel. Some funds from capital equipment/monitoring equipment are also being reallocated to personnel and fringe benefits so that the necessary monitoring can be completed to finish the project.

Amendment to Budget Description (May 27, 2005)
The University of Minnesota budget needs to be adjusted to reflect additional supplies and staff time needed to develop an additional biogas clean up system for this project. Also, additional travel was necessary for staff to be up at the Haubenschild farm to collect data and research the fuel cell. Funds for result 2 need to be adjusted to reflect staff time needed to assist with the waste streams report. Printing costs will be minimal for this report and that portion of the budget was reduced.

The MN Project budget needs to adjust their budget in order to accommodate expenses that will be incurred for the June 20, 2005 field day for the project. Funds from salaries will be shifted to printing and travel categories.

Summary Budget Information for Result 1:

LCMR Budget	**$219,125.00**
Amount Spent	**$219.123.78**
Balance	**$ 1.22**

Completion Date:
U of M: Result 1 will be completed entirely by June 30, 2005. The fuel cell will be purchased by July 1, 2004. The fuel cell will be fully installed and data collection will begin by August 30, 2004. Additional data collection will occur in FY 2005 until June 30, 2005.

The Minnesota Project: Result 1 will be completed entirely by June 30, 2005. The Minnesota project will update their website to include the on-going LCMR project by June 30, 2004. By June 30, 2005, the Minnesota Project will conduct a workshop or related educational event to engage stakeholders on the results of this project.

Result 2: Identify Compatible Waste Streams

Final Report Summary for Result 2, June 30, 2005:

The Minnesota Department of Agriculture and the U of M worked cooperatively in developing the report entitled *Opportunities, Constraints, and Research Needs for Co-Digestion of Alternative Waste Streams with Livestock Manure in Minnesota.* This report is attached as Appendix M the to full LCMR report. This report will be used as the baseline for work accomplished in the 2005 LCMR project "Manure Methane Digester Compatible Wastes and Electrical Generation." This area of study is expanding quickly as more manure digesters are being constructed throughout the nation and especially the Midwest. With current energy prices increasing and the need to treat high strength organic wastes to improve water quality, there is a great potential for co-digestion of manure with other waste streams to produce renewable energy.

Project Description: A total of $1,875 has been budgeted for Result 2. This funding will be used for the printing costs of the report. The Minnesota Department of Agriculture and the University of Minnesota will offer in-kind services to develop the report. To increase the flexibility and potential uses for manure digesters, other types of waste streams could be used to supplement the production of biogas from a manure digester. There is a need to determine specifically what types of waste streams are most compatible with a manure digester. The Minnesota Department of Agriculture and the University of Minnesota will conduct a literature review and develop a report on the following: 1) which waste stream combinations are technically feasible to blend with manure including manure not currently practical for digestion, 2) which manure and waste stream combinations produce the highest rate of biogas yield, and 3) which waste stream combinations are economically achievable.

Summary Budget Information for Result 2:

LCMR Budget	**$1,875.00**
Amount Spent	**$1,841.56**
Balance	**$ 33.44**

V. TOTAL LCMR PROJECT BUDGET (AMENDED 05-27-2005)

All Results: Personnel: $96,366
All Results: Equipment: $92,990
All Results: Development: $0
All Results: Acquisition: $0
All Results: Other: $31,644 (site preparation for fuel cell, printing, communications, travel, supplies)

Final LCMR Project Budget	
Total LCMR Budget:	$221,000.00
Total Amount Spent:	$220,965.34
Final Project Balance:	$34.66

All funds will be through professional/technical contracts from the Minnesota Department of Agriculture to the University of Minnesota, The Minnesota Project, and Dennis Haubenschild. After completion of the first report to LCMR on December 31, 2003, MDA will work on clarifying the reporting requirements by LCMR on in-kind services for this project at a future date.

TOTAL LCMR PROJECT BUDGET: $ 221,000

Explanation of Capital Expenditures Greater Than $3,500: Purchasing a fuel cell for the research project will be largest capital expense. The cost will be approximately $80,000 for the fuel cell, maintenance agreements with the manufacture, and equipment associated with connecting the fuel cell to the manure digester and the electrical grid. The maintenance agreement between the manufacture will cover maintenance of the fuel cell and components, replacement of defective parts, calibration of the fuel cell, and technical trouble shooting of problems associated with the general operation of the fuel cell. This maintenance agreement differs with the funding being granted Dennis Haubenschild (or other farmer with an operational manure digester) who will be performing daily general maintenance and upkeep needed to ensure the continuous operation of the fuel cell in the on-farm setting. The fuel cell and associated components will be under the control of the University of Minnesota. The fuel cell will be located temporarily on a Minnesota farmer's property, which is the site of an existing manure digester for data collection. After adequate data has been collected at the on-farm site, the fuel cell will be permanently stationed at the University of Minnesota. The University of Minnesota is planning on constructing a digester on the St. Paul campus on the near future and the tentative plans are to incorporate the fuel cell into that future project. The fuel cell and it's associated components will be used in the same manner as in the LCMR project throughout the equipments useful life at the University of Minnesota and if the use changes a commitment to pay back the to the Environment and Natural Resources Trust Fund an amount equal to either the cash value received or the residual value approved by the director of the LCMR if it is not sold.

Additionally, monitoring equipment ($11,677) will be leased (amended 05-27-2005) to conduct analysis of the biogas and collect data related to the project.

VI. PAST, PRESENT AND FUTURE SPENDING:

A. Past Spending: MDA spent $6,250 in FY01 to research odor emissions from manure storage areas from a dairy feedlot using a manure digester and a traditional dairy feedlot. The University of Minnesota was involved with early digestion work in the 1970's and

received funding for their research. The Agricultural Research Utilization Institute (AURI) has developed a feasibility study for manure digesters for livestock operations.

B. Current Spending:
Additional spending on this project may occur if pending funding sources for renewable energy sources are appropriated to the University of Minnesota. Also, all entities involved with pursue other sources of funding to enhance and complement this project.

C. Required Match (if applicable): Does not apply.

D. Future Spending: Fuel cell and manure digester research will continue to be pursued for decades to come. Fuel cells, which are in their infancy, will necessitate further research in applying this technology in a cost effective and reliable manner. It is anticipated that the University of Minnesota will continue to research both of these technologies, which will necessitate further funding.

VII. Project Partners:
A. Partners Receiving LCMR Funds (for more detailed information, see Attachment A):
Funds from this project will be directed from the Minnesota Department of Agriculture to the University of Minnesota, The Minnesota Project, and a farmer working with an operational digester.

University of Minnesota Biosystems and Agricultural Engineering Department: $204,375

The Minnesota Project: $7,500

Dennis Haubenschild (MN farmer with an operational manure digester) or other farmer(s) with operation manure digesters: $9,125

B. Project Cooperators:

- Dennis Haubenschild (MN farmer with an operational manure digester) or other farmer(s) with operation manure digesters
- University of Minnesota Biosystems and Agricultural Engineering Department
- Minnesota Project
- Minnesota Department of Commerce
- U.S. EPA AgSTAR Program
- Agricultural Utilization Research Institute
- Various Livestock Organizations: Minnesota Milk Producer's Associations, Minnesota Cattleman's Association, Minnesota Pork Producer's Association, and the Minnesota Turkey Growers Association.

VIII. DISSEMINATION: Information will be disseminated through publications, literature reviews, tours, press releases, and web site development. The Minnesota Project and the University of Minnesota will help coordinate this effort and will conduct meetings and/or workshops to get the results of this project to the appropriate audiences. The Minnesota Department of Agriculture will develop a manure digester web page (www.mda.state.mn.us) to make information from this project readily available, while also providing links to other research and development efforts that are being undertaken nationally and internationally.

IX. LOCATION: Work will take place at the U of M St. Paul Campus in St. Paul, MN (Ramsey County). Research may be conducted also at the Southern Research and Outreach Center in Waseca, MN (Waseca County). Also, work may take place on a dairy farm that has an operational manure digester near Princeton, MN or another Dairy farm in Minnesota that has an operational manure digester.

X. REPORTING REQUIREMENTS:
Periodic work program progress reports will be submitted not later than December 31, 2003, June 30, 2004, and December 31, 2004. A final work program report and associated products will be submitted by June 30, 2005.

XI. RESEARCH PROJECTS: Does not apply.

Attachment A: Budget Detail for 2003 Projects - All Subcontractors (Professional/Technical Contract and Service Contracts)

Proposal Title: *10(b) Advancing Utilization of Manure Methane Digester Electrical Generation*

Project Manager Name: *Paul Burns*

2003 LCMR Proposal Budget	Result 1: Budget	Result 1: Funds Spent	Result 1 Balance: June 30, 2005	Result 2: Budget	Result 2: Funds Spent	Result 2 Balance: June 30, 2005	Final Budget Balance for Project: June30, 2005	Total Budget for Project
BUDGET ITEM								
PERSONNEL:	$ 85,256.00	$ 85,254.65	$ 1.35	$ 1,594.00	$ 1,594.00	$ -	$ 1.35	$ 86,850.00
PERSONNEL: Staff benefits – @31.8%	$ 9,318.00	$ 9,317.96	$ 0.04	$ 198.00	$ 197.64	$ 0.36	$ 0.40	$ 9,516.00
Contracts								
Professional/technical: University of Minnesota Biosystems and Agricultural Engineering Department (see additional								
Professional/technical: Livestock Producer(see additional								
Professional/technical: The Minnesota Project(see additional budget pages								
Space rental: NOT ALLOWED								
Other direct operating costs								
Equipment / Tools: Fuel Cell and Related Components (5KW Fuel Cell, Associated Equipment, and Service and Maintenance Contract)	$ 79,787.00	$ 79,786.95	$ 0.05				$ 0.05	$ 79,787.00
Office equipment & computers for data acquisition system	$ 1,536.00	$ 1,535.89	$ 0.11				$ 0.11	$ 1,536.00
Capital equipment: Monitoring Equipment (Data Acquisition and On Line Gas Analysis)	$ 11,667.00	$ 11,666.38	$ 0.62				$ 0.62	$ 11,667.00
Montitoring Equipment Maintenance and Service Contracts			$ -				$ -	$ -
Land acquisition								
Land rights acquisition								
Printing and Publications	$ 1,179.00	$ 1,179.46	$ (0.46)	$ 83.00	$ 49.92	$ 33.08	$ 32.62	$ 1,262.00
Advertising								
Communications, telephone, mail, Web Link for data acquisition	$ 2,277.00	$ 2,277.28	$ (0.28)				$ (0.28)	$ 2,277.00
Office Supplies	$ 200.00	$ 200.00	$ -				$ -	$ 200.00
Site Preparation for Fuel Cell			$ -				$ -	$ -
Supplies	$ 11,511.00	$ 11,511.21	$ (0.21)				$ (0.21)	$ 11,511.00
Travel expenses in Minnesota	$ 8,322.00	$ 8,322.00	$ -				$ -	$ 8,322.00
Travel outside Minnesota Training for fuel cell operation at factory	$ 1,500.00	$ 1,500.00	$ -				$ -	$ 1,500.00
Construction								
Other land improvement								
Short Term Leasing of Equipment (Amended 01-28-05)	$ 1,696.00	$ 1,696.00	$ -				$ -	$ 1,696.00
Laboratory Services (Amended 01-28-05)	$ 4,876.00	$ 4,876.00	$ -				$ -	$ 4,876.00
Other								
COLUMN TOTAL	$ 219,125.00	$ 219,123.78	$ 1.22	$ 1,875.00	$ 1,841.56	$ 33.44	$ 34.66	$ 221,000.00

Attachment A: Budget Detail for 2003 Projects - University of Minnesota (Professional/Technical Contract)

Proposal Title: *10(b) Advancing Utilization of Manure Methane Digester Electrical Generation*

Project Manager Name: *Paul Burns*

Total LCMR Requested Dollars: $ ***221,000***
U of M Request:
$204,375

2003 LCMR Proposal Budget	Result 1: Budget	Result 1: Funds Spent	Result 1 Balance: June 30, 2005	Result 2: Budget	Result 2: Funds Spent	Result 2 Balance: June 30, 2005	Budget Balance: June 30, 2005
BUDGET ITEM							
PERSONNEL:Two (2) temporary engineering staff hired by the U of M to work on the project who are supervised by Project Investigator, Dr. Philip Goodrich, U of M Dept. of Biosytems and Agricultural Engineering	$ 70,881.00	$ 70,880.87	$ 0.13	$ 1,594.00	$ 1,594.00	$ -	$ 0.13
PERSONNEL: Staff benefits – @31.8%	$ 9,318.00	$ 9,317.96	$ 0.04	$ 198.00	$ 197.64	$ 0.36	$ 0.40
Contracts							
Space rental: NOT ALLOWED							
Other direct operating costs							
Equipment / Tools: Fuel Cell and Related Components (5KW Fuel Cell, Associated Equipment, and Service and Maintenance Contract)	$ 79,787.00	$ 79,786.95	$ 0.05				$ 0.05
Office equipment & computers for data acquisition system	$ 1,536.00	$ 1,535.89	$ 0.11				$ 0.11
Capital equipment: Monitoring Equipment (Data Acquisition and On Line Gas Analysis)	$ 11,667.00	$ 11,666.38	$ 0.62				$ 0.62
Montitoring Equipment Maintenance and Service Contracts	$ -	$ -	$ -		$ -	$ -	$ -
Land acquisition							
Land rights acquisition							
Printing and Publications	$ 179.00	$ 179.46	$ (0.46)	$ 83.00	$ 49.92	$ 33.08	$ 32.62
Advertising							
Communications, telephone, mail, Web Link for data acquisition	$ 1,527.00	$ 1,527.28	$ (0.28)				$ (0.28)
Office Supplies							
Site Preparation for Fuel Cell		$ -	$ -				$ -
Supplies	$ 11,511.00	$ 11,511.21	$ (0.21)				$ (0.21)
Travel expenses in Minnesota	$ 8,022.00	$ 8,022.00	$ -				$ -
Travel outside Minnesota Training for fuel cell operation at factory	$ 1,500.00	$ 1,500.00	$ -				$ -
Construction							
Other land improvement							
Short Term Leasing of Equipment (Amended 01-28-05)	$ 1,696.00	$ 1,696.00	$ -				$ -
Laboratory Services (Amended 01-28-05)	$ 4,876.00	$ 4,876.00	$ -				$ -
Other							
COLUMN TOTAL	$ 202,500.00	$ 202,500.00	$ (0.00)	$ 1,875.00	$ 1,841.56	$ 33.44	$ 33.44

Attachment A: Budget Detail for 2003 Projects - The Minnesota Project (Professional/Technical

Proposal Title: *10(b) Advancing Utilization of Manure Methane Digester Electrical Generation*

Project Manager Name: *Paul Burns*

Total LCMR Requested Dollars: $ *221,000*
Minnesota Project Request: $7,500

2003 LCMR Proposal Budget	Result 1 Budget: Evaluating the Feasibility of Fuel Cell/Microturbine Technology	Result 1: Budget	Result 1: Funds Spent	Total Project Balance (Result 1): June 30, 2005
BUDGET ITEM				
PERSONNEL: Project Investigator Ms. Amanda Bilek, The Minnesota Project	~~$ 6,100.00~~	$ 5,250.00	$ 5,248.78	$ 1.22
PERSONNEL: Staff benefits –				
Contracts				
Professional/technical: University of Minnesota Biosystems and Agricultural Engineering Department				
Professional/technical: Livestock Producer				
Professional/technical: The Minnesota Project				
Space rental: NOT ALLOWED	X			
Other direct operating costs				
Equipment / Tools:				
Office equipment & computers				
Other Capital equipment				
Land acquisition				
Land rights acquisition				
Printing	~~$ 250.00~~	$ 1,000.00	$ 1,000.00	$ -
Advertising				
Communications, telephone, mail, etc. (Web Development)	~~$ 375.00~~	$ 375.00	$ 375.00	$ -
Communications, telephone, mail, etc. (Telephone)	~~$ 375.00~~	$ 375.00	$ 375.00	$ -
Office Supplies	~~$ 200.00~~	$ 200.00	$ 200.00	$ -
Other Supplies				
Travel expenses in Minnesota	~~$ 200.00~~	$ 300.00	$ 300.00	$ -
Travel outside Minnesota				
Construction				
Other land improvement				
Other				
COLUMN TOTAL	~~$ 7,500.00~~	$ 7,500.00	$ 7,498.78	$ 1.22

Attachment A: Budget Detail for 2003 Projects - Dennis Haubenschild/Farmer (S

Proposal Title: *10(b) Advancing Utilization of Manure Methane Digester Electrical Generation*

Project Manager Name: *Paul Burns*

LCMR Requested Dollars: $ *221,000*
Dennis Haubenschild/Farmer
Request: $9,125

2003 LCMR Proposal Budget	Result 1 Budget: Evaluating the Feasibility of Fuel Cell/Microturbine Technology	Result 1: Funds Spent	Result 1 Balance: June 30, 2005
BUDGET ITEM			
PERSONNEL: Staff Expenses, wages, salaries – Dennis Haubenschild or other farmer for operation and maintence of on-farm fuel cell co-located with a manure digester. Time will .5 hr/day maintence for 1 year (365 days) at $50/hr	$ 9,125.00	$ 9,125.00	$ -
PERSONNEL: Staff benefits –			
Contracts			
Space rental: NOT ALLOWED	X		
Other direct operating costs			
Equipment / Tools			
Office equipment & computers			
Other Capital equipment			
Land acquisition			
Land rights acquisition			
Printing			
Advertising			
Communications, telephone, mail, etc.			
Office Supplies			
Other Supplies			
Travel expenses in Minnesota			
Travel outside Minnesota			
Construction			
Other land improvement			
Other			
COLUMN TOTAL	$ 9,125.00	$ 9,125.00	$ -