Date of Report: September 6, 2007

LCMR Final Work Program Report

I. PROJECT TITLE: 10(c) Manure Methane Digester Compatible Wastes and Electrical Generation

Total Biennial Project Budget:

LCMR Appropriation:	**Amount Spent:**	**Balance:**
$100,000	$ 94,604.89	$ 5,395.11

Other Funds: None
Funding Priority: Energy

Project Manager: Paul Burns
Affiliation: Minnesota Department of Agriculture, Agricultural Development and Financial Assistance Division (ADFA)
Mailing Address: 625 Robert Street North, St. Paul, MN 55155-2538

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Legal Citation: ML 2005, First SS, Ch. 1, Art. 2, Sect 11, sub 10(c)

Appropriation Language: 10(C) $50,000 the first year and $50,000 the second year are from the trust fund to the commissioner of agriculture to research the potential for a centrally located, multifarm manure digester and the potential use of compatible waste streams with manure digesters.

Overall Project Outcome and Results

Experience and research indicates the potential for a centrally located, multifarm manure digester and the potential use of compatible waste streams with manure digesters.

The advantage of central anaerobic digesters in terms of their larger size relative to farm scale digesters comes from their ability to process other organic wastes in addition to dairy, swine, or poultry manure. Central anaerobic digesters are able to process compatible waste streams.

Central anaerobic digesters overall appear to have the most potential for economic feasibility where:

- nuisance odors require action;
- offsite organic waste is available which can be co-digested to increase gas output and/or generate tipping fees;
- the manure solids are separated and have a high value for dairy cow bedding or as a soil amendment;
- the biogas can replace large onsite retail purchases of electricity or heat; or
- the electricity is sold to the grid in a region of the U.S. with higher-than-average electricity prices.

Central anaerobic digesters can be owned by farmers or consumers cooperatives, third party/non-farming investor(s), state or municipal government, or established as a cooperative or limited liability corporation.

Challenges unique to centralized digesters include:

- organizing the group of farms, reaching consensus and commitment to the project, and providing a mechanism for farms to leave the group,
- sanitary issues involved in transporting manure between farms, and
- the capital investment and operating costs for the manure transportation equipment and loading/unloading facilities.

Project Results Use and Dissemination

Results were disseminated at two workshops for producers and researchers.

Results will be made available to producers, producer groups, agri-businesses and researchers interested in central anaerobic digesters.

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II. and III. FINAL PROJECT SUMMARY:

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Results were disseminated at two workshops for producers and researchers.

Results will be made available to producers, producer groups, agri-businesses and researchers interested in central anaerobic digesters.

IV. OUTLINE OF PROJECT RESULTS:

Result 1: Evaluate the potential for either a centrally located digester or electrical generating facility.

The primary goals of the project were: 1) to determine the potential for a centrally located, multi-farm digester; and 2) to determine the potential use of compatible waste streams with manure digesters. The goals of Result 1 were accomplished through the following:

- Preparing a literature review, supplemented with an annotated bibliography and directory of designer and installers of central anaerobic digester
- Development of a user-friendly economic model for analyzing digester installations;
- Updating the manure digester economic feasibility spreadsheet;
- Preparing a white paper on the potential policy implications of implementing multiple farm manure digesters and co-digesting manure with other waste streams; and
- Conducting two workshops for producers, U of M and state agency staff on the results of the project.

The Literature Review

The main task of the project was to prepare a literature review (Attachment B) of the economic and technical feasibility of centralized or multiple farm manure digesters. The primary objective of literature review in the area of central anaerobic digesters was to facilitate their establishment in the state of Minnesota. More specific objectives include: 1) describing the types of digesters that might be suitable at central locations in Minnesota; 2) suggesting different forms of ownership that could alleviate the burden and risk to individual farmers; 3) indicating the type of problems that could be faced when executing a central anaerobic digester project; and, 4) demonstrating to local, state, and federal decision-makers the multiple benefits of central anaerobic digesters as a basis for informed policy discussions.

A comparison was made between Minnesota and Denmark due to the many similarities between the two entities. Denmark serves as a role model for Minnesota in the number of central anaerobic digesters that it supports while Minnesota has none even though in terms of livestock and other organic waste production Minnesota has a similar potential to benefit from the development of central anaerobic digesters.

The works discussed in the literature review suggest that the following items will increase the likelihood of the success of central anaerobic digesters in Minnesota:

1) A sufficient density of cow manure or other organic material is available;
2) Motivation for farmers to participate in central anaerobic digesters from both a financial and a societal point of view;
3) Accurate estimates of the costs of transporting the manure or other organic wastes are present, as transportation will constitute a sizable cost in the life of a central anaerobic digester;
4) Public sector support of central anaerobic digester facilities by federal, state, and local governments is present due to the recognition of external benefits such as environmental, health, "infant industry" arguments, differences between individual and social discount rates, and energy security;
5) Power purchase agreement terms and conditions negotiated with utility companies for electricity or gas generated for sale by central anaerobic digesters is supportive of financial success.

Co-generation using manure and other feedstocks can produce more energy than manure alone. Additionally, there are important food processing sub-sectors that can significantly contribute to co-generation of wastes in Minnesota, however, further study is needed to determine the economic feasibility. The potato and sugar beet processing industries can supply spoiled and rejected raw material, substandard output, and wastewater to central anaerobic digesters depending on the

feasibility of transportation. Organic wastes from dairy processing plants, meat processing and rendering facilities, catering, institutional and domestic kitchens, and restaurants are also potentially useful. Fats and oils have been identified as having high potential for addition to digesters and several digesters of Danish design in the United States are adding up to 10 percent oil to the animal manure to increase the gas output. Other sources include by-products from the developing ethanol industry, crop residues, paper mill processing wastes and even crops grown directly for energy such as corn silage or grain sorghum.

Review of costs and benefits associated with central digestion suggest that it may be difficult to infer future costs and benefits from literature values because of the wide variation and changing market conditions. Costs of manure transport to the central digester and the spent material back to the land were especially difficult to calculate.

Since central anaerobic digesters are more likely to process non-farm organic wastes they benefit other sectors of the economy. But the cost involved in transporting influent and effluent is an inherent disadvantage in the establishment of central anaerobic digesters.

Central anaerobic digesters can be set up under several ownership arrangements. They can be owned by farmers or consumers cooperatives, third party/non-farming investor(s), state or municipal government, or established as a cooperative or limited liability corporation. Currently the cost of establishing and operating central anaerobic digesters on a cash basis is high compared to their monetary returns. However, assigning monetary value for all external benefits of central digestion plants would likely result in total long-term benefits equal or greater than the costs incurred in construction and operation.

Problems associated with centralized digester operation include capital constraints, low profitability, lower-than-expected waste availability, electricity connection and pricing, and waste disposal constraints. Local, federal, and state government policy instruments that can influence the establishment, operation, and profitability of central anaerobic digesters include investment policies and grants towards initial investment allowing farmers and other investors to pass the initial hurdle of acquiring the critical level of investment; tax and subsidy policies that encourage the establishment of central anaerobic digesters and their economic feasibility; electricity connection and pricing policies that will attract new investors; support for farmer and consumer cooperatives to establish new digester generator systems; and waste disposal and environmental policies that will induce farmers and processing plants to seek anaerobic digestion as a remedy.

Waste disposal and environmental policies that encourage the establishment of central anaerobic digesters are the most frequently suggested policies in the literature. There is a wide variety in purpose and in form of these policies. Some initiatives started out to reduce greenhouse gas emissions; others started from a decision to recycle a specific amount of organic wastes by a given time; and, yet others, to protect water resources, the environment, and the public from undesirable aspects of dairy farming.

The Annotated Bibliography of References

Also prepared was an annotated bibliography (Attachment C) covering a wide range of references that were used to compile the literature review on centralized digesters. The references include research publications, reports from projects, personal communications from experts in the field and popular press reports. The significance of the reference to the report was indicated and the character of the report was also indicated so that the reader may make inferences as to the quality of the material contained in the reference. References were from a range of time periods and from both national and international sources.

An Updated Directory of Designers and Installers

An updated directory of central anaerobic digesters designers and installers was compiled (Attachment D). Contacts with engineering firms and industry officials were made to provide a list that could be used by individuals interested in learning more about anaerobic digestion for multiple farm digesters and/or multiple substrates for co-digestion.

Experienced design firms and independent developers both in the U.S. and Europe were contacted. Suggestions from these firms lead to an expanded group of firms to contact. The authors William Lazarus and Philip Goodrich made contacts at

professional meetings, at trade shows, through email, by telephone and by personal visits to research sites and digester sites in Minnesota, Wisconsin, New York, California, in Denmark, Sweden, and Germany.

The list as compiled by Philip Goodrich includes firms that the author would use as a starting place for developing a project that includes a multiple farm digester and co-digestion of energy products. The list may not include all qualified firms, but those that the author's experience and research criteria seemed best for Minnesota. Others are on self-contributed lists at AgSTAR (http://www.epa.gov/agstar/tech/consultants.html). The lists are not always up to date however.

The main criteria used in compiling this list included:

1. The firm has on farm digesters that have been completed and working;
2. The firm has the capabilities of working in cold climates;
3. The firm has the capabilities to provide after construction support for the project; and
4. The authors were able to determine that a US office exists for the firm.

Specific information that was learned during contacts with experienced designers is summarized below.

Before a project is committed to any engineering firm, it is the responsibility of the project manager to determine the current capabilities of the firm to successfully complete the project based on past performance, current economic conditions, and current personnel employed. Note, however, that there are not a large number of experienced engineers in the field.

If the digester contemplated is a large multi-input digester utilizing materials other than manure, there are a number of items that must be considered that are not usually a problem with a single farm manure digester.

1. The materials may contribute to health concerns for the farmers who are receiving the effluent from the digester. High temperature post processing of the effluent may be needed to satisfy security concerns.
2. The nature of the digester may lead to extensive environmental studies being required and hearings being held to satisfy neighbors concerned about added traffic, health concerns and materials being added to the local environment.
3. Permits from multiple regulatory bodies may be necessary if cross-jurisdictional issues arise.
4. The markets may change considerably over time and the financial projections may significantly change due to externalities that are difficult to foresee.
5. The financial inputs will be larger and a broader base of funding may be necessary for the project to succeed.
6. Strict control over the inputs from various sources will be needed to insure that toxic or dangerous materials do not enter the digester.
7. Detailed operational plans for emergencies, accidents, terrorism and extreme weather conditions need to be part of the plant manuals that are developed within the project scope.
8. Plans for adequate staffing of the plant with trained and qualified personnel are very important to the continued operation of the plant.

A White Paper on the Potential Policy Implications

A white paper on the potential policy implications of implementing multiple farm manure digesters and co-digesting manure with other waste streams was also prepared (Attachment E).

This is a short paper addressing policy implications and needs for implementing multiple farm digesters and co-digestion of manure with other sources that can be used as talking points for interested groups.

Farm-based digesters are a multi-faceted technology that offers a range of benefits. However, as a standalone electricity-supplying technology for individual farms or groups of farms, the farm-based digester has struggled in Minnesota and elsewhere in the U.S. due to generally marginal profitability.

A number of policies that may be beneficial are presented including some that are monetary incentives, some that change the relationship between regulated industries and independent producers of energy and biological products, and some that encourage the use of non-fossil fuels to reduce greenhouse gases while increasing sustainability.

No one policy will solve all the problems that are holding back the production of renewable energy from organic materials in Minnesota. A wide range of policy change opportunities exist that will allow Minnesota to achieve the goals of "20 by 2020" ahead of schedule.

Production of renewable energy by digestion uses no fossil fuel in the process. This highly efficient low input system utilizes waste materials which otherwise may be treated using fossil fuels. Developing this resource in rural Minnesota is a win-win situation for renewable energy, improving the environment, and maintaining sustainable communities.

The Manure digester Economic Feasibility Spreadsheet

The manure digester economic feasibility spreadsheet (on enclosed CD) developed by Dr. Lazarus has been updated to reflect inflation and new economic grant and loan programs that are available to assist farmers in putting in digestion systems.

This model was developed originally for use in preparing educational fact sheets on the Haubenschild digester, and then used for the Review of Agricultural Economics journal article cited in the literature review. The main updating done for this LCMR project was to add an expense line item for manure transportation, and to update the digester capital investment and the other prices to projected 2007 levels. The manure digester economic feasibility spreadsheet was used for the economic modeling of the centralized digester concept. A simpler, user-friendly economic model (discussed on page 6) was also developed and implemented as a spreadsheet, but it was not available when the economic modeling (manure digester economic feasibility spreadsheet) was done.

The modifications to the manure digester economic feasibility spreadsheet included updating the digester installation costs and adding a cost line item for the cost of the manure transportation required for the centralized digester. While adding the annual manure transportation cost was a relatively minor change to the spreadsheet structure, arriving at the manure transportation cost itself was an involved calculation carried out in a modified version of MACHDATA.XLS, downloadable at http://www.apec.umn.edu/faculty/wlazarus/machinery.html, which was originally developed for updating the extension machinery cost publication. The process was to visit Stearns County and decide on the farm sizes and the dairy herd-to-digester distances that would be analyzed – 1, 2, and 3 miles one-way. Road travel speeds and loading/unloading times were decided on in collaboration with the University of Minnesota. Collaboration considered load sizes, the number of loads, and a travel schedule to make sure one tractor and tank manure applicator would be able to complete the hauling during the time available in addition to the usual task of spreading the manure on the cropland of the farms. The MACHDATA.XLS spreadsheet uses formulas for economic depreciation and repairs that are published in the American Biological and Agricultural Engineers' Standards publication. Those formulas are based on an assumed useful life for a given machine, which can be varied to arrive at an approximate optimal combination of repairs and depreciation. A simulation over a range of machinery life spans was carried out to determine how much more frequently the tractor and tank would need to be replaced and the additional costs involved when the manure transportation activity is added. The final machinery cost assumptions we arrived at are described in the economic modeling report.

The manure digester economic feasibility spreadsheet is an annual discounted cash flow capital budgeting model. Given the high failure rates that have been experienced by older on-farm digesters, the planning horizon for the analysis was limited to ten years with a zero value even though some digesters have operated over longer life spans. The spreadsheet formulas are set up with space to expand the planning horizon to twenty years if desired. The model is set up with the capability to enter either actual historical data or projections, because the farm we worked with had data on actual operating costs, sales of electricity and digested manure or digestate, and avoided heating costs for 1999-2004. The second five years of the analysis were then projected based on averages with inflation adjustments.

As an annual discounted cash flow model, the spreadsheet is relatively complex but factors in several important considerations that simpler models ignore: inflation, leverage effects, and income taxes. The results are expressed in a number of different

measures that may be appealing to different users, such as payback period, breakeven electricity price, net present value (along with the annualized equivalent), rates of return on assets and equity, and impact on milk production cost. One unique aspect of the model is that it calculates the present value of the various operating subsidies along with the construction grants to clearly show how much of the profitability situation is due to market returns and how much is from subsidies.

A User-friendly Economic Model for Analyzing Digester Installations
A user-friendly economic model for analyzing digester installations on dairy farms was developed in an Excel spreadsheet (on enclosed CD). The model is intended to help users make rough initial calculations of the annual costs and returns to be expected from owning and operating a methane digester on a dairy farm. The model is readily usable to analyze the feasibility of multiple farm digesters.

The main issues the model addresses include: herd size, digester installation cost, amount and value of any electricity generated, co-product value, and public support. It is not intended to address the engineering or design issues, and particularly the amount of biogas output to be expected.

Workshops
Two workshops were conducted with farmers, U of M, and state agency staff to disseminate the results of the project and to present the User-Friendly Economic Model Analyzing Digester Installations. One workshop was presented using Internet "Breeze" to conduct the workshop over the Internet. It was planned that the Internet workshop would allow more people to participate and involve much less cost to participants. This was not very successful because of technical difficulties with the equipment and lack of support from the lab providing the base for the workshop. A second workshop where the participants were in the same room with the presenter gained more participation from farmers, extension staff, government and state agency staff.

Publications
The main publication from this project is the literature review that will be published in an economic or an engineering journal within the next year.

MDA Student Worker
The MDA hired one student work for the summer of 2006 to assist in meeting the goals and objectives of this LCMR project by developing educational materials and assist U of M staff with this LCMR project. Originally, the student was going to assist the MN Project with the LCMR project ***Dairy Digester;*** however, the ***Dairy Digester*** project was delayed and then extended by one year, and no longer needed the help of the student worker.

During the summer of 2006, the student worker worked on a PowerPoint presentation and short video presentations on manure digestion and centralized manure digesters. The student worker also interviewed a number of officials and leaders in government, academia, and private industry to get their feedback on the use of centralized digester systems and the use of multiple waste steams co-digested with manure.

Work objectives that were completed include:

- **Interviews with Government and Academic Officials**: The student worker conducted a series of phone and face-to-face interviews with government officials involved with energy and agricultural policy and also with academic researchers working with anaerobic manure digestion. All of the information from the interviews was inputted into a MS Access database for further dissemination. The student worker report and summary of the information is in Attachment F.
- **PowerPoint Presentation**: The student worker developed a PowerPoint presentation for MDA and University staff to use on anaerobic manure digestion. The presentation has been posted on the MDA website at http://www.mda.state.mn.us/renewable/waste/default.htm See Attachment G for a copy of the presentation.
- **Video Presentations**: The student worker developed two short video presentations for the LCMR project. These presentations were developed to help explain how anaerobic manure digestion works to a general audience. The student worker also developed a video presentation to disseminate the results of a past MDA LCMR project

involving a fuel cell running off of biogas from an anaerobic manure digester. The presentation has been posted on the MDA website at http://www.mda.state.mn.us/renewable/waste/default.htm

- **Farmfest 2006**: The student worker helped staff the MDA booth at Farmfest 2006 in Redwood County. Farmfest is a regional farm show event and typically 40,000 farmers attend this event every year. The MDA had a display on the LCMR project and the student worker helped answer questions and provide information about the objectives of this LCMR project.
- **Information Gathering**: The student worker helped MDA staff in gathering new information on centralized systems for anaerobic manure digestion. This information was used by the student worker, U of M, and MDA staff in developing work products for the LCMR project.

Remaining Balances and Budget Adjustment

The overall project had a budget balance of $5395.11. Originally, $10,000.00 was budgeted for the student worker, however, because the MN Project LCMR project ***Dairy Digesters*** was delayed and then extended by one year, the student worker was not needed, which resulted in a balance of $5379.17. There was also a balance of $15.94 remaining from the $90,000.00 budgeted for the University of Minnesota.

Budget Adjustment Explained:

The $90,000 budget to the University of Minnesota was adjusted to reflect payment for editing services and the higher salary and fringe benefits of University personnel. The details are as described as follows:

- On July 13, 2007, the contractor requested to use "Printing" and "Supplies" budget funds to pay for editing services. An editor was hired to proofread the literature review. In a telephone conversation with LCMR staff, Susan Thornton on the same date, Ms. Thornton recommended the overall budget summary include a budget adjustment column reflecting the revisions rather than submitting a budget amendment at the late date. Funds from "Printing" and "Supplies" were moved to "Other" to pay for the editing services.
- "PERSONNEL: Staff Expenses, wages, salaries" exceeded the original budget by $179.07 as a result of a change in a University of Minnesota employee classification which was paid a higher salary than the previous employee working on the project.
- "PERSONNEL: Staff benefits"exceeded the original budget by $2,688.21 as a result of a change in a University of Minnesota employee classification in a higher salary and fringe benefit classification.

The exceedances in Personnel budget items were discovered by MDA upon review of the final invoice from the University of Minnesota. Some funds from "Supplies" and "Travel expenses in Minnesota" were moved to the Personnel budget items to cover the additional costs.

V. TOTAL LCMR PROJECT BUDGET

All Results: Personnel:	$85,000	Revised: $87,867.28
All Results: Other:	$15,000	$12,132.72
TOTAL BUDGET:	$100,000	$100,000.00

Personnel: Total of $87,867.28: 1) $10,000 for a student intern hired by the MDA to assist in information gathering, report development, and outreach efforts related to the project. The intern was actively enrolled in an accredited University or College and accrued academic credit for her work. 2) $77,867.28 for U of M Biosystems and Agricultural Department Staff to conduct the work needed to fulfill the objectives of the project. **Other:** *(Specify)* $ 12,132.72 for supplies, printing, and travel expenses for the U of M Biosystems and Agricultural Engineering Department to assist with completing the objectives of the project.

VI. PAST, PRESENT AND FUTURE SPENDING: