Minnesota's Potential for Electricity Production Using Manure Biogas Resources

Final Report

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Executive Summary

Minnesota is ranked seventh nationally in dairy and dairy products and second in swine operations. The livestock industry could be a source for renewable energy using anaerobic methane digesters while responsibly managing the waste stream. Electricity and process heat could be used on the farm, while excess electricity could be sold to the local electric utility.

This report is a basic assessment of the feasibility and potential for using animal wastes in anaerobic methane digesters to create electricity in Minnesota. Anaerobic methane digesters use bacteria to break partially break down animal wastes, creating methane, which can be used for making electricity.

More specifically the report aims to:

- estimate the electricity potential for the state using anaerobic methane digesters;
- calculate the farm-size thresholds that warrant further investigation for a potential digester system; and
- quantify the impact of various incentives on these farm-size thresholds.

Anaerobic digesters and methane capture are also appropriate for processing industrial wastes, such as food waste or waste-water treatment facilities, but this report is limited to dairy and swine manures only.

Theoretically, if all the dairy and swine manure resources in the state could be utilized, 911,725 MWh of electricity could be produced, or approximately 116 MW of installed capacity (90% capacity factor). Based on economic and technical barriers, the actual utilization will be significantly lower, perhaps on the order of a few megawatts over the next ten years. The southeastern and central portions of Minnesota show the greatest potential for development.

The report used specific financial assumptions in assessing financial feasibility; however, the assumptions used here could vary greatly from farm to farm. General economic factors of a manure digester system include[1]:

- Capital costs for equipment;
- Cost of financing the project;
- Annual operating costs;
- The net production of biogas, electricity, and waste heat;
- Electrical and space heating needs on the farm;
- Amount and disposal of solid effluent;
- The opportunity to sell fuel and electricity;
- Cost saving from bedding material;
- Depreciation;
- Tax credits and tax rate;
- Implicit cost of pollution control; and
- Internal rate of return.

Not all assumptions were used in this analysis and variations in these assumptions will differ from farm to farm.

Two measures of economic valuation were used: financial feasibility and simple payback of less than ten years. *Financial feasibility* is defined as having the annual benefits of energy production and incentives exceed the annual costs of operations, maintenance, and loan repayment. A second measure of potential is through the calculation of a *simple payback of less than ten years*, i.e. total costs divided by annual benefits. Farms that meet this threshold may not be deemed financially feasible based on this report's assumptions, but warrant further investigation under the specific assumptions of a particular farm.

The report found that current digester economics limit financial feasibility to dairy farms greater than 800 cows (simple payback: 500 cows). Swine farms did not show current economic feasibility up to 12,000 swine using a complete mix digester. A more economic option for swine farms that needs further investigation is capturing methane in an anaerobic storage lagoon and using the biogas for heating applications only (space, hot water, process, etc), rather than electricity and heat. The costs of such a system are significantly reduced, while capturing some energy benefit and maximizing odor and manure containment capabilities.

Seven dairy farms exceed 1,000 cows and twenty swine farms exceed 10,000 pigs in Minnesota in 2001, indicating limited potential under current economic assumptions. However, in the case of dairy farms, this farm size limitation decreases significantly with various incentive scenarios. In the case of swine farms, incentives did not permit positive cash-flows or simple paybacks less than 10 years.

In the case of dairy farms, an analysis of incentive levels shows economic feasibility could expand to farms with minimum herd sizes of just over 300 cows with a 0% loan program or a 2.0 cent/kilowatt-hour (¢/kWh) federal tax credit (simple payback: 250 cows). A federal tax credit, similar to the federal wind production tax credit, would mirror the existing state incentive for digesters of 1.5 cents/kwh. A $500 per kilowatt ($/kW) rebate reduced the threshold to farm sizes of just over 500 cows (simple payback: 400 cows).

Every intent was made to use reasonable assumptions in modeling but caution should be exercised in using these numbers in broad applications. They should instead be used as a guide for farmers deciding whether to further investigate a digester system and/or decision-makers deciding what, if any, incentives are appropriate.

Additional barriers to further manure digester development include:

- Inability for a digester system, or broad economic modeling such as those used in this report, to capture or quantify all of the monetary benefits, such as odor abatement or enhanced fertilizer value of the effluent;
- Time investment required by the farmer during design, installation, and maintenance; and
- Initial digester costs likely requiring additional loans for the farm.

Possible opportunities for overcoming barriers:

- Advances in digester technology, such as the anaerobic pump, or decreases in digester costs, such as using composite materials for the digester tank;
- Leasing the manure as a resource to an independent energy company who develops an on-site digester, similar to the concept of leasing your land to a wind turbine developer;

- Combining manure and financial resources of multiple farms within a very close proximity in a centrally located plant;
- An on-farm digester accepting food or other suitable wastes from nearby food processing facilities for a competitive tipping fee; or
- Regulatory streamlining for new or increased-size farms installing anaerobic methane digesters.

1. Background

The main objective of this report is to assess the overall electricity potential of biogas resources in Minnesota. More specific objectives are to:

- estimate the electricity potential for the state using anaerobic methane digesters;
- calculate the farm-size thresholds that warrant further investigation for a potential digester system; and
- quantify the impact of various incentives on these farm-size thresholds.

Dairy farms and other livestock confinement facilities that generate large quantities of animal waste have been under increasing pressure to manage their manure in an effort to control and prevent air and water pollution. If handled properly, soil fertility can be enhanced by the organic material and fertilizer nutrients contained in animal waste. The potential for extracting biogas from what is generally considered a waste-stream has gained increased attention in recent years, in large part due to the successful Haubenschild digester system near Princeton, MN[•].

[•] A full-report on the Haubenschild's Farm digester is available from the Minnesota Project at www.mnproject.org.

2. Digester Technology

Anaerobic digestion is the process where complex organic molecules are degraded, producing methane gas (CH_4), carbon dioxide (CO_2), and trace gases. These gases are produced from livestock waste, food processing, and occur naturally in swamps, wetlands, lake sediments and in the gastrointestinal tract of ruminant animals[2,3]. There are approximately 31 farm based anaerobic digestion systems (ADS) operating in the United States, 15 of which are swine, 14 dairy, and 2 fowl[4]. Biogas is extracted from the manure on these farms and converted to electrical and/or thermal energy using an ADS. Biogas generally contains 60-80% methane, or 600-800 Btu/ft^3**,** which is then utilized directly as a heat source or to produce electricity[5]. A rule of thumb is that 10 dairy cows are required to power a 1 kW-generator using a plug flow or slurry-loop digester[6].

Biogas technology using anaerobic digestion systems (ADS) can be a cost-, environmental-, and neighbor-effective alternative to existing manure management strategies, if the direct and indirect benefits can be captured. By managing waste using ADS systems, there is significant reduction in biological oxygen demand (BOD), pathogens, and removal of various odor components of manure. Odor from feedlots has been the focus behind local ordinances to control feedlot expansion in Minnesota[7,8].

Important factors that must be considered in biogas production include:

- the biodegradable content of the organic material;
- digester size;
- retention time of the digester; and
- the operating temperature.

The type of digesters and time used for treating waste varies by climate, technology, and manure type. In Minnesota, due the cold winters, anaerobic lagoons are not recommended. The processing of the waste in anaerobic digesters requires temperature ranges of 35 to 40 degree

Celsius and 55 to 60 degree Celsius for bacterial growth[9]. Potential on-farm digesters applicable to this climate are:

- Covered continuous stirred tank reactor (CSTR) lagoons which have very 'slow-rate' of treatment (4-6 months to fully treat livestock waste);
- Plug flow digester that takes 15-25 days to effectively treat the waste;
- Complete mix digesters which also takes 15–20 days to treat the waste; and
- Anaerobic pump digester, a new technology with the potential to more completely accomplish the anaerobic digestion process in a shorter timeframe (no field operation experience to date however).

Storing biogas for later use is generally limited due to high costs, although the biogas can be used to heat water, which can then be stored to some extent for later use. Stored digester gas must be compressed because of its low energy content per cubic foot (25% that of propane gas)[10]. As a result, it is suggested that storing biogas for future use after gas generation is not economically feasible[11].

Summary of Benefits of Anaerobic Digesters:

- Waste Benefits
- Pathogen and/or weed seed reduction in effluent;
- Odor and fly control; and
- Production of enhanced nutrient fertilizers, soil amendments, compost, and animal bedding.

- Energy Benefits
- production and sale of electricity; and
- production and on-site use of heat.

- Environmental Benefits
- reduced carbon dioxide, hydrogen sulfide (H_2S), and methane emissions; and
- reduction of total oxygen demand (TOD), reducing the water-quality impact in the event of a spill.

3. Manure Management

Manure production from dairy farms is affected by several factors and is not only a function of the size of the herd but also[12]:

- animal weight;
- type and quantity of feed;
- type of confinement and management of manure;
- the time the manure spends in confinement; and
- foreign material collected with manure e.g. bedding material, waste feed etc.

Waste of different consistency requires different management techniques and also handling equipment. Agricultural waste may be in the form of liquid (> 95% moisture content), solid (≤ 75% moisture content), and semi-liquid (slurry) (between 75% and 95%). The total solid (TS) concentration of manure is one of the main characteristics that affect how the manure is handled[13]. Typically, the solid contents vary with the type of livestock and weight of animal within these groups. Estimates of the typical percentage solid weight content of cattle are 10-15% and swine 4-8%[14,15]. Typically for a plug flow digester the total solid concentration recommended is 11-14% whereas for a complete mix digester the recommended concentration of total solid is 3-10%[16,17]. Lower solid weight content and the addition of water in the facility cleaning process increases the volume of waste requiring management and thus increases the size and cost of the digester.

The use of an on-farm ADS requires a manure handling method that is compatible to the operation of the system. The use of water flushing for collection of manure is unsuitable for plug-flow digesters because the manure slurry will become too dilute. Sand used as bedding would be inappropriate because sand build-up will eventually clog the ADS necessitating a clean-out[18]. Haubenschild Farms incorporated in their manure management plan the use of a free-stall barn to facilitate expansion, which allowed easy scraping of the manure into a

collection pit without the use of water. Shredded newspaper from the local recycling facility was used as bedding and scraped three times per day along with the manure into the collection pit[19].

A digester is sized based on the amount of daily waste intended to be processed and the number of days the manure resides in the digester, known as retention time. Given a fixed volume or weight of manure, dairy manure has a higher total solid content. This means that the more energy per unit, the less storage required. Table 1 shows a comparison of digester sizes for a fixed biogas output rates equivalent to 50 kW of generator capacity. Larger digester volumes require more materials and increase the installation cost proportionally.

Table 1: Comparison of Approximate Size of Digesters for Processing Dairy and Swine Waste in an Anaerobic Digester

Generator (kW)	Biogas Production (ft^3/day)	Dairy Digester Volume[a] (ft^3)	Swine Digester Volume[b] (ft^3)	Corresponding Number of Dairy / Swine
50	~28,000	17,758	118,867	450 / 4,850

[(a)] 20-day retention time, Plug Flow Digester, free stall barn
[(b)] 20-day retention time, Complete Mix Digester, pull plug below barn pit, finisher pigs
Source: U.S. EPA. 1997.

After passing through the digester the manure slurry is stored until it can be applied to the field. In addition to the valuable nutrients in livestock manure, this source also supplies organic matter (OM) to the soil. Organic matter aids in improvement of the soil resource by retaining more nutrients and water, reducing the impact of wind and water erosion, and promoting the growth of beneficial micro-organisms in the soil[20].

4. Farmware Software Program

The U.S. EPA created the AgSTAR program, a voluntary program designed to encourage the use of livestock manure as a source of energy, and created the Farmware software program to identify the energy production and cost for installing ADS on dairy and swine farms based on inputs for a specific farm[21]. The software program is limited by the inputs and the assumptions made in the programming. The assumptions for the various scenarios are listed in the Appendix. The Haubenschild Farm digester provides a case in point by comparing the estimates of Farmware, an ADS engineering consultant, and the actual results from the installation:

Table 2: Comparison of Estimates for the Haubenschild Farm Manure Digester

	Farmware	Engineer	Actual
Dairy Cows	1000	1000	750
Cost ($)	$277,502	$307,700	$355,000
Generator (kW)	112	120	135*
Electricity (kWh/yr)	837,675	766,500	1,080,000

* The generator is undersized for the amount of biogas being produced.

It appears that Farmware underestimates costs and electricity production to some extent, although the Haubenschild's experience may be atypical of other digester results since the consulting engineer based his estimates on results of other digester performance, adjusted for climate. Two hypotheses are: 1) that the additional newspaper bedding materials used on the Haubenschild farm increases the energy content of the manure and is not accounted for in Farmware; and 2) that the engine-generator availability (capacity factor) is much higher than predicted (99% vs. 90%). While the actual numbers discussed below may or may not be absolutely correct, they represent a starting point for a conservative analysis. For the purposes of this analysis, the costs and the electricity production have been increased by 10% to attempt to better reflect real-world experience.

5. Potential for Energy Production in Minnesota

Dairy Energy Potential

Total dairy cattle stock for the state is estimated to be 519,700 cows. Historically, the number of cows on dairy farms in Minnesota has been small and the State has the smallest average herd size among the major production states[22]. Data indicate that 99% of all dairy farms in Minnesota have a herd size of less than 300[23]. Figures 1 and 2 show the spatial distribution of farms in Minnesota with herd size less than 300 and greater than 300 cows, respectively. The largest concentration of farms is located in the central and southeastern region of Minnesota.

Historically the number of dairy cows on farms in Minnesota has been small and based on historical trends by the year 2008[24]:

- A decline from 80% to 40% for feedlots with less than 200 dairy cows; and
- An increase from 10% to over 30% in feedlots with 500-heads and greater.

As will be shown later, larger farms are more economically viable for digester systems, so these trends support the increased viability at more Minnesota farms.

Approximately two-thirds of the Minnesota dairy herd were housed in tie-stall barns and for feedlots larger than 150 cows, free-stall housing was dominant[25]. Free-stalls, which employ mechanical scraping for collecting manure, usually have 8-14% total solids as oppose to hydraulic flush collection which has only 1-2% solids in the manure collected[26]. A higher solid content results in more energy-potential per gallon, so scraping facilities are preferable for ADS.

Farmware estimates that the total utilization of statewide dairy manure would produce approximately 435,591 MWh/yr of electricity, or roughly 55.3 MW of generating capacity (90% capacity factor). The economically and technically feasible utilization of manure will be a fraction of this total potential, perhaps equalling a few megawatts. At the county level, the potential for electricity production using dairy cattle ranks Stearns, Otter Tail, and Winona

counties first, second and third, respectively. At the regional level, the districts with the highest potential for electricity production using cattle manure are Central, Southeast, and the West Central Region (Figure 3).

Swine Energy Potential

Minnesota has the second largest number of swine operations in the country. The state ranks behind Iowa with approximately 7,500 operations[27]. The total population of hogs statewide in 1999 (using operations with a minimum of 2,000 animals) was estimated to be 5,800,000. The hogs and pigs industry has seen a 19% increase in numbers since 1988[28]. Figures 4 and 5 show the spatial distribution of swine farms with less than and greater than 2,000 animals, respectively.

Farmware estimates the total utilization of statewide swine manure would produce approximately 476,134 MWh/yr of electricity, or roughly 60.4 MW of capacity (90% capacity factor). Based on the economic analysis presented later, the actual utilization of swine manure for electricity production will be very low, much less than that for dairy cows. Swine manure may be more appropriate for the simpler technique of capturing the methane for heat (water, space, etc) rather than for producing heat and electricity. The counties with the greatest potential for production from this source are, Martin, Blue Earth, and Nicollet. At the regional level, South Central, Southwest, and the Central region were ranked first, second and third, respectively, for electricity production (Figure 6). In the case of swine operations however, economics do not appear to make complete mix digesters an attractive option for managing manure waste. Covered anaerobic lagoons appear to be a better compromise between cost and energy production but further investigation is needed to determine its operation in Minnesota's cold climate.

6. Economic Feasibility of On-Farm Production of Electricity in Minnesota

Economic feasibility of producing electricity is dependent on the inputs in a cost-benefit analysis. The costs of an ADS include the capital cost of the digester tank, cover, generator, piping, and additional manure handling equipment, as well as operating expenses. The system includes both monetary and non-monetary benefits for the feedlot owner in the form of reduced electricity and space-heating bills, reduced cost of bedding, reduced labor cost with respect to manure handling, higher quality effluent for field treatment, and the benefit of selling excess electricity to the local utility. Non-monetary benefits include some odor reduction.

Economic factors of a manure digester system[29]:

- Capital costs for equipment;
- Cost of financing the project;
- Annual operating costs;
- The net production of biogas, electricity, and waste heat;
- Electrical and space heating needs on the farm;
- Amount and disposal of solid effluent;
- The opportunity to sell fuel and electricity;
- Cost saving from bedding material;
- Depreciation;
- Tax credits and tax rate;
- Implicit cost of pollution control; and
- Internal rate of return.

The Farmware software was used to determine the amount of electricity production and the cost of the digester system for both dairy and swine operations at various animal numbers. The Farmware calculated cost of the digester system was increased by 10% for contingencies. A spreadsheet was then employed to run a cost-benefit analysis using the following assumptions:

- Variable Costs (Operation & Maintenance): 1.0 ¢/kWh
- Variable Benefits:
  - Electricity: 3.294 ¢/kWh[30]
  - State Incentive: 1.5 ¢/kWh
  - Propane Offset: 5 gallons/cow/yr and 2 gallons/pig/yr at $1.00/gal
- Fixed Costs (loan): 10-year term, 20% downpayment, 8% loan

There are increased or additional benefits that may improve the economics but were not included in this analysis, such as:

- Increased utilization of waste heat for offsetting propane or natural gas use;
- Sale of digested material for compost;
- Accelerated depreciation; or
- Increased production of electricity above estimate (i.e. due to addition of materials to the manure effluent or increased engine availability).

It bears repeating that the farm-size thresholds should not be taken as absolute, but rather guidance in determining if further investigation is necessary. Farms that do not show financial feasibility but that do show simple-paybacks of less than ten years may become viable candidates if the specific circumstances differ from those used here.

The status quo scenario was then varied based on three types of incentives:

1. Low-interest loan (0%, 2%, 4%, 6%) from based rate of 8%;
2. Federal tax credit per kilowatt-hour (2.0 cents/kWh); and
3. Rebate per kilowatt of generator installed ($100, $200, $300, $400, $500).

Table 3: Dairy Manure Digester Farm Size Thesholds Under Various Incentives.

	Status Quo	0% Loan	2% Loan	4% Loan	6% Loan	2.0 ¢/kWh tax credit
Economic feasibility*	700	300	400	500	600	300
Simple Payback+	500	-	-	-	-	250

* Annual benefits exceed annual costs, including loan repayment.
\+ Total costs divided by annual benefits is less than 10-years.

Table 3: Dairy Manure Digester Farm Size Thesholds Under Various Incentives (cont'd)

	Status Quo	$100/kW	$200/kW	$300/kW	$400/kW	$500/kW
Economic feasibility*	700	700	600	600	500	500
Simple Payback+	500	500	500	400	400	400

* Annual benefits exceed annual costs, including loan repayment.
\+ Total costs divided by annual benefits is less than 10-years.

The 0% interest loan and the federal production tax credit have the greatest impact in reducing the minimum size of farm for economic viability from 700 to 300 cows, assuming the

full value of the tax credit can be realized. The tax credit also lowers the farm size from 700 to 250 for simple payback calculations. Simple payback calculations do not take interest rates into account. A $500/kW rebate reduces the threshold from 700 to 500 and 500 to 400 for the economic feasibility and the simple payback respectively. Under this analysis, the 0% interest loan and a federal tax credit reduce the farm size threshold by well over half, making digesters more economical on smaller farms.

7. Barriers and Solutions to Anaerobic Digesters in Minnesota

Broadly quantifying the costs and benefits of manure digesters is an inexact science – no one scenario fits all. Other potential benefits of a manure digester that weren't captured in this analysis include:

- Odor abatement, both during daily operations and field application of the digestate versus untreated manure;
- In the event of a storage breach, a reduced "toxicity" of the digestate to nearby water resources versus untreated manure;
- Enhanced nutrient value and/or reduced weed and pathogen in digestate versus untreated manure;
- Sales of digestate as compost; or
- Use of digestate fibers as animal bedding, offsetting costs.

In addition to benefits not included in the analysis, the time investment required by the farmer in designing, installing, and maintaining a digester system was not included. Constructing a digester requires the organization and skills of a general contractor. Maintaining the digester system, while not difficult or time-consuming, does need to be factored into the daily farm operations. Monitoring the system, changing the generator's oil every few months, and addressing problems as they arise are to be expected. Not all farmers have the time, energy, or skills to perform all of these functions, although the functions can be hired out. Additionally, many farmers are hesitant to take on additional loans for the installation of a digester system. While digester profitability can be achieved, it is not risk-free.

There are several options for overcoming these barriers that reduce the costs, increase the benefits, or can significantly influence the "go" or "no-go" decision for a digester system. Advances in digester technology, such as the anaerobic pump, can significantly increase the methane production over a shorter time period. Although the science is sound, the anaerobic pump has not been demonstrated on a commercial scale. The Department of Commerce is

working with a major Minnesota food manufacturer to organize the demonstration of this new technology, but the application on a farm site is a few years down the road.

A significant portion of the cost of a digester is for the materials used in the digester tank, such as concrete and steel rebar. The Haubenschild's digester used 12 inch concrete walls for their tank, an additional four inches of which were requested by the Minnesota Pollution Control Agency but not specified by the designing structural engineer[31]. The use of composite materials, such as fiberglass or recycled plastics, that maintain structural integrity at a reduced cost is an idea that has been floated in the "digester community" for several years but has not come to fruition. The digester tank is probably the only design area that has potential for reducing costs significantly.

The farm-size threshold could potentially be reduced by either combining the manure and financial resources of two or more farms within a very close proximity at a centrally located digester. Another option is to use the digester as a source for other acceptable waste disposal. A food processor, for example, may find that a digester system accepting the food wastes is cheaper than the hauling and tipping fees for conventional landfill disposal. The local waste-water treatment facility, perhaps in need of increased treatment capacity, could work with a local commercial or industrial facility to treat their wastes at a digester, delaying the need for expansion.

An interesting model for reducing the time and financial burden to a farmer is leasing the manure as a resource to an independent energy company or utility, similar to a farmer leasing his land for wind turbines. The company owns the generator and manages the system, paying the farmer a benefit based on the electricity produced. Alliant Energy began a pilot program in Wisconsin where farmers can choose a lower-risk/lower-return lease model and be paid 1.5

cents/kWh or go the traditional route of owning the entire facility and being paid 6 cents/kWh[32]. All of the farmers have taken the waste-lease option that carries low financial risk, even though the return is smaller.

Finally, the junction of animal farms and expanding residential areas is becoming increasingly common. Odor is most often the contentious issue. Existing farms likely have precedence over property rights, but new farms or farms that want to expand their facilities are facing opposition in some cases. If the local community, for whatever reason or method, is blocking the new farm or expansion, the inclusion of a digester may provide an amicable solution. While the digester may not have as short a payback as the farm would like, if the digester allows the expansion or new location, then its value is enhanced by more than just the energy it produces. Streamlining the regulatory process for farms that install anaerobic digesters may provide an additional benefit that adds evidence to the digester's value in a farm's future operations.

8. Conclusions

Looking at the big picture, dairy manure digesters have the potential to generate a few megawatts of electricity but the overall electricity supply impact will remain small. Currently, manure digesters hold the most promise for larger dairy facilities, while the addition of complimentary incentives reduces the threshold significantly. A reduction in the costs of the digester installation through improvements in technology or materials, would also reduce the farm size threshold but these are in the early stages of development. Further investigation is necessary to determine a feasible method of developing a swine manure digester that balances costs, manure management, and energy capture, since a complete mix digester does not appear to be a viable option for farms in Minnesota.

9. Acknowledgements

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Appendix A: Farmware Software Assumptions.

Dairy

- 100% manure collection for 519,000 dairy cows
- Free-stall barns, flush parlor/scrape the rest, anaerobic lagoon storage, solids separator, plug flow digester
- Stearns County average climate, default values
- All lactating cows, default weight and manure values
- Cow Residence Times: 4 hours parlor, 10 hours free stall barn, 8 hours feed apron, 2 hours dry lot

Swine

- 100% manure collection for 5,800,000 finisher pigs
- Finisher pigs, pull plug or cascade dam, anaerobic lagoon storage, complete mix digester
- Stearns County average climate, default values
- All finisher pigs, default weight and manure values
- Pig Residence Times: 24 hour confinement

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Appendix B: Figures 1-6.

Figure 1: Map of Minnesota Showing Spatial Distribution of Dairy Farms with Herd Size Less than 300 Cows

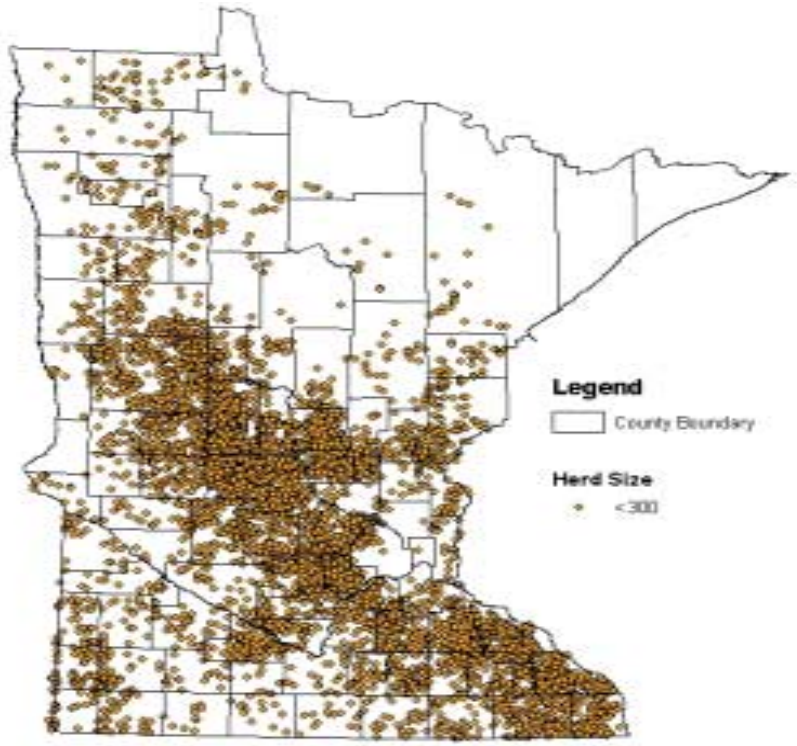


Figure 2: Map of Minnesota Showing Spatial Distribution of Dairy Farms with Herd Size Greater Than 300 Cows

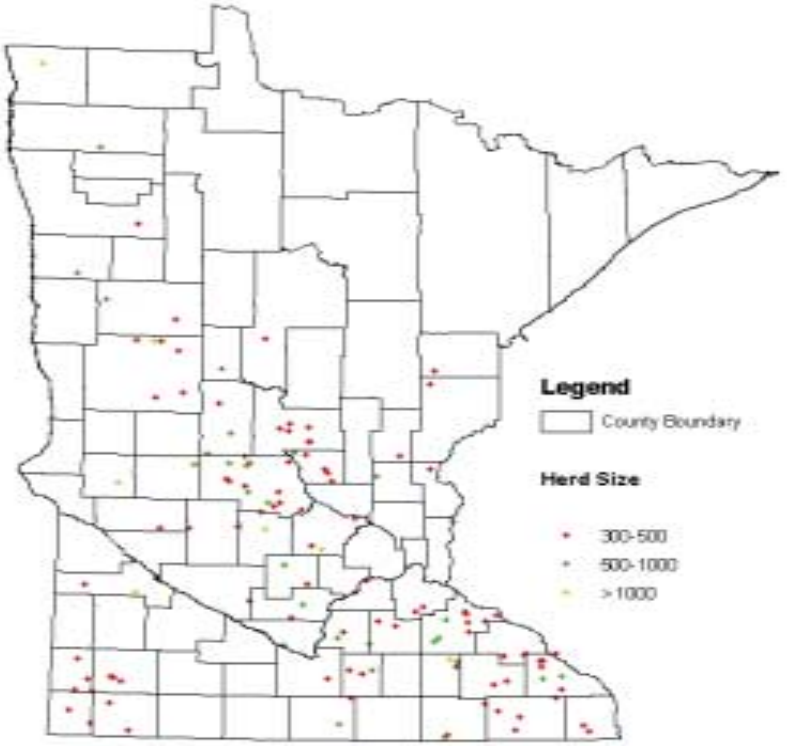


Figure 3: Minnesota Regional Potential for Electricity Production from Cattle Manure

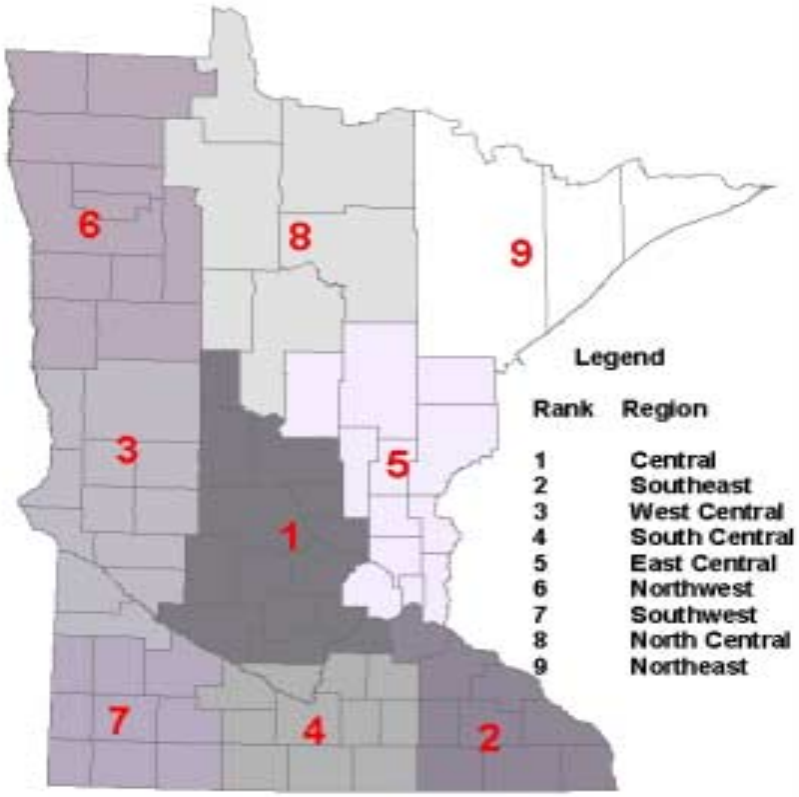


Figure 4: Map of Minnesota Showing Spatial Distribution of Swine Operation with Herd Size Less Than 2000

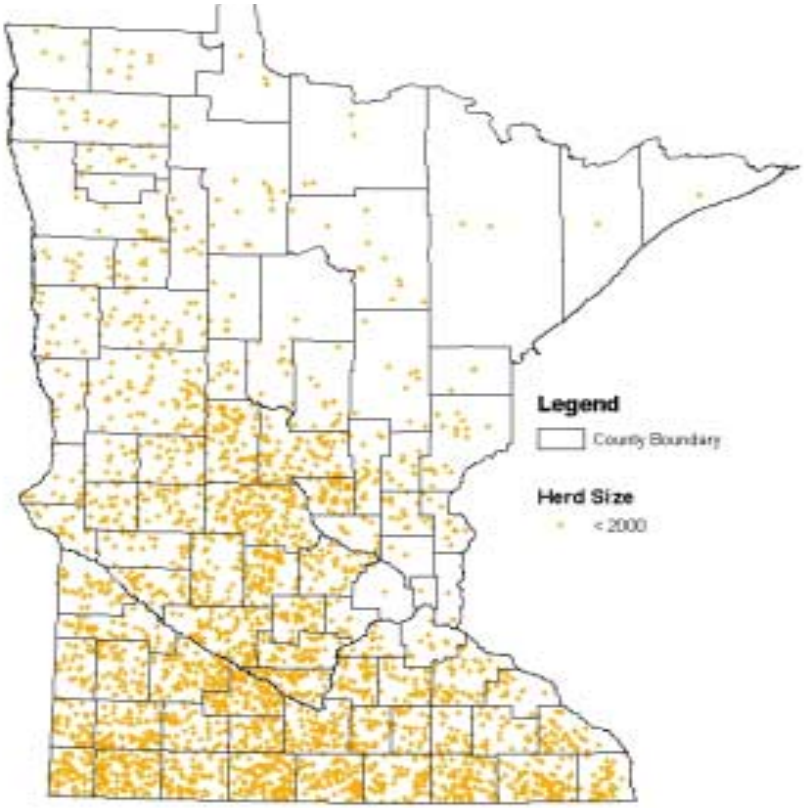


Figure 5: Map of Minnesota Showing Spatial Distribution of Swine Operation with Herd Size Greater Than 2000

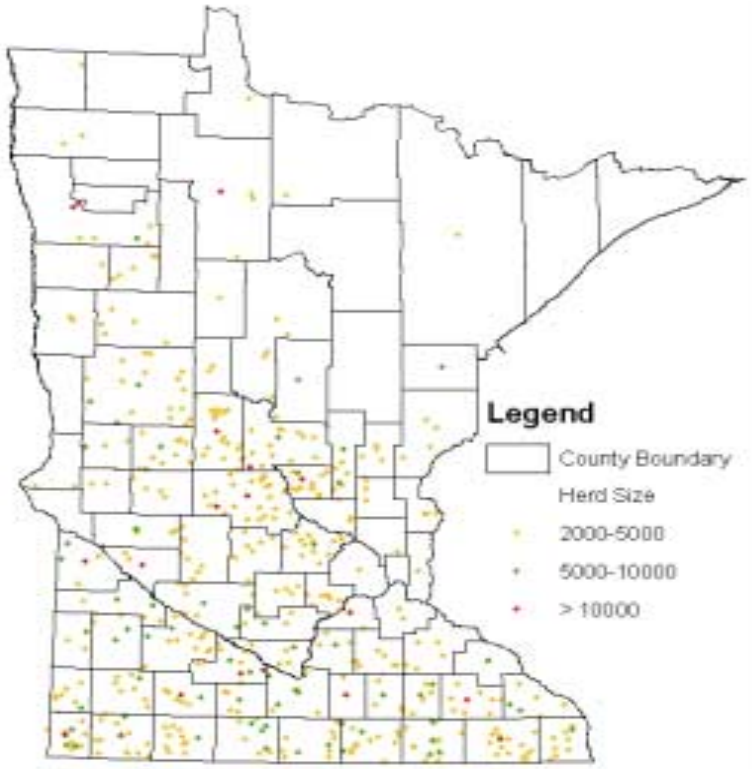
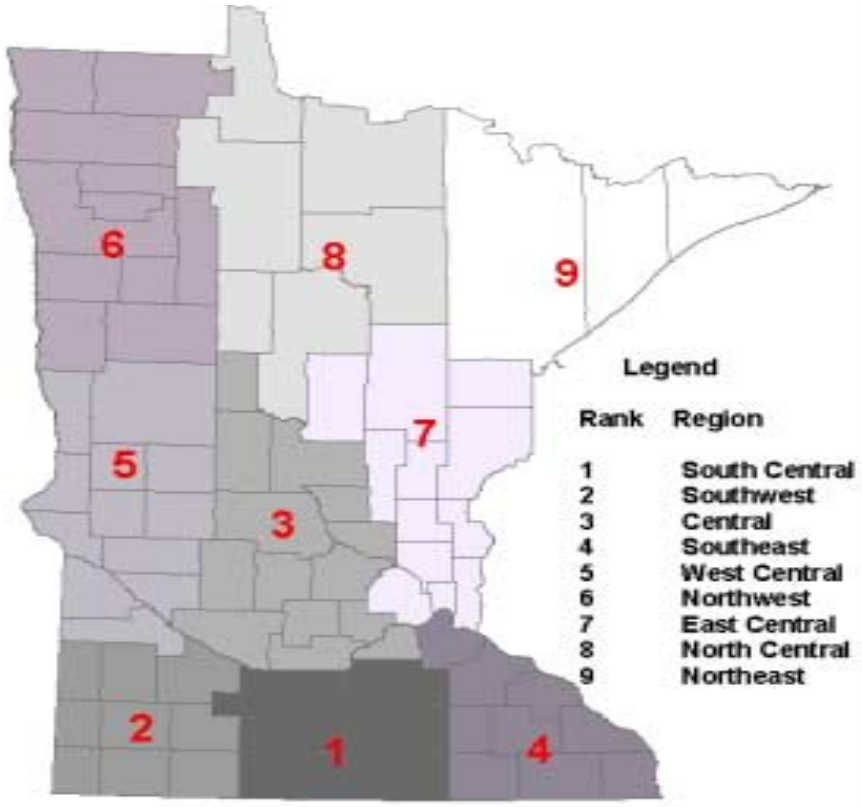


Figure 6: Minnesota Regional Potential for Electricity Production from Hog Manure



Appendix C: Financial Tables for Status Quo and Incentive Scenarios

Table 1. Dairy - Status Quo

Number of animals	200	300	400	500	600	700	800	900	1000	1100	1200
Total cost:	$129,885	$153,494	$176,180	$198,433	$220,264	$241,811	$263,084	$284,270	$305,252	$326,057	$346,842
Annual O&M/yr ($0.01/kWh):	$1,839	$2,764	$3,682	$4,607	$5,529	$6,450	$7,368	$8,293	$9,214	$10,132	$11,057
Annual Benefits ($/yr):	$9,817	$14,752	$19,652	$24,587	$29,504	$34,422	$39,322	$44,257	$49,174	$54,074	$59,009
- Electricity ($0.03294/kWh):	$6,059	$9,106	$12,129	$15,176	$18,211	$21,247	$24,270	$27,317	$30,352	$33,376	$36,423
- Propane offset (5 gal/cow, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,759	$4,146	$5,523	$6,911	$8,293	$9,675	$11,052	$12,439	$13,822	$15,198	$16,586
Electricity (kWh/yr):	183,927	276,432	368,215	460,721	552,866	645,009	736,792	829,298	921,443	1,013,225	1,105,731
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$6,185	$4,797	$4,195	$3,744	$3,442	$3,268	$3,095	$2,961	$2,880	$2,787	$2,710
Total cost ($/cow)	$649	$512	$440	$397	$367	$345	$329	$316	$305	$296	$289
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Annual loan payment	($15,128)	($17,878)	($20,521)	($23,112)	($25,655)	($28,165)	($30,643)	($33,110)	($35,554)	($37,977)	($40,398)
Net income (less O&M)	$7,978	$11,988	$15,970	$19,980	$23,976	$27,972	$31,954	$35,964	$39,960	$43,942	$47,951
Total benefit per year	($7,150)	($5,890)	($4,550)	($3,133)	($1,679)	($193)	$1,311	$2,853	$4,405	$5,965	$7,553
Benefit/cost /cow/yr	($35.75)	($19.63)	($11.38)	($6.27)	($2.80)	($0.28)	$1.64	$3.17	$4.41	$5.42	$6.29
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/cow	($272)	($149)	($87)	($48)	($21)	($2)	$12	$24	$34	$41	$48
IRR	1.8%	5.2%	7.5%	9.2%	10.6%	11.7%	12.6%	13.4%	14.1%	14.7%	15.2%
Simple Payback	16.3	12.8	11.0	9.9	9.2	8.6	8.2	7.9	7.6	7.4	7.2

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 2. Dairy - 0% Loan

Number of animals	200	300	400	500	600	700	800	900	1000	1100	1200
Total cost:	$129,885	$153,494	$176,180	$198,433	$220,264	$241,811	$263,084	$284,270	$305,252	$326,057	$346,842
Annual O&M/yr ($0.01/kWh):	$1,839	$2,764	$3,682	$4,607	$5,529	$6,450	$7,368	$8,293	$9,214	$10,132	$11,057
Annual Benefits ($/yr):	$9,817	$14,752	$19,652	$24,587	$29,504	$34,422	$39,322	$44,257	$49,174	$54,074	$59,009
- Electricity ($0.03294/kWh):	$6,059	$9,106	$12,129	$15,176	$18,211	$21,247	$24,270	$27,317	$30,352	$33,376	$36,423
- Propane offset (5 gal/cow, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,759	$4,146	$5,523	$6,911	$8,293	$9,675	$11,052	$12,439	$13,822	$15,198	$16,586
Electricity (kWh/yr):	183,927	276,432	368,215	460,721	552,866	645,009	736,792	829,298	921,443	1,013,225	1,105,731
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$6,185	$4,797	$4,195	$3,744	$3,442	$3,268	$3,095	$2,961	$2,880	$2,787	$2,710
Total cost ($/cow)	$649	$512	$440	$397	$367	$345	$329	$316	$305	$296	$289
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($10,391)	($12,280)	($14,094)	($15,875)	($17,621)	($19,345)	($21,047)	($22,742)	($24,420)	($26,085)	($27,747)
Net income (less O&M)	$7,978	$11,988	$15,970	$19,980	$23,976	$27,972	$31,954	$35,964	$39,960	$43,942	$47,951
Total benefit per year	($2,413)	($292)	$1,876	$4,105	$6,355	$8,627	$10,907	$13,222	$15,539	$17,857	$20,204
Benefit/cost /cow/yr	($12.06)	($0.97)	$4.69	$8.21	$10.59	$12.32	$13.63	$14.69	$15.54	$16.23	$16.84
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/cow	($92)	($7)	$36	$62	$81	$94	$104	$112	$118	$123	$128
IRR	1.8%	5.2%	7.5%	9.2%	10.6%	11.7%	12.6%	13.4%	14.1%	14.7%	15.2%
Simple Payback	16.3	12.8	11.0	9.9	9.2	8.6	8.2	7.9	7.6	7.4	7.2

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 3. Dairy – 2.0 cents/kWh Federal Tax Credit

Number of animals	200	300	400	500	600	700	800	900	1000	1100	1200
Total cost:	$129,885	$153,494	$176,180	$198,433	$220,264	$241,811	$263,084	$284,270	$305,252	$326,057	$346,842
Annual O&M/yr ($0.01/kWh):	$1,839	$2,764	$3,682	$4,607	$5,529	$6,450	$7,368	$8,293	$9,214	$10,132	$11,057
Annual Benefits ($/yr):	$13,496	$20,281	$27,017	$33,801	$40,562	$47,322	$54,058	$60,842	$67,603	$74,339	$81,123
- Electricity ($0.03294/kWh):	$6,059	$9,106	$12,129	$15,176	$18,211	$21,247	$24,270	$27,317	$30,352	$33,376	$36,423
- Propane offset (5 gal/cow, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,759	$4,146	$5,523	$6,911	$8,293	$9,675	$11,052	$12,439	$13,822	$15,198	$16,586
- Federal tax credit ($0.020/kWh):	$3,679	$5,529	$7,364	$9,214	$11,057	$12,900	$14,736	$16,586	$18,429	$20,265	$22,115
Electricity (kWh/yr):	183,927	276,432	368,215	460,721	552,866	645,009	736,792	829,298	921,443	1,013,225	1,105,731
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$6,185	$4,797	$4,195	$3,744	$3,442	$3,268	$3,095	$2,961	$2,880	$2,787	$2,710
Total cost ($/cow)	$649	$512	$440	$397	$367	$345	$329	$316	$305	$296	$289
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($15,128)	($17,878)	($20,521)	($23,112)	($25,655)	($28,165)	($30,643)	($33,110)	($35,554)	($37,977)	($40,398)
Net income (less O&M)	$11,657	$17,516	$23,334	$29,194	$35,033	$40,872	$46,690	$52,550	$58,388	$64,206	$70,066
Total benefit per year	($3,472)	($362)	$2,814	$6,082	$9,378	$12,707	$16,047	$19,439	$22,834	$26,229	$29,668
Benefit/cost /cow/yr	($17.36)	($1.21)	$7.03	$12.16	$15.63	$18.15	$20.06	$21.60	$22.83	$23.84	$24.72
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/cow	($132)	($9)	$54	$93	$119	$138	$153	$164	$174	$181	$188
IRR	7.3%	11.5%	14.3%	16.5%	18.3%	19.7%	20.9%	21.9%	22.8%	23.6%	24.3%
Simple Payback	11.1	8.8	7.6	6.8	6.3	5.9	5.6	5.4	5.2	5.1	5.0

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 4. Dairy - $500/kW Rebate

Number of animals	200	300	400	500	600	700	800	900	1000	1100	1200
Total cost:	$119,385	$137,494	$155,180	$171,933	$188,264	$204,811	$220,584	$236,270	$252,252	$267,557	$282,842
Annual O&M/yr ($0.01/kWh):	$1,839	$2,764	$3,682	$4,607	$5,529	$6,450	$7,368	$8,293	$9,214	$10,132	$11,057
Annual Benefits ($/yr):	$9,817	$14,752	$19,652	$24,587	$29,504	$34,422	$39,322	$44,257	$49,174	$54,074	$59,009
- Electricity ($0.03294/kWh):	$6,059	$9,106	$12,129	$15,176	$18,211	$21,247	$24,270	$27,317	$30,352	$33,376	$36,423
- Propane offset (5 gal/cow, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,759	$4,146	$5,523	$6,911	$8,293	$9,675	$11,052	$12,439	$13,822	$15,198	$16,586
Electricity (kWh/yr):	183,927	276,432	368,215	460,721	552,866	645,009	736,792	829,298	921,443	1,013,225	1,105,731
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$5,685	$4,297	$3,695	$3,244	$2,942	$2,768	$2,595	$2,461	$2,380	$2,287	$2,210
Total cost ($/cow)	$597	$458	$388	$344	$314	$293	$276	$263	$252	$243	$236
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($13,905)	($16,015)	($18,075)	($20,026)	($21,928)	($23,855)	($25,692)	($27,519)	($29,381)	($31,164)	($32,944)
Net income (less O&M)	$7,978	$11,988	$15,970	$19,980	$23,976	$27,972	$31,954	$35,964	$39,960	$43,942	$47,951
Total benefit per year	($5,927)	($4,027)	($2,104)	($46)	$2,048	$4,116	$6,262	$8,444	$10,579	$12,778	$15,008
Benefit/cost /cow/yr	($29.64)	($13.42)	($5.26)	($0.09)	$3.41	$5.88	$7.83	$9.38	$10.58	$11.62	$12.51
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/cow	($225)	($102)	($40)	($1)	$26	$45	$60	$71	$80	$88	$95
IRR	3.0%	6.9%	9.6%	11.8%	13.6%	15.0%	16.2%	17.3%	18.2%	19.0%	19.8%
Simple Payback	15.0	11.5	9.7	8.6	7.9	7.3	6.9	6.6	6.3	6.1	5.9

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 5. Swine – Status Quo

Number of animals	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
Total cost:	$230,594	$275,843	$320,229	$363,991	$407,275	$450,177	$492,766	$535,090	$577,187	$619,088	$660,815
Annual O&M/yr ($0.01/kWh):	$1,803	$2,707	$3,610	$5,015	$5,417	$6,320	$7,223	$8,127	$9,030	$9,934	$10,837
Annual Benefits ($/yr):	$9,644	$14,475	$19,306	$26,541	$28,967	$33,798	$38,629	$43,460	$48,290	$53,121	$57,952
- Electricity ($0.03294/kWh):	$5,940	$8,915	$11,891	$16,519	$17,842	$20,818	$23,794	$26,770	$29,745	$32,721	$35,697
- Propane offset (2 gal/pig, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,705	$4,060	$5,415	$7,522	$8,125	$9,480	$10,835	$12,190	$13,545	$14,900	$16,255
Electricity (kWh/yr):	163,921	246,046	328,171	455,885	492,421	574,546	656,671	738,796	820,921	903,046	985,171
Electricity (kWh/yr):	180,313	270,651	360,988	501,474	541,663	632,001	722,338	812,676	903,013	993,351	1,083,688
Generator size (kW):	21	31	42	52	62	73	83	94	104	115	125
Total cost ($/kW)	$10,981	$8,898	$7,624	$7,000	$6,569	$6,167	$5,937	$5,692	$5,550	$5,383	$5,287
Total cost ($/pig)	$115	$92	$80	$73	$68	$64	$62	$59	$58	$56	$55
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($26,858)	($32,129)	($37,298)	($42,396)	($47,437)	($52,434)	($57,395)	($62,324)	($67,228)	($72,108)	($76,968)
Net income (less O&M)	$7,841	$11,768	$15,696	$21,526	$23,551	$27,478	$31,406	$35,333	$39,260	$43,188	$47,115
Total benefit per year	($19,017)	($20,360)	($21,603)	($20,870)	($23,886)	($24,956)	($25,989)	($26,991)	($27,967)	($28,920)	($29,853)
Benefit/cost /pig / yr	($9.51)	($6.79)	($5.40)	($4.17)	($3.98)	($3.57)	($3.25)	($3.00)	($2.80)	($2.63)	($2.49)
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/pig	($72)	($52)	($41)	($32)	($30)	($27)	($25)	($23)	($21)	($20)	($19)
IRR	-5.2%	-2.7%	-1.0%	1.3%	1.0%	1.7%	2.3%	2.8%	3.2%	3.6%	3.9%
Simple payback	29.4	23.4	20.4	16.9	17.3	16.4	15.7	15.1	14.7	14.3	14.0

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 6. Swine – 0% Interest Loan

Number of animals	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
Total cost:	$230,594	$275,843	$320,229	$363,991	$407,275	$450,177	$492,766	$535,090	$577,187	$619,088	$660,815
Annual O&M/yr ($0.01/kWh):	$1,803	$2,707	$3,610	$5,015	$5,417	$6,320	$7,223	$8,127	$9,030	$9,934	$10,837
Annual Benefits ($/yr):	$9,644	$14,475	$19,306	$26,541	$28,967	$33,798	$38,629	$43,460	$48,290	$53,121	$57,952
- Electricity ($0.03294/kWh):	$5,940	$8,915	$11,891	$16,519	$17,842	$20,818	$23,794	$26,770	$29,745	$32,721	$35,697
- Propane offset (2 gal/pig, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,705	$4,060	$5,415	$7,522	$8,125	$9,480	$10,835	$12,190	$13,545	$14,900	$16,255
Electricity (kWh/yr):	180,313	270,651	360,988	501,474	541,663	632,001	722,338	812,676	903,013	993,351	1,083,688
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$10,981	$8,620	$7,624	$6,868	$6,364	$6,083	$5,797	$5,574	$5,445	$5,291	$5,163
Total cost ($/pig)	$115	$92	$80	$73	$68	$64	$62	$59	$58	$56	$55
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Annual loan payment	($18,448)	($22,067)	($25,618)	($29,119)	($32,582)	($36,014)	($39,421)	($42,807)	($46,175)	($49,527)	($52,865)
Net income (less O&M)	$7,841	$11,768	$15,696	$21,526	$23,551	$27,478	$31,406	$35,333	$39,260	$43,188	$47,115
Total benefit per year	($10,606)	($10,299)	($9,922)	($7,593)	($9,031)	($8,536)	($8,016)	($7,474)	($6,915)	($6,339)	($5,750)
Benefit/cost /pig / yr	($5.30)	($3.43)	($2.48)	($1.52)	($1.51)	($1.22)	($1.00)	($0.83)	($0.69)	($0.58)	($0.48)
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/pig	($40)	($26)	($19)	($12)	($11)	($9)	($8)	($6)	($5)	($4)	($4)
IRR	-5.2%	-2.7%	-1.0%	1.3%	1.0%	1.7%	2.3%	2.8%	3.2%	3.6%	3.9%
Simple payback	29.4	23.4	20.4	16.9	17.3	16.4	15.7	15.1	14.7	14.3	14.0

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 7. Swine – 2.0 cents/kWh Federal Tax Credit

Number of animals	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
Total cost:	$230,594	$275,843	$320,229	$363,991	$407,275	$450,177	$492,766	$535,090	$577,187	$619,088	$660,815
Annual O&M/yr ($0.01/kWh):	$1,803	$2,707	$3,610	$5,015	$5,417	$6,320	$7,223	$8,127	$9,030	$9,934	$10,837
Annual Benefits ($/yr):	$13,658	$20,500	$27,341	$37,703	$41,025	$47,866	$54,708	$61,550	$68,392	$75,233	$82,075
- Electricity ($0.03294/kWh):	$6,347	$9,527	$12,707	$17,652	$19,067	$22,246	$25,426	$28,606	$31,786	$34,966	$38,146
- Propane offset (2 gal/pig, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,705	$4,060	$5,415	$7,522	$8,125	$9,480	$10,835	$12,190	$13,545	$14,900	$16,255
- Federal Tax Credit ($0.020/kWh):	$3,606	$5,413	$7,220	$10,029	$10,833	$12,640	$14,447	$16,254	$18,060	$19,867	$21,674
Electricity (kWh/yr):	180,313	270,651	360,988	501,474	541,663	632,001	722,338	812,676	903,013	993,351	1,083,688
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$10,981	$8,620	$7,624	$6,868	$6,364	$6,083	$5,797	$5,574	$5,445	$5,291	$5,163
Total cost ($/pig)	$115	$92	$80	$73	$68	$64	$62	$59	$58	$56	$55
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($26,858)	($32,129)	($37,298)	($42,396)	($47,437)	($52,434)	($57,395)	($62,324)	($67,228)	($72,108)	($76,968)
Net income (less O&M)	$11,855	$17,793	$23,731	$32,689	$35,608	$41,546	$47,485	$53,423	$59,361	$65,300	$71,238
Total benefit per year	($15,003)	($14,335)	($13,567)	($9,707)	($11,829)	($10,888)	($9,910)	($8,901)	($7,866)	($6,808)	($5,730)
Benefit/cost /pig / yr	($7.50)	($4.78)	($3.39)	($1.94)	($1.97)	($1.56)	($1.24)	($0.99)	($0.79)	($0.62)	($0.48)
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/pig	($57)	($36)	($26)	($15)	($15)	($12)	($9)	($8)	($6)	($5)	($4)
IRR	-0.5%	2.5%	4.4%	7.4%	6.9%	7.8%	8.5%	9.1%	9.6%	10.0%	10.4%
Simple payback	19.5	15.5	13.5	11.1	11.4	10.8	10.4	10.0	9.7	9.5	9.3

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Table 8. Swine - $500/kW Rebate

Number of animals	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
Total cost:	$220,094	$259,843	$299,229	$337,491	$375,275	$413,177	$450,266	$487,090	$524,187	$560,588	$596,815
Annual O&M/yr ($0.01/kWh):	$1,839	$2,764	$3,682	$4,607	$5,529	$6,450	$7,368	$8,293	$9,214	$10,132	$11,057
Annual Benefits ($/yr):	$10,233	$15,377	$20,484	$25,628	$30,754	$35,879	$40,987	$46,131	$51,256	$56,364	$61,508
- Electricity ($0.03294/kWh):	$6,474	$9,730	$12,961	$16,217	$19,461	$22,704	$25,935	$29,191	$32,435	$35,666	$38,922
- Propane offset (2 gal/pig, $1/gal):	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
- State Incentive ($0.015/kWh):	$2,759	$4,146	$5,523	$6,911	$8,293	$9,675	$11,052	$12,439	$13,822	$15,198	$16,586
Electricity (kWh/yr):	183,927	276,432	368,215	460,721	552,866	645,009	736,792	829,298	921,443	1,013,225	1,105,731
Generator size (kW):	21	32	42	53	64	74	85	96	106	117	128
Total cost ($/kW)	$10,481	$8,120	$7,124	$6,368	$5,864	$5,583	$5,297	$5,074	$4,945	$4,791	$4,663
Total cost ($/pig)	$110	$87	$75	$67	$63	$59	$56	$54	$52	$51	$50
payment period (yrs)	10	10	10	10	10	10	10	10	10	10	10
Interest on loan	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Down payment (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	0	0	0	0	0	0	0	0	0	0	0
Annual loan payment	($25,635)	($30,265)	($34,853)	($39,309)	($43,710)	($48,125)	($52,444)	($56,734)	($61,054)	($65,294)	($69,514)
Net income (less O&M)	$8,394	$12,613	$16,802	$21,021	$25,225	$29,429	$33,619	$37,838	$42,042	$46,232	$50,450
Total benefit per year	($17,241)	($17,652)	($18,050)	($18,288)	($18,485)	($18,695)	($18,825)	($18,896)	($19,012)	($19,063)	($19,063)
Benefit/cost /pig / yr	($8.62)	($5.88)	($4.51)	($3.66)	($3.08)	($2.67)	($2.35)	($2.10)	($1.90)	($1.73)	($1.59)
Discount rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
NPV/pig	($66)	($45)	($34)	($28)	($23)	($20)	($18)	($16)	($14)	($13)	($12)
IRR	-3.9%	-1.2%	0.7%	2.0%	3.0%	3.9%	4.5%	5.1%	5.6%	6.0%	6.4%
Simple payback	26.2	20.6	17.8	16.1	14.9	14.0	13.4	12.9	12.5	12.1	11.8

Source: Electricity, generator size, and total cost from U.S. EPA Farmware Software. Electricity and total cost inflated 10% each from output values.

Appendix D: End Notes

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