Arnold Schwarzenegger
Governor

DAIRY POWER PRODUCTION PROGRAM

DAIRY METHANE DIGESTER SYSTEM 90-DAY EVALUATION REPORT - KOETSIER DAIRY

PIER CONSULTANT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
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WESTERN UNITED RESOURCE DEVELOPMENT, INC.

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I. Program Background

The purpose of the Dairy Power Production Program (DPPP) is to encourage the development of biologically based anaerobic digestion and gasification ("biogas") electricity generation projects on California dairies. Objectives of the program include developing commercially proven biogas electricity systems that can help California dairies offset the purchase of electricity and providing environmental benefits by potentially reducing air and ground water pollutants associated with storage and treatment of livestock wastes.

The California Energy Commission (Energy Commission), acting under authority of the Legislative enactment in 2001 of Senate Bill (SB)5X (Section 5(b)(5)(C)(i)), appropriated and encumbered funding for the Dairy Power Production Program (DPPP). Western United Resource Development, Inc. (WURD) was selected by the Energy Commission as the Contractor for this program.

To date, a total of 14 projects have been approved for grants totaling $5,792,370. The projects have an estimated generating capacity of 3.5 megawatts.

Two types of assistance were made available for the grant program: buydown grants, which cover a percentage of the capital costs of the proposed biogas system, and incentive payment grants for generated electricity. Buydown grants cover up to 50% of the capital costs of the system based on estimated energy production, not to exceed $2,000 per installed kilowatt, whichever is less. Electricity generation incentive payments are based on 5.7 cents per kilowatt-hour of electricity generated by the dairy biogas system, which totals the same amount as a buydown grant paid out over five years.

The grant program is overseen by an advisory group comprising representatives from the California dairy industry; California Department of Food and Agriculture; California Energy Commission; California State Water Resources Control Board; Sustainable Conservation; University of California; and U.S. Environmental Protection Agency AgSTAR Program.

II. Dairy Profile

The dairy owner applied for an incentive payment grant from the Dairy Power Production Program with the purpose to refurbish an existing non-operational plug flow digester system.

Koetsier dairy

For the 90-day study period, October through December 2005, there were an average of 2,253 cattle on the dairy, of which 1,233 were lactating cows, 163 dry cows, 837 heifers and 20 bulls. The lactating cows are housed primarily in freestall barns where they spend approximately 21 hours each day. They spend the other three hours in the milking parlor. The dry cows and heifers spend approximately 12 hours in drylots and 12 hours in feed aprons. The calves and bulls are housed separately.

The dairy is located in Tulare County on 180 acres, of which 125 acres are used for growing corn and winter forage. The dairy owner also rents 310 adjacent acres for farming cropland, currently corn and winter forage. In 2006, 200 of these acres will be used for planting alfalfa.

III. Costs/Funding

The dairy owner applied for DPPP funding for the refurbishment of a non-operational plug flow digester system. At the time of application for funding, total project costs were estimated at $381,850. The dairy owner was awarded an incentive payment grant for $190,925, to be reimbursed at 5.7 cents per kilowatt-hour of electricity generated by the dairy biogas system, paid out over a maximum of five years. So far, the dairy owner has received $13,455.31 in incentive payments.


Plug flow digester

To date, the dairy owner has estimated expenditures amounting to $389,474 towards project completion, or $7,624 over the projected cost of the project. However, not all project costs have been reported, and the dairy owner expects to incur additional costs as the project is fine tuned. Extra expenses were incurred due to inflation over time, as material and construction costs increased between project planning in late 2001, when initial costs were estimated, and the actual time of project completion in late 2005.

The dairy owner operates the system himself. The dairy owner and staff spent much time maintaining the system and monitoring performance. Approximately one to two hours per day are dedicated to the digester project alone, with an additional five hours a day spent collecting manure. The dairy previously operated on a flush system, but to enhance biogas production for this digester refurbishment project, the dairy switched to vacuum trailer collection of manure, necessitating additional staff time of about five hours a day for this process. Additionally, when an oil change or other maintenance is required, the time requirement is increased. It takes approximately one hour to change the oil in one engine. Oil changes are scheduled every 500 hours or approximately every 20 days (assuming the engine runs 24 hours/day). Operating costs for oil, oil sampling, spark plugs, air cleaner, valves, filters, and time spent monitoring the system amount to approximately $450 per month, at minimum. Operating costs associated with manure collection amount to approximately $2,250 per month.

IV. Timeline

The original application was submitted to Western United Resource Development, Inc., on December 14, 2001. After thorough screening and review of the application, the advisory group approved the project for funding in March 15, 2002. It was originally expected that the project would begin operating by September 30, 2002. However, due to a number of outside obstacles (as explained below), the system did not begin operational until October 1, 2005.

V. Outside Obstacles

Low milk prices have had a significant impact on participants in the program. Beginning in late 2001, low milk prices began to put a strain on a dairy farmer's ability to obtain funds to invest in methane digester projects. Prices received by dairy farmers were at the lowest levels witnessed in over 25 years. Though dairy markets are typically cyclical in nature, producers experienced more than 20 months of extremely low prices. These low prices were, in most months, below a dairy producer's cost of producing milk.

Another major roadblock to completion of this project was difficulty in obtaining a Rule 21 interconnection permit from Southern California Edison (SCE) so that the project could generate power parallel with the main grid. SCE made several personnel changes over the course of the project. The loss of continuity in project oversight caused some delays and led to the utility's requiring additional system testing.

On December 1, 2004, a connecting rod broke on one of the generator motors, breaking a hole through the side of the motor block. The motor had to be replaced, delaying the project by a couple of months.

Another obstacle facing this project was the cumbersome and time consuming process of getting net metering legislation passed to allow net electricity generated by a utility customer to be credited against electricity consumed. Although advantageous, this legislation, AB 2228 (Negrete McLeod), was not passed until 2003. After the law's passage, issues with the utility's interpretation of tariffs had to be worked out with the California Public Utilities Commission. It should be noted that AB 2228 sunsets on January 1, 2006; however, new legislation, AB 728 (Negrete McLeod), was recently signed by the Governor. This new bill extends and expands the biogas net metering program through December 2009.

VI. Animal Distribution

On average, from October through December 2005, there were an average of 2,253 cattle at the dairy, of which 1,233 were lactating cows, 163 dry cows, 837 heifers and 20 bulls.
The lactating cows are housed primarily in freestall barns where they spend approximately 21 hours each day. They spend the other three hours in the milking parlor. The dry cows and heifers spend approximately 12 hours in dry lots and 12 hours in feed aprons. The calves and bulls are housed separately.

VII. Manure Collection and Processing

As previously noted, the dairy previously operated on a flush system. To increase biogas production, the dairy converted to a scrape system as part of this refurbishment project. The feed aprons and freestall alleys are now scraped twice daily. One trailer-mounted Loewen 3,750 gallon capacity vacuum unit is used to collect the manure. Undiluted manure is dumped directly into the digester.

Trailer-mounted Loewen vacuum unit

VIII. Biogas Utilization System

The concrete mesophilic (35°C or 95°F) plug flow digester has a hydraulic retention time of about 22 days. The digester has a V-shaped bottom and measures 30 feet wide x 180 feet long. The depth at the center of the digester is 16 feet, while measuring 12 feet deep at the sides. The digester is covered with a flexible, impervious top. Approximately 24,142 gallons of manure slurry are fed to the digester per day. To enhance decomposition of the manure, waste heat from the engine is used to heat the digester to approximately 100°F. A heat exchanger located on the generator produces hot water that is circulated through heat exchange lines in the digester. The generator runs continuously, unless shutdowns are necessary for maintenance, to maintain the digester temperature.

At the time of the grant application, it was estimated that the system would produce approximately 80,524 cubic feet per day of biogas. The produced biogas, with an estimated 70% methane, is used to power one of the available 135-kW capacity Caterpillar G342 engines. During the 90-day study period, the second 135-kW capacity Caterpillar G342 engine was not used. The dairy owner reports having no incentive to power the second generator to produce surplus electricity for which he would have received little to no compensation. Therefore, the dairy owner underfeeds the digester and flares the gas that is not used by the one engine. With an estimated system capacity of 260 kW, it was originally estimated that 5,300 kWh per day could be generated.

Digested manure flows out of the digester into a concrete effluent storage tank from which it is pumped to a screw press separator. The separated solids are composted and used as bedding for the cows in the freestall barns. The liquid effluent gravity flows to a storage pond where it is then applied as irrigation to surrounding cropland at agronomic rates.

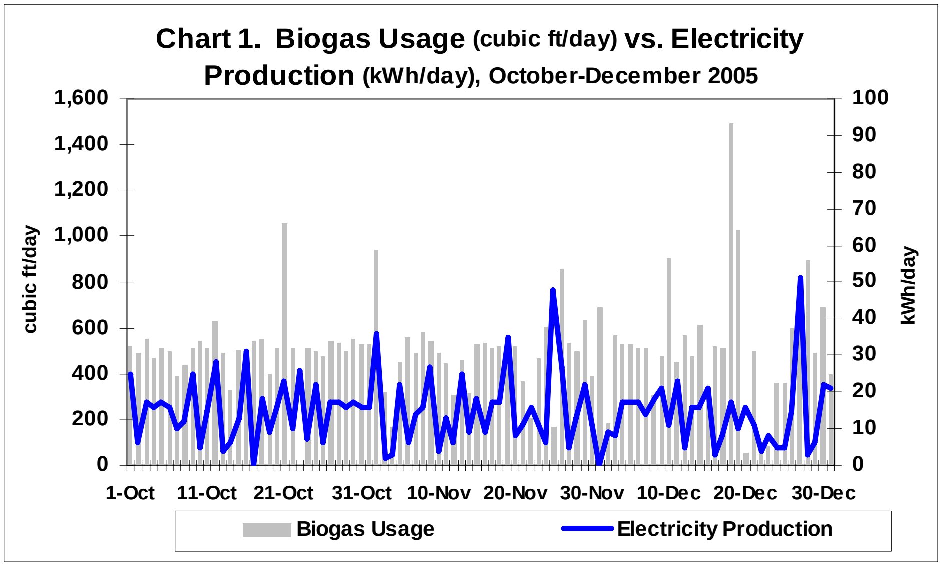
IX. Biogas and Energy Production

Biogas is transmitted through 150 feet of pipeline to the generator building located next to the digester. The gas is used to fuel one of the internal combustion natural gas engines. In the initial design specifications, it was estimated that the digester would produce 80,524 cubic feet of biogas per day from manure from 1,500 lactating cows. An estimated electricity production of 5,300 kWh/day from a total available capacity of 260 kW was expected. Given an estimated average of 5,300 kWh/day, it is assumed that the engine operates at 85% capacity.

Although biogas was produced as early as fall 2002, the system was officially operational as of October 1, 2005, and has been producing electricity from biogas continually since that date. Some generator failures have recently been reported (beginning mid-March 2006) but will not be analyzed for the purpose of this report.

Issues with the biogas and electricity production meters should be noted before further discussion. The biogas meter is currently located inside the generator building and measures only the biogas used by the generator. The excess biogas that is flared is not represented in the figures reported below. The dairy owner has purchased and plans to install a meter at the digester to measure total biogas produced by the system. Additionally, measured electrical production represents only net electrical production due to a two-way meter used during the study period. The meter spins backwards when power is pulled from the utility. Therefore, the meter figures reported for electrical production will be reduced by the amount of power pulled from the grid. The dairy owner has purchased and installed (following the study period) a one-way meter to accurately report total electrical production.

Chart 1 compares biogas usage to electricity production for the 90-day startup period. Reported biogas usage declined slightly from an average of about 50,194 cubic feet/day in October to about 48,243 cubic feet/day in November. Biogas usage increased in December, with reported biogas output reaching an average of 52,552 cubic feet/day. However, it should be noted that the system experienced the least amount of downtime in December with 8 hours of down time in December, 35 hours in November, and 36 hours in October. Again, the biogas measured is gas that went into the engine and does not include gas that was flared when the engine was either off or being run in limited output mode during startup and benchmarking.



Electricity production reached an average of 1,804 kWh/day in October and rose to 1,892 kWh/day in November. Electricity production declined slightly to an average of 1,753 kWh/day in December. The system was operational an average of 23 hours/day in October, 23 hours/day in November, and 24 hours/day in December with total downtime of 36 hours in October, 35 in November, and 8 hours December. This falls short of the estimated 24 hours per day and 365 days per year operational capacity assumed above. Again, it must be noted that measured electrical production represents only net electrical production due to a two-way meter used during the study period. Additionally, only one of the available generators was used during this period. Only one engine was used because there is no market for the surplus electricity produced.

Beginning October 2005, the dairy owner has taken advantage of the 2003 net metering law, AB 2228 (Negrete McLeod), which allows electricity generated by a customer to be credited against electricity consumed. Under the local utility Southern California Edison (SCE) net metering program, an electric meter is used to measure and track the “net” difference between the amount of electricity produced and the amount of electricity consumed during each billing period. This is done on a time-of-use basis according to the customer’s rate schedule. Twelve monthly billing cycles commencing on the anniversary date of final interconnection is considered the “relevant period.”

At the end of each billing period, a credit is given for any energy generated that is above the energy consumed (net generation). Only the generation rate component of the total retail rate is used in the calculation of generation credits. All other charges, including but not limited to transmission charges, distribution charges, public goods charges, nuclear

Engine generator

decommissioning charges, monthly basic service fees, minimum charges, demand charges, and non-energy related charges, are calculated prior to the netting of energy supplied or produced, for all energy supplied to the dairy. If energy consumption is greater than the energy produced, the customer is billed the difference. SCE offers the customer an opportunity to "bank" charges for electricity produced in excess of consumption in the form of a credit. This credit can be applied to future generation-related charges on other accounts included in net metering. However, any credits remaining at the end of the 12-month billing period are not paid out by the utility and are forfeited by the customer-generator. Likewise, any unbilled generation charges that cannot be offset by accrued generation credits must be paid to the utility company.

The main dairy meter (referenced as "parent" account by SCE) and five other dairy accounts (referenced as "child" accounts by SCE) are included in net metering on the dairy. Total savings from electricity generation at the dairy are a combination of things. For any time-of-use in which electricity production exceeds usage, a generation credit would be accrued, valued at the applicable generation rate. In addition, because the dairy's main load is connected to the generators, the second saving, which is the largest savings, come from the offset of electricity purchased from the utility company in any given month. For instance, when compared to the same month's usage in 2004, the kWh purchased from the utility declined by 43,681 kWh in October, 52,170 in November, and 42,578 in December. It should be noted that savings from demand charges are not reflected in the calculated savings from the kWh declined.

Engine generator room

The dairy is on the TOU-PA-5 rate schedule, which specifies that maximum demand is established by the measured maximum kilowatt input recorded during any 15-minute metered interval. So, at any point when the digester system was down (for example, due to maintenance), that period of highest recorded demand was used to establish the demand charges for the month. The dairy owner was able to successfully reduce total demand in October and November 2005; however, December 2005 demand increased slightly. Demand charges averaged $699 for October-November 2004 compared to $568 for October-November 2005. This difference amounts to an estimated average demand cost savings of about $132 per month.

The dairy owner may be able to further reduce demand charges if the second generator is brought on-line. With both generators operating, total generator capacity reaches 270 kW, while the average recorded demand at the dairy is an estimated 138 kW October-December 2004. This should mean that one generator could be down at any given time and the system would nearly be able to offset the dairy demand of the "parent" account (during summer months with greater demand this may not hold true). However, it would require much effort by the dairy owner to ensure optimal performance and the operational timing of each generator. Additionally, the dairy owner will need to compare the potential cost savings to the additional cost and time associated with running a second generator. To date, due to the small reimbursement for excess generated power, the dairy owner has found no reason to take on the added burden and cost associated with bringing the second generator on-line.

So, because demand charges were not reduced even though total kWh purchased from the utility declined significantly, only the energy charge portion of the full retail rate can be used to estimate the savings from the offset. Analyses of the utility bills show this to be an estimated $0.06 per kWh.

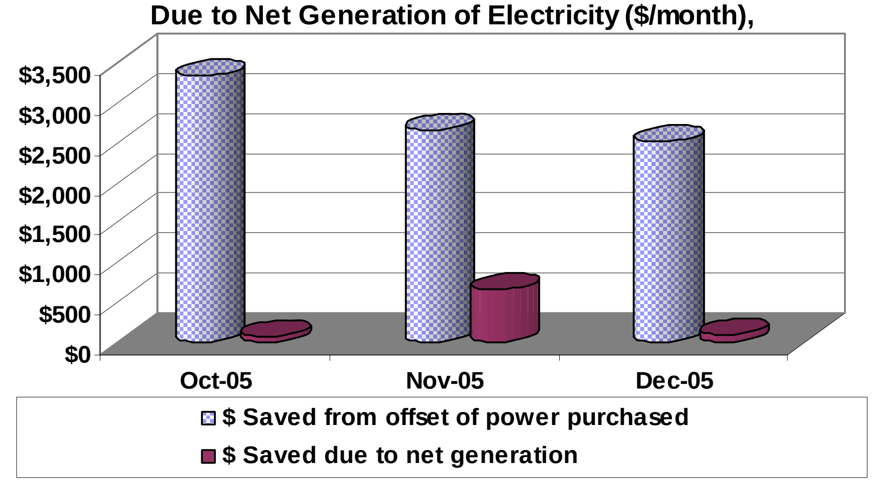
Other savings, though much smaller during most of the study period, came from any net generation (times at which generation exceeded consumption at the dairy). During the 90-day study period, there was a limited amount of net generation credits generated. Savings due to net generation alone amounted to approximately $63.51 in October, $656.25 in November, and $86.23 in December for a total of $806 for the three-month period. As previously mentioned, these generation credits can be used towards offsetting generation charges of the other dairy accounts ("child" accounts). Generation charges for the child accounts amounted to $290.84 in October, $119.40 in November, and $461.94 in December for a total of $872.18 for the three-month period. So, for the study period, the generation credits ($806) amounted to nearly the level needed to pay the unbilled generation charges for the other dairy accounts. For the study period, the net generation credit averaged $0.03 per kWh.

Net metering with SCE began in October 2005. Estimated savings due to electrical production October-December 2005 are approximately $8,390. Estimated average monthly savings October-December 2005 averaged approximately $2,800 per month. Again, the largest portion of these savings came from the offset of electricity purchased from the utility. The remainder was the generation credits detailed above.

The dairy owner is hopeful that someday the utility will purchase the excess energy produced on the dairy. However, there are currently no power purchase agreements available to biogas customer generators and no requirement for the utility to pay the full retail rate for this energy. Net metering is currently the only benefit available to the dairy owner.

Chart 2 compares monthly cost savings from generated electricity for the 90-day period. Savings are broken into estimated savings from the offset of power purchased from the utility and estimated savings due to net generation.

Chart 2. Estimated Savings Due to Offset of Power Purchased from Utility ($/month) and Estimated Savings Due to Net Generation of Electricity ($/month),

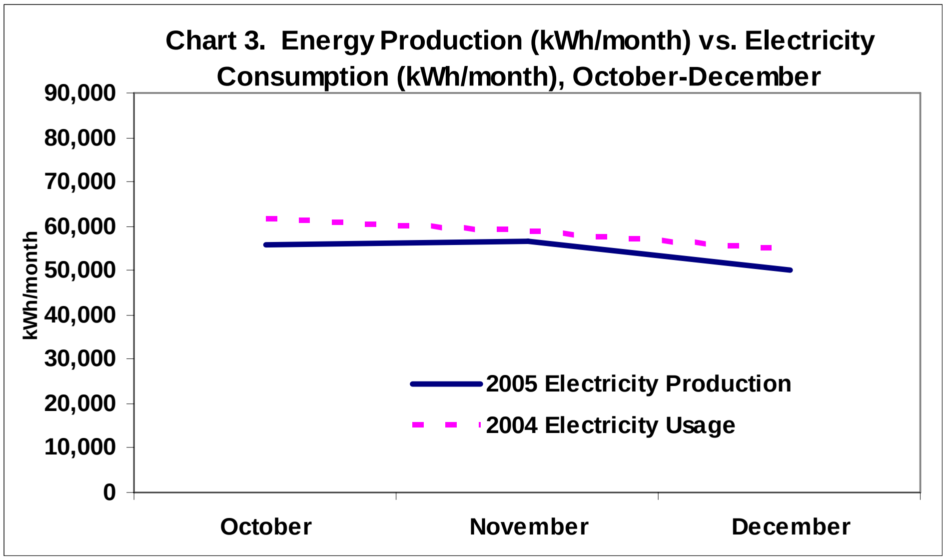


Assuming an average monthly cost savings of $2,800, the estimated payback period for this project is approximately 5.9 years.[1] This payback takes into account only those costs

[1] Assumes an estimated $198,549 in total out-of-pocket refurbishment expenses for the dairy owner above total grant funding of $190,925. Using an estimated total project cost of $389,474 (or without grant funding), the

associated with the refurbishment. Any costs incurred from the original installation were not included. If the second generator is brought on line, the monthly savings moving forward could possibly exceed current performance, further reducing the payback period.

Also, it is interesting to note that the dairy owner has applied to the Chicago Climate Exchange (CCX) to sell his greenhouse gas credits. Therefore, the dairy owner will be making efforts to optimize his biogas production and will be carefully metering his biogas quantity and quality. Because of this, system performance figures for the coming year will likely reflect optimal operation of the system. Potential revenues to be generated are not yet known.



X. Energy Usage

On average, from October through December 2004, approximately 58,163 kWh/month or 1,878 kWh/day of electricity is needed to supply the on-farm electric needs. This amount includes the usage for the main dairy account ("parent") and the five additional dairy accounts ("child" accounts).

Chart 3 compares electricity usage for the dairy (October-December 2004) to electricity production for each month (October-December 2005). Once again, it is likely that the reported electricity production figures do not fully represent the full amount of electricity generated due to the use of the two-way meter during the study period.

Table 1 compares the peak, mid-peak, and off-peak energy usage for the main dairy or "parent" account October-December 2004 and October-December 2005. Due to on-farm electrical production, electrical usage (or power purchased from the utility) was reduced in mid and off-peak time of use periods in 2005 when compared to 2004. For 2005, electricity usage from the utility is primarily in the off-peak hours, with 53% of the usage falling in this category; 40% of the electricity usage in mid-peak, with the remaining 7% falling into the peak category.

Table 1	**"Parent" Peak Usage**		**"Parent" Mid-Peak Usage**		**"Parent" Off Peak Usage**	
	2004	**2005**	**2004**	**2005**	**2004**	**2005**
October	742	1,330	21,136	3,858	29,672	2,681
November	0	0	19,682	792	35,911	2,631
December	0	0	20,258	3,479	31,221	5,422

estimated payback period is increased to 11.6 years. The estimated total project cost does not include cost savings to due the possible sale of byproducts or offset of natural gas or propane needs.

XI. System Performance

The performance of the system thus far has been below original expectations. However, it should be noted once more that only one available generator is being used and the problems with both the biogas and electrical meters distort actual performance figures. Table 2 compares the system design performance calculations with the actual performance for the 90-day period October through December 2005. Given that these are considered startup months and the data covers a very short period, these should be considered preliminary results.

In the grant application, biogas production was expected to reach 80,524 cubic feet/day from the manure from 1,500 lactating cows, or 53.7 cubic feet/day of biogas per lactating cow. The daily biogas production was estimated to result in electricity generation of 3.53 kWh per cow per day. For the 90-day period studied, the design calculations for biogas were not matched. There are several reasons the digester did not perform at original expectations. First, as previously mentioned, the biogas production figures during the study period represent only the biogas that was utilized by the digester. Flared biogas was not measured. The dairy owner has purchased and plans to install a gas meter at the digester to measure total biogas produced by the system.

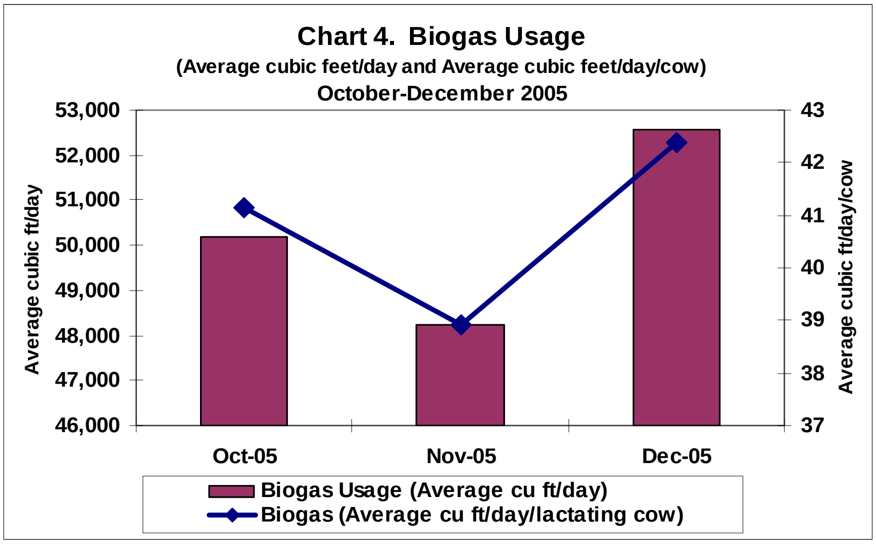
Table 2: Digester Design and Actual Performance

	Design	**Actual October-December 2005 Average**
Cows (lactating)	1,500	1,233
Manure Slurry	Scrape	Scrape
Total gallons per day	24,142	24,142
Digester Specifications		
Type	Plug flow	Plug flow
Digester Feeding Mode	Intermittent (2X day)	Intermittent (2X day)
Retention Time (days)	22	22
Gas Production*		
Total (cubic feet per day)	80,524	50,329
Per Lactating Cow (per day)	53.7	41
Electrical Output		
Generator Capacity (kW)	260	135 KW Only one of the 135 kW generators operational
Generator Availability (operational hours/day)	20.4	23
Total (kWh/year)**	1,934,500 given 260 kW at 85% capacity	651,360 or 34% capacity
Total per day (kWh)	5,300	1,785
Total per cow (kWh/day)	3.53	1.45

* Measured biogas production is only that biogas utilized by the generator. Flared biogas (approximately 15-40% is not metered at this time). More gas is flared when the system runs continuously, as gas production is higher when the digester temperature is kept high.

**Measured electrical production represents net electrical production due to the two-way meter used during the study period (meter spins backwards when power is pulled from the utility).

It should also be noted that in September 2003 the dairy participated in a herd retirement program. The original project design was based on the 2001 population of 1,500 milking cows, but the dairy has since reduced its herd and now milks an average of only 1,233 cows, thus generating a smaller quantity of biogas.



For the 90-day period, an average of 50,329 cubic feet of biogas per day was metered. This resulted in an average metered biogas production of 41 cubic feet/day per cow for an average of 1,233 lactating cows. This resulted in an average electricity generation of 1.45 kWh per cow per day. Chart 4 compares the average cubic feet of biogas production per day and per cow for October, November, and December 2005. Again, not all manure reaches the digester, and not all the gas reaches the engine. A portion of the gas is flared since any electricity produced above the site load is not purchased by the utility.

As noted above, the average electricity generation was 1,785 kWh per day compared to an originally estimated 5,300 kWh per day. Again, meter logs for electricity production do not reflect an accurate picture of the total electricity produced by the digester system. The meter is a two-way meter that runs backwards when power is pulled from the grid. Therefore, the meter logs really represent the net of electricity produced and electricity pulled from the grid.

The dairy owner has noted that the main problem with operating the digester system thus far has to do with the lack of a gas filtration mechanism in his system. Without a filtration mechanism, the gas is somewhat dirty, which causes intake problems and makes it hard to run the generator smoothly. The spark plugs have to be cleaned frequently, which is time consuming and necessitates shutting down the system for about an hour. The dairy owner has said that he will work with the system designer to install a filtration system to scrub the biogas.

The dairy owner has also pointed out that the system is designed to work as a whole, and efficiency of the entire system can be affected by a small problem in one of the components. For example, after the study period, a parallel module in the interconnection equipment malfunctioned, and it took three weeks to have the unit repaired.

Manure storage pit

During this time, the generator was not able to run parallel to the grid; therefore, it could not run at full power, so the digester temperature decreased, resulting in lower gas production for that period.

It has recently come to the dairy owner's attention that dairy staff had been using too much water to flush the lanes prior to vacuuming. This resulted in volatile solids being flushed away and a higher than necessary volume of water going into the digester, thus diluting the manure and reducing biogas production. The dairyman has since corrected this problem and has seen an immediate increase in biogas production.

Because the project is still in the startup phase, some system adjustments and improvements have been required. The dairy owner continues to monitor system performance and to make modifications as necessary. Additionally, the dairy owner will likely start using biogas to fuel the second 135kW generator to produce additional electricity. The production of additional electricity will allow the dairy owner to capture his full grant funding within a shorter time frame.

XII. Heat Utilization

Recovered heat is used to heat the digester in order to maintain a temperature of approximately 100°F. This has been helpful in enhancing the decomposition of manure.

The dairy facility uses propane for heating. At this time, there are no cost savings associated with the use of recovered heat. The dairy owner is considering using the excess heat to heat parlor water for barn cleanup. The dairy owner also plans on using recovered heat for hot water for four residential houses and one swimming pool located on the dairy property.
If this plan is implemented, additional cost savings could occur.

XIII. Dairy Owner Qualitative Feedback

On a scale from one to four, the dairy owner was asked to rate his experience in a number of areas concerning the digester project. The specific questions, along with their monthly and average rankings, are included in Table 3.

Table 3: Qualitative Questions

Questions Ranked 1-4, with 1=poor and 4=excellent	**October 2005**	**November 2005**	**December 2005**	**Average**
1. **Ease in operating the biogas production and biogas to electricity systems**	2	2	2	2
2. **Extent to which system gives advantage to your dairy manure management**	3	3	3	3
3. **Extent to which the system helps with odor control**	3	3	3	3
4. **Extent to which the system helps with reducing water use for manure management**	4	4	4	4
5. **Extent to which system helps address electricity issues important to your dairy operation**	1	1	1	1
6. **Overall satisfaction with the system so far**	2	2	2	2
7. **Any other comments or recommendations?** Electrical & motor equipment maintenance is a large part of system time requirement				