ECONOMICS OF PRODUCING METHANE GAS FROM COW MANURE TO GENERATE ON-FARM ELECTRICITY

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ABSTRACT

This study examines the economic feasibility of substituting electricity generated on dairy farms by methane gas systems for electricity purchased from local utility companies. Electric power is an important input in the operation of a dairy farm. The central question was which source of this input was the cheaper? Herd sizes included in the study were 50, 100, 200 and 300 cows. The cost of methane generated electricity is compared with the cost of purchased electricity. Results are presented by size of dairy herd.

INTRODUCTION

The rising cost of energy has increased the interest of dairymen in on-farm generation of electricity by using methane gas produced from animal manure. From 1974 to 1981, the cost of electricity increased 83 percent for Maryland farmers and 97 percent for Northeast farmers.[1] A dairy farm requires a relatively large amount of electricity and also produces substantial quantities of manure. By fermenting the manure in a digester, the methane gas produced will provide fuel for generating most of the farm's electrical needs. This possibility raises the economic question of whether or not the on-farm produced electricity is more economical than the same amount of energy purchased from the local power company.

OBJECTIVE

This paper explores the economics of using dairy cow manure to produce methane gas which in turn is used to fuel an engine which generates most of the dairy farm's electrical needs.

ANALYTICAL METHOD

The most common method of providing the dairy farm's electrical energy is simply to purchase it from the local power company. Another method is to produce the energy on the farm. When there is more than one method of supplying an input, analysis is necessary to determine the least-cost method. The cost of electricity produced by on-farm methane gas systems is compared with the cost of electrical energy purchased from the power company.

The nature of the cost of purchased electricity and the cost of methane generated electricity is substantially different. Purchased electricity is fully deductible as a business expense in each accounting period. On-farm methane systems require long-term capital investments which can be recovered only over a number of years. This difference introduces capital recovery (depreciation) and the cost of capital use (interest or opportunity cost). It also leads to the question of what is the most efficient use of capital. Even if the methane generated electricity is cheaper than purchased energy, the ultimate answer depends on whether or not the capital requirements for the methane system would yield a greater return if used in another segment of the farm business. In this study, the return to capital in methane systems was determined but no comparison was made with returns from alternative uses.

FACTORS AFFECTING SYSTEM DESIGN

Although the digestion process and the resulting production of methane can be achieved with any size herd, the utilization of the energy generated is very dependent on the daily duration and level of demand. The daily electrical energy demand closely follows the work patterns on the farm. During periods of little work activity small amounts of electricity are used, such as for occasional water pumping and other automatic random use equipment. However, during feeding, milking, milk cooling and other high energy chores, the electrical demand is high. The daily peak demand for electricity occurs during the morning and evening chore time periods. This peak demand for electricity may be four times the minimum demand during the day.

Other factors to consider are the degree of automation, milk production and the number and size of electric motors on the farm.

SYSTEM SELECTION

When a farmer develops his own energy production system, it must be matched with his demands in order to be satisfactory. However, this is difficult to do on a dairy farm with a four-fold change in electrical demand in a twelve hour period. The selection of electrical generation equipment large enough to meet the peak demand will always ensure enough electricity. However, the cost of equipment and maintenance is excessive if the peak loads only last four or five hours a day. The specific fuel consumption of an engine-generator more than doubles as the generator load decreases from 100 to 25 percent. In other words, it takes twice as much methane to produce a kilowatt hour of electricity at 1/4 load than is required to produce the same amount of electricity at full load. Therefore, a generator selected to meet the peak demand will oper-

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[1] Agricultural Prices, Crop Reporting Board, SRS, USDA. October 1974 and October 1981. The average for the Northeast was 6.43 cents per kwh in 1981 and 3.27 cents in 1974.

ate at low efficiency most of the time and the average cost of the electricity produced will be high.

The alternative system requires a smaller generator and operates at full load at all times. Although a more efficient conversion mechanism, the smaller generator does not have the capacity to provide enough electricity during high demand periods.

A solution to the selection dilemma is to modify the farmstead electrical demand through a program of scheduling use. Demand scheduling would reduce the magnitude of the peak load and broaden the use period. In most circumstances demand scheduling is simply developing a sequence of operations so that high demand motors are not started or operated at the same time.

For the systems in this study, the generators were sized to handle peak loads and would be operated during maximum use periods and continue until the day's methane supply was burned. The remainder of the day's electrical needs would be purchased from the utility company.

The most dominant factor affecting the size of all equipment in a methane-electrical system on a dairy farm is the number of cows. Herd sizes selected for this study were 50, 100, 200 and 300 cows. This range in size represents most of the commercial dairy herds in Maryland.

The details of electrical energy production, requirements, generator and engine size and hours of operation are shown in Tables 1 and 2. The

Table 1. Energy Output from Methane Gas, Generator and Engine Requirements and Amount of Electricity Produced, by Size of Dairy Herd[a]

Item	Number of Dairy Cows			
	50	100	200	300
1. Potential gross energy in Methane (mil. Btu per day)[b]	1.19	2.38	4.76	7.14
2. Generator (rated kw)[c]	10	20	40	60
3. Engine hp[d]	20	40	80	120
4. Peak load (kw)	9	18	36	54
5. Engine operation (% of full load)	53	55	58	62
6. Generation plant (average operating efficiency)	18	18.5	19	19.5
7. kwh generated per day[e]	63.5	130.0	272	408.0
8. Generator operation (hrs. per day)	14.8	14	11.5	11.3
9. Hot water kwh per day displaced by heat exchange[f]	15	30	60	90
10. Purchased electricity (kwh per day)	9.2	20	50	63

[a]Unless specifically noted, the basic data in this table are based on a synthesis of author's estimates and data contained in works shown in references.

[b]Btu = British Thermal Unit.

[c]kilowatt (1000 watts)

[d]hp = horsepower

[e]kwh = kilowatt hour

[f]Heat from engine used to heat water for dairy plant thus reducing the amount of purchased electricity.

Table 2. Summary of Electricity Produced and Replaced by Methane Systems and Amount Purchased from Utility Company[a]

Item	Number of Dairy Cows			
	50	100	200	300
1. kwh generated and displaced per day[b]	79[c]	160	332	498
2. kwh generated and displaced per year	28,835	58,400	121,180	181,770
3. kwh purchased per year	3,358	7,300	18,250	22,995
4. Total kwh use	32,193	65,700	139,430	204,765
5. Total kwh per cow	644	657	697	683
6. Percent of use generated or displaced	90	89	87	89

[a]Refer to basic data in Table 1.

[b]Displaced kwh results from utilizing energy from engine heat exchanger to heat water for the dairy plant (see line 9, table 1).

[c]Rounded up from Table 1.

four methane systems (based on herd size) were designed to supply from 87 to 90 percent of total electrical requirements.

The amount of electrical needs which would be purchased during the period when the generators are silent is based on the following estimates.

Use rates during the non-operational period:[2]

50 cows	1 kwh/hr.
100 cows	2 kwh/hr.
200 cows	4 kwh/hr.
300 cows	5 kwh/hr.

These requirements plus the amount of energy generated by the methane systems add to an annual requirement of 644 to 697 kwh per cow (Table 2). A recent survey of dairy farms in Carroll County, Maryland,[3] indicated a range of annual electrical use of 241 kwh to 834 kwh per cow with an average of 550. As expected, the annual consumption will vary widely with the degree of mechanization. The total use shown in Table 2, although above the average use found in the survey, is believed to be reasonable for modern dairy farms.

[2] Rounded to nearest whole number. Amounts of kwh are author's estimates.

[3] Survey conducted by Walter Bay, Extension Agent, Agricultural Science, Carroll County, Maryland, 1980.

INVESTMENT REQUIREMENTS

The major components of a methane gas-electrical generation system are an engine, generator, plug flow digester, gas bag, building and equipment for operating and monitoring the system. The estimated cost of these components and the total investment for each of the four systems are shown in Tables 3 and 4. These costs were obtained primarily from manufacturers, contractors and research reports. Costs do not include any fees or expenses that might be charged by consulting engineers.

The total investment in the systems (Table 4) ranged from $10,413 for 50 cows to $54,843 for 300 cows. Investment per cow declined between 50 and 100 cows then leveled off at $183 per cow, indicating that there is insignificant economy to size above 100 cows. The reason for this is that the size of the major components vary in approximately the same proportion as number of cows.

The engine was the most expensive investment, accounting for 35 to 40 percent of the total. As shown in Table 3, the total investment in the engine includes the overhaul costs.

The digester and the protective building (including housing for the engine, generator and various instruments) were the second largest investment items. Combined, they were about 34 percent of total investment. About 70 to 75 percent of total outlay was for the engine, digester and building.

Table 3. Estimated Investment in Engine Based on Complete Overhaul Every 2 Years and Replacement at end of 8 Years.[a]

Item	Number of Cows and Generator Size			
	50 10kw	100 20kw	200 40kw	300 60kw
Engine Initial Cost	$2,640	$5,180	$10,360	$15,540
Overhaul One	396	777	1,554	2,331
Overhaul Two	396	777	1,554	2,331
Overhaul Three	396	777	1,554	2,331
8 Year Total	$3,828	$7,511	$15,022	$22,533

[a]Cost of overhaul is 15 percent of engine cost. Systems are designed to supply 87 to 90 percent of farm electrical requirements. Engine initial cost obtained from manufacturers and dealers. Overhaul costs are dealers and author's estimates. Life of engine is based on engineering data.

Table 4. Estimated Total Investment in Systems[a]

Item	Number of Dairy Cows			
	50	100	200	300
Engine	$3,828	$7,511	$15,022	$22,533
Generator	1,760	2,220	4,440	6,660
Digester[b]	1,500	3,000	6,000	9,000
Building	2,000	3,500	6,500	9,750
Gas Bag[c]	225	450	900	1,350
Other equipment[d]	1,100	1,850	3,700	5,550
Totals	$10,413	$18,531	$36,562	$54,843
Investment per Cow	$208	$185	$183	$183

[a]All investment costs were obtained from manufacturers, dealers and contractors. Investment for a regular manure disposal system is not considered because it is assumed that a system is in place on each farm.

[b]Size based on 30 cu. ft. per cow. Data from publications listed in references.

[c]Calculated at 6 sq. ft. per cow. Data from publications listed in references.

[d]Mechanical and electrical equipment for operating and monitoring systems including water heating equipment.

ANNUAL COST OF SYSTEMS

Overhead Costs. Overhead costs are depreciation, interest on average investment, repairs, taxes and insurance. These costs are treated as fixed during the selected capital recovery period. As shown in Table 5, the annual overhead costs ranged from $1,911 for the 50 cow system to $10,219 for the 300 cow system. The largest cost item in overhead was depreciation, accounting for approximately 50 percent of the total.

Labor and Management Costs. The amount of labor required to operate a methane-electrical system is relatively small, assuming a properly designed and functional system. However, management time will likely equal or exceed direct operational labor. The estimated total time to operate and manage the systems is presented in Table 6. The cost per hour was set above the average farm rate to allow higher pay for supervision and management.

On some farms, the additional labor and management would be supplied by the existing (fixed) labor and management force. This situation would occur when the regular labor and management are under-utilized. In this case, the added labor and management would not be an added cost. In this analysis it was assumed that the labor and management required by the four systems would be added cash costs.

Total Costs. The sum of overhead, labor and management costs equals total annual costs of owning and operating the methane systems (Table 5). Total cost ranged from $2,735 for 50 cows to $12,168 for 300 cows. The rate of increase in cost was less than the rate for herd size due mostly to a lower rate of increase for labor and management. A reference to total investment in Table 4 shows that the only significant decrease in investment costs occurred between 50 and 100 cows.

COST OF METHANE GENERATED AND REPLACED ELECTRICITY COMPARED WITH PURCHASED ELECTRICITY

The cost of electrical energy generated and replaced by the methane systems was higher than the average cost of purchased electricity in Maryland in 1981. The average price paid by Maryland farmers in 1981 was 6.4 cents per kwh.[4]

[4] Agricultural Prices, Crop Reporting Board, SRS, USDA. October, 1974 and October, 1981. The average for the Northeast was 6.43 cents per kwh in 1981 and 3.27 cents in 1974.

Table 5. Total Annual Cost of Owning and Operating Methane Systems.

Cost Item	Number of Dairy Cows: 50	100	200	300
Depreciation[a]	$979	$1,797	$3,560	$5,341
Interest on Average Investment[b]	674	1,189	2,342	3,514
Repairs, Taxes and Insurance	258	464	907	1,364
Total Overhead	$1,911	$3,450	$6,809	$10,219
Labor and Management[c]	824	1,049	1,499	1,949
Total Annual Cost	$2,735	$4,499	$8,308	$12,168
Per Cow	$55	$45	$42	$41

[a]Depreciation rates were 12.5 percent (8 years) for the initial cost of engines and gas bags; 50 percent (2 years) for each engine overhaul and 6.66 percent (15 years) for digester, building, generator and other equipment. Salvage value was zero for all items and only straight line depreciation was used. The new cost recovery system recently added to the Tax Code was considered by the authors to be inappropriate for this type of business analysis.

[b]The rate was 14 percent of average investment for the recovery period.

[c]See Table 6.

Table 6. Estimated Hours and Cost of Labor and Management Required to Operate and Manage Methane Systems.

Number Dairy Cows	Hours Per Year[a]	Hours Per Cow	Annual Labor and Management Cost ($4.50/hr.)	Cost Per Cow
50	183	3.7	$824	$16.48
100	233	2.3	1,049	10.49
200	333	1.7	1,499	7.50
300	433	1.4	1,949	6.50

[a]Author's estimates. Only one system was observed in operation.

The average total cost (overhead plus labor and management) of the methane produced electricity ranged from a high of 9.49 cents for the 50 cow herd to a low of 6.69 cents per kwh for the 300 cow herd (Table 7). Most Maryland farmers are paying in the range of 5 to 8 cents per kwh for purchased electricity.

Based on overhead cost only (labor and management excluded) the electricity generated and replaced by the methane systems costs slightly less than the average price of purchased current, except for the 50 cow system. The average cost of purchased electricity at 6.40 cents falls between the upper and lower cost range of methane produced energy with a relatively small difference.

RETURN TO CAPITAL

The annual costs shown in Table 5 include a charge of 14 percent for the use of capital. However, there were indications that in some cases the return to capital was less than 14 percent and in others it was more. What then was the actual return? By removing the assumed cost of capital from total cost, the difference between the remaining cost (cash plus capital recovery) and the value of electricity generated and replaced is a payment for capital use. Return to capital was then determined by the ratio of capital payment to average investment (Table 8).

For the 50 cow system the return to capital never reached the assumed 14 percent. The returns were negative through 7 cents per kwh and only a positive 11.1 percent at 9 cents for purchased electricity. In general, returns did not equal or exceed 14 percent for the 100 to 300 cow system.

Any return that is less than the cost of borrowed capital or less than what the market would pay for invested funds, is a signal that the investment might be unwise. No judgment was made here concerning the returns that were above the assumed 14 percent. Their importance would depend on the returns from alternative uses of capital.

CONCLUSION

For most Marlyand dairymen, the general conclusion from this study is that on-farm generation of electricity by the use of methane gas produced from cow manure is not an attractive alternative to electrical energy purchased from utility companies. However, the few dairymen who are paying 8 cents per kwh or more for purchased electricity and have over 100 cows, can reduce their cost of electricity by investing in the on-farm methane systems.

These conclusions are based on cost and price relationships existing in 1981. If the price of electrical energy increases at a faster rate than the investment cost of the methane systems, on-farm generation would become more economically feasible. Most likely, prices and cost will change in approximately the same proportion.

Table 7. Cost of On-Farm Methane Produced Electricity Compared with Purchased Electricity.[a]

Number Dairy Cows	kwh Produced and Replaced	Cost Per kwh (cents) Total Cost	Overhead Only	Average Cost Purchased[b]
50	28,835	9.49	6.63	6.40
100	58,400	7.70	5.91	6.40
200	121,180	6.86	5.62	6.40
300	181,770	6.69	5.62	6.40

[a]See Table 5 for overhead and total annual cost of methane systems.

[b]Average price paid by Maryland farmers for purchased electricity in 1981 as reported by Statistical Reporting Service, USDA, October 1981. The average for the Northeast for the same period was 6.43 cents per kwh.

Table 8. Percent Return to Capital Invested in On-Farm Methane Systems

Item	Price Per Kilowatt-hour (Cents) 5	6	7	8	9
	(Dollars)				
50 Cow System					
Capital Payment	-619	-331	-43	246	534
Average Investment[a]	4811	4811	4811	4811	4811
Return (percent)	-12.9	-6.9	-1.0	5.1	11.1
100 Cow System					
Capital Payment	-390	194	778	1362	1947
Average Investment	8489	8489	8489	8489	8489
Return (percent)	-4.6	2.3	9.2	16.0	22.9
200 Cow System					
Capital Payment	93	1305	2517	3728	4940
Average Investment	17116	17116	17116	17116	17116
Return (percent)	0.5	7.6	14.7	21.8	28.9
300 Cow System					
Capital Payment	444	2252	4070	5888	7705
Average Investment	25091	25091	25091	25091	25091
Return (percent)	1.8	9.0	16.2	23.5	30.7

[a]Average investment is original cost plus salvage value divided by 2. Salvage value was zero for all items. Only average investment was used because part of the original investment was recovered each year by depreciation.

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