PRODUCTION AND SALE OF ENERGY AND NUTRIENTS FROM A MULTI-FARM DIGESTER

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SUMMARY:
An investor-owned anaerobic digestion system was designed to process the wastes from several dairy farms totalling 900 cows. The resulting biogas will fuel a 97 KW engine-generator producing both electricity for sale to the utility, and waste heat for digester heating and supplemental greenhouse heating. The digested solids and liquids will be marketed as nursery soil and fertilizer, respectively.

KEYWORDS: METHANE, WASTES, ANAEROBIC DIGESTION, MANURE

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INTRODUCTION

The concentration of a large number of dairy cows on farms close to the expanding cities presents a problem in waste management. Technologies developed in the U.S. in the 1970's for the derivation of energy from animal wastes offers the opportunity for the creation of a new industry which will achieve both control of pollution from dairy manure runoff and income from the sale of the energy and byproducts of the process. (Cournoyer, et al., 1984; Walker, et al., Pigg and Yetter, 1984, Weeks, 1984)

This paper describes the work of one of the new companies in this field in Northern California, Bio Energy, Inc. They were founded in September, 1984, to design, build and operate scientific waste processing systems, beginning with cow manure produced on dairies. The first such system in California was the Marinelle digester, built in 1982 on a 300-cow dairy in Marin County, California. Personnel from Bio Energy had key roles in the design and construction of this digester. Two or three 900-cow capacity plants are planned for construction in Sonoma County, California, and one plant ten times larger will be built in the San Joaquin Valley in the next two years.

Bio Energy's first project will be located on a dairy farm near Petaluma, Sonoma County, California, and will serve that dairy and three others. This plant will produce the following sources of revenue:

- **Biogas**: converted into electricity, and heat for the digester and greenhouse at the site;
- **Fibrous Solids**: for a horticultural soil amendment and animal bedding;
- **Nutrient-rich Liquid**: a base for organic fertilizers; and
- **Fresh Produce and Flowers**: from the greenhouse/garden operation.

This project, called the Sonoma Digester, is innovative with respect to it involving multiple farms. The digester is strategically located near several dairy farms enabling the manure to be hauled to a central location to take advantage of a larger operation than could
otherwise be carried out on a single farm. The larger digester and accompanying businesses enable the operation to be managed and maintained as a separate business, independent of the dairy farm operation.

A limited partnership will be created to finance this project. The capital and start-up costs are estimated to be $460,000 for the digester and accompanying facilities to be described in this paper. The estimated after-tax internal rate of return of this project over the ten-year life is 18 percent.

BACKGROUND

For many years, animal waste management was simple. Farmers were accustomed to locating animals near creeks so their wastes could be easily disposed of. As the density of people and farm animals increased, so did the problem of pollution from the manure, and farmers were forced by government regulation and public outcry to store their manure until it could be spread on nearby fields. This remains the current practice on most of the dairies in Sonoma County. When the immediate problem is to dispose of the raw manure, the rate at which it is applied to the land is rarely related to the plant needs. If excess nutrients are applied, they may be washed out of the fields by rainfall and into streams and lakes. Thus the pollution problems that resulted from dumping manure into creeks are only moderately reduced.

Advanced animal waste management begins with the recognition that manure is a valuable resource that can be transformed from a pollutant into many useful products. Controlled anaerobic digestion is a biological process which converts the pollution-causing volatile solids within the manure into energy while enhancing the availability of important organic nutrients for plant growth. Research funds made available during the 1970's financed advanced methodologies and structural designs for the application of this process. The plug-flow digester concept, together with effective methane utilization ideas were conceived and developed in a decade of work at Cornell University (Williams, et al., 1975; Jewell, et al., 1982, 1985). This design made use of low cost materials, and simple operating procedures so that the overall cost effectiveness of the digestion system was enhanced. These design criteria have been the basis for many digester installations throughout the U.S. and Canada.
In California there are approximately 1,000,000 cows on 2,800 dairies. These cows produce approximately 60,000 tons of manure each day. There are currently six operational digesters in dairies in California, serving 0.4 percent of the California bovine population. This is representative of digester activity in other dairy regions of the U.S. Although a number of companies have been formed to build digesters on a commercial basis, their activity has waned recently due to lower energy prices, expensive designs, and insufficient attention to equipment maintenance and product marketing.

In spite of the unfavorable energy prices, there are still opportunities for the use of anaerobic digestion technologies on dairy farms. This because of the situation facing the dairy industry in the U.S. today. The products of this industry are perishable and expensive to transport, so the point of production must necessarily be close to the consuming public. This creates two interconnected problems:

1) The expansion of the suburbs toward the dairy farms has resulted in skyrocketing land prices and the ultimate abandonment of the dairy "Green Belt" regions; and

2) The encroaching suburbs require increasingly strict management of dairy animal waste, mainly because of odor, flies and pollution.

These twin problems present both a challenge and an opportunity for the industry that will provide advanced, scientific management of animal waste. The challenge is to structure the waste management companies such that the farmers are able to participate in the economic benefits and therefore remain in business. The opportunity exists because the economically hard-pressed farms are faced with costly Government-mandated manure management practices; advanced manure management such as anaerobic digestion can both satisfy the pollution regulations and provide valuable products for profitable sale.

THE SONOMA DIGESTER: PROCESS DESCRIPTION

The Sonoma Digester will be a manure treatment facility requiring a daily supply of fresh manure from approximately 900 cows. It will be built on two hectares of land to be leased from a 350-cow dairy farmer near Petaluma, California. In addition to the manure from this farm, manure will be trucked to the plant as needed from three nearby dairies. Cheese whey from local cheese factories may also be added. Figure 1 shows an overall schematic of the system, including materials and energy flows.
The electrical generating capacity of the Sonoma Digester is 97 kW, just under 100 kW, which is the maximum amount of electricity for which the utility, Pacific Gas and Electric Company (PG&E) will currently enter into purchase contracts with an independent power producer in Sonoma county. It will produce over 6600 cubic meters of separated solids and 14,000,000 liters of liquid fertilizer per year. Approximately 1320 cubic meters of the solids will be sold as animal bedding; the remainder will be sold as soil amendment. In addition to these products, the Sonoma Digester will direct some of its excess heat, and a small portion of its solid and liquid products into a greenhouse facility which will produce a large quantity of organic vegetables and herbs 12 months a year.

The manure management process at the Sonoma Digester will consist of the following steps:

1) Cow urine and feces will be scraped on a daily basis into a centrally-located collection tank at each dairy. Here the manure will be mixed with water to the consistency required for transport, about 12 percent solids.

2) A tanker truck will pick up the manure from each dairy and haul it to the central digester. Depending upon the contract negotiated with the dairyman, the truck will return a load of digested manure to the farmer's fields as fertilizer in exchange for his fresh manure. The one-way trip will average 2-1/2 miles.

3) At the plant, the manure will be discharged from the truck into the mix tank, mixed with manure from the host dairy, and pumped into the digester with an 18 kW chopper-type manure pump. The total input will be 49,000 liters per day, and the digester retention time will be 17 days. The digester volume is 833 cubic meters, and the temperature will be held at 38°C.

4) Production of 1692 cubic meters of biogas per day will fuel an internal combustion engine which will drive an electric generator, which produces a gross output of 97 kW.

5) The effluent will flow out of the digester to a storage tank, from which it will be pumped to a "squeezer," a mechanical device designed to remove the coarser, partially digested fibrous material. These solids will then be composted a few days before being sold as bedding, and composted for four weeks before being sold as soil amendment. The remaining effluent will be the liquid fertilizer. It will either be shipped directly to a customer or stored in a pond on site.
The specific products to be marketed by the Sonoma Digester are as follows:

**Electricity:** volatile solids in the manure are converted to methane, a clean-burning gas with medium energy content (22.4 MJ/cu.m), which will power a 97 KW engine-generator 24 hours/day, 365 days per year, except for 10% downtime for maintenance. This makes a total of net output of 765,000 kWh/year.

**Heat:** approximately 19,000 MJ/day waste heat from the engine will be captured for productive use.

**Bio Mulch:** an organic fibrous material akin to peat moss useful as an organic soil amendment for the horticultural industry and as a superior animal bedding for dairies. Production capacity: 20 cu.m/day.

**Organic Fertilizer:** an odorless, organic liquid fertilizer, including many micronutrients. Capacity: 43,310 liters/day.

**Greenhouse/Garden:** Heat, mulch and fertilizer will be used on site to produce vegetables, herbs and flowers desirable by the best restaurants and boutique produce markets of San Francisco Bay Area.

**MARKETING AND DISTRIBUTION OF THE PRODUCTS**

**Electricity**

All electricity produced by the engine generator, less approximately 10% used on site, will be sold to PG&E. Bio Energy intends to execute a standard PG&E surplus sales contract which includes provisions for a time of delivery price schedule for the sale of electricity. At the anticipated price of $.065/kWh, the revenue from electricity sales will be $50,000.

**Heat**

Approximately one-third of the recoverable heat produced by the engine will be used to maintain the digester at 38°C, its optimum temperature. A portion of the remaining heat will be applied to the greenhouse during the winter. There are no current plans to sell any of the excess heat.
Animal Bedding

Dairies that participate in this project will be strongly encouraged to use Bio Mulch as bedding for their cows. This will reduce maintenance costs to digester equipment which is vulnerable to sand, one of several common bedding materials. The bedding will be made available to participating dairymen for $9.20/cu.m FOB the plant, which is the going rate for other types of bedding. Twenty percent of the supply of Bio Mulch has been allocated for the dairies, amounting to about 4 cu.m per day, or 1320 cu.m per year, worth about $12,000.

As bedding, Bio Mulch has the potential to help with dairy profitability. This results from the fact that it is soft and resilient (non-irritating), and that it is almost entirely free from E. coli bacteria. Consequently its use can be important in lowering the incidence of mastitis in the dairy herd. Management at the Mason-Dixon farm in Pennsylvania (600 cows) estimated an increase in income of $25,000/yr after switching to this bedding. A recent bulletin from the University of California Cooperative Extension's Sonoma County Dairy Advisor states that the value of good mastitis control for an average Sonoma herd would be over $25,000 annually from increased milk production. A small additional benefit will accrue from the reduced cost of treating infected cows.

Mulch

Studies have shown that the digested solids are an excellent mulch material for bedding plants and nursery operations (Williams and Regan, 1985). Approximately 75 percent of the material produced from the manure solids squeezer will be sold to landscapers, intensive commercial growers and home gardeners. This will amount to about 15 cubic meters per day, or almost 5000 cu meters per year, worth $21 per cu.m, for a total revenue stream of over $105,000 annually. This is expected to be the most important source of revenue early in the life of the Sonoma Digester. Another 5 percent will be used in the greenhouse/garden operation, and the remainder will be sold to participating dairies as bedding material as explained above.

The initial marketing effort will be directed toward landscape contractors and intensive commercial growers, some of whom could take the entire supply. Market studies of soil amendments in Sonoma County indicate that the Bio Mulch can be sold to local users in bulk.
Organic Liquid Fertilizer

This is a new product which is sufficiently different from standard synthetic fertilizers that three years of development appears to be required before revenue could become attractive. Nevertheless, the presence of significant quantities of micronutrients and nitrogen in a form immediately accessible to plant life, in addition to its purely organic composition, makes the liquid fertilizer very attractive for use in organic agriculture. Several commercial organic farmers are eagerly waiting for their first sample. A local organic fertilizer company has also expressed interest in bottling and marketing the liquid to upscale urban gardeners. In addition, the micronutrient content makes the liquid potentially very attractive to Sonoma County vintners.

It is anticipated that until a sufficient commercial market is developed, the fertilizer will be returned to participating dairies when the manure truck collects a load of manure. This liquid fertilizer will be exchanged as an offset to the manure purchase price with the dairyman. It is expected that most of the other dairymen will agree to a similar arrangement. Dairymen will bear responsibility for storage and application to their fields. In the event dairymen do not have storage space available, the fertilizer will be stored at the digester facility and the transportation cost charged to the dairyman when it is delivered. The fertilizer will also be used in the greenhouse and garden at the digester site, and will be sold to any commercial growers or interested visitors, FOB at the digester.

Bio Energy expects minimal revenue from liquid fertilizer sales in the first year. Second year sales are expected to equal approximately $15,000 from manure cost offsets and sales to a few local commercial organic farmers. One or two vineyard contracts could significantly increase this estimate. By the fourth year, when the product is established in the retail market, the sales will increase to approximately $50,000. This is based on a sales price of approximately $5 per cubic meter, and marketing 70% of the output, or about 10,000 cubic meters per year.

Greenhouse and Garden

San Francisco Bay Area restaurants have successfully fostered a new California cuisine. This cuisine emphasizes the use of the freshest locally-grown, chemical-free produce available. The restaurant demand for fresh, beautiful, healthy produce has spawned and active commercial organic farmer movement and resulted in the celebration of this produce at festivals
such as the annual “Tasting of the Summer Produce.” This is a gala event which places local produce in the same light as the world-renowned wines from this region.

Horticultural efforts will be directed toward three ends:

1) To produce top quality vegetables, herbs and flowers year-round;

2) To demonstrate the value of and stimulate a market for the digester products; and

3) To build a reputation for the produce and digester products through classes (tuition charged) designed to introduce others to state-of-the-art intensive organic gardening.

The bulk of the revenue from this segment of the digester operation will come from produce sales. The top end of the market will be targeted and, at first, only greenhouse produce will be capable of meeting the required standard. Approximately two years will be necessary to develop the clay soil at the site to the level needed to support top quality, full production in the outdoor garden.

Selection of crops will be creatively market oriented. Winter crops will likely include primarily tomatoes, herbs and flowers from the greenhouse, and garlic from the garden. Specialty vegetables will be included later in the season. A major effort will be made to work with local chefs and produce buyers to meet market demand. A small portion of the growing area will be devoted to new varieties: the specialty vegetable market favors trend setters, not followers.

Marketing will be done directly at first to the multitude of quality restaurants and produce markets within a 40 kilometer radius of the plant. A personal relationship between the head gardener and local chefs will be established. When production exceeds the capacity of the head gardener to handle the marketing, the company will turn to Wine Country Cuisine in nearby Santa Rosa and later to Greenleaf Produce in San Francisco or other produce brokers that specialize in organic produce. Total revenue expected from the greenhouse and garden is expected to be about $54,000 per year.
COST/BENEFIT SUMMARY

The total capital cost of the Sonoma Digester, including digester, engine-generator, greenhouse, solids handling, and trucks, as well as contingencies and start-up capital, is $460,000. The yearly operation costs, including labor, material, maintenance, and management, will be approximately $133,000.

The benefits, as explained above, are summarized below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>$50,000</td>
</tr>
<tr>
<td>Animal Bedding</td>
<td>12,000</td>
</tr>
<tr>
<td>Biomulch</td>
<td>$105,000</td>
</tr>
<tr>
<td>Liquid Fertilizer</td>
<td>50,000</td>
</tr>
<tr>
<td>Greenhouse/Garden</td>
<td>54,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$271,000</strong></td>
</tr>
</tbody>
</table>

Thus the simple payback without consideration for tax benefits or interest on borrowed money, would be as follows:

\[
\text{Simple Payback} = \frac{460,000}{271,000/\text{yr} - 133,000/\text{yr}} = 3.33 \text{ Years}
\]

In summary, this paper describes a manure processing system, the Sonoma Digester, whose products include not only generated electricity, but also superior animal bedding, nursery mulch, liquid fertilizer, and greenhouse and garden products. Such a diversity of products guarantees a more stable economic future for the plant, whose simple payback is 3.33 years. When a ten-year stream of revenue and costs are analyzed, taking into account tax advantages and interest rates, the after-tax internal rate of return was calculated to be 18 percent per annum.
REFERENCES


FIGURE 1. BIO ENERGY, INC.
MANURE PROCESSING SYSTEM
PLANT # 1

100% of Manure from 900 Cows @ 55 kg per head;
49,000 kg per day;
@ 12% T.S. = 5,890 kg
@ 80% V.S. = 4,710 kg

MIX TANK

MANURE SLURRY LINE

MIX AND FEED PUMP

DIGESTER HEATING LOOP
WATER JACKET HEAT

ENGINE-GENERATOR

BIOGAS LINE

FLAME-ARRESTER/RELIEF VALVE

DIGESTER

VOLUME @ 833 CU M

TEMPERATURE @ 38°C

PLUG FLOW

Volatile Solids Removal
@ 40% x 4,710 kg V.S. = 1885 kg per day

Bioas Production;
@ 0.36 cu m per kg V.S. added;
1696 cu m per day
@ 22.4 MJ per cu m = 37,980 MJ per day;
@ 25% thermal efficiency and
@ 90% electrical efficiency;

37,980 MJ x 0.25 x 9 = 97 KW
3.6 MJ/kWh x 24 hrs

GREENHOUSE

WASTE HEAT FROM ENGINE

GREENHOUSE COVERING THE DIGESTER

DIGESTER

Sediment/Drip Trap

FRESH VEGETABLES TO MARKET

ELECTRICITY TO UTILITY
97 KW, or
2328 kWh/day

LIQUID FERTILIZER (LF)
49,000 kg effluent
- 5,690 kg BS
= 43,310 kg
= 43,310 liters/day

MANURE SQUEEZER

BEDDING SOLIDS (BS)
5,690 kg per day
@ 25% total solids
= 1420 kg T.S.
@ 285 kg per cu m
= 20 cu m per day

EFFLUENT TANK

Effluent:
49,000 kg influent
- 1,885 kg V.S. removed
= 47,115 kg effluent per day
@ 8.5% T.S.,
4000 kg total solids per day