FEASIBILITY STUDY ON IMPLEMENTING ANAEROBIC DIGESTION TECHNOLOGY ON HUMBOLDT COUNTY DAIRY FARMS

Funded by: State of California Community Development Block Grant
01-EDBG-782

Submitted to: Humboldt County Economic Development Office

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June 1, 2003

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Executive Summary

The purpose of this report is to consider the feasibility of implementing anaerobic digestion (AD) technology as a means of dairy manure management on Humboldt County dairy farms. Funding for this project was supplied by the State of California Community Development Block Grant # 01-EDBG-782 through the Humboldt County Economic Development Office.

Current trends in milk production have forced dairies to intensify their operations. The larger herd numbers required by today's dairy operators in order to stay in business have led directly to an increase in manure production. The volume of manure has become a social and environmental issue. Dairies also consume significant amounts of energy in their daily operation. Anaerobic digestion of manure is a promising technology that has been shown to effectively address many of the problems associated with manure management while providing a reliable energy resource. AD technology has the ability to offer substantial benefits to dairy operators. In many cases, without the implementation of AD technology on U.S. farms, many farmers would have been forced to cease their operation.

There are a variety of AD systems used on U.S. farms, including covered lagoon digesters, complete mix digesters, and plug flow digesters. Choosing the appropriate system depends on many factors including local weather conditions, local water tables, manure collection technique, manure storage capacity, and end use of AD products. The U.S. Environmental Protection Agency's *AgStar Handbook* offers five preliminary screening questions that should be considered to determine whether AD technology is a suitable manure management technique for Humboldt County. Based on the screening questions, it would appear that many Humboldt County pasture-based dairies are not currently ready to consider implementing AD technology as part of their manure management plan. Some of the larger dairies in the county may be able to benefit from a plug flow AD system. In order to conduct an analysis, a suitable Humboldt County pasture-based dairy is defined. In summary, the dairy would have at least 400 cows that are housed in freestall barns for a portion of the year. A more extensive description of these requirements are listed on page 9. A dairy meeting these criteria could consider a plug flow digester as part of their manure management plan, as long as benefits besides energy production can be realized.

A digester on such a Humboldt County dairy could produce between 4 million and 6.4 million cubic feet of biogas and 124,000 to 198,000 kilowatt-hours of electricity annually, leading to potential annual avoided electrical costs of $11,100 to $23,800. Valuable thermal energy for water or space heating could be recovered from the engine-generator set displacing between 3,400 and 5,500 therms of natural gas per year, leading to a potential annual savings of $2,800 to $4,500 on heating costs. The digester would also produce enough fiber each year for an additional annual income of $4,800 to $8,000. Manure pit maintenance costs could be reduced by $9,000 per year. In summary, anaerobic digester products and avoided operation and maintenance (O&M) on current manure storage systems have a capacity to generate up to $45,000 for a suitable Humboldt County dairy.

One of the main issues discouraging dairy operators from utilizing AD technology in their manure management plan is the high capital investment necessary for installing the system. A plug flow system for a suitable Humboldt dairy would cost between $500 and $1,000 per cow, leading to an installed cost of $200,000 to $400,000 for the complete system. Expected operations and maintenance costs of an AD project may be another deterrent. Based on costs reported for existing systems, O&M costs for a typical Humboldt County digester designed to handle the manure from 400 dairy cows are estimated to be $10,000 to $20,000 annually.

In the best case scenario, an AD system installed on a Humboldt County dairy without funding assistance has an economic payback period of approximately 5.6 years. This length of time is often considered too long for a project to be considered viable solely on an economic basis. In the worst case scenario, the project will not pay for itself during the system's expected lifetime. Without significant financial assistance, AD systems are only a viable option for Humboldt County dairies whose operators place significant value on intangible benefits such as odor control, decrease in fly populations, and environmental stewardship.

Fortunately, there are many programs designed to help dairy operators fund and install AD systems on their farms. With these types of assistance, implementation of AD technology on a suitable Humboldt County dairy would become more feasible than previously indicated. The best case payback period is reduced to 2.6 years with outside financial assistance. The Dairy Power Production Program (DPPP) offers up to 50% of project capital cost or up to $2,000/kW capacity. The remaining portion of the project cost could be partially offset with PG&E's Self-Generation Incentive Program (SGIP) that would pay a rate of $1,500/kW or up to 40% of the projects' capital cost. The available financial assistance can significantly decrease the simple payback period of an AD system installed on a suitable Humboldt County dairy. These results, combined with the project's intangible benefits, could make AD technology a viable option for a local dairy's manure management system. The USDA's Rural Development Program also offers funding for purchase of renewable energy systems, including biogas generators, by agricultural producers.

Anaerobic digestion is a technology that has been shown to effectively manage dairy manure while yielding resources with significant financial and intangible value. The smaller pasture-based dairies of Humboldt County initially appear to be ill-suited for the implementation of this technology, but under the right circumstances, a suitable Humboldt County dairy could effectively use a plug flow digester as part of their manure management plan.

INTRODUCTION

Current trends in milk production have forced dairies to intensify their operations. The larger herd numbers required by today's dairy operators in order to stay in business have led directly to an increase in manure production. The volume of manure produced, which was once manageable when herd sizes were smaller and less densely populated, has become a social and environmental problem. Inadequate capturing, storage, and treatment techniques increase manure's capacity to degrade local air, soil, and water quality. Pollutants generated by mismanaged livestock manure include biochemical oxygen demand (BOD), pathogens, nutrient loading, methane, and ammonia[1]. Costs associated with increased regulation of these pollutants have left many dairy operators struggling to survive. This affects not only the dairy operators and their families, but also the health of the local economy.

Dairies consume significant amounts of energy. Dairy energy loads include chiller systems to cool milk, air compressors to operate milking equipment, heaters or boilers for providing hot process water, and various types of pumps. Similar to other business owners, especially here recently in California, dairy operators have to face increasing and uncertain energy costs. The ability to buffer themselves against this uncertainty would prove to be an valuable asset.

Anaerobic digestion (AD) of manure is a promising technology that has been shown to effectively address many of the problems associated with manure management while providing a reliable energy resource. AD is by no means a new technology. It has been used on a small scale for many centuries in India and China. In Europe, AD systems have become common on many farms. When properly designed, constructed, and managed, AD systems have been a successful manure management tool on U.S. farms since 1972. Using manure as the only input, an anaerobic digester yields three valuable outputs: biogas, solid fiber, and a nutrient-rich liquid. In addition, AD technology offers a host of intangible benefits that help keep farms operational. The principal reasons a dairy farmer would consider installing an AD system include the following:

<u>On-site energy production.</u> By recovering biogas and producing energy on the farm, dairy operators can reduce or eliminate monthly energy expenses. Electricity produced by utilizing biogas in an engine-generator can be used on the farm or sold to a local utility. Thermal energy for heating water or buildings can be acquired by directly burning biogas in a boiler or furnace, or from a heat recovery system connected to the engine-generator set.

<u>Generation of stable, high quality liquid fertilizer and solid soil amendment.</u> Digestion does not reduce the quantities of nutrients in manure. The process converts them to new,

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[1] Lusk, P. (1998) *Methane Recovery from Animal Manures: A Current Opportunities Casebook.* 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, D.C.

more soluble, and often more available forms[2]. The liquid, commonly called filtrate, is a valuable fertilizer that can be applied directly to the land. The AD process converts the chief nutrients in manure, nitrogen, phosphorus, and potassium, into a soluble form that is more readily available to plants. In the process of anaerobic digestion, the organic nitrogen in the manure is largely converted to ammonium, a primary constituent of commercial fertilizer, which is readily available and utilized by plants. The AD process also produces an essentially sterile fiber that is nearly free of weed seeds and pathogens. The solid fiber can be used as livestock bedding material or as an excellent soil amendment.

Reduction in odors. AD systems have the ability to reduce offensive odors from overloaded or improperly managed manure storage facilities. These odors impair air quality and may be a nuisance to nearby communities, particularly as new residential and commercial development continue to expand into historically agricultural areas. Biogas systems reduce these offensive odors because volatile organic acids, the odor-causing compounds, are consumed by biogas-producing bacteria.

Reduction in ground and surface water contamination. Digester effluent is a more uniform and predictable product than untreated manure. Its higher ammonium content allows better crop utilization, and its physical properties allow easier land application. Properly applied, digester effluent reduces the likelihood of surface or groundwater pollution. Once the filtrate is properly applied, the risk of further ammonia losses is extremely small compared to raw manure. There are three reasons for this: 1) due to the lower viscosity of the filtrate, it penetrates faster into the soil. 2) soil ammonium adsorption is high, resulting in low washout. 3) ammonium is more readily available to plants than the organic nitrogen found in untreated manure; hence, the uptake through nitrification is faster, and the chance for washout is reduced[3].

Reduction in public health risk**.** Heated digesters reduce manure pathogen populations dramatically in a few days. Many farmers have reported that their AD system has substantially decreased fly populations on their farm[4].

AD technology has the ability to offer substantial benefits, both economic and intangible, to dairy operators. In many cases, without the implementation of AD technology on U.S. farms, many farmers would have been forced to cease their operation.

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[2] Lusk, P. (1998) *Methane Recovery from Animal Manures: A Current Opportunities Casebook.* 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, D.C.

[3] Lusk, P. (1998) *Methane Recovery from Animal Manures: A Current Opportunities Casebook.* 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, D.C.

[4] Roos, K.F., and Moser, M.A. (1997) *A Manual for Developing Biogas Systems at Commercial Farms in the United States*. AgStar Handbook. U.S. Environmental Protection Agency, Washington, D.C. EPA-430-B-97-105

DESCRIPTION OF THE TECHNOLOGY

Anaerobic digestion is a biological process in which bacteria break down organic matter in an airless environment, with biogas as the end product. Biogas derived from dairy manure is comprised of approximately 60% methane (CH_4), 40% carbon dioxide (CO_2), and trace amounts of other gases, including hydrogen sulfide (H_2S). Due to its high methane content, biogas can be used as a fuel for energy conversion devices. Alternatively, it can simply be flared, as the resulting carbon dioxide makes a lesser impact on global climate than the methane. Anaerobic digestion can occur within three different temperature ranges: psychrophilic, mesophilic, and thermophilic.

Psychrophilic digestion occurs at temperatures below 68°F and is usually associated with systems that operate at ground temperature. Psychrophilic AD has the lowest biogas production rate of the three temperature ranges. The production rate is susceptible to seasonal and diurnal fluctuations in temperature, making it difficult to predict how much biogas will be available.

The mesophilic range is between 68°F and 105°F. The optimal temperature for mesophilic AD is approximately 100°F, which is nearly the same as the body temperature of dairy cattle. This allows the same bacteria at work in a cow's ruminant system to continue breaking down the excreted organic matter for a period of several days. Digesters operating in the mesophilic range require constant heating in order to maintain a temperature of 100°F.

The thermophilic range is between 110°F and 160°F. The elevated temperature allows for the highest rate of biogas production and the lowest hydraulic retention time (HRT). The HRT is the amount of time material must remain in the digester before it is sufficiently processed. Digesters that operate in the thermophilic range require substantial amounts of energy to maintain the proper temperature and are prone to biological upset due to temperature fluctuations. To avoid upset, they require closer monitoring and maintenance. Another drawback is that the effluent is not odor free.

There are a variety of AD systems used on U.S. farms. Choosing the appropriate system depends on many factors including local weather conditions, local water tables, manure collection technique, manure storage capacity, and end use of AD products. Following is a brief description of the three most common digester types used on U.S. dairy farms, presented in ascending order of applicability to Humboldt County.

Covered Lagoon

Covered lagoons are the least technical and least expensive of the AD systems used on U.S. dairy farms. They require large land areas, have the lowest biogas production rate, and can only be used in areas with low water tables. Covered lagoons are not normally heated, therefore they operate approximately at ground temperature in the psychrophilic range. This technique is designed to work in a warm climate on diluted manure with less than 2 percent solids content. Dairies that use water to flush feeding lanes, freestall barns, and other surfaces could consider this AD technology as part of their manure management plan, especially if the main priority is to reduce odors associated with manure storage.

Biogas is captured by placing an impermeable floating cover over part or all of the manure storage lagoon. Biogas production rates vary based on the temperature of the lagoon, which in turn is affected by daily and seasonal fluctuations in ground temperature, air temperature, and feedstock temperature.

Complete Mix Digester

Complete mix digesters are the most technical and most expensive to build and operate of the AD systems used on U.S. dairy farms. The heated tank can be placed either above or below ground and is designed to treat manure with a solids content between 2 percent and 10 percent. The manure slurry is continuously mixed either mechanically or by using pumped gas circulation to keep the solids in suspension. It is often operated in the thermophilic range, thereby generating biogas at a high rate. Substantial amounts of energy are required to maintain digester temperature and mix the digester contents. The high capital and energy costs generally limit complete mix AD systems to large farms or centralized facilities.

Plug Flow Digester

Plug flow digesters are designed to handle undiluted dairy manure with an 11% to 14% solids content. The standard design consists of a covered rectangular concrete tank that holds approximately 20 days worth of manure. Each time fresh manure is added to the plug flow digester, which is normally done daily, an equal volume of digested manure is forced out at the other end. Biogas is captured in the space between the digesting material and the cover. A daily plug of manure requires about 20 days to pass through the digester.

Digestion is carried out by mesophilic bacteria in a temperature range of 95°F and 103°F. The manure in the digester must be continuously heated in order to maintain the optimal temperature range. This heat can come either from engine waste heat or from the biogas stream itself. As with the complete mix digester, the long, constant exposure to heat kills most pathogens and weed seeds in the manure. Plug flow digesters only work with undiluted dairy manure. It is the optimal design for dairies that scrape manure daily and that are looking to acquire energy from the biogas stream.

DETERMINING THE FEASIBILITY OF AD TECHNOLOGY IN HUMBOLDT COUNTY

In order to determine whether AD technology is a suitable manure management technique for Humboldt County, five preliminary screening questions need to be considered[5].

(1) *Does the dairy have at least 300 cows from which 100% of the manure is collected regularly?* Dairies of this size and larger can generate the amount of biogas necessary to make the project financially viable. In Humboldt County there are many dairies

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[5] Roos, K.F., and Moser, M.A. (1997) *A Manual for Developing Biogas Systems at Commercial Farms in the United States*. AgStar Handbook. U.S. Environmental Protection Agency, Washington, D.C. EPA-430-B-97-105

with at least 300 cows, but few of them can collect 100% of the manure because the cows are pastured for a substantial portion of the year.

(2) *Is manure production and collection stable year-round?* AD systems are generally designed to handle a consistent feeding rate. This is done to ensure a constant flow of biogas and a consistent HRT. In the wet winter months in Humboldt County, dairies that house their cows in freestall barns can collect 80% to 100% of the produced manure. In the dry months, cows are either sent to pasture or given access to corrals. While cows are being pastured, only about 30% of the manure can be collected from feeding and milking areas. About 40% to 55% can be collected from cows that spend time in corrals[6]. This variability in available manure can make it difficult to design and operate an effective AD system.

(3) *Is the current manure management system compatible with AD technology?* Biogas technology requires the manure to be collected regularly at a single point and to be free of large quantities of bedding and other undigestible foreign material. Many dairies in Humboldt County collect their manure regularly to a central location and therefore could consider AD technology. Dairies that scrape manure could consider a plug flow system, which requires a relatively high percentage of solids in the manure. Dairies that flush would be limited to a covered lagoon system because of the low percentage of solids in flushed manure. However, covered lagoon systems are not practical in most Humboldt County dairylands because of the high water tables in the Arcata Bottoms and Ferndale areas. Disregarding the water table problem, the relatively cool weather in the county would substantially limit the production of biogas in unheated lagoon systems. For lagoon systems in Humboldt County, the main benefit of the system would thus be odor control.

(4) *Is there a use for the recovered energy?* All dairies in the county have a substantial demand for electrical and thermal energy. These demands could be met in whole or in part by producing energy on-site through the implementation of AD technology and an associated engine-generator.

(5) *Is someone able to manage the system efficiently?* Dairy operators in the county would need to ask themselves if they are willing and able to spend the necessary time and energy to keep their AD system working well. An AD system requires someone to pay regular attention to system operation, provide necessary repair and maintenance, and have the desire to see the system succeed.

There is another question that local dairy operators need to answer that is not part of the AgStar screening process. That question is:

(6) *Does the dairy operator own the land or hold a lease with a remaining lifetime in excess of the project's expected lifetime on the land that is currently being used for*

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[6] Burke, D.A. (2001) *Dairy Waste Anaerobic Digestion Handbook: Options for Recovering Beneficial Products From Dairy Manure.* Environmental Energy Company

the dairy operation? Unless this can be positively answered, the significant capital investment necessary to build an AD system would not be justified.

A RECOMMENDED BIOGAS SYSTEM DESIGN FOR HUMBOLDT COUNTY

Using the previous screening questions, it would appear that many Humboldt County dairies are not currently ready to consider implementing AD technology as part of their manure management plan. Some of the larger dairies in the county may be able to benefit from a plug flow AD system if other benefits besides energy production are considered. In order to conduct an analysis, a suitable Humboldt County pasture based dairy would need to fit the following profile:

(1) Manure from at least 400 cows can be collected on a regular basis.
(2) Cattle are housed in freestall barns during the wet season. This allows for maximum manure collection for a portion of the year.
(3) During the months the cattle are given access to pasture or corrals, the cattle spend enough time around the barn and feeding area in order to collect at least 40% of the manure.
(4) Undiluted manure, free of undigestible material, is scraped daily into a single collection point. Plug flow digesters do not operate properly if the solids content falls below 11%.
(5) A qualified operator is available to spend time daily, normally less than 30 minutes but occasionally up to a few hours, in order to maintain proper operation of the digester without sacrificing the dairy's main priority, the well-being of the herd.
(6) The land on which the dairy exists is owned, or a long-term lease is secured, by the dairy operators.

If these criteria can be met, local dairy operators could consider a plug flow digester as part of their manure management plan, as long as benefits besides energy production can be realized. The other types of digesters have drawbacks that prevent them from being used in Humboldt County. The high capital costs, high operating and maintenance expenses, and technical complexity of complete mix digesters make them a poor choice for Humboldt County. The high water tables and cooler climate of the county are not compatible with effective operation of a covered lagoon digester.

There are AD systems currently in operation on U.S. farms that were designed and built by the farm operator, but this approach is not normally recommended. Design and installation of an AD system should be conducted by an engineering firm experienced with the complicated design calculations, technical requirements, and regulatory issues associated with these systems. Appendix A lists companies with a proven track record in the design and installation of successful AD systems on U.S. farms.

ESTIMATE OF BIOGAS, ENERGY, AND FERTILIZER PRODUCED BY A SUITABLE DAIRY IN THE COUNTY.

According to published reports and actual case studies, 50 to 80 cubic feet of biogas can be produced per cow per day when 100% of a cow's manure is collected[7]. A suitable Humboldt County dairy, as defined previously, would have the capacity to produce substantial amounts of biogas, electrical and thermal energy, digested fiber, and nutrient rich substrate from a plug flow digester. These products would have an immediate positive impact on the dairy operation.

A complete plug flow AD system for a suitable Humboldt County dairy could be constructed on a footprint of less than one-quarter of an acre. Based on a dairy size of 400 cows and the rest of the assumptions from the previous section, such a digester would produce between 4 million and 6.4 million cubic feet of biogas annually with an approximate energy value of 600 Btu/per cubic foot. Using an engine-generator efficiency of 23%, between 124,000 and 198,000 kilowatt-hours of electricity (kWhe) would be produced annually. These values assume the engine-generator would be on-line 85% of the year and that 10% of the generated electricity would be used for parasitic loads such as compressors, pumps, and blowers. Many Humboldt County dairies are charged for their electricity at a time of use (TOU) rate of $0.09 to $0.12 per kWh[8], leading to potential annual avoided electrical costs of $11,100 to $23,800.

Valuable thermal energy for water or space heating could be recovered from the engine-generator set. A conservative estimate of 2,800 Btu/kWhe produced[9] would displace between 3,400 and 5,500 therms of natural gas per year. Current natural gas rates of $0.98 per therm during the winter and $0.65 per therm during non-peak periods lead to a potential savings of $2,800 to $4,500 on heating annually . The digester would also produce approximately 800 cubic yards of valuable fiber each year[10]. This virtually pathogen- and weed seed-free fiber has multiple uses. It can be used as freestall bedding or as a high quality soil amendment. Dairy operators have reported receiving between $6 to $10 per cubic yard when the material is sold as a bulk soil amendment, for an additional annual income of $4,800 to $8,000. When used as freestall bedding, dairy operators have saved $20 to $50 per cow annually with an added benefit of lower mastitis rates[11]. Another area of substantial savings arises from manure pit maintenance due to

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[7] Roos, K.F., and Moser, M.A. (1997) *A Manual for Developing Biogas Systems at Commercial Farms in the United States*. AgStar Handbook. U.S. Environmental Protection Agency, Washington, D.C. EPA-430-B-97-105

[8] Cherry, R. (30 May, 2003) Personal communication. PG&E

[9] Lusk, P. (1998) *Methane Recovery from Animal Manures: A Current Opportunities Casebook.* 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, D.C.

[10] White, J., and Van Horn, C., (1998) *Anaerobic Digester at Craven Farms: A Case Study.* Oregon Office of Energy, U.S. DOE DE-FG51-94R020021

[11] Lusk, P. (1998) *Methane Recovery from Animal Manures: A Current Opportunities Casebook.* 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, D.C.

less frequent cleanings and operation of manure spreaders. Annual savings of $9,000 can be realized for a 400 cow dairy[12].

The AD process produces a weed seed-free and nutrient-rich filtrate. Dairy operators currently using AD technology have reported savings due to reduced herbicide and commercial fertilizer use when they apply the filtrate to their land. However, the typical Humboldt County dairy uses very little, if any, herbicides or commercial fertilizers on its pasture lands. These benefits are thus of little financial value to local dairy operators. The main benefits to the Humboldt County dairy operator of using digester filtrate on their land would be greater ease of manure handling and higher quality forage material in the pasture. The digested filtrate is a liquid that is much easier to manage, store, and then later apply to the pastures than raw manure. Destruction of weed seeds and increased nutrient value of the filtrate could allow for higher yields from pasture lands.

A plug flow digester installed on a suitable Humboldt County dairy thus has the potential to generate income for the dairy operator through avoided costs and revenue. Energy savings alone will range from approximately $14,000 to $28,000 annually. The sale of digested fiber could generate up to $8,000 annually and avoided manure pit cleanouts could save up to $9,000 a year. In summary, anaerobic digester products and avoided O&M on current manure storage systems have a capacity to generate up to $45,000 for a suitable Humboldt County dairy.

WATER QUALITY BENEFITS FROM UTILIZING AD TECHNOLOGY.

Studies show that digester heat and retention time destroy fecal coliform bacteria that are present in raw cow manure by more than 99%. This can potentially reduce the amount of bacteria polluting a local watershed and possibly harming aquatic resources. Separation of solids during the digester process removes about 25% of the nutrients from manure[13]. These benefits may be of limited value to Humboldt County dairy farmers, however, as most of the manure that infiltrates local waters appears to come from manure deposited on the pastures, not manure that is captured and stored. There is currently no available data regarding the effect of dairy manure on local watersheds.

COST OF THE EQUIPMENT AND INSTALLATION, OPERATING EXPENSES, AND PAYBACK PERIOD.

One of the main issues discouraging dairy operators from utilizing AD technology in their manure management plan is the high capital investment necessary for installing the system. A plug flow system for a suitable Humboldt dairy would cost between $500 and $1,000 per cow, leading to an installed cost of $200,000 to $400,000 for the complete system[14]. The complete system includes manure collection, the anaerobic digester, gas handling equipment, engine-generator and switchgear, effluent separation and storage equipment, engineering costs, permitting fees, and labor. A system that is both well engineered and maintained has the capacity to remain functional for 20 years or more.

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[12] Langerwerf, L. (14 February, 2003) Personal communication. Langerwerf Dairy, Durham, CA.
[13] White, J., and Van Horn, C., (1998) *Anaerobic Digester at Craven Farms: A Case Study.* Oregon Office of Energy, U.S. DOE DE-FG51-94R020021
[14] Moser, M. (12 February, 2003) Personal communication. RCM Digesters, Inc., Berkeley, CA.

Anticipated operation and maintenance costs of an unfamiliar technology may be another factor discouraging many dairy operators from implementing AD projects. In reality, however, these costs tend to be modest. Once installed, the cost of O&M on the system is heavily dependent on the quality of the equipment used and the dedication of the operator to keep the system running as well as possible. Engine-generator maintenance is estimated to be approximately $0.015 per kWhe produced for an annual cost of $1,800 to $3,000. This cost includes regular oil and filter changes, spark plugs, and an amortized estimate for major overhauls during the life of the system[15, 16]. O&M for the remainder of the system is more difficult to estimate. A good rule of thumb is that complete system O&M is approximately 5% of the initial capital cost[17]. Total annual O&M for a typical Humboldt County digester designed to handle the manure from 400 dairy cows is estimated to be $10,000 to $20,000.

In order to evaluate the economic viability of an AD project, a simple payback period is calculated for best case, median, and worst case scenarios. The results are summarized on an annual basis in Table 1.

Table 1. Economic summary and simple payback period for an AD system installed on a suitable Humboldt County dairy.

	Best Case	**Median Case**	**Worst Case**
Capital cost	$200,000	$300,000	$400,000
Annual value of electricity	$23,824	$17,496	$11,168
Annual value of thermal energy	$4,558	$3,703	$2,849
Annual value of fiber	$8,026	$6,420	$4,815
Annual savings on lagoon cleanout	$9,000	$4,500	0
Annual O&M	$10,000	$15,000	$20,000
Simple payback period	5.6 years	17.5 years	> 20 years

In the best case scenario, an AD system installed on a Humboldt County dairy will pay for itself in 5.6 years. This length of time is often considered too long for a project to be considered viable solely on an economic basis. In the worst case scenario, the project will not pay for itself during the system's expected lifetime. Without significant financial assistance, AD systems are only a viable option for Humboldt County dairies whose operators place significant value on intangible benefits such as odor control, decrease in fly populations, and environmental stewardship. High capital costs and the inability to collect adequate amounts of manure, due to the pasture-based dairy economy of Humboldt County, currently make these systems economically infeasible, unless substantial assistance can be found to defray the initial costs.

[15] White, J., and Van Horn, C., (1998) *Anaerobic Digester at Craven Farms: A Case Study.* Oregon Office of Energy, U.S. DOE DE-FG51-94R020021

[16] Ross, C.,Drake, T., and Walsh, J. (1996). *Handbook of Biogas Utilization, Second Edition*. Muscle Shoals, AL: Southeastern Regional Biomass Energy Program.

[17] Ross, C.,Drake, T., and Walsh, J. (1996). *Handbook of Biogas Utilization, Second Edition*. Muscle Shoals, AL: Southeastern Regional Biomass Energy Program.

There are many programs designed to help dairy operators fund and install AD systems on their farms. A few of these programs are described in the following section. With these types of assistance, implementation of AD technology on a suitable Humboldt County dairy would become more feasible than the previous analysis indicates. The Dairy Power Production Program (DPPP) offers up to 50% of project capital cost or up to $2,000/kW capacity. The remaining portion of the project cost could be offset with PG&E's Self-Generation Incentive Program (SGIP) that would pay a rate of $1,500/kW or up to 40% of the projects' capital cost.

The capacity of the engine-generator set for the suitable Humboldt County dairy would be approximately 40 kW. This system size would make $80,000 available from the DPPP and $48,000 to $60,000 available from the SGIP. The revised economics are summarized in Table 2.

Table 2. Revised economic summary and simple payback period for an AD system installed on a suitable Humboldt County dairy assuming financial assistance from the DPPP and SGIP.

	Best Case	**Median Case**	**Worst Case**
Revised capital cost	$92,000	$180,000	$280,000
Annual value of electricity	$23,824	$17,496	$11,168
Annual value of thermal energy	$4,558	$3,703	$2,849
Annual value of fiber	$8,026	$6,420	$4,815
Annual savings on lagoon cleanout	$9,000	$4,500	0
Annual O&M	$10,000	$15,000	$20,000
Simple payback period	2.6 years	10.5 years	> 20 years

As Table 2 indicates, available financial assistance can significantly decrease the simple payback period of an AD system installed on a suitable Humboldt County dairy. These results, combined with the intangible benefits discussed previously, could make AD technology a viable option for a local dairy's manure management system.

FUNDING SOURCES CONTRIBUTING TO IMPLEMENTATION OF AD TECHNOLOGY ON DAIRY FARMS.

Funding is available from a variety of sources to assist dairy operators with the costs of installing and operating an AD system on their farm. A brief description of some funding options follows.

Grants

The primary source of funding for dairy farm biogas projects in California recently has been the Dairy Power Production Program (DPPP). This program was funded by the State under Senate Bill 5X and is administered by the Western United Resource Development Corporation (WURD), a dairy operators' industry association. This program was originally funded with $9.6 million and, as of September 2002, had approved $2.5 million in funding for nine projects representing approximately 1.5 MW in generating capacity.

The program offers two funding alternatives. The "buydown" option provides up to 50% of project capital costs or $2,000/kW capacity, whichever is less, in up-front funding. The applicant is required to demonstrate the technical feasibility of their project to receive funding. Under the "incentive" option, considered to be riskier financially, the applicant is not required to prove feasibility in advance and is given a 5.7¢/kWh incentive for energy generation up to 50% of project capital cost over the first five years the project is in operation. Most applicants to the program have chosen the buydown option in order to get up-front capital. DPPP grants cannot be combined with any other form of State of California energy funding.

As of June 2003, funding is still available from the DPPP. For more information, call Kathi Schiffler at (209) 527-6453. The program's website is www.wurdco.com, or write to:

> Western United Resource Development, Inc.
> 1315 K Street
> Modesto, CA 95354

In a May 2003 telephone conversation, Ms. Schiffler pointed out some important limitations on the Dairy Power program. Some dairy operators have inquired about aggregating their manure to more cost-effectively operate a multi-dairy digester. WURD consulted with the State and have expressed the opinion that this may not be an appropriate use of DPPP funds, in part because it raises regulatory concerns about permitting and licensing requirements for the digester system operator, who in accepting manure from other parties for processing would be operating as a commercial waste handler. There are also regulatory issues connected with the hauling of manure between farms on public roads.

Ms. Schiffler also provided information on concerns expressed to the California Public Utilities Commission (CPUC) by her organization and others that California's investor-owned utilities have structured their proposed net-metering rates applicable to dairy biogas projects in a way that would under-compensate dairy operators for electricity generated via such projects. In response to complaints by WURD and other groups, the CPUC has suspended implementation of these electric tariffs until they can resolve the fairness issue. In general, PG&E and other major California utilities have shown reluctance to purchase electricity from their customers who use distributed generation. They are under no legal obligation to buy biogas-generated electricity, although recent State legislation will require them to buy a percentage of their energy from "green" generating sources, including biogas, by 2017.

PG&E's "Self-Generation Incentive Program" offers financial incentives for up to 1.0 MW of on-site distributed generation systems. Biogas projects would be compensated at a rate of $1,500/kW or up to 40% of the projects' capital cost, whichever is less, at program level 3-R (internal combustion engines and small gas turbines operating on renewable fuel). Certain restrictions apply to this incentive program, among them that the electricity generated by the system must be used on-site, and the equipment installed needs to be factory-new and carry a minimum three-year warranty. See www.pge.com/selfgen for more information, or contact:

Self-Generation Incentive Program
P.O. Box 770000
Mail Code B29R
San Francisco, CA 94177
(415) 973-6436

According to WURD's Kathi Schiffler, WURD does not place any restriction on combining their grant with PG&E's ratepayer-supported incentive program. However, she reports that PG&E will deduct the portion of a project supported by WURD from the total project cost *before* calculating the portion of the project cost the utility will support. For example, a $200,000 project receiving $80,000 in support from WURD could not be eligible for more than $48,000 (40% of the remaining $120,000 project cost) from PG&E.

The USDA's Rural Development Program is offering funding for purchase of renewable energy systems by agricultural producers. A total of $23 million is available nationwide, to be disbursed in individual grants of $10,000 to $500,000. The grant cannot exceed 25% of total project costs, and the 75% match provided by the applicant cannot include any other federal funds. While biogas systems are eligible under this grant program, note that "operating, maintaining, routine repairs, or fuel costs for biogas or biomass renewable energy projects" are specifically *not* eligible for funding. The original grant proposal deadline of June 6, 2003 was recently extended to June 27, 2003. For more information or to download the Notice of Funds Availability, see:

www.rurdev.usda.gov/rd/farmbill/9006resources.html or contact:

Charles Clendenin, USDA Rural Development
430 G Street, Agency 4169
Davis, CA 95616-4169
(530) 792-5825

Tax Credits

At this time there appears to be no state or federal tax incentive for biogas-based electricity generation other than standard equipment depreciation. The federal government offers a Renewable Electricity Production Credit to commercial/industrial taxpayers, which includes "closed-loop biomass" systems where crops are grown specifically to produce electricity. IRS Form 8835, used to apply for the credit, explicitly excludes manure-based generation systems. The State of California's Solar or Wind Energy System Credit specifically applies only to photovoltaic and wind energy systems.

CONCLUSION

Anaerobic digestion is a technology that has been shown to effectively manage dairy manure while yielding resources with significant financial and intangible value. The smaller pasture-based dairies of Humboldt County initially appear to be ill-suited for the implementation of this technology, because of the high initial capital cost of these systems and the fact that local pasture-based operations may not allow for adequate manure collection. Under the right circumstances, which include the acquisition of available funding, a suitable Humboldt County dairy could effectively use a plug flow digester as part of their manure management plan.

The plug flow digester would produce biogas and an effluent that could be separated into a solid fiber and a liquid filtrate. The biogas can be used to generate electrical and thermal energy for on-site use, thereby reducing energy expenses. The fiber can be sold as a high quality soil amendment or used as animal bedding. The liquid filtrate can be land applied as a high quality fertilizer. Intangible benefits such as odor control and decreased fly populations are invaluable if the operation plans to expand or if residential areas are located nearby.

APPENDIX A: SYSTEM CONSULTANTS AND DESIGNERS

Listed below is the contact information for companies that specialize in designing AD systems. They were chosen for their proven track record with dairy-based systems. This is not to be considered an exhaustive list because many other companies can assist in the development of farm-based AD projects.

RCM Digesters, Inc.
P.O. Box 4715
Berkeley, CA 94704
Phone: (510) 658-4466
Fax: (510) 658-2729
Website: www.rcmdigesters.com
e-mail: contact@RCMDigesters.com

Environomics
P. O. Box 371
Riverdale, NY 10471
Phone: (718) 884-6740
Fax: (718) 884-6726
Website: www.waste2profits.com
e-mail: environomics@waste2profits.com

APPENDIX B: QUICK REFERENCE SUMMARY TABLE

BIOGAS COST & BENEFIT CALCULATIONS

	Worst Case		Best Case	
Number of cows	400			
CAPITAL AND MAINTENANCE COSTS				
Capital Costs				
Digester system cost per cow	$1,000		$500	
Total digester system cost	$400,000		$200,000	
Avoided O&M Costs				
Lagoon cleanout annual cost	$9,000		$9,000	
Source: Langerwerf				
O&M Costs				
Engine generator maintenance				
cost per kWh generated	$0.015			
annual cost	$1,861		$2,978	
Fiber recovery system maintenance				
cost per yd^3	$1		$1	
annual cost	$803		$803	
Complete system (5% of capital)	$20,000		$10,000	
AVOIDED COSTS AND REVENUE OPPORTUNITIES				
Avoided Energy Costs				
Season	Wet	Dry	Wet	Dry
Cows	400	400	400	400
Months	4	8	4	8
Biogas (ft^3/cow/day)	50	50	80	80
Fraction manure collected	0.85	0.4	0.85	0.4
ft^3/day	17000	8000	27200	12800
ft^3/season	2,067,200	1,945,600	3,307,520	3,112,960
BTU/ft^3	600	600	600	600
BTU/day	10,200,000	4,800,000	16,320,000	7,680,000
BTU/season	1,240,320,000	1,167,360,000	1,984,512,000	1,867,776,000
Genset efficiency	23%	23%	23%	23%
Gross kWh/day	687	323	1,099	517
Gross kWh/season	83,560	78,645	133,696	125,831
kW capacity	29	13	46	22
Net avail. electricity	90%	90%	90%	90%
Plant availability	85%	85%	85%	85%
Net kWh/season	63,923	60,163	102,277	96,261
BTU heat/season	178,985,369	168,456,818	286,376,591	269,530,909
Therms heat/season	1,790	1,685	2,864	2,695
Avoided elec. Rate ($/kWh)*	$0.09	$0.09	$0.12	$0.12
Avoided gas rate ($/th)*	$0.98	$0.65	$0.98	$0.65
Seasonal avoided elec costs ($)	$5,753	$5,415	$12,273	$11,551
Seasonal avoided gas costs ($)	$1,754	$1,095	$2,806	$1,752
Annual avoided energy costs ($)	$14,017		$28,383	
*Source: Robert Cherry, PG&E				
Soil Amendment Revenue Opportunity				
Seasonal cubic yards fiber	413	389	413	389
Value ($/$yd^3$)	6	6	10	10
Seasonal value	$2,481	$2,335	$4,134	$3,891
Annual value	$4,815		$8,026	
Simple Payback w/o Funding	51.1 years		5.6 years	
[capital cost/(annual revenue-annual O&M costs)]				

Funding Opportunities - See report for more information

Dairy Power Production Program	50% of capital cost or $2,000 per kW capacity
PG&E Self-Generation Incentive Program	40% of capital cost or $1,500 per kW capacity
USDA Rural Development Program	$10,000 to $500,000 but not to exceed 25% of total project cost

Land area required for housing	Length (ft)	Width (ft)	Area (ft^2)	
Digester	150	40	6000	
Engine-generator and Switchgear	25	25	625	
Effluent collection	20	20	400	
Solids separator	50	25	1250	
		Total	8275	ft^2
			0.19	acre