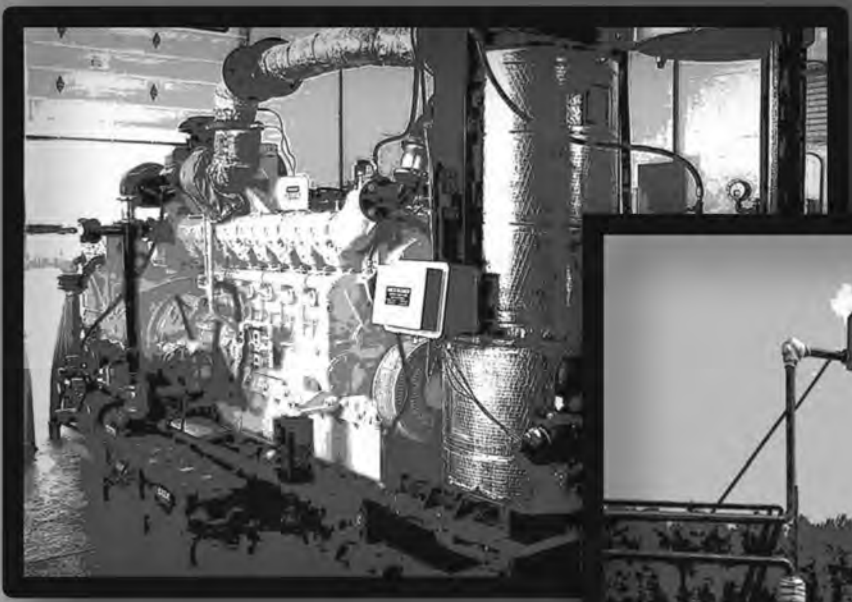
Cooperative Approaches for Implementation of Dairy Manure Digesters



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Abstract

Anaerobic digestion of dairy manure produces biogas that can be captured and used for fuel while offering environmental benefits. Dairy farmer use of anaerobic digesters is not widespread due to various challenges, including high costs and inadequate return. A cooperative approach could address the challenges through improved negotiating strength; technical assistance for digester design, installation, and operation; management and marketing services; and/or financial guidance and assistance. Cooperative efforts may allow milk producers to remain focused on milk production while lowering costs and/or increasing returns from energy and byproduct sales.

Keywords: Anaerobic digestion, biogas, cooperatives, carbon credits, dairy, methane, renewable energy

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Carolyn Betts Liebrand and K. Charles Ling
Agricultural Economists
Rural Development
Rural Business-Cooperative Service
STOP 3252, 1400 Independence Ave., S.W
Washington, DC 20250-3252

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Highlights

Dairy operations routinely handle about 500 billion pounds of cow manure produced each year by collecting it, storing it, and spreading it over the land. In the beginning of the 21st century, the convergence of a number of factors, such as the changing structure of milk production, the shrinking local land base on which to spread dairy manure, environmental issues, and rising energy costs accompanied by a focus on renewable energy, have heightened interest in an alternative method for handling dairy manure: anaerobic (in the absence of oxygen) digestion (decomposition) to produce biogas for use in energy production. Anaerobic microbes naturally occurring in manure feed on the manure and give off gas (containing methane) and biologically stabilized effluent (odor mostly eliminated).

There were 95 known anaerobic digester projects on 85 dairy operations utilizing dairy manure in 2007. They used four basic types of systems: plug flow (the majority), complete mix, covered lagoons, fixed film, and other types. Each type of system provides an environment for anaerobic methane-producing bacteria to thrive and requires a manure collection system, air-tight (or limiting) container, effluent storage and handling system, and gas handling and utilization equipment.

The rate of conversion of organic matter to biogas depends upon the environment in the digester, the characteristics of the manure feeding it and the consistency of manure additions to the digester. A typical lactating dairy cow's manure could support the production of 47.1 cubic feet of biogas per day, or 1.37 lbs of methane per cow per day (assuming the biogas has 65 percent methane).

Biogas can be directly burned on the farm for various purposes, or it can be cleaned and conditioned for sale to commercial gas systems. Of the 95 anaerobic digester projects utilizing dairy manure, 87 percent produced electricity. At least 45 percent of those generating electricity also captured the heat energy from the engine-generator (cogeneration). Just a few sent the biogas into a commercial pipeline, or flared the biogas—not utilizing its energy.

The net economic impact of installing an anaerobic digester on a dairy operation depends on the dairy's ability to utilize the biogas and digestate (manure solids remaining after anaerobic digestion of the manure). Utilization of the end products of manure digestion can lower the dairy operation's operating costs, add income from sales, or provide a combination of avoided expenses and increased revenue. The benefits of anaerobic digestion that have been observed or predicted include:

Energy	• Avoided electricity purchases • Electricity sales • Natural gas sales • Heat for farm use from generator engine
Byproducts	• On-farm use or sale of digested solids and effluent
Carbon Credits	• Sales of carbon credits for the reduction of methane emissions
Environmental	• Reduced odor • Reduced environmental risk, mitigation expense

Capturing the benefits of anaerobic digestion will likely require additional expenses, such as purchase, operation, and maintenance of equipment to use the biogas and to prepare the byproducts for use or sale, as well as increased management time and skill.

The 85 dairy operations known to have installed anaerobic digesters represent less than 1 percent of the licensed dairy farms in the United States. The barriers to adoption are often unique to each producer's situation. The decision to install a digester is dependent upon the policies of the local utility, local regulations, local fuel and electricity rates, access to grants and financing, and the operator's knowledge, skill, and level of risk aversion. The challenges to adoption include: electricity rates and interconnection issues; system design flaws; the limited number of digester providers and lack of information; additional time and skill required to manage the digester adequately; the lack of ability to capture value from byproduct use or sale; and difficulties in obtaining financing and/or funding.

A cooperative approach may be one way for dairy operators to overcome obstacles to the successful use of anaerobic digesters. Dairy producers could take one of two basic approaches: (1) an existing dairy cooperative could provide services related to the adoption of anaerobic digester technology as a part of its member services, or (2) a group of similarly-situated dairy farmers could form a separate entity to address their specific needs. The group effort may be more effective and efficient than each farmer facing the challenges of adopting anaerobic digester technology alone. Collective effort may enhance the economic feasibility of anaerobic digesters by lowering their installation and operating costs, increasing returns from energy and byproduct sales, or both, while allowing milk producers to remain focused on milk production.

A cooperative effort could focus narrowly on one obstacle or one opportunity, or it could incorporate multiple functions. Alternatively, a cooperative could focus on one effort initially and gradually take on more functions as it builds on its successes. Cooperation could be effective in several areas:

Energy	• Improved compensation for electricity produced • Favorable terms for connecting to the electrical grid • Natural gas marketing
Byproducts	• Technical guidance on utilizing digested solids and effluent on the farm • Marketing research and development for byproduct sales
System design	• Technical guidance for design/installation • Negotiated prices for digester components/installation • Provider screening
Management	• Technical guidance to boost biogas production • Management assistance to reduce operating costs
Carbon Credits	• Negotiation of prices and terms of trade • Facilitation of the aggregation of carbon credits for trading • Verification of greenhouse gas reduction claims

Furthermore, in the case of a centralized digester collecting manure from local dairy farms, a cooperative could provide manure and effluent shipping coordination and services, relieving the members of the management burden. If the centralized digester is itself cooperatively-owned, the risk, capital costs, digester operating and maintenance responsibilities, byproduct marketing, and so forth would be shared by the producer-members.

One way a cooperative effort could be funded would be to charge a per cow fee based on the number of milk cows on each member's operation. Alternatively, a cooperative could mark up prices and fees for its products and services to cover the cost of its overhead in providing them. The farmers using the service or benefit should be the ones funding its availability.

As with the anaerobic digester technology itself, dairy producers will have to evaluate if the benefits of acting together to address their needs in utilizing a digester outweigh the costs.

Anaerobic Digester System

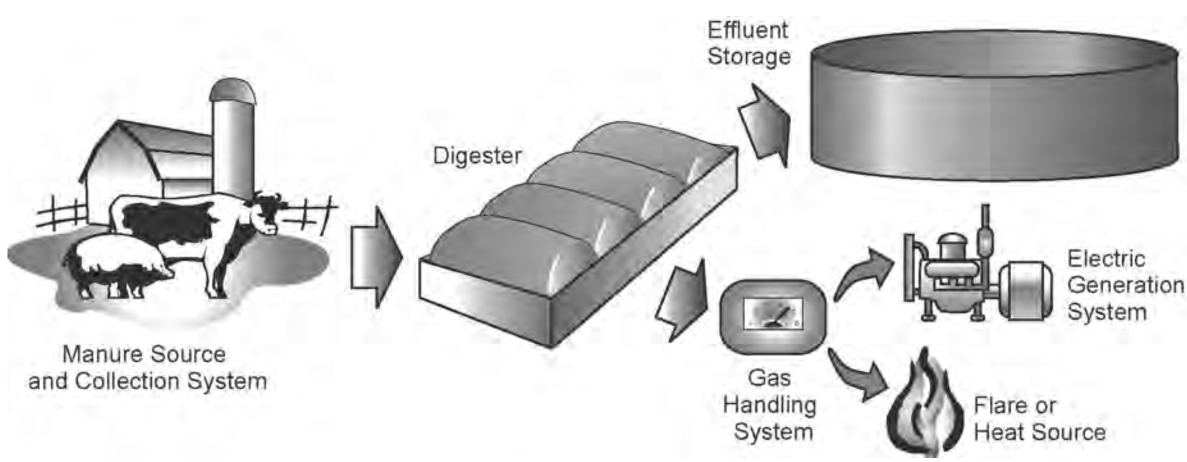

Illustration courtesy of U.S. Environmental Protection Agency (EPA)

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Carolyn Betts Liebrand and K. Charles Ling
USDA Rural Development

Introduction

In 2007, the United States had 9.158 million milk cows on 71,510 operations. These cows produced 185.6 billion pounds of milk along with an estimated 500 billion pounds of manure. This byproduct of milk production is routinely handled by collecting it, storing it, and spreading it over the land. In the beginning of the 21st century, the convergence of a number of factors, including the changing structure of milk production, the shrinking local land base on which to spread dairy manure, environmental issues, and rising energy costs accompanied by a focus on renewable energy, have heightened interest in alternative methods for handling dairy manure.

In the past decade (1997-2007), the number of operations with 500 or more milk cows increased by 38 percent to 3,215 operations in 2007. Almost one-half (48.9 percent) of the Nation's dairy herd was housed on an operation with more than 500 milk cows—almost double the number in 1997 (4.5 versus 2.3 million head). This concentration of cows has intensified concern about the impact of large animal operations on the environment.

In 2003, the U.S. Environmental Protection Agency (EPA) strengthened and clarified rules contained in Clean Water Act regulations requiring concentrated animal feeding operations (CAFO—operations with 700 or more mature animals) to follow a nutrient management plan when applying manure to crop or pasture land to minimize threats to water quality. In addition, increasing non-agricultural use of land in dairy areas challenges traditional manure handling methods and makes compliance with CAFO rules more complex. And, rural residents appear increasingly unwilling to tolerate odors and other emissions (ammonia, nitrous oxide, methane, carbon dioxide, hydrogen sulfide, and volatile organic compounds) from large dairy operations (*Eastern Research Group*).

Finally, fuel, lube, and electricity expenses made up 5.3 percent of the operating costs of producing milk in the U.S. in 2006, amounting to $116 per cow on average (*Economic Research Service—ERS*). These energy expenses were 21.1 percent higher than in 1997.

The runup in energy prices in the 1970s triggered interest in anaerobic (in the absence of oxygen) digestion (decomposition) of animal manures on U.S. farms to produce biogas for use in energy production. Anaerobic microbes naturally occurring in manure feed on the manure and give off gas containing methane, carbon dioxide, and trace amounts of other compounds (box 1).

Lessons learned from previous efforts in producing biogas from manure resulted in improved design, operation, equipment, and cost-effectiveness of anaerobic digestion systems (*EPA AgSTAR Handbook*). Since 2001, concern over energy prices and availability has intensified and focused governments local to worldwide on developing renewable energy sources. At the same time, concern over the buildup of carbon dioxide, methane and other so-called “greenhouse gasses” (gasses which are thought to cause an increase in the Earth's temperature) have led Federal, State and local governments to encourage farmer use of anaerobic technology.

Box 1—Composition of Biogas from the Anaerobic Digestion of Dairy Manure

	"Typical"	WI farm[1]	NY farm[2]
	Percent by volume	%	%
Methane CH_4	60-70	55.9	59.1
Carbon Dioxide CO_2	30-40	43.8	39.2
Hydrogen Sulfide H_2S	300-4,500 ppm	.0310	.193
Ammonia NH_3	Trace	NA	1.5055
Hydrogen (H_2)	Trace	NA	
Nitrogen gas (N_2)	Trace	NA	
Carbon Monoxide (CO)	Trace	NA	
Moisture (H_2O)	Trace	NA	
Other[3]	Trace	NA	
SOURCE: NCRS			

1 Case study (Martin 2005)
2 Case study (Martin 2004)
3 Particles, halogenated hydrocarbons, nitrogen, oxygen, organic silicon compounds, etc.

Anaerobic Digestion

Anaerobic digestion systems attempt to provide an optimal environment for anaerobic methane-producing bacteria to thrive. The components of a digester system for a dairy operation include: manure collection, anaerobic container, effluent storage and handling, and gas handling and utilization.

Manure collection

A flowing, uniform manure slurry collected daily on a regular schedule is ideal. The common practices of flushing or scraping manure from freestall or drylot dairy cattle housing can provide manure suitable for anaerobic digestion, but pre-treatment may be required to adjust the amount of solids in the manure to meet the requirements of the digester. Bedding from the cow housing facilities can mix in with the manure, so bedding like sand may not be suitable.

Anaerobic digester

The anaerobic digester unit is a sealed (air tight) container (such as a tank or lagoon) that provides a suitable environment for anaerobic bacteria to thrive and a means of capturing the biogas. Manure is added daily to the digester and spends about 20 days flowing through the digester before exiting to the effluent storage and handling system. The size of the digester is determined by the number of cows whose manure will be feeding into it and the rate of digestion. The more conducive the environment is for growth of the methane-producing bacteria (methanogens), the shorter the time required to digest the manure and the greater the biogas production.

Growth of methanogens can be encouraged by maintaining higher temperatures, providing a media that the bacteria can cling to, and/or by concentrating ("recycling") the bacteria (*Wright*). To maintain optimal bacterial growth, most digesters require a heating system—typically hot water pipes running through the digester—to keep digester contents around 100 ^{o}F (mesophilic conditions). Thermophilic conditions (120-140 ^{o}F) offer advantages but are more costly to support due to the added cost of maintaining higher temperatures. The higher temperatures encourage a higher level of biogas production per unit of time and also offer greater sterilization of the effluent (*ATTRA, Wright*).

Several basic types of anaerobic digesters are in use today: plug flow, complete mix, covered lagoons and fixed film (see box 2). The systems are typically uniquely adapted to the individual dairy operation where they are installed. By 2007, EPA had identified 95 anaerobic digester projects utilizing dairy manure in the United States: 58 were plug flow systems, 18 were complete mix digesters, and 13 were covered lagoons (table 1). Most of the digesters were operated at mesophilic temperatures, except for the lagoon systems where psychrophilic (low temperature) conditions are typical (*Kramer*).

Box 2—Types of Anaerobic Digesters

- Plug Flow - Long, rectangular concrete tank with an air-tight cover where manure flows in one end and out the other. Sometimes the tank is U-shaped, with the entrance and exit at the same end. Influent manure first enters a mixing pit, allowing solids to be adjusted by adding water. Then as manure is added the “plug” of manure slowly pushes the older manure down the tank. The tank is typically heated to maintain a mesophilic or thermophilic environment, often using recovered heat from the biogas burner. The tank volume commonly holds 15 to 30 days worth of manure and waste water, or in other words, a hydraulic retention time (HRT) of 15-30 days. Plug flow digesters require 11 to 13 percent total solids in the manure and work well with scraped dairy manure.

- Complete Mix - A complete mix digester has a sealed, cylindrical concrete or steel tank where manure is mechanically kept in suspension or “mixed” by a motor-driven impeller, pump, or various other devices. It is also referred to as a “continually stirred tank reactor.” The manure is typically heated to maintain a mesophilic or thermophilic environment, often utilizing recovered heat from the biogas burner. The tank commonly holds 15 to 20 days worth of manure and waste water, or 15-20 day HRT. Slurry manure that is scraped or flushed with 3 to 10 percent total solids works best in this system.

- Covered Lagoon - An earthen lagoon fitted with a cover to contain and facilitate collection of biogas is the least expensive type of digester to install and operate. A covered lagoon is the least controlled system with the lowest gas production and the longest retention time due to its psychrophilic environment. In northern climates, there may be no gas production in cold weather. Odor may not be totally eliminated due to incomplete digestion. Best suited for flush manure collection systems with total solids of 0.5 to 3 percent.

- Fixed Film - A concrete or steel tank that is filled with plastic media called “biofilm.” The biofilm supports a thin layer of anaerobic bacteria and maintains a concentrated population of mesophilic or thermophilic methanogens, supporting a larger volume of biogas production and shorter HRT (6 days or less) than the other digester types. Works best with flushed manure with less than 5 percent total solids. Slowly degradable solids must be separated out before entering this type of digester.

Sources: EPA 2005; NRCS

Table 1—Operational anaerobic digesters on dairy farms, identified by the U.S. EPA, 2007

	Number	Percent
Status		
Design	1	1.1
Startup	13	13.7
Steady state	79	83.2
Shutdown[1]	2	2.1
Total projects [2]	95	100.0
Type		
Plug flow[3]	58	61.1
Complete mix	18	18.9
Covered lagoon	13	13.7
Other[4]	6	6.3
Total projects	95	100.0

SOURCE: U.S. Environmental Protection Agency (EPA), 2007 http://www.epa.gov/agstar/pdf/digesters_dairy.xls

[1] 1 covered lagoon and 1 fixed film digester were shut down.
[2] 95 projects located on 85 dairy operations--where 5 operations each had 2 operating digesters. (Five of the 95 projects were centralized operations fueled with dairy cow manure but not located on a dairy operation.)
[3] Includes 56 horizontal plug flow, 1 vertical plug flow and 1 flush system plug flow.
[4] Includes: 2 fixed film; a manure activation system, an induced blanket reactor and 2 not identified.

Effluent storage and handling

Manure that has been anaerobically digested is considered "biologically stabilized," meaning the effluent has few compounds remaining that could continue decomposing and thus most of the compounds that contribute to odor are eliminated.

The digested effluent's fertilizer value is enhanced over raw manure because the chemical form of some of the nutrients in manure is changed to a form more readily available to growing plants. Anaerobic digestion is also reported to denature weed seeds, reduce pathogens such as Johne's disease organisms and fecal coliform, and to be less attractive to flies and rodents (*Moser 1997*). The volume of effluent leaving the digester is only minimally reduced in mass from raw manure, but reportedly is easier to handle relative to raw manure due to its increased homogeneity and somewhat lower solids content. Adequate storage for the effluent must be provided until it can be disposed of, typically by application to land and crops.

On many operations, the effluent is run through a separator and the digested solids are collected and used for other purposes—such as bedding for dairy cattle, organic fertilizer, soil amendment, compost, and/or potting soil (*EPA AgSTAR Handbook, Moser 2007, Mullins*). The remaining liquid effluent is typically spread (sprayed) on fields.

Biogas production and handling

The rate of conversion of organic matter to biogas depends upon the environment in the digester, the characteristics of the manure feeding it, and the consistency of manure additions to the digester. However, the volume of biogas generated from the anaerobic digestion of manure can be theoretically predicted. A typical lactating dairy cow's manure could support the production of 47.1 cubic feet of biogas per day (*NRCS*). If the biogas contains 65 percent methane, this would mean 1.37 lbs of methane per cow per day (see box 3).

Compounds inadvertently entering the digester (such as chemical spills, footbath compounds, and antibiotics) can hinder microbial growth, reducing biogas output. Conversely, digester performance can be enhanced by certain operating practices that boost the organic matter in

Box 3—Characteristics of lactating dairy cow manure and biogas potential

Component	Units	Per cow
Weight	Lbs/day	150.00
Volume	Cubic feet/day	2.40
Moisture	Percent	87.00
Total Solids	Lbs/day	20.00
Total Volatile Solids	Lbs/day	17.00
Chemical Oxygen Demand	Lbs/day	18.00
Biological Oxygen Demand	Lbs/day	2.90
Nitrogen	Lbs/day	0.99
Phosphorous	Lbs/day	0.17
Potassium	Lbs/day	0.23
Biogas production[1]	Cubic feet//day	47.10
Methane production[2]	Cubic feet/day	30.60
Methane (CH4)[2]	Lbs/day	1.37
Btu[3]	1,000 Btu/day	30.90
kWh[4]	Per day	2.00
Annual kWh per cow		744.00

Source: ASABE 2005.

[1] 90% of the manure collected; 30% conversion rate of COD to methane; 6.3 Ft3 CH4 per lb COD; 65% CH4 in biogas (NRCS)

[2] Biogas with 65% CH4 weighing .717 kg/meter3 (NRCS).

[3] Represents an average biogas with 65% CH4, where CH4 has a heating value of 1,010 Btu/ft3 CH4 (EPA 2005)

[4] 66.6 kWh per 1,000 ft3 CH4 ; assuming 25% thermal conversion efficiency and 90% run-time (EPA 2005)

the influent, such as the type of bedding (for example, shredded newspaper) or whether the dairy is in a position to accept additional organic matter, such as food processing waste. Manure with 25 percent added organic material could boost biogas production 76 percent above that of dairy manure alone (*Scott*).

Data from 86 operating dairy manure digesters indicated methane production rates from 0.28 to 1.59 lbs methane per cow per day (using reported methane emissions reductions as a proxy for methane production, table 2). The simple average of methane production reported by these digesters was .81 pounds of methane per cow per day, only 60 percent of the theoretical yield of 1.37 pounds. However, there were digesters in Idaho, Washington, Oregon, California, and Florida whose reported methane yields (1.59, 1.58, 1.56, 1.52, and 1.44 pounds per cow per day, respectively) exceeded the theoretic yield per cow.

Equipment to collect the gas includes: piping, gas pump or blower, gas meter, pressure regulator, and condensate drain (*EPA AgSTAR Handbook*). On some operations, a gas "scrubber" is installed to remove hydrogen sulfide from the biogas. When biogas is burned, the hydrogen sulfide is converted to oxides of sulfur (which are regulated as air pollutants—potentially requiring an air emission permit). The hydrogen sulfide can pose problems to equipment that burns the biogas because as exhaust gasses cool, oxides of sulfur combine with moisture to form highly corrosive sulfuric acid, which can shorten the equipment's useful life (*NRCS*). If the engine can maintain running temperatures high enough to avoid acid formation, the corrosion problem can be minimized.

Table 2—Operational anaerobic digesters on dairy farms identified by the U.S. EPA, by State, 2007

			Methane emissions reductions			
	Projects	Average population feeding digester	Average	Total	Range lbs/cow/day	
	number	*cows*	*lbs/cow/day*	*MT/year*	*min*	*max*
California	16	2,510	1.18	7,691	0.72	1.52
Connecticut	2	400	0.85	85	0.44	1.26
Florida	1	250	1.44	60	na	na
Georgia	1	1,135	na	na	na	na
Idaho	2	2,900	1.59	1,531	na	na
Illinois	4	725	1.32	449	na	na
Indiana	3	3,517	0.48	840	na	na
Iowa	1	700	1.29	149	na	na
Maryland	1	150	0.50	13	na	na
Michigan	3	2,750	0.68	871	0.41	1.23
Minnesota	2	1,975	0.84	407	0.42	1.25
New York	16	945	0.42	955	0.28	1.21
Oregon	5	1,135	1.30	1,208	0.53	1.56
Pennsylvania	10	838	0.60	936	0.35	1.28
Texas	1	10,000	0.81	1,339	na	na
Utah	1	1,200	na	na	na	na
Vermont	4	1,110	0.37	271	na	na
Washington	2	2,250	1.06	579	0.54	1.58
Wisconsin	20	1,474	0.74	3,510	0.41	1.25
U.S. total[1]	95	1,624	0.81	20,892	0.28	1.59

Totals may not add due to rounding.
SOURCE: U.S. Environmental Protection Agency (EPA), 2007
http://www.epa.gov/agstar/pdf/digesters_dairy.xls

[1] 9 projects did not report methane emissions reductions (2 of which were shut down.)

Biogas use

Biogas can be used on the farm as fuel in various applications, or it can be cleaned and conditioned for sale to commercial gas systems (box 4). Biogas can be used for fuel in any equipment that normally uses propane or natural gas, including boilers, heaters, chillers, or mobile engines. In addition, biogas can be used for generating electricity via an internal combustion engine or gas turbine. Importantly, waste heat from the stationary engines can provide heating and/or hot water for farm use and/or heating the digester. This combined heat and power is known as cogeneration—the simultaneous production of two forms of energy (electrical and thermal) from one fuel source (biogas). Alternatively, the biogas can simply be "flared" or burned off (this destroys the methane through combustion but does not convert the energy in methane to useful purposes).

Of 95 anaerobic digester projects on U.S. dairy operations, 83 produced electricity (29 did not specify the biogas end use, but did report installed kWh capacity). At least 37 captured the heat energy from their engine-generator (cogeneration). Just four projects sent the biogas into a commercial pipeline, while only two projects flared the biogas, and three did not specify end use of the gas (table 3).

Box 4—Biogas Use Options

● Direct Combustion:		
	Boilers	Biogas can fuel boilers for hot water for farm use.
	Engine generators	Biogas can fuel engine generators to produce electricity for on-farm use, sale to a utility, or both. Heat from the stationary engine can be captured and used on-farm.
	Flare	Methane is destroyed, but heat and energy are not captured.
	Mobile engines	Biogas must first be cleaned of hydrogen sulfide and compressed.
	Space heaters	Biogas can power space heaters for farm buildings.
● Pipeline		Biogas can be trucked or piped to a nearby pipeline and sold commercially. Biogas must be cleaned and compressed.

Source: NRCS, Krich

Capital cost

The capital cost of plug flow digesters on 10 U.S. dairy operations averaged $285,404 for the digester alone (table 4). These 10 farms had manure from 120 to 2,285 cows feeding the digesters. The per cow capital cost ranged from $194 to $1,557 and averaged $536 per cow. While the smallest farm did have the highest cost per cow for the digester, the largest farm did not have the lowest cost per cow. And, the farms with the second and third smallest number of cows had relatively low costs per cow for their digester. The digester capital costs averaged 60.8 percent of the total system costs (digester plus electric generation equipment), but ranged widely from 44.3 to nearly 80 percent of the total system costs.

Benefits and Costs

The net economic impact of installing an anaerobic digester on a dairy operation depends on the dairy's ability to utilize the biogas and manure effluent. Utilization of the end products of manure digestion can lower the dairy operation's operating costs, add income from sales, or provide a combination of avoided expenses and increased revenue. Capturing the benefits of anaerobic digestion will likely require additional expenses, such as purchase, operation, and maintenance of equipment to use the biogas and to prepare the byproducts for use or sale, as well as increased management time and skill. Furthermore, the intangible benefits of anaerobic digestion should not be overlooked, even if difficult to quantify in terms of dollars and cents. The various benefits and costs of digester outputs that have been observed or predicted are (see box 5 for a summary):

- *Electricity*—Various arrangements have been used to capture the value of electricity generated by the combustion of biogas from anaerobic digestion of manure (see box 6). The annual value of avoided electricity purchases or electricity sales may amount to $69 per cow, based on an electricity rate of 9.46 cents per kWh (2006 U.S. commercial average) and assuming the digester supports the generation of 2 kWh per cow per day. However, electricity prices vary widely from State to State, making the biogas-generated electricity more or less valuable to a dairy operation depending upon its location (15.51 cents/kWh in New York to 5.16 cents/kWh in Idaho). Furthermore, if the utility pays for electricity at a rate representative of its avoided generation cost, the value of electricity from biogas will be much lower (for example, operating expenses for generation averaged 3 cents per kWh in 2006 for fossil/steam

Table 3—Biogas end use, operational anaerobic digesters on dairy farms, identified by the U.S. EPA, 2007

	Number	Percent		Number	Percent
Biogas end use					
Flared full time	2	2.1			
Pipeline gas	4	4.2			
Boiler/furnace fuel	3	3.2			
Electricity:	83	87.4			
			Electricity alone	15	15.8
			Cogeneration	30	31.6
			Electricity and fuel	2	2.1
			Cogeneration and fuel	7	7.4
			Installed kWh capacity, but no end use reported	29	30.5
				83	87.4
No end use or kWh capacity reported	3	3.2			
Total	95	100.0			
Installed capacity of electricity generating equipment					
100 kwh or less	19	22.9			
101-150 kWh	23	27.7			
141-300 kWh	22	26.5			
More than 300 kWh	18	21.7			
Not reported	1	1.2			
	83	100.0			

SOURCE: U.S. Environmental Protection Agency (EPA), 2007
http://www.epa.gov/agstar/pdf/digesters_dairy.xls

Table 4—Capital costs for plug flow anaerobic digesters on dairy farms with electricity generating equipment[1]

	Average	Min	Max
Digester capital cost	$ 285,404	$ 68,641	$ 472,479
Digester cost per cow	$ 536	$ 194	$ 1,557
Total system cost per cow[2]	$ 848	$ 299	$ 1,959
Digester portion of total capital costs	60.8%	44.3%	79.5%

SOURCE: NRCS

[1] Data from 10 projects on dairy farms that identified their capital cost for the plug flow anaerobic digester and for their electricity generation system. Two of these farms each had 2 digesters.

[2] Includes capital cost of electric generation equipment along with digester capital costs.

Box 5—Possible benefits and associated costs from byproducts of anaerobic digestion of dairy manure

By Product	Benefits	Costs
Electricity	• Avoided electricity purchases • Electricity sales	• Electricity production equipment • Operation and maintenance • Required upgrades to electrical system • Sales negotiation, legal fees
Biomethane	• Natural gas sales	• Biogas collection • Gas cleaning • Storage/ transportation
Heat	• Heat/hot water	• Equipment, operation, and maintenance
Digested solids	• Avoided bedding purchases • Sales of separated solids	• Equipment, operation, and maintenance • Sales negotiation and/or marketing
Carbon Credits	• Sales	• Aggregation fee • Trading fee • Verification costs
Fertilizer	• Lower energy use in handling effluent • Avoided purchases • Flexibility in timing for land application • Improved nutrient quality • Lower herbicide use • Sales	• Sales negotiation and/or marketing
Environment	• Reduced odor • Reduced water contamination risk • Avoided lawsuits • Pathogen reduction • Methane destruction/capture • Tipping fees	• Substrate management and negotiation

powered plants).The cost of electricity production on dairy operations using a plug flow digester may amount to $66 to $95 per cow (based on reported biogas production costs for dairy plug flow digesters of 9 to 13 cents per kWh and assuming the digester output supports 2 kWh per cow per day, *NRCS*). Operating and maintenance costs could be $4 to $7 per cow (based on reported biogas production costs for dairy plug flow digesters of 0.6 to 1 cent per kWh, *NRCS*). Additional costs may be necessary to upgrade the farm's existing electrical system to 3-phase power, purchase switching gear, and so forth, if the dairy plans to sell electricity to the grid. Furthermore, there may be expenses for legal assistance to negotiate contract rate, length, and interconnection requirements with the utility.

Box 6—Arrangements for selling on-farm generated electricity

- **Biogas Sales**—Dairy operation sells biogas to a utility that operates the on-farm generator. Thus, all electricity produced is owned by the utility, and the dairy operation purchases all electricity used by the dairy operation from the utility at retail rates. The capital and operating costs of the energy generation system are borne by the utility. One version of this arrangement is a 3-way partnership between a dairy operation, a utility, and a third party digester management firm. The management firm installs, operates, and finances the digester. The utility installs, operates, and owns the generation equipment and buys the biogas. The dairy supplies the biogas and site for the digester and electricity generation equipment, and eventually owns the digester.

- **All electricity sold**—Dairy operation sells all its biogas-generated electricity to a utility (typically at the utility's avoided cost rate) and purchases all the farm's electricity needs from the utility at retail rates.

- **Surplus electricity sales**—Dairy operation produces electricity for use on the farm. Any excess electricity generated is sold to the utility (typically at the utility's avoided cost rate), and any excess power consumption by the dairy is purchased at the going retail rate. Some utilities will also charge such dairies a standby charge to cover the utility's expense in having electricity available in case the farm needs it.

- **Net metering**—If the utility offers it, the dairy operation is charged only for the net difference between the amount of electricity consumed and the amount the dairy generates with its biogas. The requirements and terms vary between States.

Source: U.S. Environmental Protection Agency (EPA) AgSTAR Handbook

- *Biomethane*—A few projects have upgraded the biogas to pipeline quality and provided methane to a nearby commercial natural gas pipeline. The value of biogas sold as pipeline quality gas could be around $71 per cow (based on the U.S. natural gas wellhead price of $6.39 per 1000 cubic feet for 2007 and assuming the digester produces 30.6 cubic feet of methane per cow per day). Similar to electricity, the price for natural gas varies according to location, from $5.69/1000 cubic feet in Arizona to $7.12/1000 cubic feet in New York in 2007.

  The cost for biogas production reported by 12 dairies for their plug flow digesters averaged $4.33/1000 cubic feet of biogas (*NRCS*). That would amount to $74 per cow per year (assuming digester output of 47.1/cubic feet biogas/cow/day). The cost of upgrading the biogas to pipeline quality may be as much as $3.88/1000 cubic feet of biogas, or $67 per cow per year (*NRCS*). In addition, there may be costs for storage and transportation to the pipeline that could add as much as $3.70/1000 cubic feet of methane, or $41 per cow, assuming digester output of 30.6 cubic feet methane/cow/day (*Krich)*.
- *Heat*—Nearly half of the engine fuel energy can be recovered by capturing waste heat from the engine jacket and exhaust gas and used for maintaining the temperature in the digester, heating farm buildings, water, and/or alley floors. Avoided fuel purchases for heating will depend on the price of fuel and the ability of the operation to utilize the heat. Case-study farm reports on the value of this heat ranged from $3 to $10 per cow (*Kramer, Lazarus, Moser 2007*). The equipment required to capture and utilize this heat would require additional expenditures.
- *Digested solids*—One case farm saved an estimated $19 per cow by using the separated solids in lieu of purchased bedding for the cows (*Lazarus*). Some case farms have reported sales of separated solids amounting to $27 and $40 cow (*Moser 2007*). Using digested solids as cow bedding also may improve cow health (lower veterinary expense) and improved milk production (increased revenue).

  However, additional equipment and operating costs for separating the digested solids from the effluent would be required—possibly amounting to $30 per cow (*Lazarus*). In addition, use of digested solids as bedding requires careful attention (operator time) to avoid potential for increased health problems (for example, mastitis leading to higher veterinary expenses and lower milk production and sales).
- *Carbon-credits*—Methane captured from anaerobic digestion of dairy cow manure may be qualified to receive carbon credit if it is collected and prevented from emitting into the atmosphere. The sale of

carbon credits based on capturing this methane could amount to $25 per cow, depending upon the going price of carbon credits. See the Carbon Credits section below for further explanation.

- *Fertilizer*—Improved fertilizer value (over raw manure) allows less fertilizer purchases or even some sales of effluent, and less viable weed seeds potentially lower herbicide costs. The minimal odor of the effluent may allow more flexibility in the timing of land application than for raw manure. This flexibility may afford economic benefits to the dairy operation, but it is hard to quantify the value of such factors as less downtime, convenience, and reduced need to hire custom applicators. Case-study farms have also reported savings from lower energy requirements for handling the effluent due to its increased homogeneity and lower solids content. These benefits of the digested effluent were reported by one case farm to total $39 per cow per year (*Lazarus*). While a dairy operation may not need any additional equipment to handle the effluent for fertilizer, if the effluent were to be sold there may be additional costs associated with negotiation and marketing.
- *Environment*—Odor reduction increases the quality of life or farm residents and neighbors, may reduce the likelihood of lawsuits or complaints, and/or may facilitate the ability to continue or begin dairy operations at the site (*Kramer*). Thus, the digester may be valued as "insurance" against disgruntled neighbors and possible nuisance lawsuits, and regulatory compliance issues (*Lazarus*, 2003).

Furthermore, some firms may be willing to pay the dairy a tipping fee for disposal of their organic waste. One report estimated the fee to be as high as $300 per cow (*Scott*). However, this additional substrate will require increased management and negotiation.

Challenges to Adoption and Use of Digesters

Drawing from a survey of U.S. farmers who had received Federal funding in 2003 and 2004 for anaerobic digester systems (*Mullins*), EPA (and other researchers') observations of existing digester projects (*EPA AgSTAR Handbook*), and USDA analysis of anaerobic digester technology (*NRCS*), several issues faced by users of the technology have been noted. These challenges include:

Electricity rates and interconnection

Connecting distributed generation from an on-farm, biogas-fired generator to the electrical power grid raises safety, power quality, technical, legal, and procedural issues (*Haynes*). The expertise necessary to connect to the power grid and to negotiate a power purchase agreement (transmission access) is likely to be expensive as well as time consuming (*Booz Allen Hamilton*). In fact, EPA recommends that farm owners consult an expert for information and guidance in negotiating an inter-connection contract when the utility does not have standard procedures and policies in place. Negotiation of rates sufficient to offset a significant portion of the cost of producing the biogas is essential to the economic feasibility of an anaerobic digester. However, some utilities only offer rates reflective of their avoided generation cost, which are well below retail rates. And, new regulations governing air emissions from the engine generator sets are expected to hinder future projects in California (*Western United Dairymen—WUD*).

System design

Some anaerobic digester projects were hindered by system design flaws, such as incorrect sizing, incorrect system for the dairy's method of manure handling, incompatibility between the digester and related equipment, a limited number of digester providers, lack of information provided by the digester companies, poor serviceability, and a suspected conflict of interest when the design engineers also sold digester components.

Operator skill and time

Thoughtful management of the anaerobic digester to maximize biogas output is essential to success and requires about 1 hour per day of a trained operator's time, year round. Some anaerobic digester projects suffered when managed by personnel lacking motivation and incentive to manage the digester adequately. Additional skills supporting the economic feasibility of a digester include marketing and negotiation (for energy and other byproduct sales), engine maintenance and repair (to keep operating expenses low when utilizing the biogas for heat and/or energy), and innovation (finding uses for the byproducts and effectively implementing them).

Utilizing byproducts

Economic feasibility would not have been supported by just the value of energy produced from anaerobic digestion alone (at 2006 energy prices, *NRCS*). Some successful adopters approached the anaerobic digester as a potential profit center, capturing value by utilizing both biogas and byproducts (liquid effluent, digested solids) on-farm, selling them off-farm, or both.

Financing and Funding

In places where local bankers are unfamiliar with anaerobic digester technology obtaining financing can be difficult. Also, the grant process to obtain financial assistance to offset the cost of installing an anaerobic digester can be cumbersome. In some cases the rules limited how the biogas could be used.

Cooperative Approaches

The 85 dairy operations known to have installed anaerobic digesters represent a tiny fraction of the 59,135 licensed dairy herds in the United States in 2007. That few dairy operations have taken advantage of this technology indicates that there are barriers to adoption.

A cooperative approach may be one way for dairy operators to overcome obstacles to the successful use of anaerobic digesters. Dairy producers could take one of two basic approaches: (1) an existing dairy cooperative could provide services related to the adoption of anaerobic digester technology as a part of its member services, or (2) a group of similarly situated dairy farmers could form a separate entity to address their specific needs. In the first case, care would need to be taken to treat equitably members of the existing cooperative who do not adopt the technology. The second approach may be more risky to start up than operating under the umbrella of an existing cooperative. In either case, a cooperative organization would operate under the principles of user-owned, user-controlled, and user-benefitted.

A cooperative effort may be more effective than each farmer would be if facing the challenges of adopting anaerobic digester technology alone. A cooperative could play a role in negotiation, providing services, and/or marketing, or by operating a centralized system.

Negotiation

A cooperative may engage (either by employment or by contract) experts to negotiate rates and terms of trade with utilities, digester suppliers, food processing firms, and so forth. A group of dairy producers would have more market power to command favorable terms or gain higher quality expertise to address their specific needs than producers acting as individuals would have.

- *Utilities*—A group of dairy producers may provide more incentive for a common utility to agree to compensate them for their electric generation at adequate rates and/or to develop standard procedures and contracts for interconnection agreements. Where pipeline access is feasible, a cooperative could negotiate gas purchase agreements with the pipeline transmission company and assist in acquiring the rights of way necessary to get to the pipeline.
- *Digester suppliers*—A cooperative could employ or contract with technical experts to develop and/or review contract terms and design standards for anaerobic digesters and identify qualified providers. Offering a digester design and installation company a critical mass of potential adopters could make it more economical for the company to better meet the needs of dairy operations wishing to install anaerobic digesters.
- *Food processing wastes*—A few dairy farms have successfully mixed food wastes from food processing and food service firms with the cow manure. This added organic matter increases biogas output (*Scott*). A cooperative could negotiate contract terms and charges (“tipping fees”) for substrate with the food processing firms. The cooperative could also coordinate shipments, perhaps among several local farms with digesters.
- *Community digesters*—In a few places (California's Inland Empire Utilities Agency and Oregon's Port of Tillamook Bay, for example), communities operate anaerobic digesters to treat dairy cow manure and other organic waste for the environmental benefits the process offers. A cooperative of dairy producers delivering manure to the project could negotiate tipping fees charged for manure deliveries and other terms. Cooperative coordination or operation of manure delivery could enhance efficiencies in transportation and system performance and ensure biosecurity (transporting manure to a central location introduces the potential for pathogens to be transferred between farms).

Services

A cooperative could hire or contract with technical experts to provide information, leads, analysis, and expertise. This would allow members to avoid the full cost of finding and vetting such expertise. Services might include:

- *Technical assistance* could be carried out in a similar fashion to the way milk production field services are currently provided by many dairy maketing cooperatives. The cooperative could furnish expert guidance in one or more of the specifics of utilizing an anaerobic digester—interconnection requirements, digester operations, preparation and utilization of digestate, troubleshooting, advice on equipment selection, and so forth.
- *Digester management* services could be provided by the cooperative to manage anaerobic digester operations for member farms. The cooperative's trained professionals would focus on maximizing the potential of biogas production so the dairy producer-member can remain focused on dairying. The producer member would pay fees to the cooperative to set up, operate, and manage the digester. This may be especially helpful when the dairy is importing additional organic matter (such as food processing wastes) for addition to the digester.
- *Back-up equipment* could be jointly owned by cooperative members and rented to members when their biogas-utilization equipment is down for repairs or maintenance. When an engine generator is taken out of service for repairs or maintenance, the biogas cannot be utilized nor is there any heat available for useful purposes, resulting in lost efficiency (*NRCS*). Cooperative ownership would ensure that this back-up equipment could be operated on biogas and that it would be available on a timely and least-cost basis. Furthermore, the cooperative might also schedule tune-ups and maintenance for members' engines and boilers, perhaps employing its own expert mechanic.

  Alternatively, dairy producers delivering manure to a centralized digester may benefit by cooperatively operating a manure hauling service. The cooperative would own the manure- and effluent-hauling equipment, coordinate delivery schedules, and provide labor and management.
- *Financing information and/or grant management* could be provided by a cooperative on behalf of members. Financial assistance to offset at least a portion of a digester's capital costs appears to be necessary for some digester systems to cash flow (*NRCS*). A cooperative could build a clearinghouse of information, identifying funding sources relevant to digester projects; provide members with assistance in grant writing and management; develop educational materials for loan officers unfamiliar with anaerobic digester projects; and arrange access to financing.

Marketing

A cooperative could assist members in marketing products derived from anaerobic digestion by researching potential uses for digested solids, developing standardized marketing materials and product guidelines, or even by assisting utilities in developing and marketing “green energy” produced on member farms. A group marketing effort would represent a larger volume than an individual dairy, which could increase marketing efficiencies and effectiveness or even open up new marketing channels. Possibly, a cooperative could operate a common byproduct packaging and distribution venture for members located in close proximity.

Centralized systems

It may be more cost-efficient for a group of closely located, small- and medium-sized dairy producers to operate a common digester fed by member farms' manure than if each of the producers installed a digester on their own operations. The advantages to a centralized digester are that risk, capital costs, digester operating and maintenance responsibilities, and byproduct marketing would be borne by the cooperative. The cooperating farms would have to be located such that hauling or piping manure from farm to digester and effluent to fields is economically and logically feasible. And, protocol to mitigate the biosecurity risk of potential pathogen exchange between participating farms would be necessary.

The cooperative digester would need to capture value from the biogas-selling electricity to a utility or natural gas to a pipeline—and meet regulations that may be more stringent than for on-farm digesters (*Bothi*). The cooperative could also partner with other entities for mutual benefit. For example, a cooperative digester could partner with firms that produce organic wastes or with factories that can utilize the energy produced by anaerobic digestion. The costs and responsibilities of anaerobic digestion would be further reduced for the producer-members while the factory or firm potentially lowers its cost of production and/or waste disposal (*Bowman*).

Another cooperative effort would be for strategically located farms with on-farm digesters to transport biogas (by truck or pipeline) to a cooperatively owned, centralized gas conditioning and compressing plant for input into a commercial pipeline. The cooperative effort could include management of biogas transportation logistics and marketing of the gas.

Funding

One way that a cooperative effort could be funded would be to charge a per cow fee based on the number of milk cows on each member's operation. A basic membership fee could serve to set up the framework for offering digester-related services. Further fees could be charged over and above the basic membership fee when a member directly utilizes a particular service. This would ensure that the members who benefit from a service are the ones supporting it financially. This fee-for-service plan may be the most equitable in the case where an existing dairy cooperative provides support to the subset of its members who elect to utilize the anaerobic digester technology.

Alternative to per cow or per farm fees, a cooperative could charge on a pay-as-you-go basis for its products and services. This also ensures that the farmers using the service or benefit are the ones funding its availability.

A larger membership fee may be required to set up a separate entity to address digester issues specific to the group of dairy producers. Start-up and overhead costs would be borne solely by the cooperating members.

As with the anaerobic digester technology itself, dairy producers will have to evaluate if the benefits of acting together to address their needs in utilizing a digester outweigh the costs. The value of a cooperative effort depends upon its effectiveness in enabling members to increase net returns to anaerobic digestion (see box 7 for a summary of possible benefits of cooperative efforts).

Box 7—Possible benefits of a cooperative effort to support the adoption of anaerobic digesters by dairy producers

Energy	● Improved compensation for electricity produced ● Favorable terms for connecting to the electrical grid ● Natural gas marketing
Byproducts	● Technical guidance on utilizing digested solids and effluent on farm ● Marketing research and development for byproduct sales
System design	● Technical guidance for design/installation ● Negotiated prices for digester components/installation ● Provider screening
Management	● Technical guidance to boost biogas production ● Management assistance to reduce operating costs
Carbon Credits	● Aggregation and trading ● Reduced fees

Carbon Credits

Methane captured from anaerobic digestion of dairy cow manure may be qualified to receive carbon credit if it is collected and prevented from discharging into the atmosphere. According to the Second Assessment Report (1996) of the Intergovernmental Panel on Climate Change (IPCC), the Global Warming Potential of methane is equivalent to 21 times that of carbon dioxide[1]. This means that in terms of global-warming potential, reducing one metric ton of methane gas emissions has the same impact as reducing 21 metric tons of carbon dioxide emissions.

A business or organization may strive to reduce its contribution to global warming potential by taking steps to mitigate the firm's direct or indirect greenhouse gas emissions. In case its effort is short of its own mitigation goal (or cap), the firm may want to offset its shortfall by purchasing greenhouse gas reduction credits ("carbon credits") from others who could provide credible net reduction claims. In this way, the firm disciplines itself by paying a financial penalty for not meeting its own emissions reduction goal, while offering incentives to offset providers such as dairy farmers who capture methane from anaerobic digestion of cow manure for use as fuel. This so-called cap-

[1] Although IPCC has updated the Global Warming Potential of methane to 23 carbon dioxide equivalents in its Third Assessment Report (2001) and to 25 in the Fourth Assessment Report (2007), 21 carbon dioxide equivalents continues to be used for consistency in greenhouse gas inventory reporting (EPA 2008).

and-trade scheme works to cut overall greenhouse gas emissions, which are usually measured in carbon dioxide equivalents.

Trading mechanisms

In the United States, various schemes for buying and selling carbon credits are in varying stages of evolvement. The transaction could be by private negotiations. Or, the trading could be through formal exchange mechanisms, for example:

- *Cash market:* The Chicago Climate Exchange claims to be "North America's only and the world's first global marketplace for integrating voluntary legally binding emissions reductions with emissions trading and offsets for all six greenhouse gases." It was launched in 2003 (*Chicago Climate Exchange*). Trading on this exchange may be characterized as similar to a commodity cash market.
- *Futures market:* The Chicago Climate Futures Exchange, a wholly-owned subsidiary of the Chicago Climate Exchange, "is a CFTC designated contract market which offers standardized and cleared futures contracts on emission allowances and other environmental products." (*Chicago Climate Futures Exchange*).

  The Green Exchange contracts began trading in March 2008. However, the Commodity Futures Trading Commission (CFTC)-regulated Green Exchange is expected to launch during the first quarter of 2009. A partnership between New York Mercantile Exchange and Evolution Markets, the Green Exchange claims that it "will be the most globally integrated marketplace for the trading of environmental products. It will enable market participants to gain exposure to environmental trading markets and manage their risk via a diversified product slate; from Europe's carbon allowances and Kyoto-based carbon credits to U.S. voluntary carbon credits, renewable energy credits, and emissions allowances." (*Green Exchange*).
- A*uction:* The World Green Exchange, launched by the World Energy Exchange in February 2008, brings together buyers and sellers of carbon credits (among other green commodities) by holding auctions. The Exchange claims the auction process provides "a superior price discovery mechanism by enabling buyers and sellers to see what the market will command in real time, thus allowing the true forces of market competition to deliver the efficient pricing result." (*World Green Exchange*). Occasionally the Chicago Climate Exchange also conducts auctions for members to fulfill specific needs.

Just like all traded commodities, certain standards and specifications are required of carbon credits to facilitate the transaction. Possible basic requirements of the underlying offset projects include:

- The capture of methane gas from anaerobic digesters must actually result in net reduction of carbon emissions as compared with a certain base period.
- The claim of carbon credits (i.e., net reduction of carbon emissions) must be measurable and verifiable.
- The ownership of the claim of carbon credits must be clearly established.

On the Chicago Climate Exchange, the closing price of Carbon Financial Instrument Vintage 2008 started the year at $1.90 per metric ton of carbon dioxide equivalent. It rose to peak at $7.40 at the end of May and the beginning of June, and then declined to $4.00 on July 15. The simple average for the first 137 trading days of 2008 was $4.98, which amounts to an extra income of about $25 per lactating cow per year for dairy farmers who have carbon credits to sell. This potential revenue will not fully cover the cost of installing anaerobic digesters. But at least the sale of carbon credits might partially offset the cost of animal waste treatment. (Under certain conditions, further credit also may be available if the captured methane gas is used as fuel for electricity generation.)

There are costs involved in selling carbon credits to cover administrative and trading expenses. If the credits are sold through an aggregator, the costs may include one or all of the following: (See for example, *Michigan Conservation and Climate Initiative; National Farmers Union; Iowa Farm Bureau*.)

- An aggregation fee charged by the aggregator, the going rate of which is around 10 percent of the value of the carbon credits, amounting to around $2.50 per cow at the carbon credit value cited above. (More about aggregation is explained below.)
- A trading fee, such as fees for registration and sales through the Chicago Climate Exchange. For example, one aggregator quoted a trading fee of $.20 per metric ton of carbon dioxide equivalent, amounting to $1 per cow per year.
- A project verification fee(s), if the anaerobic digester system and the claim to the carbon credits need to be verified. (Initial and annual verifications may be required.)

Cooperative roles for carbon credit trading

The current number of digesters may not constitute a critical mass for cooperatives in any region to play a significant role in marketing carbon credits at this time. However, as a membership service, a dairy cooperative may want to inform members about the opportunity of generating some returns from marketing carbon credits, as some cooperatives have already done.

If installations of anaerobic digester systems for treating animal waste become more common, a critical mass of members may ask their cooperative to pool and help market their carbon credits. Pooling is most likely necessary to assemble (aggregate) a large enough volume for efficient marketing. The reason is that a lactating cow weighing 1,376 pounds generates methane that is equivalent to about 5 metric tons of carbon dioxide annually (*ASABE; NRCS*). That amount is only about one 20th (5 percent) of the size of a Chicago Climate Exchange's Carbon Financial Instrument contract (i.e., a contract represents 100 metric tons of carbon dioxide equivalent). In other words, it would take 20 to 25 cows a year to satisfy one single contract.

The Chicago Climate Exchange defines aggregators as "Entities that serve as the administrative representative, on behalf of (greenhouse gas) offset project owners, of multiple offset-generating projects" (parenthesis added). The Exchange further stipulates that "Offset projects involving less than 10,000 metric tons of CO_2-equivalent per year should be registered and sold through an Offset Aggregator." Offsetting 10,000 metric tons of carbon dioxide-equivalent by flaring methane produced from anaerobic digestion of dairy manure would require the waste of more than 2,000 lactating cows. However, only 595 dairy operations had that many cows in 2007, just 3.5 percent of all U.S. farms with more than 100 milk cows (*USDA National Agricultural Statistics Service*). Therefore, most dairy farms would need to register and trade through an aggregator.

Through joint actions by members, a cooperative may be able to bargain for lower marketing fees and/or higher returns. Depending on the needs of the members, a cooperative may have some roles to play in the marketplace for carbon credits:

- A cooperative may engage a broker(s) to negotiate with carbon credit purchasers on prices and terms of trade.
- A cooperative may act as a broker to negotiate with carbon credit purchasers on prices and terms of trade.
- A cooperative may engage an aggregator(s) to trade carbon credits for members.
- A cooperative may act as an aggregator if there is enough volume of carbon credits generated by members. In essence, the function of an offset aggregator is similar to that of a milk-pool administrator, and dairy cooperatives are well experienced in pooling operations.
- A cooperative may form a joint venture with other cooperative(s) to provide aggregator services to members. The joint venture would have a broader membership base to operate.
- As verification of the anaerobic digester system and the claim of greenhouse gas reduction is usually required, a cooperative may engage verifiers or have verifiers on its field service staff to carry out the function.

Thus, a cooperative could help its members maximize the benefit available from the sale of carbon credits by negotiating the highest prices possible for the credits and minimizing the costs associated with their sale.

Summary

There are many dairy operations that meet basic criteria for successful use of an anaerobic digester. However, use of anaerobic digesters on U.S. dairy farms is not wide-spread to date. The set of barriers to adoption is often unique to each producer's situation. The decision to install a digester is dependent upon the policies of the local utility; local regulations; local fuel and electricity rates; access to grants and financing; and the operator's knowledge, skill, and level of risk aversion.

A cooperative effort may be one way to overcome the obstacles to adoption more efficiently and effectively than each dairy producer acting alone. It may enable milk producers to remain focused on milk production while obtaining the benefits of anaerobic digestion of their cattle's manure. Collective effort may enhance the economic feasibility of anaerobic digesters by lowering their installation and operating costs, increasing returns from energy, byproduct, and/or carbon credit sales.

A cooperative effort could focus narrowly on one obstacle or one opportunity, or incorporate multiple functions. Alternatively, a cooperative could focus on one effort initially and gradually take on more functions as it builds on its successes. This cooperative effort could be conducted under the umbrella of an existing dairy marketing cooperative or organized as a separate entity.

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Rural Business–Cooperative Service

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Rural Business–Cooperative Service (RBS) provides research, management, and educational assistance to cooperatives to strengthen the economic position of farmers and other rural residents. It works directly with cooperative leaders and Federal and State agencies to improve organization, leadership, and operation of cooperatives and to give guidance to further development.

The cooperative segment of RBS (1) helps farmers and other rural residents develop cooperatives to obtain supplies and services at lower cost and to get better prices for products they sell; (2) advises rural residents on developing existing resources through cooperative action to enhance rural living; (3) helps cooperatives improve services and operating efficiency; (4) informs members, directors, employees, and the public on how cooperatives work and benefit their members and their communities; and (5) encourages international cooperative programs. RBS also publishes research and educational materials and issues *Rural Cooperatives* magazine.