Sustainable Economic, Marketing, Environmental and Financial Opportunities for Biogas Recovery Systems

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Selected Paper prepared for presentation at the 2010 WERA-72 Agribusiness Research Emphasizing Competitiveness and Profitability Meeting, Santa Clara, CA, June 13-15, 2010.

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Abstract

Livestock producers operating large-scale confinement operations, such as dairies, are looking for ways to handle and dispose of manure that are cost effective and efficiently meet odor and pollution policies. Farm level production of biogas using anaerobic digesters is one solution that helps control methane emissions. Methane is an odorless gas that can be used to generate electricity, develop fiber products (such as fiber boards, decking, cow pots and building materials) and potting medium as a soil or peat replacement and livestock bedding, establish carbon credits, or provide other value-added products like fertilizer and raw gas or transport fuel, thereby having marketability and economic value. Substantial environmental benefits of odor control, water quality protection, and greenhouse gas reductions also exist. Because of the tangible and intangible benefits possible from reducing methane emissions via anaerobic digesters, biogas recovery systems are prudent financially as well, with single-digit payback periods, double-digit simple rates of return, approximately $1 million (USD) in net present value, double-digit internal rates of return, and relatively large benefit-cost ratios associated with the savings over time.

Biogas Recovery Systems

There are four (4) components to a biogas recovery system: a manure collection system, an anaerobic digester, a biogas collection system, and a gas use device (Figure 1). The three (3) most prominent biogas recovery system designs used at United States farms are the (Figure 2):

- Covered anaerobic lagoon – the least costly, simplest and most commonly used; uses a flexible cover over a liquid manure (0.5% - 3.0% total solids); needs high average ambient temperatures (located between 40 degrees north and south latitudes) to produce more methane;
- Plug flow digester – a long, narrow heated tank with either a rigid or flexible cover; limited to dairy manure collected by scraping (a semi-solid manure of 11% - 13% total solids); and
- Complete mix digester – an enclosed, heated tank with either a mechanical, hydraulic, or gas mixing system; works best when there is some dilution of excreted manure (a slurry of 3% - 11% total solids) with process water, such as milking center wastewater.

Anaerobic digesters could include other organic waste feed stocks, other than manure. These feed stocks could include, as examples, cheese whey, ice cream, brewery waste, winery waste, and greases and oils (US/EPA).

An overview of the complexity and costliness of each of these three digester processes follows:

Digester Process	Process Complexity	Operational Complexity	Capital Costs	Operating Costs
Covered lagoon	low	low	low	low
Plug flow	low	low	low	low
Complete mix	medium	medium	medium	medium

There are four (4) potential advantages to installing and utilizing a biogas recovery system (US/EPA):

- Economy of scale – significant economic benefits occur as the biogas production capacity increases;
- Marketing leverage – marketing of energy/fuels and electricity, by-products, and co-products enhances total revenue and improves cash flow;
- Financing – increased availability and sources of venture capital, as well as grants, tax credits, and renewable energy programs for financial assistance exist, and acceptable financial management values for payback period, simple rate of return, net present value, benefit-cost ratio, and internal rate of return result; and
- Environmental benefits – odor control, water quality protection, and greenhouse gas reductions are the three substantial environmental benefits.

Environmental Opportunities

One of the biggest challenges facing dairy operators is managing manure and process water in a way that reduces odor and protects environmental quality at a reasonable cost. Biogas recovery systems will reduce odors, protect water quality, and reduce greenhouse gas emissions, as shown in the following table (US/EPA):

Option	Odor Control	Greenhouse Gas Reduction	Water Quality Protection
Covered Lagoon	Excellent	High	Good
Heated Digesters	Excellent	High	Good

(complete mix and plug flow both rely on external heating)

In order to capture these environmental opportunities, one approach is the AgSTAR program, a voluntary outreach effort jointly sponsored by EPA, USDA, and US Department of Energy that encourages the use of methane recovery (biogas) technologies at confined animal feeding operations that manage manure as liquids or slurries. These technologies reduce methane emissions while achieving other environmental benefits. The AgSTAR program provides technical support to livestock waste management that integrates policy development and implementation, technological solutions, capacity building, and regional connections.

The Methane to Markets (M2M) program also explains how the values associated with the co-products of biogas capture and methane reduction enhance the economic feasibility of any manure management system. The M2M program is a multi-national collaborative effort in over 60 countries that focuses on reducing greenhouse gas emissions through appropriate manure management strategies.

Society must also recognize the importance of reducing methane emissions, controlling odor, improving water quality, and generating rural or community economic activity, and that the positive value of these intangibles improves the quality of life of the citizenry. Participation in the Methane to Markets and the AgSTAR programs help mitigate greenhouse gas emissions and climate change. The recovery and use of methane is recognized as a valuable source of clean energy, a means to advance energy security, a way to improve environmental quality, and a process that reduces greenhouse gas emissions.

Marketing Opportunities

Co-product markets are essential for the economic viability of anaerobic digesters and establishing value for the reduced methane emissions processes. An Environmental Protection Agency (EPA) sponsored partnership of building public and private sector alliances to advance the recovery and use of methane at livestock manure management operations is entitled "Methane to Markets," which suggests that there is market value in the by- and co-products of manure management. Reducing methane emissions (methane is a potent greenhouse gas when released to the atmosphere) can yield substantial economic, environmental, financial, and marketing benefits.

Biogas is 60% - 65% methane, with carbon dioxide, hydrogen sulfide and trace amounts of water accounting for the remaining 35% - 40%. It is a medium-Btu fuel that can be used to generate electricity (hence, electricity becomes an avoided cost) for potential selling to others or the utility company, or biogas can be burned in natural-gas or propane boilers and space heaters as a waste heat source, while having market value.

Carbon credits also have market value. In the US, the Chicago Carbon Market is the principal agricultural carbon credit market that establishes value for the reduced methane emissions from manure using an anaerobic digester.

Various fiber products can also be marketed from the manure. Fiber boards and decking planks are examples of fiber products that use 50% dried manure and 50% recycled corrugated products. An extension of the fiber boards and decking is the manufacture of building materials from recycled products. Cow pots formed from manure and recycled products are marketed for use as biodegradable flower pots and containers for the landscape and environmental horticulture industry. A potting medium as a soil/peat replacement can also be developed as a fiber product for the horticultural industry. Bedding for the livestock industry is yet another fiber-based product provided from dried manure.

Other value-added co-products include fertilizer (repeated sampling and testing must occur to ensure consistency of product) and raw gas for flaring as well as transport fuel. All of the aforementioned products generate marketing leverage.

Economic Opportunities

In identifying profitable biogas recovery systems for dairy operations, the common characteristics are dairies with milking herds of more than 500 head located in flushed free-stall barns – this is where the economies of scale exist. Profitability depends on the ability of the entrepreneur to recover the capital and operating costs at a reasonable rate of return, and to generate a long term income stream. Specifically, three economic aspects influence the overall profitability of the operation: the size of the operation plus local factors (construction costs; energy prices; farm management practices), the manure management system utilized (manure handled in a liquid, slurry or semi-solid state; collection frequency), and the current/forecast energy prices (avoided cost of electricity; possible sale of excess electricity; waste heat recovery; sale of carbon credits through brokerage houses to global greenhouse gas markets).

The costs and benefits facing the individual farmer are crucial in adoption of anaerobic digester systems. These costs include: capital costs for digester and generation equipment, operation and maintenance expenses, costs of adapting existing manure handling and storage to biogas systems, and the farmer's time costs in learning about and maintaining the system.

Experience demonstrates, however, significant economic benefits as biogas production capacity increases, although the cost of anaerobic digestion of dairy cattle manure for biogas production and utilization will vary with the system type and size, type of livestock operation, and site specific conditions. Using vendor quotes to provide preliminary guidance for estimating capital costs, the data represents the cost of the digester, the engine-generator set, engineering design, and installation (excluding utility line upgrades and interconnection equipment costs and fees. The total capital cost of the three anaerobic digestion systems – the complete mix, the plug flow, and the covered lagoon –is shown in Figure 4, whereas the capital cost per dairy cow for the three systems is shown in Figure 5; both figures are shown with respect to the number of dairy cows for the specific design (www.epa.gov/agstar).

The financial benefits include: avoided costs of electricity if the biogas is used onsidte for generation that replaces electricity purchased; avoided propane, fuel oil, or natural gas purchases if the waste heat is recovered from generation and used for space and water heating; revenues from the sale of excess electricity or from the sale of methane gas; avoided costs (or revenues from sales) of bedding and other fiber products; avoided costs of commercial fertilizer and herbicides deriving from improved fertilizer value of digester effluent over raw manure; and revenues from the sale of carbon credits in greenhouse gas markets.

Profits are quite sensitive to the availability of revenues from the sale of electricity or carbon credits. Few large dairies would find a digester investment to be profitable without significant support for capital costs, carbon credit revenues, or revenues from electricity sales. Farmers may qualify for carbon credits if they can capture methane and prevent it from emitting into the atomosphere. If farmers can provide credible claims of reduction in methane emissions, they may be able to sell the carbon credits in private transactions or in organized exchanges, thereby gaining further revenues from an investment in a digester. Credits traded on the Chicago Climage Exchange (CCX) varied over 2008 from $1.90 per metric ton to $7.40, with a mean price of $4.98 (Liebrand and Ling, 2008). If a lactating dairy cow produces five metric tons of methane in a year (five credits), then the farm could realize $25 per cow per year from the sale of carbon credits at a credit price of $5, and a farm with 2,000 cows could realize $50,000 in additional revenues. The farmer who had already invested in an anaerobic digester would bear some additional costs of qualifying for credits, for metering equipment and for fees paid to intermediaries, but the additional net revenues could make the project as a whole profitable. The costs to be borne by farmers for digester adoption, as well as the benefits accruing to them, are subject to considerable uncertainty (Stokes, Rajagopalan and Stefanou, 2008).

Financing Opportunities

Due to the scale of the project, additional sources of venture capital may be available as well as assistance from grants, tax credits, or renewable energy programs as noted in the 2008 Farm Bill. In reviewing the protocol for quantifying and reporting the performance of anaerobic digestion systems for livestock manures, an approach for evaluating the economic and financial viability is established. Sections of the financial analysis to be included are a write-up of the general approach; the boundary conditions; the annual capital cost (which embodies two assumptions: recovery of the capital invested and the retirement of debt financing will occur at the same interest rate and as an annuity over the useful life of the system, and an estimate of the useful life of the system must be made, typically 20 years); annual operation, maintenance, and other costs; annual revenue; and net income.

With the covered lagoon total capital costs and capital cost per cow both being graphically portrayed as being low relative to the plug flow and complete mix anaerobic digester systems, as well as the covered lagoon system being the most commonly employed of the three systems, the financial analysis data is being shown for the covered lagoon system only. Rather than calculating the information suggested as protocol, financial data representing the five financial evaluation tools of the payback period, the simple or accounting rate of return, the net present value, the benefit – cost ratio, and the internal rate of return were calculated for each of five dairy operations with approximately 2,000 head of dairy cows and then the averages determined where applicable. The monetary savings in the calculations are from avoidable costs (electricity purchased and transportation off-site of manure, primarily), and do not include revenue generated from the marketing of any of the products mentioned in the discussion of “marketing opportunities.”

Payback Period	12.5 years
Simple or Accounting Rate of Return	8.0%
Net Present Value (10%, 20 years)	approximately $600,000
Benefit – Cost Ratio	4.075
Internal Rate of Return	approximately 25%

Manure Use for Energy and Fertilizer

In the manure management storage systems typically used on livestock confinement operations (dairy or swine), little oxygen can dissolve into the mix, which creates anaerobic (without air) conditions. Certain microbes that are naturally found in manure feed on organic materials in the manure. The bacteria function best in anaerobic conditions, and they give off biogases, primarily methane and carbon dioxide. Manure spends about 20 days flowing through the digester to the effluent storage and handling system.

The methane captured from the manure can be used as a feedstock for electricity generation. Farmers could then reduce their purchase of electricity and fuels, and might be able to sell excess electricity or methane. Society can gain because an existing product (manure-based methane gas) would replace some fossil fuels used for the same purpose. In addition, the manure effluent that is left after anaerobic digestion has few remaining decomposable compounds. Decomposition is what creates odor, so digestion also provides a solution to odor problems.

Manure-to-energy systems are in limited commercial use in the US. Only 91 commercial dairy farms were using digesters by the summer of 2008, with another 64 projects in the construction, design or planning (CDP) phase. These 155 farms accounted for 0.2% of all dairy farms and 2.9% of all dairy cows in the US. About 4.5% of dairy farms with at least 2,000 cows have digesters, and another 3.4% are in the CDP phase, but they account for just 8% of the cows on dairy farms with at least 2,000 head (EPA).

About 15.8 million acres of cropland, equivalent to about 5% of all US cropland, are fertilized with livestock manure. This estimate is based on data drawn from several sources and is subject to some uncertainty; nonetheless, manure is used only on a small fraction of US cropland. Patterns of manure use are driven by the agronomic needs of crops and by transport costs, which limit the distance that manure can be moved and create close links between types of livestock and certain crop commodities. In particular, dairy cow manure tends to be collected in a slurry, and the high moisture content of slurry creates even higher transport costs. The manure, however, can be applied on-farm to corn, and with its high nutrient uptake for nitrogen, corn is an attractive option for livestock operations by providing a livestock feed – a sustainable farming operation can result.

Identified Barriers or Opportunities to Biogas Recovery System Implementation

To summarize the marketing, economic, financial, and environmental opportunities, there are several identified barriers to successful utilization of biogas recovery systems for implementing methane capture and utilization projects. These barriers, summarized below, are really masked or hidden opportunities for future collaboration and investigation, rather than negative consequences.

Institutional Barriers:

- ✓ Not enough current or contemporary research that either models or evaluates the realities of current technologies.
- ✓ Environmental laws not adequately enforced, so free-rider encouragement and no incentive to participate.
- ✓ Lack of information on the economic performance of the livestock sector and manure management scenarios, on the market value of by-products and co-products from livestock manure, and on the social valuation of environmental output or products.
- ✓ Power generation with biogas may not be an appealing choice due to regulations and costs of installation, operation and transmission of the energy components.

Technological Barriers:

- ✓ Too much heterogeneity with respect to size and use of the biogas recovery technology.
- ✓ Few developers of anaerobic digestion technologies, especially for the smaller livestock operations (animal units).
- ✓ Lack of guidelines for development, construction, installation, and performance evaluation of anaerobic digestion systems.
- ✓ Relatively high operational and maintenance costs.
- ✓ Lack of comprehensive waste management and wastewater management plans for livestock manure.

Economic Barriers:

- ✓ Uncertainty with regards to profitability levels for livestock producers, especially dairy farms (market values of fixed assets, prices for inputs and fluid raw milk, costs of doing business).
- ✓ Livestock producers unaware of emission markets (carbon credits) or by-products and by- or co-product markets, as incentives to participate.
- ✓ Difficulty in valuing positive externalities (water and air quality) of operations, especially those in densely populated areas (centralized markets).
- ✓ Uncertainty as to how to capture environmental value-added by public and private stakeholders – should there be an environmental subsidy to the private operator?
- ✓ Need for a common protocol for quantifying and reporting total economic performance of anaerobic digestion systems – a protocol that recognizes the informational needs of any funding or management agency/business/organization.

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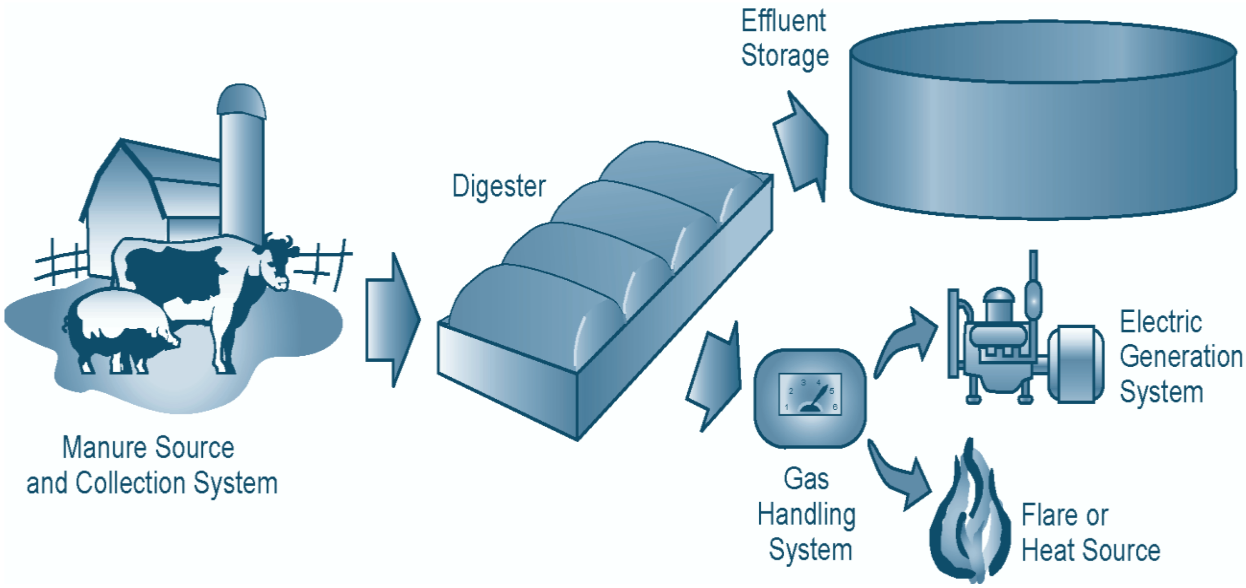

Figure 1. Schematic showing the components and products of a biogas recovery system.

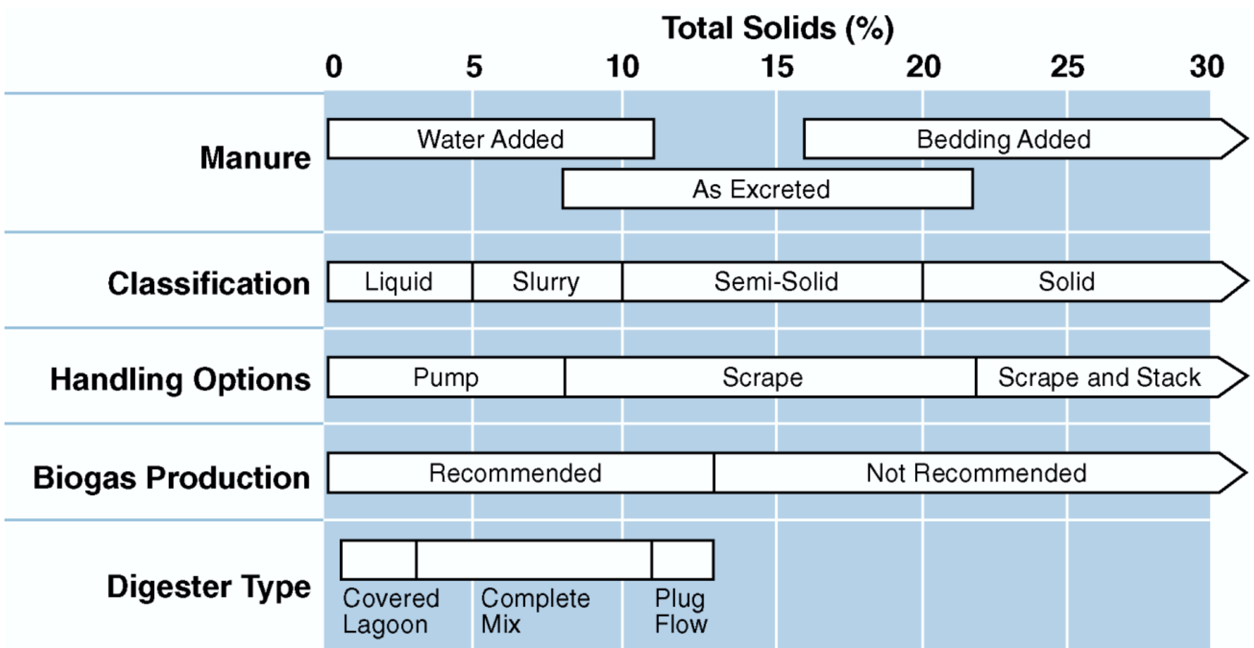

Figure 2. Appropriate manure characteristics and handling systems for specific types of biogas digester systems.

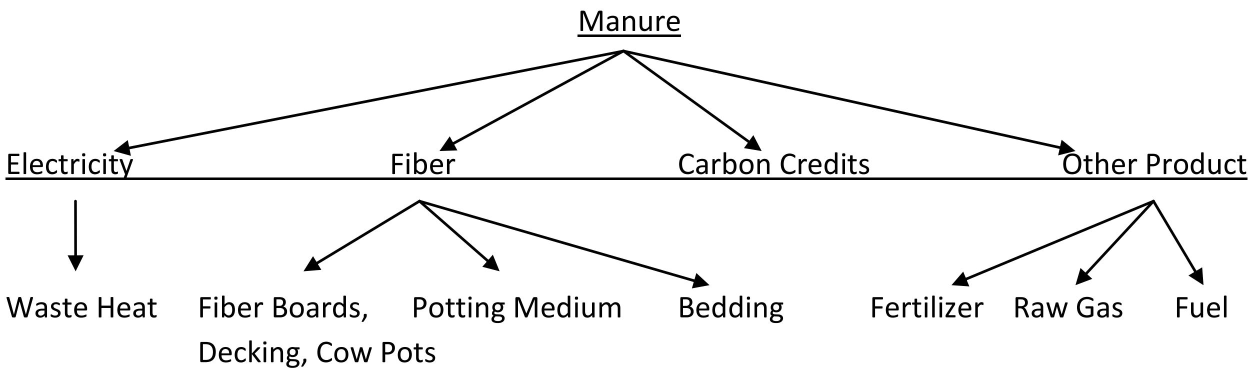

Figure 3. Marketable by-products and co-products of manure.

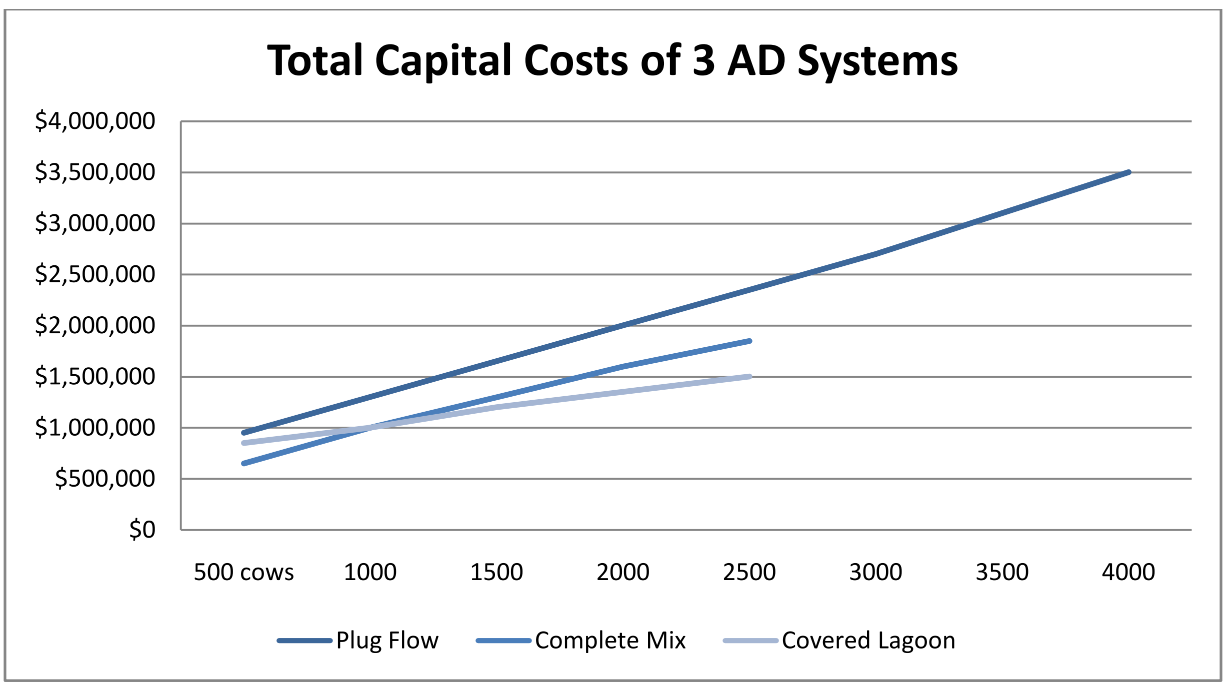

Figure 4. Total Capital Cost of Complete Mix, Plug Flow, and Covered Lagoon AD Systems.

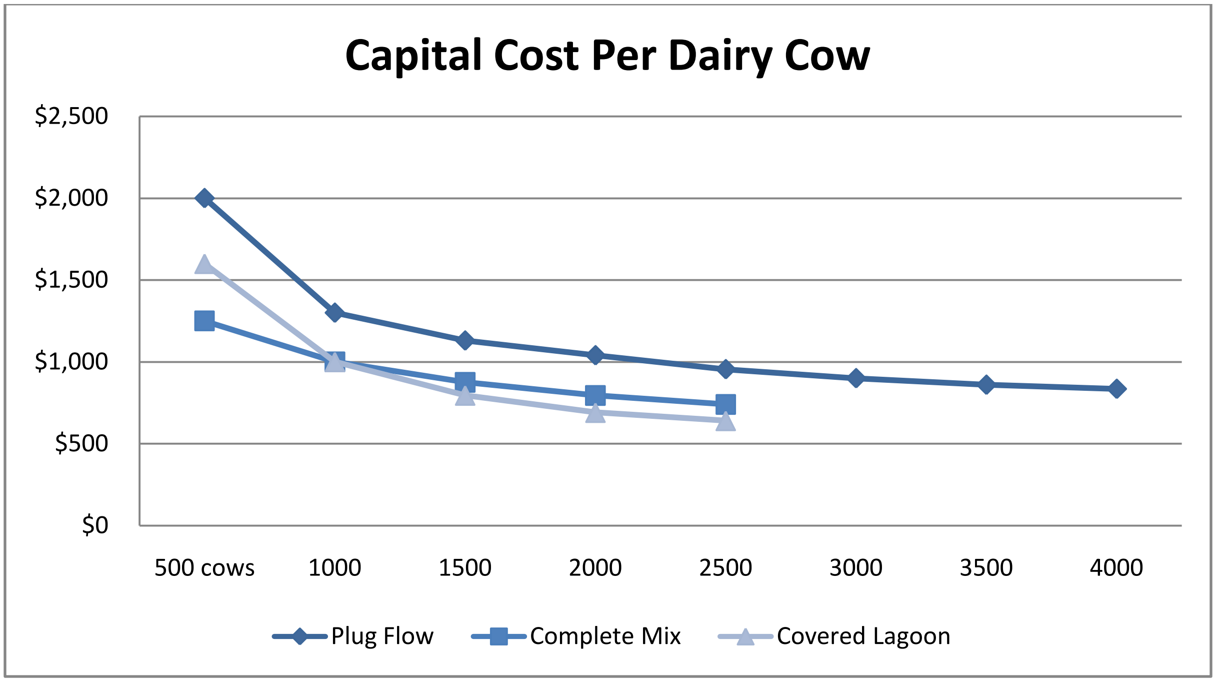

Figure 5. Capital Cost Per Dairy Cow for Complete Mix, Plug Flow and Covered Lagoon Systems.