Feasibility Report of a Cooperative Dairy Manure Management Project in St. Albans/Swanton, VT

The Vermont Agency of Agriculture, Foods, & Markets
And The
Economic Development Council of Northern Vermont

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Foreword:

We find this to be an exciting project with significant potential and wish to express our thanks to Spencer Bennett and all those who helped make this report possible. With apologies to any we may miss we wish to thank the following:

The farmers of the St. Albans Bay area

Economic Development Council of Northern Vermont

Vermont Department of Buildings and General Services

Vermont Department of Corrections

Vermont Agency of Agriculture, Food and Markets

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USDA Rural Development

Franklin County Industrial Development Corporation

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APPENDICES:

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1. EXECUTIVE SUMMARY

The St. Albans and Swanton, Vermont area contains an intense concentration of dairy farms. It also is the site of the Vermont Northwest State Correctional Facility. The opportunity exists for a manure management system that generates electricity and heat for consumption by the Correctional facility. The manure management system will improve odor, reduce nutrient run-off, and provide other benefits for the farms, the environment, and the community. Nutrient control and phosphorous reduction are important goals to the area farms and the environment.

This report investigates several scenarios for anaerobic digestion of the farms' agricultural wastes: one central digester, several mini-central digesters, many local cooperative digesters, and individual farm digesters, and the course of "no action". Several methods for transporting the fresh manure to a central digester are discussed.

At first glance, the transportation cost exceeds the value of the electricity produced by the digester. Only when all the benefits and revenues are compared to the expenses can this project be fully appreciated. Then, the large environmental and public impacts are added to the electricity, heat, and by-products to make this a compelling project.

It is recommended that the One Central Digester proposal be studied further, and that the Recommendations in Section 7 of this report be implemented. The unique opportunity to construct a comprehensive manure management system with these parameters should be acted upon:

A. A dense cow population.

B. The presence of the Vermont Department of Corrections correctional facility that requires reliable electricity and heat, and is located central to the dense cow population above.

C. Strong environmental need to control and reduce agricultural contaminants.

Considering that 226,000 tons per year would be processed to produce renewable, reliable, local electricity, and that the resulting digested manure becomes a controlled-application liquid fertilizer and a landscape material, this project appears to have earned the right to additional study. The financial analysis shows a positive cash flow of $0.71/ton for this project when 50% of the capital costs are covered by grants.

The valuable benefits resulting from this project are significant. The potential positive impact to the farming community in Vermont alone is large. This project has wide appeal as it combines the advantages of managing agricultural wastes, generating electricity, creating a landscape/fertilizer material, reducing odor issues, and creating jobs.

2. BACKGROUND

Introduction

The purpose of this Report is to identify the technical, business, and community impacts of the implementation of several alternative manure management scenarios for farms in the St. Albans and Swanton, VT area, and explore the integration of this project with the Vermont Department of Correction Correctional facility's energy and electrical consumption at its facility in St. Albans.

A. Compilation of dairy populations, housing, and current manure practices

B. Report of the Correctional facility's consumption of electricity and heat.

C. Review of current and proposed manure management methods

D. *Investigation of options to determine technical feasibility, financial viability, and community impact.*

E. *Model capital investment and operating expenses and income associated with four options*

F. *Identify risks and issues associated with the options*

G. *Quantify community and environmental benefits associated with the options*

H. *Recommend action.*

Several current circumstances and practices have resulted in the opportunity for a dairy manure management system that could provide significant benefits to the community, the local dairy farms and its many neighbors, the environment, the State of Vermont, and the community.

1. The area of St. Albans and Swanton has a high concentration of dairy farms, and consisting of approximately 10,000 head of cows, heifers, and calves within a six mile radius. Current agricultural waste practices are causing concern for groundwater quality in the local bodies of water and in Lake Champlain, which is adjacent to many of these farms.
2. The State of Vermont Department of Corrections correctional facility is located central to this dairy population concentration. The Correctional facility consumes energy in the form of electricity and heat, and is interested in a local, renewable energy source. Further, it has purchased greenhouses to produce food that will require additional energy consumption.
3. Several manure management systems are explored, including anaerobic digestion. With anaerobic digestion, the manure produces a gas that can cogenerate electricity and heat. The digested manure has improved odor, and is reported to increase crop yields. One such system exists in Middlebury, VT, and has been in operation since 1982. Additional benefits are discussed.
4. The opportunity exists to create a cooperative anaerobic digestion system to be created that will provide energy to the Correctional facility, and additional benefits to the farms, the environment, and the community.
5. The important input of the Steering Committee and the local farmers is integral to the development of this Report. Additionally, the support of the USDA/Rural Development agency is noted.
6. The initial response of many parties is that this project is worthy of consideration. These parties include: many of the local farmers, the Vermont Department of Corrections, the Vermont Agency of Agriculture, Foods, and Markets, the Economic Development Council of Northern Vermont, Inc, Vermont Department of Buildings and General Services, USDA Rural Development, Vermont Public Service Department, Franklin County Industrial Development Corporation, and others.
7. The Report investigates the dairy manure practices and availability, proposes several anaerobic digestion alternatives, and suggests financial and energy solutions that will support a business venture.

Acronyms

Biogas: A natural gas produced from the anaerobic digestion of dairy manure that typically consists of 60% methane (CH_4), 40% carbon dioxide (CO_2), and is 100% saturated with water (H_2O). Biogas burns with oxygen to form carbon dioxide and water.

Cogeneration: The act or process of converting the potential energy in a fuel into heat and electricity by burning the gas in an engine-generator set (see below).

Genset: When an engine is connected to a generator to make electricity from a fuel, it is called an engine-generator set, or genset. It is assumed that this set also includes the controls necessary for the use of the electricity, and usually includes heat exchangers for the recovery of heat from the engine jacket cooling water and, occasionally, the exhaust manifold.

3. CURRENT SITUATION

3.1 Dairy Farms' Situation

Current Dairy Management Practices in the St. Albans/Swanton, VT area

The St. Albans/Swanton area farms are primarily dairy facilities. The majority of the farms are free-stall, with some tie-up or stanchion barns present. Many of the barns are of recent construction, and have some method for limiting exposure of the herd to extreme hot or cold weather. The milking cows are generally housed indoors, with calves and heifers having limited or no pasture time.

Given the current value of milk (which is that of approximately 1972), it is difficult for farms to remain viable with their current operation. It is unlikely that individual area farms would implement a manure management plan due to financial constraints.

Significant regulatory and legislative pressures make most dairy farm managers and owners consider implementing improved manure management techniques. Given the current low value of milk, dairy farms have few options for funding these new programs.

The current situation is that current manure management will continue until changes are necessary, probably by regulatory pressures. Semi-solid or solid manure will be spread on soil, and then incorporated via plowing or harrowing when the soils can carry the weight of tractors.

This Report investigates a manure management system that can provide a manure management system that benefits the farmers while significantly improving the environment ahead of regulatory concerns.

Current Manure Management Methods

Because of the predominance of clay and clay-type soils, much of the manure is spread in the fall or other available times when the tractors and spreaders can safely tread on the soil without damaging crops and getting stuck in the mud. The result of this practice and the density of cows in the area may relate to the distribution of nutrients to unintended soils, which is a great concern to several groups including the farmers and regulatory agencies.

This unfortunate distribution of nutrients to unintended water and soils is of great concern to the US Environmental Protection Agency and to the State of Vermont Agency of Natural Resources.

Odor and over-the-road transport of manure in farm manure spreaders are important issues that present significant local and community concern. Odor complaints rise when undigested, stored manure is field applied. This odor can be more pronounced than in the raw manure.

Typically, manure is stored in static, un-mixed storage ponds until ready for application to the soil. As a static pond, stratification occurs as sand settles to the bottom, and hay, straw, and other lignin-containing particles tend to form a layer at the surface. A tractor-mounted pump achieves partial suspension of the stratified pond, and then loads manure spreaders for field application. While smell is subjective, often the odor from a static pond is a subject of complaints.

Additionally, many farms have fields distant to their cow housing or manure storage facilities. This necessitates transporting the manure on the public roads with tractors and manure spreaders. Several issues are of concern:

1. The tractor is slow moving with respect to the vehicular traffic.
2. Some wastes may inadvertently be deposited on the roadway. This may result from over-filling the manure spreader, or the accidental release of more liquid components of the manure.
3. The tractor treads may cause soil or manure to be distributed along sections of the road.
4. The transportation of undigested manure is an odor issue especially after being agitated from a pond or being loaded by bucket from a manure pack.

Location of Farms

The attached Survey Map of Select St. Albans and Swanton Dairy Farms shows the relative location of farms in the target area. The high concentration of these farms allows several potential manure management options, which will be investigated in this Report.

3.2 Current State of Vermont Department of Corrections Energy Conditions at the St. Albans facility

Current Energy Consumption

The Vermont Department of Corrections facility in St. Albans, VT uses conventional energy sources, and consists of 93,417 square feet of buildings for 250 inmates.

- Electricity: Supplied by Central Vermont Public Service Company, Rutland, VT. Annual consumption is approximately 1,280,000 kWh at a cost of $122,000.
- Natural gas: A natural gas pipeline supplies natural gas to the facility. Annual consumption is approximately 11,550,000,000 sCF.

Table of Energy Consumption

The electric and natural gas consumed by the facility is shown on the table below.

Energy Consumption at the Vermont Department of Corrections Facility at St. Albans, VT

	Electric Demand KW	Electric Energy kWh	Elec. Energy Converted to BTU	Cost
September	222	88,200	300,938,400	$8,590
October	228	96,200	328,234,400	$8,449
November	218	114,600	391,015,200	$12,171
December	216	110,000	375,320,000	$11,863
January	228	113,200	386,238,400	$12,185
February	216	113,000	385,556,000	$12,005
March	208	108,400	369,860,800	$9,025
April	200	100,600	343,247,200	$8,516
May	208	102,800	350,753,600	$8,716
June	220	112,200	382,826,400	$10,255
July	238	107,000	365,084,000	$10,187
August	232	113,600	387,603,200	$10,553
TOTAL	**2,634**	**1,279,800**	**4,366,677,600**	**$122,515**
Average/mo	220	106,650	363,889,800	$10,210
Annual/SF	0.028	13.7	46,744	$1.31

	sCF	BTU	Cost
Natural gas consumption, annual:	11,000,000	11,550,000,000	Not available
Total energy consumption:		15,916,677,600	Not available

Note that the peak demand is 238 kW, and the average demand is 148 kW. The average cost is $0.0957/kWh.

Correctional facility Energy Issues

Concerns of the management relative to the use of energy in the future include:

A. Reliability and cost of electricity

B. Reliability and cost of heat

C. Local weather conditions

D. Security

Proposed Expansion of Energy Needs

List all issues and problems associated with the current business applications (as defined above). Examples include: lack of control over future costs for energy, and a concern over the deliverability of energy from remote sites during extreme weather or other events.

The facility is adding a greenhouse operation soon, and will be consuming more electricity and heat when this facility is in operation. This may make the proximity of a large digester system more attractive to the Correctional facility, as the greenhouse may utilize cogenerated heat from the digester to heat the greenhouse and digested fertilizer as a valuable, local plant nutrient.

Correctional facility Issues Relative to a Proposed Project

These issues appear to be the most significant with respect to any potential integration with a comprehensive manure management project that would cogenerate heat and electricity. The single largest issue is security for the Correctional facility.

1. Correctional facilityer security: control, confinement, tracking, and communication
2. Energy security: reliability of electric and natural gas delivery. This includes backup systems for both energy sources.
3. Costs: the stability and predictability of energy is a large issue of concern.
4. Other energy uses may be possible.

4. MANURE MANAGEMENT ALTERNATIVES

4.1 Potential Manure Management Technologies

Most manage manure practices have not changed for decades. The most prevalent methods of managing manure are the following:

- **Daily spreading of raw dairy wastes as a semi-solid**: **Advantage**: no accumulation of wastes at the barn(s). **Disadvantage**: Difficulty of spreading due to soil conditions and weather. Loss of nutrients. Degradation of water quality. Note that Vermont statutes prohibit the spreading of manure on frozen ground: daily spreading is not allowed from December 15 to April 1 in Vermont.
- **Periodic spreading of manure pack as a solid**: **Advantage**: Allows some flexibility in timing. **Disadvantage**: Soil and weather are still factors, as is nutrient run-off. Odor is an issue.
- **Periodic spreading of stored dairy wastes as a liquid or semi-solid**: **Advantage**: Manure is delivered annually or semi-annually to the soil. **Disadvantages**: Odor and stratification in the storage pond are large concerns.

Beyond these basics, new methods for managing manure have been developed in the last twenty five years:

a. **Vertical storage usually with mixing apparatus**: Example: Harvestore Slurrystore. **Advantages**: controlled application. **Disadvantages**: Capital cost, periodic pumping to minimize stratification, and odor.

b. **Horizontal storage ponds, commonly as an earthen dike**. **Advantages**: controlled application, relatively lower cost. **Disadvantages**: Stratification, safety, and odor.

c. **Anaerobic digestion**: Examples include vertical and horizontal digesters. **Advantages**: Generates electricity and heat, may include separating technologies. Odor improvements. Pathogen reduction. **Disadvantages**: Capital cost, operating engine-generator and separation equipment, operator knowledge and expertise.

Most dairy farms see these three alternatives as all having high capital cost. Several Slurrystore systems exist in Vermont. Many dairy farms have installed a storage pond or “manure pit’ for their manure. Vermont only has one anaerobic digester: Foster Brothers Farm in Middlebury, VT, which started operation in 1982.

Manure Management System	Advantages	Disadvantages	Relative Cost
Vertical storage	Small footprint.	Odor. Stratification. Requires pump. Cost and difficulty of mixing. Manure transported by tractor No energy production. No by-product production.	High
Storage ponds	Low cost. Low technology	Stratification requires periodic cleaning of the pond. Cost and difficulty of mixing. Some odor issues. Manure transported by tractor No energy production. No by-product production.	Low
Anaerobic digestion	Produces energy. Manure transported by secure truck at road speeds. Significant reduction of pathogens. Allows reclamation of solids for bedding or other uses. Odor improvement.	Requires operating and maintenance.	High

Anaerobic digestion is the only alternative that presents many advantages and few disadvantages. Therefore, anaerobic digestion is the recommended process for this project.

4.2 Central versus Individual Digesters

Many factors determine how potential manure management alternatives could be structured. Foremost is the cooperation of the farms, as the ultimate decisions must be accepted and approved by every owner of each farm.

This Report proposes several options for managing manure, and is meant to facilitate the decision-making process for all parties. The range of solutions starts with a manure digester on each farm, and ranges to one central digester for all farms. In this manner, the four active alternatives discussed here gives direction to the decisions that can be made.

Alternative	Advantages	Disadvantages
No action	No change or investment	Environmental concerns may force farms to install a system or cease operation. Manure transported by tractors. Odor
Individual Farm Digesters	Each farm controls their own digester. Manure digested on-site. Net metering is available.	Each farm operates their own digester. No economies of scale No sharing of knowledge.
Many Local Cooperative Digesters	Minimum transportation May suit specific sites. Decent economies of scale and knowledge.	May not match the needs of the Correctional facility Low value for electricity. No sharing of knowledge.
Several Mini-Central Digesters	May suit specific sites. Good economies of scale and knowledge. Manure transported by secure trucks at road speeds.	May not match the needs of the Correctional facility. Digested manure can be deposited to pond distant from a farm.
One Large Central Digester	Best economies of scale and knowledge. Meets or exceeds Correctional facility's needs. Manure transported by secure trucks at road speeds. All manure is in one location for further processing.	Increases mileage for collection. Digested manure can be deposited to storage pond distant from a farm.

The central digester is a strong candidate for the best solution to the manure problem in this area.

4.3 Range of Digester Configurations

The Survey map indicates that a mixture of systems may result in the best solution. A hybrid layout may consist of a mixture of central and individual digesters. Factors that determine a potential layout include these:

1. Farm management: Site-specific needs, layout, and management styles.
2. Environmental concerns: Driveways or pipelines that may need to cross a wetland, a brook, or other delicate feature.
3. Physical concerns: Vehicular paths or pipelines that may need to cross a bridge or other improvement that poses a winter time freezing hazard to the manure in the pipe.
4. Distance: The layout of potential smaller central digesters must consider the cow population available in the area.
5. Legal issues: Owner of the land and rights-of-ways in transporting the manure and siting the facility is a concern.
6. Correctional facility match-up: The presence of the State of Vermont Department of Corrections correctional facility provides an advantageous electricity and heat consumer. Matching a digester to the correctional facility's needs is an opportune financial consideration.

For this Report, it is assumed that all farms are willing to consider participation in this work. Certainly each farm owner will need much detail and information before a preliminary indication is possible. This Report is the first iterative round in the eventual process that could lead to a comprehensive manure management system for this area.

> Note 1: The locations of all dairy farms is approximate, and is meant to be relative to the area and not an exact, precise, or accurate representation of the actual location of any structure(s) or cow population(s).
>
> Note 2: Any reference to names, sizes, or management practices is solely for use within this Report. Any other use of this information or inferred information is not the responsibility of the Agency or the author.

Individual farm digesters: Farms have been able to select manure management systems, but the economic climate for large capital investments is poor. Some farms have installed storage ponds for raw manure, but handling the semi-solid stored manure presents issues of stratification and odor. More elaborate systems require high capital commitments. Farmers may be interested in the economies of scale achieved when combining the agricultural wastes from two or more farms. See below.

Local cooperative digesters: Nearby farms with over 300 animal units may consider the costs and benefits of their own cooperative digester system.

These farms may be optimal sites for their own digester, with participation from one or more neigboring farm. Groupings could be created along these guidelines:

- Cooperative Digester 1: Based at C, with B, T and A.
- Cooperative Digester 2: Based at H, with D, E, F, and G.
- Cooperative Digester 3: Based at J, with I.
- Cooperative Digester 4: Based at K with L

- Individual Digester 5: Based at M
- Cooperative Digester 6: Based at R or S, with U, Q, V, P, O, and N.
- Cooperative Digester 7: Based at W or X, with Y
- Individual Digester 8: Based at Z.

Several mini-central digesters (MCD): The layout of farms indicates that three mini-central digesters is a potential solution. One MCD would be located at the Vermont DOC correctional facility. We have selected the following farms as potentially participating in "mini-central digesters':

Potential mini-central digester participants	Animal Equiv. Units	Digester output: kWh	Digester input: tons/year
MCD_1: G, H, I, J, K, M, & L	4600	950	100,000
MCD_2: A, B, C, D, E, F, N, O , P, & T	2430	475	53,000
MCD_3: Q, S, U, R, V, W, Y, X, & Z	3250	550	73,000
		TOTAL:	226,000

One central digester: One central digester allows for the best economy of scale, and places all functions at one location. However, the transportation for this alternative is slightly higher than that of the mini-central digester concept. The one central digester would be located to match the energy needs of the Vermont Department of Corrections correctional facility.

4.4 Manure Transportation Alternatives

Manure must be handled, and needs to arrive at a digester site by some method. Three alternatives are presented here: no off-site transport, transport via a pipeline, and transport via a vehicle. For the purposes of this Report, transport to several mini-central digesters or one central digester has the same advantages and disadvantages, and is not listed separately.

Manure delivery	Advantages	Disadvantages
Individual farm digester	Manure is digested on-site.	Debris (sand, metal, wood, etc.) will need to be separated. Digested manure is transported by tractor and spreader: vehicular speed and spillage issues.
Tractor delivery	Manure is transported very short distances to an on-site digester or local cooperative digester.	May result in more transportation of manure via tractors on the roads than currently exists.

	Minimizes mileage.	
Off site Transport via Pipeline	No manure is transported on the roads. Raw and digested manure pipes could be placed in the same trench. Low annual cost	Environmental: crossing brooks, bridges, wetlands Accumulation of biofilm reduces pipe diameter over time. Distance to digester Freezing weather Debris (sand, metal, wood, etc.) will block pipe Separation prior to pumping requires many separators Digester output reduced due to farm separation. Additional pump stations will be necessary Maintenance of pumps, etc. Cost of on-site and booster pumps High capital cost of pipeline
Off-site Transport via Truck with container	Secure tank minimizes road spillage. Manure is transported both ways via truck. Trucks operate at close-to-road speeds. Debris separated at digester. Digester output maximized. Satellite storage ponds	All raw and digested manure is transported on the roads. Capital cost of trucks and containers. Operating cost of trucks and containers.

A. Pipeline Description and Discussion: Manure entering a pipe flows due to gravity or pressure. As the St. Albans/Swanton area is relatively flat, any benefit from gravity is negligible. Therefore, pumping will be required if a pipeline is considered. Manure is 12-14% total solids, or 86-88% water.

Pumping manure presents many problems, which compound as distance increases. Issues include sawdust, sand, rocks, wood/lumber, after-birth, mucus, and many other components. To be pumped, these extraneous components must be separated from the urine and fecal matter. This requires that a separator be located and operated at each farm. The raw separated ‘liquid’ manure slurry (8-10% total solids, or 90-92% water) would be pumped, while the raw separated ‘solid’ manure (25-35% solids, or 65-75% water) would remain on the farm.

Raw manure is recognized as ‘self-sealing’, which means the bacteria create a water-tight seal by adhering to objects. In pipes, this becomes ‘biofilm’ or an accumulation of manure that can progressively reduce the diameter of the pipe.

Cold weather is an issue both before and after the pump. Frozen manure is difficult to pump, so any farm modifications must minimize heat loss. Additionally, raw manure can freeze in the pipe, so the pump should be sized to provide flowage through the pipe continuously. This constant motion prevents or reduces freezing during cold winter spells. This is a concern even though a pipeline would be laid to minimize freezing issues due to the considerable difficulties that would be encountered if the material did freeze.

The size of the pump is also an issue because of the high solids content of the raw liquid manure (municipal wastes are 1-3% total solids while this material is 8-10% total solids). Pumping a raw liquid manure slurry miles will require a large pump even though the hourly flow may not be large. This pump would be powered by electricity. The capital and operating costs are considerable factors.

Environmental issues are significant. Even a careful plan would require wetlands crossings, intersections with brooks and bridges, as well as initial erosion and disruption concerns.

B. Transportation description and discussion: Vehicular transport poses its own issues and concerns. Raw manure would be collected from the farm and transported to the digester for digestion. After digestion, the manure is processed with nutrients returned to the farms. The liquid portion is returned to the storage ponds on each farm's site, while the digested solid manure may be utilized by the farms or sold as a commercial product.

The next step here is to investigate the methods to reduce excess nutrients in the fields.

Each farm will require modifications to allow easy access to the raw manure. Raw manure (12-14% total solids or 86-88% water) may be pumped from the barn, may be pushed off a floor-level dock, or may flow by gravity in a pipe or trench to a storage pond.

Weather and the expected contaminants (concrete, wood, metal, after-birth, etc.) are concerns. If the raw manure freezes in a holding pit or in a metal container, a significant problem exists. Note that many of the barns are of recent construction, and minimize frozen manure inside their structures. Care would be needed to keep this manure from freezing before it can arrive at a digester.

The truck required would access the manure one of several systems: vacuum pump, container service, or tank truck.

Vacuum truck service would occur in this manner:

1. The vacuum truck is loaded with digested liquid manure at the digester, and heads to the designated storage pond.
2. The truck drives to the storage pond, where the liquid manure is unloaded.
3. The truck then drives to the barn, and draws the raw manure into the tank.
4. The truck then drives to the digester and unloads the raw manure.
5. Go to step one.

Assuming good planning, the manure in the vacuum truck scenario would be held in a holding pit in or adjacent to the barn so that little or no heat loss occurs.

Transway Vacuum Trucks, a supplier of vacuum trucks to the Northeast, explained its operation: a rotary vane, positive-displacement blower creates a vacuum in the tank that draws the manure up to the tank via a 3" diameter hose. A truck-mounted unit can carry 3,000-4,000 gallons, while a trailer-mount would carry 6,000-8,000 gallons, both assuming an aluminium tank to minimize weight.

A 300 CFM blower would take 30 minutes to load and cost $130,000-150,000 for the truck, tank, and blower. A 5,000 CFM unit would load in 5 minutes but cost $200,000.

P & P Septic Service, Burlington, VT has experience pumping raw manure, and does not recommend it. Their truck took 6 hours to vacuum 30,000 gallons (5,000 gallons per hour). He recommends an agricultural pump located at each farm that would fill a tank truck or sludge container.

Container service would require that a container be dedicated to a farm.

1. The container-less truck would arrive at the barn, take the container to the central digester, and unload the raw manure,
2. The container would then be loaded with digested liquid manure,
3. The truck would drive to the storage pond, and unload,
4. The truck drives to the barn, and re-set the container
5. Go to step 1.

The container service is subject to heat loss unless an enclosed, covered structure protects the container.

Galbreath, one of the leading manufacturers of containers and hoists, suggested aluminium roll-off containers with removable lid. The lid would be removed when the container is set in-place to receive manure. The container would be constructed with tapered gussets to minimize manure sticking to the container during cold weather. Truck and hoist costs $100,000, containers are $8,000 each.

Tank truck with on-site farm pump would have the on-site pump fill the truck with the raw manure.

1. The tank truck would be filled with digested liquid manure at the digester, and heads to the next farm.
2. The truck drives to the storage pond, where the liquid manure is unloaded.
3. The tank truck would back up to the on-farm reception pit and fill tank.
4. The truck then drives to the digester and unloads the raw manure.
5. Go to step 1.

This alterative uses equipment already in use on farms. Houle manufactures the Agi-pump, which would agitate and pump manure from a pit to a truck or spreader. The 4” pump with a 20 horsepower electric motor costs approximately $6,500 plus installation, piping, power, roof, and pit.

For efficiency, the truck needs to be loaded in both directions, which minimizes road time and expense while providing secure transportation of the materials.

Frozen manure is a concern during Vermont’s winters. Only eight (30.7%) of the twenty six farms are “cold” barns, with all of the remaining farms being considered “warm”. During extreme weather, more frequent truck manure collection may be required or some other schedule incorporated to cope with extreme weather conditions.

One further refinement was made evident by several farm owners: Most farms operate fields that are distant from their barns. Several of these farms have storage ponds on these distant fields. With a central digester, the truck is able to transport the digested liquid manure to an off-site storage pond, and then drive to that farm’s barn. This alternative would replace many tractor/spreader movements of raw manure from the barn to the distant storage pond.

At this point, no selection of a transportation method is being made, but the tank truck system appears to be the best solution.

Comparison of Manure

Transportation Alternatives

Issue	Vacuum truck	Container truck	Tank truck
Environmental concerns		Spillage even if container is covered	Spillage
Community concerns	Vehicular miles	Vehicular miles	Vehicular miles
Farm concerns	Initial farm modifications: manure interception, driveway, manure pit, roof, and access. Snorkel contamination	Initial farm modifications: manure interception, driveway, enclosure, overhead door, and roof.	Initial farm modifications: manure interception, driveway, enclosure, and roof.
Capital costs at the farm	Manure pit and enclosure	Building for container	Manure pit with pump and enclosure
Capital costs for the central digester	Trucks with tank and hydraulic snorkel.	Trucks with container loading equipment. Container for each barn Spare containers	Tank trucks Pump and pit for each farm.
Operating costs	Slowest process Labor Fuel Farm enclosure maintenance Repairs and maintenance Replacement costs Vacuum maintenance	Frozen manure in container Labor Fuel Farm enclosure maintenance Repairs and maintenance Replacement costs Container repairs.	Labor Fuel Farm enclosure and pump maintenance Repairs and maintenance Replacement costs Pump repairs

Farm modifications: Before we end this discussion of manure delivery alternatives, farm modifications needs to be discussed. Some farms will need substantial modifications, while others may integrate into a digester system easily.

1. Manure storage: The raw manure needs to be collected in one or more central locations
2. Manure movement: Once in a storage pit, the manure needs to be homogenized, then pumped to the truck or pipeline.
3. Enclosure: The storage pit needs to protect the raw manure from cold weather and rain. This probably necessitates building walls, roof, and a door.
4. Access: Either the pipeline or the truck needs to interconnect with the storage pit. This work can involve a pipeline with check valves, or a driveway.
5. Other: Until an on-site farm survey is achieved, we should anticipate some additional work being required.

The cost of these modifications needs to be included in the overall project cost of the digester system that is selected for implementation. Budget costs are included in this Report, which approximates anticipated costs until a detailed estimate is performed with the cooperation and consent of each farm owner.

4.5 Integration with the VT DOC Correctional facility

The Correctional facility's needs are an important parameter because of the financial stability present if the digester can meet and exceed the heat and electrical requirements. The Correctional facility has a peak demand of approximately 240 kWh, and a levelized consumption of 150 kWh.

A digester could be sited to integrate well with the needs of the Correctional facility. The biogas would be converted to electrical and heat energy in a genset. The electricity would be consumed by the Correctional facility, with the potential option of selling excess electricity to the local utility, Central Vermont Public Service Company, Rutland, VT.

The cogenerated heat would be dedicated to (1.) the heat requirements of the digester to maintain mesophylic temperature, and then (2.) the heat needs of the Correctional facility. Generally, the biogas is consumed in a genset, which cogenerates heat and electricity. The heat and electricity in excess of the parasitic needs of the digester are available to the Correctional facility.

Another proposal is to supply the Correctional facility with biogas, and have the Correctional facility supply and maintain the genset. Cogenerated heat would be returned to the digester to maintain optimum operation.

Another biogas option is the direct combustion of the biogas into heat in a boiler. Several issues cloud this option:

1. Few if any boiler manufacturers certify their equipment for biogas use
2. Biogas contains hydrogen sulphide, which forms sulphuric acid that causes serious corrosion with metals. Gensets usually operate continuously, so any acid has a short retention time.
3. Use of the biogas for direct heating would diminish the fuel available for cogeneration.

A potential future synergy between the digester and the Correctional facility is the integration of greenhouses to the Correctional facility. The greenhouses will need electricity, heat, and nutrients, all available from the anaerobic digester. This potential is not given an economic value at this time.

Using another technology, biogas can be processed to remove most of the carbon dioxide, water, and hydrogen sulphide, and become a ‘pipe-line quality’ fuel.

4.6 By-products of Digestion

The by-products are biogas (used for heat and electricity), digested liquid manure, and digested solid manure. The prevalence of clay and clay-type soils allows for this Project to use the solids for a commercial fertilizer.

The current manure management practice is to spread the majority of the manure in the fall. With the digested liquid manure that could be available, the manure can be applied as a liquid or irrigated. Either way, a much larger fraction of the nutrients can arrive to be utilized by the crops than currently arrives.

One important consideration in the layout of this proposal is the phosphorous loading in the soil of the St. Albans and Swanton area.   The digested liquids retain 60-80% of the phosphates from their original level, with the rest of the phosphates in the digested solids.

A conventional screw press is recommended to accomplish the primary separation. This results in two fractions: a solid and a liquid fraction. The solids are a material that appears similar to chewing tobacco, and is 35% dry matter. These solids contain 20-40% of the phosphate in the manure. (If additional phosphate removal is desired, then the separated liquids may be centrifuged, which can remove approximately 25% of the phosphates from the screw press, for a total reduction in the liquid of 40-45% from the original level.)

The liquids are approximately 5-8% total solids, and flow easily, stay relatively homogeneous in a storage pond, and can be applied with a spreader tank or irrigation system. With the proposed system, the digested liquids would be applied to the crops when they can receive the nutrients. Currently, a semi-solid manure usually is spread only before plowing.

Digested liquid manure:

Digested liquid manure is a reduced-odor fertilizer that is intended for use by the farms that generated the raw manure. This product is dramatically different from the raw manure:

1. Reduced odor: Generally, the digested liquid manure has a reduced odor compared to fresh or stored manure.
2. Reduced solids: The digester has consumed the mucus, and the separator has removed the sawdust, corn cobs, 2 x 4s, etc. leaving this liquid fraction at 5-8% total solids. The Middlebury digester flows this material 1,500’ via gravity in a 4” diameter pipe to its storage pond.
3. Reduced phosphates: 20-40% of the phosphates are in the separated solids that will be used off-farm.
4. Minimal pathogens: The anaerobic digester greatly reduces the presence of many pathogens by subjecting them to the 20+ days of heat in the digester. ‘Bio-security’ is an issue that needs to be addressed more fully.
5. Most weed seeds are killed.
6. Minimal stratification in the storage pond.

The on-site farm fertilizer option in common usage, but other uses are possible. This material is an excellent fertilizer: the farm in Middlebury, VT has increased crop yield by using this material. One additional advantage is that it can be applied via irrigation. This foliar application delivers nutrients to the leaves and roots of crops during the optimal growth season. At this time, no financial benefit is assigned to any increase in crop yields due to the controlled application and foliar application of the digested liquids.

The potential exists for the digested liquid manure to be used as a commercial fertilizer, but is not known to be used as such at this time. Technology exists to separate the nutrients from the liquids, but is not included in this Report.

Digested solid manure

Digested solids have been used for several purposes: bedding, landscaping, fertilizer, potting soil amendment, and similar uses. These uses are possible because the solids share these qualities with the liquids: reduced odor, reduced pathogens, and reduced weed seeds.

> **Bedding**: These exothermic solids have been used by cows as bedding, especially in the colder months of the year. Care must be taken to ensure the bedding is dry enough, and is handled to avoid pathogen regrowth.
>
> **Fertilizer and soil amendments**: The digester in Middlebury, VT sells a bagged fertilizer based on their digested solid manure, plus other products. Wholesale value of the fresh solids would be in the range of $3-6/ton. This material composts to a rich medium, but loses 75% of it mass while composting, but the addition of other products during composting (bark, other manures, etc.) increase the mass beyond the original. Bulk compost sells for approximately $30/ton. Exact values for the bagged fertilizer were not available for this report, but are in the range of $80 to $240/ton.
>
> This composted product is a valuable soil amendment. The marketing of this product is a possible next step for this project.

Local markets exist for these solids by landscaper, gardeners, and “do-it-your-self” homeowners. This market is large, especially when the potential market area includes the nearby Burlington area. However, the market for this product has several local suppliers. A market study is recommended.

4.7 Regulatory Issues

These local, state, and national regulatory departments would be involved if this project proceeds to the pre-construction phase: local building and zoning permits, driveway permits, vehicular permits, air emissions licensing, electric generation permit, and commercial development permit. Other regulatory issues may also apply to a project of this size and nature.

5. COMPARISON OF OPTIONS

5.1 Physical Constraints

Each of the four alternative manure management alternatives’ physical attributes and concerns are described as follows:

5.1.1 Option 1 – Individual Farm Digesters

Overview

A dairy farm has the option to construct an anaerobic digester for its manure management system. In selecting this option, the farm's owners accept the responsibility of creating, financing, building, managing, and operating the system. Each farm can net-meter their electrical production against the electricity currently being purchased.

Assumptions

Most farm owners are considering some form of improved manure management due to the phosphorous loading in the St. Albans/Swanton watershed area. Anaerobic digestion/separation is a positive alternative that offers several benefits at a competitive cost to competing systems.

Issues

Each farm has full responsibility for the success or failure of its system. Significant factors include siting, integrating digester with the existing barn(s), financing, designing and building the system, start-up, operation of the system, maintenance, sale of products, distribution of the digested manure.

Constraints

The farms in the St. Albans/Swanton area have proven their management capabilities already. The management of a digester system requires additional time, insight, and understanding which will add to the duties of all level of personnel in dealing with the day-to-day manure issues.

A cooperative management company could operate the digesters. This would provide a safety net of knowledge and experience to minimize risks to the farms (see below).

Risks

The farms are already dealing with their manure, so these issues remain constant for the farm's management, such as severe winter weather. Additional risks come in ensuring proper genset maintenance, switchgear maintenance, heat transfer maintenance, separator servicing, and similar issues.

5.1.2 Option 2 - Local Cooperative Digesters

Overview

Eight groupings of local cooperative digesters are proposed so that several farms may share the responsibility of initiating and operating a digester. Herd size and proximity are the determining factors in selecting these groupings. The ability and willingness of farms to cooperate with their neighbour is assumed to be possible. This Report explores the benefits and risks of cooperating. Only the host farm may net meter their electrical production and consumption, and is limited to 150 kW maximum.

Assumptions

The siting for local cooperative digesters is based on the proximity of farms and cows to minimize transportation while enjoying some economies of scale. In this scenario, much of the manure may be transported by the farmers or in a pipeline due to the short distance involved. Truck transport would be used if necessary. The electricity is to be sold wholesale, or matched to the Correctional facility.

Issues

This cooperative concept builds on the ability of neighboring farms to share the management, operation, and risks of manure management via digester. This includes dealing with problems in the raw manure getting to and entering the digester, to dealing with the allocation and delivery of the digested manure.

Obviously, if this option is selected, a management company could be created to deal with all the issues. In this manner, the operating company would be responsible for the maintenance, operation, and sale of by-products. This significantly improves the position of the saleability of any marketable digested solids.

No full-scale integration with the Correctional facility is anticipated in this option.

Constraints

This alternative has the same constraints as the individual digester except that several farms would share the responsibilities. Net electric metering in Vermont cannot exceed 150 kWh.

Risks

These are the same as the individual digester.

5.1.3 Option 3 – Mini-central Digesters

Overview

The step between local cooperative digesters and one central digester is the concept of three mini-central digesters. This concept is derived from the distribution of farms and herds, the intent to limit the transportation costs and road mileage, and the advantage of scale of fewer, larger digesters.

Assumptions

This option sites the mini-central digester at or near the largest farm in the area, called the ‘anchor’ farm. Manure would be transported by truck (not be farm tractors) due to the distances involved. One of the mini-digesters is located to accommodate the energy needs of the Correctional facility.

Operation and management of these mini-central digesters would be performed by a cooperative, or subcontracted to a company devoted to transporting manure, operating the digesters, and maintaining the equipment including the separators and gensets.

The electricity is sold wholesale, or to the Correctional facility.

Issues

The benefits of economies of scale are balanced with the increased mileage of manure transport. The cooperative concept works well for this option, as it builds on the ability of neighboring farms to share the management, operation, and risks of manure management via digester. This includes dealing with problems in the raw manure getting to and entering the digester, to dealing with the allocation and delivery of the digested manure.

Constraints

Proximity of farms and their herd size together with the need to minimize road mileage dictate the location of the mini-central digesters. Transportation cost is a major on-going expense.

Risks

Severe winter weather may freeze manure at the farm, delaying its entrance to the digester. Manure from several farms will be mixed in the digester, digested at 105° F, separated, and the liquid portion returned to a storage pond. The potential exists for pathogens and weed seeds to be spread from farm to farm via this alternative, although the anaerobic digestion process is known to generally reduce the incidence of week seeds and to reduce pathogens.

5.1.4 *Option 4 – One Central Digester*

Overview

The manure from all cooperating farms is digested in one, central digester in this alternative. Raw manure is transported to the digester, and digested liquid manure is returned to the farms via a network of routes. Trucks are loaded in both directions. This digester would be located to cooperate with the energy needs of the Correctional facility.

Assumptions

Management of one central digester is more efficient than in the other alternatives.

Issues

Manure transport involves the most miles compared to the other alternatives. A business/farmer cooperative builds on the ability of area farms to share the management, operation, and risks of manure management via digester. This includes dealing with problems in the raw manure getting to and entering the digester, maintenance of gensets and separation equipment, to dealing with the allocation and delivery of the digested manure.

Constraints

Reaching additional farms would involve dramatic increases in mileage with minimal increases in electricity generated. Transportation cost is a major on-going expense.

Risks

Same as with the mini-central digester system.

5.2 Financial Issues

The financial aspect of the four alternatives relate directly to the capital expenditure and the revenue/expense issue. To receive a benefit, the capital and operating expenses need to be less than the revenues.

5.2.1 Capital expenditure (CAPEX)

a. Vehicle or pipeline expenses: The tank truck alternative is chosen for the purposes of this financial study because of the physical and operational advantages. The capital costs for the tank truck option is as follows;

1.	Tank trucks:	3 at $100,000	$300,000
2.	Tanks:	3 at $8,000	24,000
3.	Contingency		26,000
		Total	$350,000

Note that this report indicates that just under two trucks are required for both the mini-central digester and one central digester scenario. Therefore, it is assumed two trucks will be operating 24 hours a day, and one vehicle is available in case of repairs, maintenance, etc. If further study indicates that a back-up hoist truck is available on a reliable basis nearby, then it may be possible to operate with only two trucks within the ownership of this project.

b. Cost of digester facility or facilities and the genset costs (including switchgear, heat transfer equipment, etc.): The costs vary according to the size of the digester. The costs herein are from the United States Environmental Protection Agency's AgSTAR program to promote the anaerobic digestion of agricultural wastes.

   Additionally, three types of horizontal digesters are possible: (a) In the southern half of the US, the manure pond suffices due to the small heat losses, (b) A second method is to install a small, sloped, concrete pond with a biogas container/cover, and (c) a concrete digester with biogas container/cover and a roof structure to prevent wind and snow loads from acting on the biogas cover. The third option is chosen as it provides the most complete digestion, the best environmental security, and the best long-term reliability for Vermont's climate.

c. Separation equipment:

   1. Conventional screw-press built for continuous operation is available and operates well on digested dairy manure. The largest unit costs $74,000 plus ancillary equipment (pump, etc), and is rated at 140 gpm. For safety, it is advisable to have additional capacity which allows for repairs and maintenance.

      The smallest unit is rated at 50 gpm for commercial uses, but is observed to have only a 22 gpm through-put with digested cow manure due to its physical and biological characteristics. A similar down-rating of the largest unit would be used for the central digester scenario.

   2. Future optional centrifuge: A centrifuge provides further separation of water from the other constituents including phosphates. These units cost $60,000 each, plus ancillary equipment, but would provide substantial phosphate reduction. A dissolved air floatation system would remove additional nutrients from the water fraction leaving the centrifuge, but is not proposed at this time.

d. On-site farm modifications: See "Preliminary Farm Modifications Budget" attached.

   Total budget for this line item: $672,000

e. Land costs: This is estimated at $30,000 for local cooperative digesters, $50,000 for each of the mini-central digesters, and $100,000 for the one central digester.

f. Start-up including digester, personnel, etc.

   1. Heat to start digester in the form of fuel for the genset, which co-generates heat and electricity (which would be sold or used on-site).

   2. Labor and transport for the initial manure

   3. Setting up the office and similar expenses

   4. Training costs.

5.2.2 Revenues

a. **Electricity**: The electricity generated from this Project is local, reliable, and renewable. As such, it may represent a premium when rate negotiations commence. For this Report, we have set the value at $0.065/kWh. The Vermont Department of Corrections correctional facility is paying $0.09573/kWh for its electricity currently. This amounts to approximately 7% of the electric generation capacity of the one central digester.

   Every increase in $0.01/kWh increases the revenue of this Project by $171,000. The value of this electricity has a large impact on the viability of this Project, and should be negotiated for the maximum benefit of this Project.

   Note that the efficiency of generating electricity increases with the size of the engine, so the revenues of the individual farm digesters is approximately 10% less that the one central digester. Similarly, the local cooperative digester electric revenue is approximately 5% less for the same reason. Also, electric production is calculated at 8,000 hours/year, or approximately 9% unproductive.

b. **Heat energy**: Heat has a value, which is allocated as follows: A local cooperative digester's heat is useful on that specific farm, and is assigned a value of $5,000/digester. This heat can be used in existing structures, to heat water, or for new uses (greenhouses, etc.). We realize that no existing farm is capable of paying this amount for its current application, but would either sell the heat to a business that could use it, or construct a new profit center to purchase the heat. Mini-central digester heat is also useful to the host farm and to the Correctional facility. Again, a host farm would pay $5,000 for the heat, but the Correctional facility would receive $125,000 of heat for current or proposed uses. The sole central digester would only provide heat to the Correctional facility (and potentially to its greenhouses, which would result in additional revenue from the sale of this heat).

d. **Odor**: The improved/reduced odor of the digested liquid cow manure is assigned a value $10/cow/year. We do not stipulate or suggest its source at this point.

e. **Solids/bedding**: The separated solid cow manure has a value for one of several purposes: bedding for member farm cows, a wholesale landscaping material, a retail fertilizer, or other similar uses. The digested solids amount to just over 4 tons/cow per year. Composted alone, it would lose about 75% of its mass. Conventional composting adds other matter during the composting (bark, sand, straw, shavings, chicken manure, and other organic wastes) so the mass after composting exceeds the original mass.

   Its value (as contribution margin) is set for each Alternate: A is $30/cow/year, B is $45/cow/year, and C is $60/cow/year.

f. **Farmer/member contribution**: Farmers know that improvements to their manure management system will be necessary in the future. There is always a cost that accompanies a benefit, so in each Alternative we have used these values: A is $10/cow/year, B is $15/cow/year, and C is $20/cow/year.

g. **Environmental improvement value:** The environmental impact of this project is assigned these values in each Alternate: A is $0/cow/year, B is $10/cow/year, and C is $20/cow/year. This would be paid by parties that benefit from the positive impacts of this project.

5.2.3 Operating expenses (OPEX)

a. **Debt service**: The entire capital cost in Alternative A would be paid at 8% interest over 96 months (8 years). In Alternatives B and C, grant money from governmental or other sources would contribute 50% of the capital expense to improve the ability of this project to proceed. Grant money for individual farms may be available, but would not be as high as might be obtained from a collective solution to the area's manure problem.

b. **Transportation costs**: See "Transportation Costs" spreadsheet attached.

c. **Replacement set-aside**: A fund is established to pay for upcoming replacement of pumps, vehicles, tanks, and other equipment.

d. **Genset operation and maintenance:** For the purpose of this Report, this figure is set at 25% of the value of the electricity sold, but would not vary if a higher value of the electricity is negotiated.

e. **Separation equipment**: This pays for the labor and materials needed to separate the digested cow manure.

f. **Administration**: A central office is needed to handle the administration of this project except for individual farm digesters. No costs are allocated for administration of the individual farm digesters.

5.2.4 Non-Financial benefits: the environment and the community

Identify all other non-financial costs associated with each option. Non-financial benefit examples include:

a. Improved nutrient management has a regional impact on the soils of these two municipalities, water quality in the local streams and ponds, and in Lake Champlain.
b. Improved odor is a benefit would be enjoyed by many people in the area, especially visitors and people not familiar with farm settings.
c. Safer roads by reducing the use of tractors on the roads
d. Creation of jobs is a benefit of this project.
e. Local generation of electricity provides a near-by, reliable, renewable power source.
f. Local production of landscaping medium/fertilizer.

5.2.5 Risks

The risks are as follows:

a. Availability of diesel fuel for the trucks
b. Bio-security when combining manure from farms
c. Equipment break-down or performance issues
d. Availability of manpower
e. Ability to secure grants to provide capital and/or operating money.

These exists the option of integrating an alcohol distillation process with the digester. The still would produce a liquid fuel from shell corn, using co-generated heat from the digester. The spent mash is an improved feed for cows, and the thin stillage could be digested to provide approximately 40% of the heat for the still.

5.2.6 Summary

In summary, this Project shows that a group of local generators of cow manure can work together to produce financial and non-financial benefits that improve the economy and environment of the region. It should be noted that this Report is the first in an iterative process, and that all figures are preliminary.

Economically, we note that the transportation cost approaches the net value of the electricity. An anaerobic digester project has compound profit and expense items, and only when all the benefits are accumulated can this project be financially viable.

The financial proformas show a net operating range from a loss of approximately $2.86 per ton to profitability of $2.51 per ton, relative to the variables identified above. Alternate B is the most likely proforma, and shows a benefit of $0.71 to $0.94 per ton for the central digester proposals.

Considering that 226,000 tons per year would be processed to produce renewable, reliable, local, and dispatchable electricity, and that the resulting digested manure becomes a controlled-application liquid fertilizer and a landscape material, this project appears to have earned the right to additional study.

The valuable benefits resulting from this project far outweigh the risks. The potential positive impact to the farming community in Vermont alone is significant. Add to that impact the advantages of generating electricity, creating a landscape/fertilizer material, reducing odor problems, and creating jobs, and this project has wide appeal.

5.3 Environmental Issues

Environmental issues remain an important factor in deciding the fate of a project. The proposed anaerobic digester provides positive solutions to current problems:

A. Phosphorous loading in Lake Champlain is a large concern, and agricultural manures contribute to this loading.

B. In another vein, the attractive Lake Champlain shoreline is now being populated by people who appreciate the view and lifestyle that country-side, lake-front living provides, but complaints are increasing about smells from spreading stored manure.

C. The current manure handling system can be improved by applying anaerobic digestion technology, but economic incentives are not present to do so.

These concerns were addressed in a memorandum from the Vermont Agency of Environmental Conservation by Paul Wishinski dated 10-1-82 about the anaerobic digester system in Middlebury, VT:

> “The system at Foster Brothers Farm is an example of an innovative way to improve on traditional farming practices by improving manure management, increasing farm income and at the same time reducing pollution problems due to odor and runoff of farm wastes. Renewable energy for use by outside consumers is also produced, at a lower air pollutant emission rate than is possible by most other energy production methods using fuel combustion.”
>
> “Since Foster Brothers Farm presently is operating a working digester, generating electricity, and selling electric power to the utility, this farm represents a model of what could become more common system in Vermont.”

5.4 Community Issues

These issues are of concern to the local and regional communities:

A. **Water quality**: Efforts continue to improve water quality in the brooks, ponds, and Lake Champlain. This project would result in the improved handling of 226,000 tons of cow manure, a significant quantity of a material most people find objectionable.

B. **Air quality**: As manure cannot be spread from December to April, the stored manure is off-gasing methane to the atmosphere. Methane is a green house emissions gas, which is a concern as is the odor of this stored manure.

With the proposed digester system, the methane is combusted to form carbon dioxide and water, which would be released to the atmosphere. NO_x is present in the combusted emissions, but we offer this again from the memorandum from the Vermont Agency of Environmental Conservation by Paul Wishinski:

> "Biogas is estimated to have a BTU rating of approximately 500 BTU/ft.^{3} whereas natural gas is approximately 1,000. Therefore, the heat of combustion per cubic foot of gas burned would be less, in all likelihood resulting in less NO_x."

> "Biogas retains condensed moisture from the digestion process. The water introduced by the biogas would suppress combustion temperatures, acting similar to water injection systems used in gas turbines to control NO_x."

C. **Odor**: This issue is important enough to be its own subject. Stored manure generally has a worse odor than fresh manure, and can even become highly objectionable especially to people not familiar with agricultural methods. This project would result in an improved odor of the manure via anaerobic digestion, which is a desirable outcome.

Again from the Wishinski memorandum we quote:

> "The odor associated with the raw manure is definitely not present in the digested effluent nor in its constituents when separated out."

> "While standing there talking for 15 to 20 minutes, and with a brisk breeze blowing towards us across the liquid in the pond, there was absolutely no odor present."

> "The Air Program and indeed the Agency should encourage the installation of anaerobic digesters to alleviate odor problems stemming from the storage of raw manure in liquid holding ponds when it is economical to do so. The energy and environmental benefits to society appear significant."

D. **Road safety**: Safety issues exist whenever tractors take to public roads. Add any spillage of raw manure to the slow speed of the tractor, and complaints will be made by angry drivers. This project addresses this issue by using trucks with tanks to transport the manure both in its raw state and digested state. These trucks will be driven by commercial, trained drivers using proper road safety.

E. **Local generation of electricity**: Voltage stabilization is an achievable goal by the proposal to generate electricity in this farm community with a Correctional facility located some distance from St. Albans. Security is provided by being a non-centralized generating facility based on cow manure. Just as milk trucks must operate daily, we can count on cows to produce manure daily. And this manure is the feed-stock of the anaerobic digester.

F. **Employment**: These jobs would be created to operate this proposed Project:

Truck drivers:		9
Facility personnel		6-10
Administration:		2- 3 .
	TOTAL:	17-22 jobs.

The economic impact of these jobs is significant to these communities.

5.5 Recommendations

It is recommended that the One Central Digester proposal be accepted, and that the Recommendations in Section 7 of this report be implemented. The unique opportunity to construct a comprehensive manure management system with these parameters should be acted upon:

A. A dense cow population largely in "warm" barns.

B. The presence of the Vermont Department of Corrections correctional facility that requires reliable electricity and heat, and is located in the midst of the dense cow population above.

C. Strong environmental need to control and reduce agricultural contaminants.

6. FINANCIAL PRO FORMAS

6.1 ALTERNATE A: MOST CONSERVATIVE

A. Member farms receive benefits from the management of their manure, and pay $10/cow/year.

B. Separated solids have a contribution margin of $30/cow/year. Phosphates are only reduced minimally.

C. No grant money reduces the CAPEX.

D. No financial value is placed on the improvement to the environment.

6.2 ALTERNATE B: GRANTS PAY 50% of CAPEX

This option is similar to Alternate A, except grant money is used to reduce the CAPEX by 50%.

A. Member farms now would pay $15/cow/year, which amounts to the net profit for the one central digester. If the farmers hold an equity interest, then some or most of their money could be returned each year.

B. Separated solids have a contribution margin of $45/cow/year.

C. Grant moneys reduce the CAPEX by 50%.

D. The positive environmental impact of the Project has a value of $10/cow/year to regional entities benefiting from the proper management of manure to conserve nutrients, minimize run-off, reduce fertilizer consumption, improve odor, reduce greenhouse emissions, and generate electricity from a renewable, reliable source.

6.3 ALTERNATE C: SAME AS B PLUS OTHER BENEFITS

Grant money reduces the CAPEX by 50%, and other benefits become revenues for the project:

A. Member farms now would pay $20/cow/year, or approximately 36% of the net profit. If farmers owned part of this Project, they could see their money returned each year.

B. Separated solids have a contribution margin of $60/cow/year.

C. Grant moneys reduce the CAPEX by 50%.

D. The positive environmental impact of the Project has a value of $20/cow/year to regional entities benefiting from the proper management of manure.

6.4 FINANCIAL RECOMMENDATION

Anaerobic digesters have compound profit centers, and provide valuable environmental benefits. Each revenue and expense needs to be analyzed and confirmed, including the availability of grant money for capital and operating expenses. Additionally, other potential synergies such as heating greenhouses, integrating with an alcohol distillation process, or new agricultural fertilizer/planting items may be attracted to this Project.

Alternate B is recommended as the basis for evaluation of this Report. The other Alternates reflect financial aspects that either are more stringent or more lenient that Alternate B. On the basis of Alternate B, we find that the financial aspects of this scenario are marginally profitable.

However, the environmental, community, and economic impacts of strengthening Vermont farms and their communities with this project are very strong. This project should be fully investigated to explore in detail the wide-ranging cost, revenues, and impacts this creative project would provide to its farmers, the community, the environment, and the State of Vermont.

7. RECOMMENDATIONS

Based on the selected option above, this Report recommends this course of action:

A. That this Project be studied further to refine the financial and operational details.

B. That this further study be coordinated by a Vermont Agency to coordinate the Next Stage Plan as shown below.

C. That the Vermont Agency selected above concurrently seeks out grants or other funding for capital and operating moneys.

D. That the ‘next stage’ plan (as defined below) is approved for execution.

E. That the required budget is allocated in order to undertake the ‘next stage plan’.

F. That the required resources are allocated in order to undertake the ‘next stage plan’.

8. NEXT STAGE PLAN

This Report recommends these actions:

A. Contact local and regional governmental agencies to determine the value of the environmental improvement as a result of this project.

B. Meet with the potential member farms to determine their participation in this Project.

C. Study the end use of the separated solids including use as a cow bedding, landscape material, or retail fertilizer.

D. Investigate methods to reduce phosphorous.

E. Investigate the availability of grant money:

F. Negotiate for the value of electricity from this renewable, reliable energy source. This includes contacting utility companies, the Vermont Department of Corrections correctional facility in St. Albans, and other options.

G. Contact the Vermont Department of Corrections correctional facility to assess the feasibility of integrating this Project with their facility in St. Albans.

H. Investigate the use and value of cogenerated heat by the Correctional facility or other entities. This includes diverting a portion of the heat from the gensets to the Correctional facility for space heating, or a portion of the biogas for direct combustion.

I. Confirm the selection of the transportation method by researching companies that pump manure as proposed in this Report. Confirm the methods, availability, efficiency, and budget for the transportation of manure as discussed. Confirm the equipment set-aside amount.

J. Report on research in (1) weed and pathogen reduction in anaerobic digestion, and (2) increase crop yields due to controlled application of digested manure.

K. Confirm the operating and maintenance costs of the gensets by contacting potential suppliers and/or operators.

L. Establish a more detailed plan to administer this project on an on-going basis.

M. Combine the information obtained above in a more detailed Report for review by the Vermont Agency of Agriculture, Food, and Markets.

The ultimate success of this project may be determined by the ownership of the project. This may take the form of a “farmers’ cooperative”, a private corporation such has a limited liability corporation, or a combination of the two. There is good sense in the positive involvement of all the farms in the profitability of this project, as the farmers have control over the raw product. But the marketing of by-products, daily digester operation, and equipment maintenance all need expert business acumen. Therefore, we add this final action:

N. Recommend the optimal structure for this entity.

-End-

Appendix A: Primer on Anaerobic Digestion of Dairy Wastes

Anaerobic digestion of manure is a biological process that occurs in the absence of oxygen. The bacteria release a gas called "biogas" that is 60% methane and 40% carbon dioxide. The digested manure has an improved odor, and reduced pathogens. Some digesters separate the digested manure to arrive at a solid fertilizer or bedding material, and a liquid fertilizer than can be bulk applied or irrigated to crops in controlled applications.

Brief History of Anaerobic Digestion

The first farm digesters were built by the Gobar Research Institute starting in 1957. L. John Fry, the father of anaerobic digestion, built several digesters in South Africa during the sixties and seventies. In China, over seven million (7,000,000) digesters were in operation by 1978.

Cornell University and Pennsylvania State University both pioneered digester work starting in the mid-1970s. Cornell continues their work, having built and operated horizontal (plug-flow or hydraulic displacement) and vertical (mixed reactor) digesters.

The U.S. Department of Energy funded several digesters during its work around 1980. Dozens of digesters were built during the 1980s. Many have ceased operation due to operator inexperience, a declining dairy market, and other issues.

Today, the U. S. Environmental Protection Agency operates the AgSTAR program to promote the anaerobic digestion of agricultural wastes. AgSTAR promotes digestion to reduce agricultural water and air contaminants including nutrients to surface/groundwater and methane releases (an important greenhouse gas).

A Review of the Digester Process

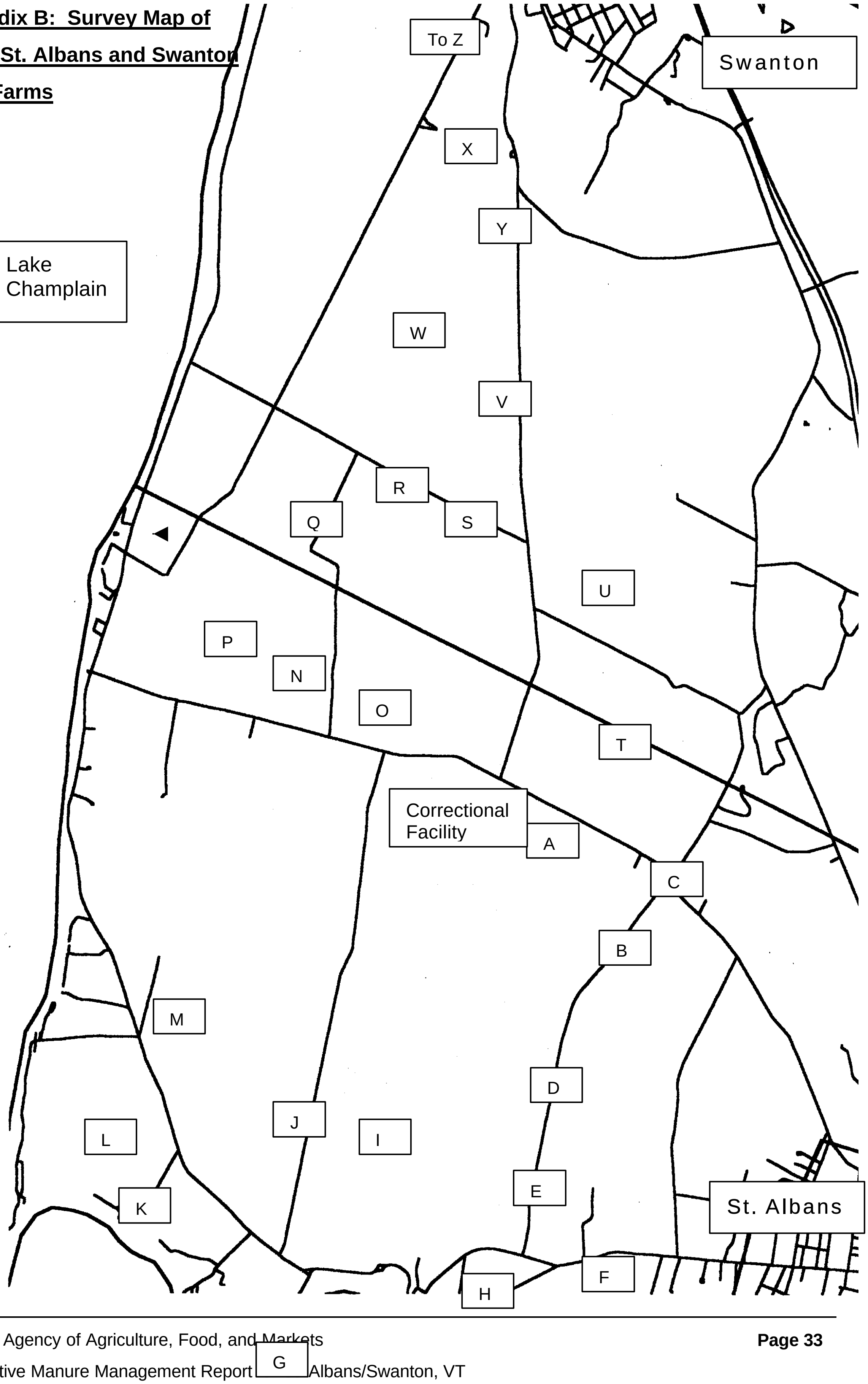
All the manure (fecal matter, urine, bedding, waste feed, etc.) and milk house wastes (milk room and parlour wastes) are digested at 95-105^{o} F for 20-25 days. The biogas fuels an engine-generator set (genset) that cogenerates electricity and heat. The electricity may be used on-site or sold. The methane (CH_4) burns with oxygen (O_2) to form carbon dioxide (CO_2) and water (H_2O). As the biogas is 100% saturated with water, NO_x emissions are reduced. Biogas is best used in stationary engines as there is a large parasitic energy to compress methane to a liquid fuel.

Heat exchangers recover the heat from the engine jacket water and the exhaust gases, with efficiencies in the range of 35% to 55% of the input energy. The recovered heat maintains the digester at its optimum temperature, with additional heat dissipated to the atmosphere or used for other purposes.

The digested manure is a reduced-pathogen fertilizer, and may be separated with screw presses into a liquid and solid fraction. The liquid can be field applied or irrigated on crops. The solids may be used as a bedding for cows, as a landscape material, or as a fertilizer (bulk, wholesale, or retail).

Vermont has one operating anaerobic digester: Foster Brothers Farm in Middlebury, VT. This system started in operation in 1981, and has added (circa 1986) a solid fertilizer business for the digested solids. Gross sales from the solid fertilizer have grown to exceed milk revenues (information about net profitability is not available).

Appendix B: Survey Map of Select St. Albans and Swanton Dairy Farms



Appendix C: Census of Select Farms

in the St. Albans/Swanton area of VT

Conducted on March 18, 2003 by Dan Scruton and Spencer Bennett

							Manure management				
ID	**Temp.**	**Collect**	**Move**	**Storage**	**Housing**	**Temp.**	**Collection**	**Movement**	**Holding**	**Bedding**	**Comments**
A	C	T	O	L	Freestall	Cold	Tractor scrape		Manure pit	Sawdust	
B	C	P	L	S	Freestall	Cold	Manure pack	Loader		Sawdust	
C	C	T	O	L	Freestall	Cold	Tractor scrape		Manure pit	Sawdust	No milkers at this site
D	C	T	O	L	Freestall	Cold	Tractor scrape		Manure pit	Sawdust	
E	W	T	O	L	Freestall	Warm	Skidsteer		Manure pit	Sawdust	
F	W	T	P	L	Freestall	Warm	Tractor scrape	Pump	Manure pit	Sawdust	
G	C	G	L	S	Tiestall	Cold	Gutter cleaner	Spreader	Stack	Sawdust	
H	C	T	P	L	Freestall	Warm	Tractor scrape	Pumps (2)	Manure pit	Sawdust	
I	W	T	O	L	Freestall	Warm	Tractor & alley		Manure pit	Sawdust	
J	C	A	G	L	Freestall	Warm	Alley cleaner	Gravity	Lagoon	Sawdust	5 month storage
K	C				Freestall	Warm				Sawdust	
L	W	P	L	S	Freestall	Cold	Manure pack	Loader	Solid	Sawdust	
M	W	T	G	L	Freestall	Warm	Tractor scrape	Gravity		Sawdust	3 day storage indoor gutter
N	W	T	P	L	Freestall	Cold	Tractor scrape	Pump	Manure pit	Sawdust	
O	W	P	L	S	Freestall	Cold	Manure pack	Loader	Daily	Sawdust	
P	W	T	O	L	Freestall	Warm	Tractor scrape		Manure pit	Sawdust	
Q	W	A	P	L	Freestall	Warm	Alley cleaner	Pump	Manure pit	Sawdust	
R	W	P	P	L	Freestall	Warm	Gravity channel	Pump	Manure pit	Sawdust	
S	W	A	P	L	Freestall	Warm	Alley cleaner	Pump	Manure pit	Sawdust	
T	W	A	P	L	Freestall	Warm	Alley cleaner	Pump & grav	Manure pit	Sawdust	
U	W	G	P	L	Freestall	Warm	Gutter cleaner	Pump	Manure pit	Sawdust	Picket dam pit
V	W	G	P	L	Freestall	Warm	Gutter cleaner	Pump	Manure pit	Sawdust	Liquid storage
W	W	A	G	L	Freestall	Warm	Alley cleaner	Gravity	Manure pit	Sawdust	
X	W	P	L	L	Freestall	Warm	Manure pack	Loader	Manure pit	Sawdust	Roof over pit
Y	W		P	L	Freestall	Warm		Pump	Manure pit	Sawdust	
Z	W		P	L	Freestall	Warm		Pump	Manure pit	Sawdust	Minimal sand

Note: All names, values, and numbers are estimated, and are intended for general use in a Feasibility Study.
As such, accuracy is not warranteed.

Temp=**W**arm or **C**old　　Collect= **T**ractor, **A**lley, **G**utter, or **P**ack

Move= **P**ump, Push **O**ff, **G**ravity, or **L**oader　　Storage= **L**agoon or **S**pread

Appendix D: Transportation Time: Central Digester Alternatives

ID/no.	Trips/day 4000	Miles	One Central Digester Miles/day	Miles	Mini-Central Digesters: Digester 1 Miles	Digester 2 Miles	Digester 3 Miles
A	0.8	1	0.8	0.8		0.7	
B	0.7	1	0.7	0.7		0.5	
C	2.2	1	2.2	2.2		4.9	
D	0.2	2.5	0.6	0.2		0.0	
E	2.5	3	7.5	2.5		6.2	
F	0.9	3.5	3.1	0.9		0.8	
G	0.9	4.5	3.9	1.0	0.9		
H	4.4	4	17.6	2.0	8.8		
I	3.8	2.5	9.4	1.0	3.8		
J	3.4	2.5	8.6	0.5	1.7		
K	3.4	4.5	15.3	2.0	6.8		
L	0.5	5	2.7	2.5	1.3		
M	4.0	5.5	22.2	3.0	12.1		
N	1.2	2.5	2.9	2.5		2.9	
O	0.3	2	0.6	1.5		0.4	
P	1.0	3	3.0	3.0		3.0	
Q	1.2	3.5	4.4	1.0			1.2
R	2.9	3.5	10.3	0.5			1.5
S	2.9	2.5	7.3	0.5			1.5
T	1.8	2.5	4.6	1.5		2.8	
U	1.1	2	2.2	1.5			1.7
V	1.1	2.5	2.7	2.5			2.7
W	1.4	4.5	6.3	2.5			3.5
X	1.1	5	5.6	3.0			3.3
Y	0.7	4	2.9	3.5			2.6
Z	1.9	7	13.1	5.0	0.0	0.0	9.3
Total:	46.5	85	**160.5**		**35.4**	**22.3**	**27.3**

Total one-way miles to service all farms:			**160.5**	**miles**		**85.0**	**miles**
Round trip miles:			320.9	miles		170.1	miles
Driving time at this speed:	25.0	mph	**12.8**	hours of driving time		**6.8**	hours
	This represents		**29%**	of the trucks' time		**18%**	of trucks' time
Add truck time other than driving:							
Load truck with digested liquids		8.0	minutes				
Unload digested liquids		5.0					
Drive from lagoon to barn		5.0					
Load truck with raw manure		10.0					
Unload raw manure		8.0					
Misc.: weather, talking, paperworl		5.0					
Non-drive minutes per trip:		41.0	minutes =	0.68	hours/trip	0.68	hours/trip
Trips				46.5	trips	46.5	trip
				31.8	hours	**31.8**	hours
			This represents	**71%**	of the trucks' tin	**82%**	of trucks' time
Total truck time per day:				**44.6**	hours	**38.6**	hours
Hours per day				24	hours/day	24.0	hours/day
Trucks required: assuming continuous operation (24/7)				**1.9**	Trucks	**1.6**	Trucks
Jobs created:	2.0	24	38.0	**9**	Jobs		

Farm Manure Production:

		Cubic feet	Gallons	Pounds	Tons
10,200 cows:	**Daily**	20,400	153,000	**1,269,900**	635
	Weekly	142,800	1,071,000	**8,889,300**	4,445
	Monthly	606,900	4,551,750	**37,779,525**	18,890
	Yearly	7,282,800	54,621,000	**453,354,300**	226,677

TEST: 3215.9 Gallons/trip

Transportation Cost for One Central Digester

	Rate	Units		Monthly	Yearly
Labor for drivers (10% non-productive)	$18.00	8.6	drivers	$26,292	$315,501
Fringe benefits		20%		$5,258	$63,100
Fuel: miles/day, $/gallon, miles/gallon	320.9	$1.50	6.0	$9,627	$115,528
Maintenance	320.9	0.2		$7,702	$92,422
Licenses, etc.				$7,702	$46,211
Contingency		50%	of labor	$13,146	$78,875
	Total cost:			**$69,727**	**$711,639**

Transportation cost: $/mile:	$ 6.08	Transportation cost: $/cow/yr.	$69.77

Transportation Cost for Three Mini-Central Digesters

	Rate	Units		Monthly	Yearly
Labor for drivers (10% non-productive)	$18.00	7.4	drivers	$22,738	$272,856
Fringe benefits		20%		$4,548	$54,571
Fuel: miles/day, $/gallon, miles/gallon	170.1	$1.50	6.0	$5,103	$61,230
Maintenance	170.1	$0.20	/mile	$4,082	$48,984
Licenses, etc.				$4,082	$24,492
Contingency		50%	of labor	$11,369	$68,214
		Total Cost:		**$51,921**	**$530,347**

Transportation cost: $/mile:	$ 8.54	Transportation cost: $/cow/yr.	$51.99

Appendix E: Preliminary Farm Modifications Budget

For Mini-Central or Central Digester Modifications at the Farm.

Farm ID.	**Temp. W or C**	**Collect. T,A,G,P**	**Move P,O,G,L**	**Storage P,S**	**Housing**	**Temp.**	**Collection**	**Movement**	**Manure management** Holding	**Pump/pit**	**Budget**
A	Cold	Tractor	Push off	Pond	Freestall	Cold	Tractor scrape		Manure pit		**$25,000**
B	Cold	Pack	Loader	Spread	Freestall	Cold	Manure pack	Loader		Not acceptable	
C	Cold	Tractor	Push off	Pond	Freestall	Cold	Tractor scrape		Manure pit		**$45,000**
D	Cold	Tractor	Push off	Pond	Freestall	Cold	Tractor scrape		Manure pit		**$15,000**
E	Warm	Tractor	Push off	Pond	Freestall	Warm	Skidsteer		Manure pit		**$40,000**
F	Warm	Tractor	Pump	Pond	Freestall	Warm	Tractor scrape	Pump	Manure pit	Intercept	**$15,000**
G	Cold	Gutter	Loader	Spread	Tiestall	Cold	Gutter cleaner	Spreader	Stack		**$30,000**
H	Cold	Tractor	Pump	Pond	Freestall	Warm	Tractor scrape	Pumps (2)	Manure pit	Intercepts	**$15,000**
I	Warm	Tractor	Push off	Pond	Freestall	Warm	Tractor & alley		Manure pit		**$45,000**
J	Cold	Alley	Gravity	Pond	Freestall	Warm	Alley cleaner	Gravity	Lagoon		**$40,000**
K	Cold				Freestall	Warm					**$40,000**
L	Warm	Pack	Loader	Spread	Freestall	Cold	Manure pack	Loader	Solid	Not acceptable	
M	Warm	Tractor	Gravity	Pond	Freestall	Warm	Tractor scrape	Gravity			**$50,000**
N	Warm	Tractor	Pump	Pond	Freestall	Cold	Tractor scrape	Pump	Manure pit	Intercept	**$15,000**
O	Warm	Pack	Loader	Spread	Freestall	Cold	Manure pack	Loader	Daily	Not acceptable	
P	Warm	Tractor	Push off	Pond	Freestall	Warm	Tractor scrape		Manure pit		**$25,000**
Q	Warm	Alley	Pump	Pond	Freestall	Warm	Alley cleaner	Pump	Manure pit	Intercept	**$15,000**
R	Warm		Pump	Pond	Freestall	Warm	Gravity channel	Pump	Manure pit	Intercept	**$15,000**
S	Warm	Alley	Pump	Pond	Freestall	Warm	Alley cleaner	Pump	Manure pit	Intercept	**$15,000**
T	Warm	Alley	Pump	Pond	Freestall	Warm	Alley cleaner	Pump & grav	Manure pit		**$25,000**
U	Warm		Pump	Pond	Freestall	Warm	Gutter cleaner	Pump	Manure pit	Intercept	**$15,000**
V	Warm	Gutter	Pump	Pond	Freestall	Warm	Gutter cleaner	Pump	Manure pit	Intercept	**$15,000**
W	Warm	Alley	Gravity	Pond	Freestall	Warm	Alley cleaner	Gravity	Manure pit		**$25,000**
X	Warm	Pack	Loader	Pond	Freestall	Warm	Manure pack	Loader	Manure pit	Not acceptable	
Y	Warm		Pump	Pond	Freestall	Warm		Pump	Manure pit	Intercept	**$15,000**
Z	Warm		Pump	Pond	Freestall	Warm		Pump	Manure pit	Intercept	**$20,000**
											$560,000
										Contingency:	**$56,000**
							8,935	Total Head Count		Total budget	**$672,000**
							9,872	Total Animal Equivalent Co		$/cow	**$68.07**
										Ave. cost per farm:	**$ 30,545.45**

Note: All names, values, and numbers are estimated, and are intended for general use in a Feasibility Study. As such, accuracy is not warranteed.

Temp=Warm or Cold Collect= Tractor, Alley, Gutter, or Pack Move= Pump, Push Off, Gravity, or Loader Storage= Pond or Spread

Appendix F: Capital Costs

		On-site construction costs			Off-site construction costs					
	Unit $	Land	Digester & genset	Separation equip.+bldg.	Farm modifications	Transport system	Start-up	Internal costs	**Contingency** & Misc.(5%)	TOTAL ($/cow)
A. Individual farm digesters	10,200	$0	$4,202,400	$2,278,000	$672,000	$0	$330,000	$150,000	$360,000	**$7,992,400**
No. of digesters	**22**		$412	$223	$ 30,545.45	$0	$15,000	$5,000		$784
B. Local cooperative digesters	10,200	$240,000	$4,528,800	$1,675,000	$672,000	$0	$240,000	$120,000	$350,000	**$7,825,800**
No. of digesters	**8**	$30,000	$444	$164			$30,000	$9,000		$767
C. Mini-central digesters	10,200	$150,000	$3,417,000	$1,474,000	$672,000	$350,000	$180,000	$120,000	$310,000	**$6,673,000**
No. of digesters	**3**	$50,000	$335	$145			$60,000	$20,000		$654
D. Central digester	10,200	$100,000	$3,233,400	$1,055,708	$672,000	$350,000	$125,000	$120,000	$275,000	**$5,931,108**
No. of digesters	**1**	$100,000	$317	$104			$125,000	$35,000		$581
						24/7				

NOTE: Digester and genset unit costs from AgSTAR.
Separation equip. and building costs from this study.
Transportation is assumed day and night: additional trucks would be required if transport would be from 6 am to 6 pm.

Appendix G: Operating Costs

Financial projection: one full year of operation

Alternate A

10,200 Cows

Farmer/member contribution	$10 /cow/year
Value from other potential by-products:	$0 /cow/year
Environmental improvement value	$0 /cow/year
Portion of central digester capital cost paid by grant(s)	0 %

	Individual Farm Digesters		Local Cooperative Digesters		3 Mini-Central Digesters		One Central Digester	
REVENUES	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**
Electricity	$0.065	$1,001,437	$0.065	$1,057,073	$0.065	$1,112,708	$0.065	$1,112,708
Prison								
Heat	$0		$5,000	$40,000	$5,000	$10,000		
Prison						$125,000		$125,000
Additional use of heat						T.B.D.		T.B.D.
Sale of gas to pipeline								
Odor	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
Solids/bedding	$30	$306,000	$30	$306,000	$30	$306,000	$30	$306,000
Farmer/member contrib.	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
Other potential by-products	$0	$0	$0	$0	$0	$0	$0	$0
Envir.improvement value	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL REVENUES		**$1,511,437**		**$1,607,073**		**$1,757,708**		**$1,747,708**
EXPENSES								
Debt service: 100% finan.	$7,992,400	-$1,355,832	$7,825,800	-$1,327,570	$6,673,000	-$1,132,009	$5,931,108	-$1,006,154
8%	annual interest							
96	months or 8 years							
Transportation cost		$0		$0		-$530,347		-$711,639
Replacement set-aside						-$100,000		-$100,000
Genset oper. & maint.	25%	-$250,359	25%	-$264,268	25%	-$278,177	25%	-$278,177
Separation equip: L&M	6000	-$156,000	20000	-$160,000	75000	-$225,000	150000	-$150,000
Administration		$0		-$75,000		-$150,000		-$150,000
TOTAL EXPENSES		**-$1,762,191**		**-$1,826,838**		**-$2,415,533**		**-$2,395,970**
NET PROFIT (LOSS)		**-$250,754**		**-$219,765**		**-$657,825**		**-$648,262**
NET PROFIT (LOSS) PER TON:		-$1.11		-$0.97		-$2.90		-$2.86

NOTE: Every $ 0.01 /kWh changes revenue by $171,186

Appendix G: Operating Costs

Financial projection: one full year of operation

Alternate B

10,200 Cows

Farmer/member contribution	$15 /cow/year
Value from other potential by-products:	$0 /cow/year
Environmental improvement value	$10 /cow/year
Portion of central digester capital cost paid by grant(s)	50 % Central Only

	Individual Farm Digesters		Local Cooperative Digesters		3 Mini-Central Digesters		One Central Digester	
REVENUES	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**
Electricity	$0.065	$1,001,437	$0.065	$1,057,073	$0.065	$1,112,708	$0.065	$1,112,708
Prison								
Heat: local	$0		$5,000	$40,000	$5,000	$10,000		
Prison						$125,000		$125,000
Additional use of heat						T.B.D.		T.B.D.
Sale of gas to pipeline								
Odor	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
Solids/bedding	$45	$459,000	$45	$459,000	$45	$459,000	$45	$459,000
Farmer/member contrib.	$15	$153,000	$15	$153,000	$15	$153,000	$15	$153,000
Other potential by-products	$0	$0	$0	$0	$0	$0	$0	$0
Envir.improvement value	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
TOTAL REVENUES		**$1,817,437**		**$1,913,073**		**$2,063,708**		**$2,053,708**
EXPENSES								
Debt service: as noted	$7,992,400	-$1,355,832	$7,825,800	-$1,327,570	$6,673,000	-$566,004	$5,931,108	-$503,077
8%	annual interest							
96	months or 8 years							
Transportation cost		$0		$0		-$530,347		-$711,639
Replacement set-aside						-$100,000		-$100,000
Genset oper. & maint.	25%	-$250,359	25%	-$264,268	25%	-$278,177	25%	-$278,177
Separation equip: L&M	6000	-$156,000	20000	-$160,000	75000	-$225,000	150000	-$150,000
Administration		$0		-$75,000		-$150,000		-$150,000
TOTAL EXPENSES		**-$1,762,191**		**-$1,826,838**		**-$1,849,529**		**-$1,892,893**
NET PROFIT (LOSS)		**$55,246**		**$86,235**		**$214,180**		**$160,815**
NET PROFIT (LOSS) PER TON:		$0.24		$0.38		$0.94		$0.71

NOTE: Every $ 0.01 /kWh changes revenue by $171,186

Financial projection: one full year of operation

Alternate C

10,200 Cows

Farmer/member contribution	$20	/cow/year
Value from other potential by-products:	$10	/cow/year
Environmental improvement value	$20	/cow/year
Portion of central digester capital cost paid by grant(s)	50	% Central only

	Individual Farm Digesters		Local Cooperative Digesters		3 Mini-Central Digesters		One Central Digester	
REVENUES	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**	Unit	**Dollars/yr.**
Electricity	$0.065	$1,001,437	$0.065	$1,057,073	$0.065	$1,112,708	$0.065	$1,112,708
Prison								
Heat: local	$0		$5,000	$40,000	$5,000	$10,000		
Prison						$125,000		$125,000
Additional use of heat						T.B.D.		T.B.D.
Sale of gas to pipeline								
Odor	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
Solids/bedding	$60	$612,000	$60	$612,000	$60	$612,000	$60	$612,000
Farmer/member contrib.	$20	$204,000	$20	$204,000	$20	$204,000	$20	$204,000
Other potential by-products	$10	$102,000	$10	$102,000	$10	$102,000	$10	$102,000
Envir.improvement value	$20	$204,000	$20	$204,000	$20	$204,000	$20	$204,000
TOTAL REVENUES		**$2,225,437**		**$2,321,073**		**$2,471,708**		**$2,461,708**
EXPENSES								
Debt service: as noted	$7,992,400	-$1,355,832	$7,825,800	-$1,327,570	$6,673,000	-$566,004	$5,931,108	-$503,077
8%	annual interest							
96	months or 8 years							
Transportation cost		$0		$0		-$530,347		-$711,639
Replacement set-aside						-$100,000		-$100,000
Genset oper. & maint.	25%	-$250,359	25%	-$264,268	25%	-$278,177	25%	-$278,177
Separation equip: L&M	6000	-$156,000	20000	-$160,000	75000	-$225,000	150000	-$150,000
Administration		$0		-$75,000		-$150,000		-$150,000
TOTAL EXPENSES		**-$1,762,191**		**-$1,826,838**		**-$1,849,529**		**-$1,892,893**
NET PROFIT (LOSS)		**$463,246**		**$494,235**		**$622,180**		**$568,815**
NET PROFIT (LOSS) PER TON:		$2.04		$2.18		$2.74		$2.51

NOTE: Every $ 0.01 /kWh changes revenue by $171,186