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Combined Energy Management Feasibility Study

Evaluation of Combining Anaerobic Digestion and Geothermal Exchange Technology at the Proposed Lusk Dairy Facility in Springfield, Colorado

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Chapter 1 General Project Assessment

Project Overview

This feasibility study evaluates financial and energy impacts of combining two renewable energy technologies on a single project site. The available options of biogas generation from anaerobic digestion of manure and geothermal heating and cooling via ground source heat exchange are being considered. Biogas, generated through anaerobic digestion of dairy cow manure has a long but spotty history of success in the dairy industry. Geothermal heating and cooling through ground source heat exchange technology is gaining prominence as energy costs continue rising to levels where significant capital investment can be offset by lower long term net energy requirements. Both of the technologies being considered here have positive energy management potential at this site due to prevailing high costs of both electricity and natural gas.

The overall project considers the facility requirements for a prospective 3,000 milking head integrated dairy and feed mill operation. The project is being considered by the Lusk family due to the presence of the following key economic advantages at their existing farming location.

- Close proximity to primary feed source that reduces feed costs
- Adequate renewable water source and quality
- Positive weather patterns
- Excellent topographic characteristics
- Adequate proximal land for manure management of a large dairy
- Isolated location to minimize neighboring community issues
- Proximity to existing and planned dairy processing facilities
- High water demands that can be used as heat source and/or sink

Completion of this study requires compilation and integration of background planning data for the Lusk dairy facility operation along with technical and financial analysis of each contributing component. This is accomplished by requesting, reviewing and analyzing the detailed facility information available from the owner and his respective system and equipment contractors and vendors.

Contributing Parties and Background Information

The parties involved and their role in developing and/or providing information for this project study are shown below:

1) Office of Energy Management and Conservation – Project Funding, Review and Approval

2) Environmental Systems and Solutions LLC – General Project Management and Anaerobic Digestion System Engineering

3) EMC, Engineers – Ground Source Heat Exchange Engineering

4) Lusk Feed Lots – Project Owner

5) Mason Dairy Contractors – Dairy Facility Design and Construction

6) Ferrell-Ross, Inc. – Feed Mill Design and Construction

The following background information was requested from the Lusk Feed Lots and the two prime facility contractors:

1) Facility Site Plans

2) Milking Parlor Building Plans

3) Free Stall Layouts

4) Manure management plan

5) List of all electrical and gas operated equipment

6) Mechanical and electrical drawings

7) List of all heating and cooling equipment and specifications

8) Projected run times and demands for all equipment

9) Any energy evaluations and projections available relative to the projected operations costs for this facility

The Lusk dairy project is in the conceptual planning stage and as such, the contractors and vendors were able to provide budget level information relative to all the above requests. Similarly, they were able to provide budget level operations information relative to power, thermal and water usage. In the following sections, the information has been compiled for analysis relative to integration with manure biogas energy potential and geothermal heating and cooling potential.

Water and Waste Assessment

Overview

This 3,000 milking head dairy is considered a large facility by most standards. As free stall designs and high producing milking systems have been developed, dairy herd sizes have continued to increase from the 'large' dairies of the past less than 1,000 head. With the larger sizes have come larger overall system challenges related to feed supply and handling, water supply and conservation, waste management and disposal and energy use and conservation. The primary driving force for the large modern dairy is reduced overall unit production costs which can only be optimized through application of detailed system planning and engineering efforts. This study's goal is to evaluate the optimal net potential renewable energy system for this site.

Dairy Design Criteria

The general basis of design for this dairy is tabulated below in **Table 1 – Lusk Dairy Basis for Design** and provides the criteria used by the vendors and contractors in establishing the facility needs.

Table 1 – Lusk Dairy Basis for Design

Component	Design Parameter
Parlor design	Rotary Floor
Design Head	3,500
Milking Head:	3,000
Milk; lb/day/Head	65
GPD/Head	7.7
Initial Milk Temp	100 F
Target Milk Temp to Storage	32 F
Milk Flow Rate (lb/min)	155 (~18gpm)
Ground H_2O Temp	58 F
Water Consumed (gpd/cow)	40
Consumptive Water Flow (gpd/gpm)	120,000/83
General Water Uses (gpd/gpm)	50,000/34
Manure Production (gpd/cow)	13
Solids Level (% TS)	12
Manure Production (lbs/cow/day)	120
Manure Production (gpm)	40
Design Manure Temp	60 F

Note: Milking operations are 21 hours each day with 3 hours for extensive facility and process cleaning

Dairy and Feed Mill Energy Assessment

The primary energy uses on the Lusk dairy and feed mill consist of the following:

1) Milk Cooling

2) Cow Cooling (seasonal use of 200 – 1 HP Fans)

3) Parlor Cooling (Continuous use of 60 – 1 HP Fans)

4) Parlor Lighting and Parlor Heating (radiant only; when outside temps are < 32F)

5) Freestall and yard lighting

6) Well/water supply pumps

7) Irrigation pumps

8) Water Distribution pumps

9) Feed Mill Equipment Motors

10) Feed Mill Boiler

The energy required to operate the proposed facility is based upon the facilities required to provide adequate support to service the above design criteria and general demands. **Table 2 – Dairy Energy Requirements** indicates the energy demands expected of the milking operations and **Table 3 – Feed Mill Energy Requirements** indicates the energy demands expected to process the cattle feed for onsite use.

Table 2 – Dairy Energy Requirements

	% Run	kWh	$/day	$/Yr
Major Equipment	80%	6,049	$ 544	$198,714
Seasonal Fans	40%	1,825	$ 164	$ 59,967
Small Equipment	60%	500	$ 45	$ 16,425
Total		**8,375**	**$ 754**	**$ 275,105**

Note: Power cost is assumed at $0.09/kw-hr

Table 3 – Feed Mill Energy Requirements

	Total HP	HP-Hr/Day	kWh /Day	$/Day
Total Electrical per day	284.58	2,697	2,011	$ 181
Annual Electrical (350 days)				**$ 63,351**
	MBTU/Hr	**HP**	**MBTU/day**	**$/Day**
Gas Boiler Firing Rate	10.5	250	126	$ 1,260
Annual Gas(350 days)				**$ 441,000**

Note: Power cost is assumed at $0.09/kw-hr; Gas is assumed at $10.00/MBtu

The energy use patterns of each facility are substantially different which will be factored into the best energy recovery solution in the final assessment. In general, the dairy base load will occur for approximately 21 hours each day when the normal milking operations are active. When not milking, the milk cooling demand will be gone and the primary demand will be for electrical needs. These will be limited to fans, lighting and water supply pumps.

Unlike the dairy demand, the feed mill demands are focused over 12 hours each day. This pattern provides a special challenge to a biogas production facility that optimally functions on a continuous basis. The greatest single energy demand and cost is the gas-fired boiler providing steam for the corn flaking operation. Optimal use of onsite biogas for this application will require up to 12 or more hours of storage capacity and will be compared in capital and operations costs to continuous production of electricity and low level heat from an engine generator.

Facility Management

Manure Management

A wide variety of manure management approaches can be applied on large dairies such as the proposed Lusk operation. If not extensively evaluated, very expensive and inefficient operations can result. However, if example operations can be found to compare, an efficient and optimally profitable program can be developed. The factors considered when developing the best approach are:

1) Bedding Material (straw, shredded paper, wood(chips, sawdust), compost, sand)

2) Bedding material recovery

3) Final manure disposal options

4) Scrape

5) Scrape and Flush

6) Vacuum collection

7) Flush

All of the above issues were reviewed with the owner and the facility designers. After extensive consideration of known manure handling issues as they relate to facilities of this size, this operation will use a scrape and flush approach to move manure to the central collection pit. This combination will result in a target manure solids level of ~8% and will facilitate efficient fiber recovery through screening and composting operations. A majority of the compost will be used as bedding and excess compost will be used for soils conditioning in the feed production areas adjacent to the dairy operation. A portion will also be made available for sale to outside parties depending on the local and regional demand. There are several examples of successful composting operations in Colorado that utilize compost in conjunction with normal fertilizer applications and are seeing measurable and profitable benefit to themselves and commercial customers.

With the above decision, the plug flow anaerobic digestion option is essentially eliminated from further consideration due to the low solids concentration. The primary anaerobic digestion options for the Lusk Dairy are:

1) Covered lagoon

2) Partial or Complete mechanical mix

3) Upright cylinder

General Dairy Layout

A critical component in a large modern dairy is the physical layout. Due to the size and complexity of these facilities, animal behavior, physical needs, regular feeding and manure handling must be properly integrated and designed to minimize operations costs. In cooperation with Mason Dairy Contractors (MDC), a general layout has been developed that is illustrated in **Figure 1 – Lusk Dairy General Facility Layout**. This geometry will be integrated into the Lusk site such that the low point will be where the manure collection pit is shown. This approach facilitates both ease in manure management and efficient hydraulic flushing of the slabs to maintain a clean operation.

Design Criteria

Based on the previously described manure management plan at this facility, the basic design criteria that can be considered appropriate for each process at this location are listed below:

Table 4 – Digester Design Criteria

	Technology		
Criteria	**Covered Lagoon**	**Complete Mix**	**Upright Cylinder**
Detention Time	46 Days	17 Days	7 Days
Required Volume	2,600,000 gallons	960,000 gallons	400,000 gallons
Loading Rate	7.5 lbs VS/1000 ft^3/day	20 lbs VS/1000 ft^3/day	50 lbs VS/1000 ft^3/day
Liquid Depth	15 Feet	38 Feet	46 Feet
Cover Design	Insulated Membrane	Fixed	Fixed
Mechanical Mixing	Bottom Submersible	External Pump	External Pump
Hydraulic Mixing	Top Pump with Piping	External Pump	External Pump
Biogas Storage	None	None	None
Flare	Candle	Candle	Candle
Energy Recovery- Boiler	125 HP – 5.6 MBtu/hr	125 HP – 5.6 MBtu/hr	125 HP – 5.6 MBtu/hr
Electrical Energy Recovery	450 KW	450 KW	450 KW
Feed Solids % TS	4-8	4-8	4-8
Manure Heating	NA	.8 MBtu/Hr	.8 MBtu/Hr
Heat Maintenance	NA	.021 MBtu/Hr	.025 MBtu/Hr

System Designs

In order to develop general budget estimates of the above designs, preliminary process flow diagrams were prepared for each system. These diagrams provide a general illustration of the required components and in conjunction with the general site layout and design criteria provide a basis for developing a system estimate. The process flow diagrams are; **Figure 2 – Covered Lagoon Digester; Figure 3 – Complete Mix Digester; Figure 4 – Upright Cylinder Digester**

Budget Costs

With the above systems being considered appropriate general technology, a preliminary design and construction estimate has been prepared for each of the alternatives. **Table 5 – System Cost Estimates** below provides a summary of the estimated capital costs. The detailed basis for each estimate is provided as **Attachment 1 – Detailed Project Estimates**. These estimates represent a compilation of components for a complete system capable of producing and delivering biogas to a final utilization point. These values do not reflect costs for handling manure before and after the systems nor do they

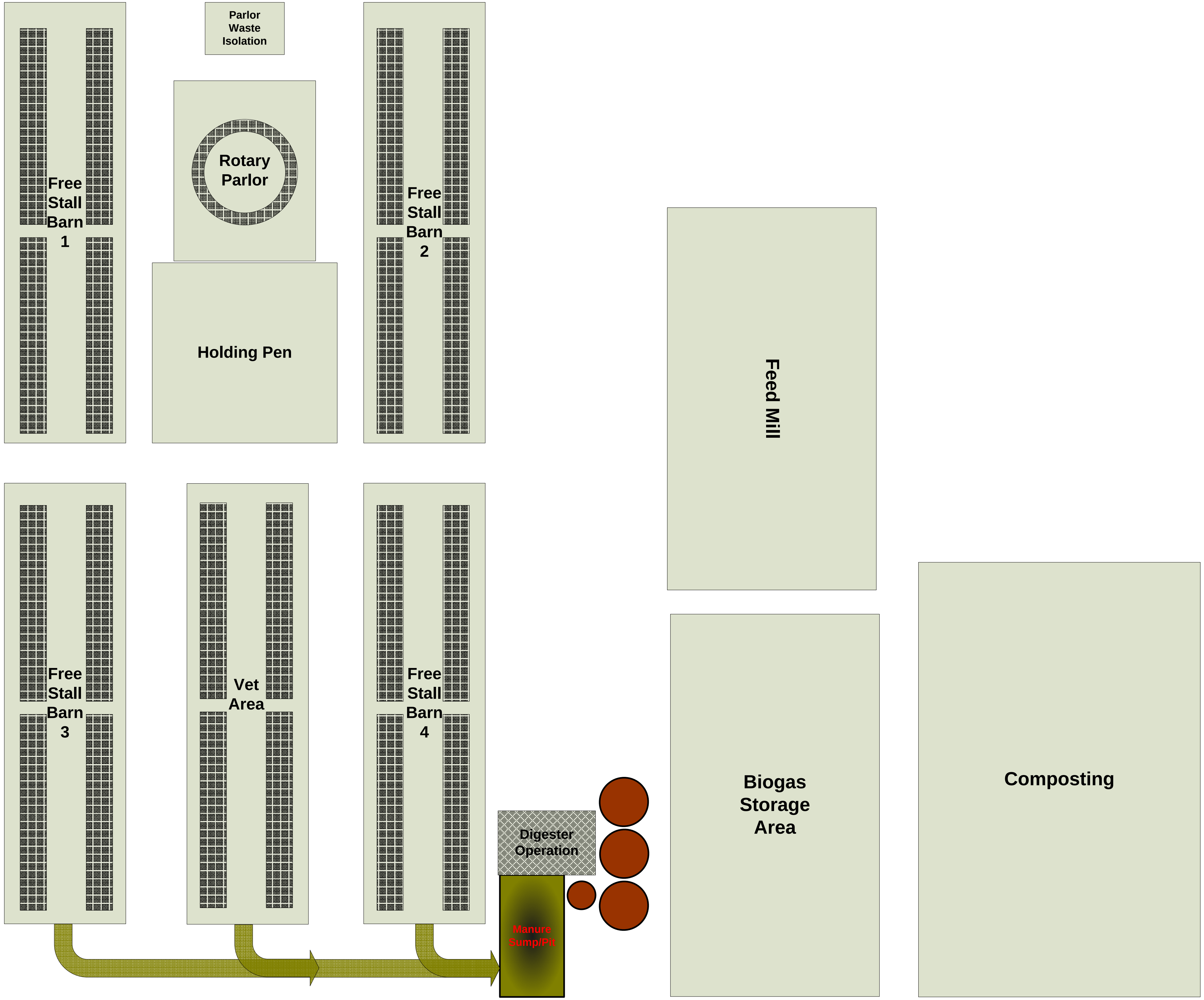

Figure 1 – Lusk Dairy General Facility Layout

Springfield, Colorado
Manure Digester and Geothermal Energy Study
General Facility Conceptual Layout

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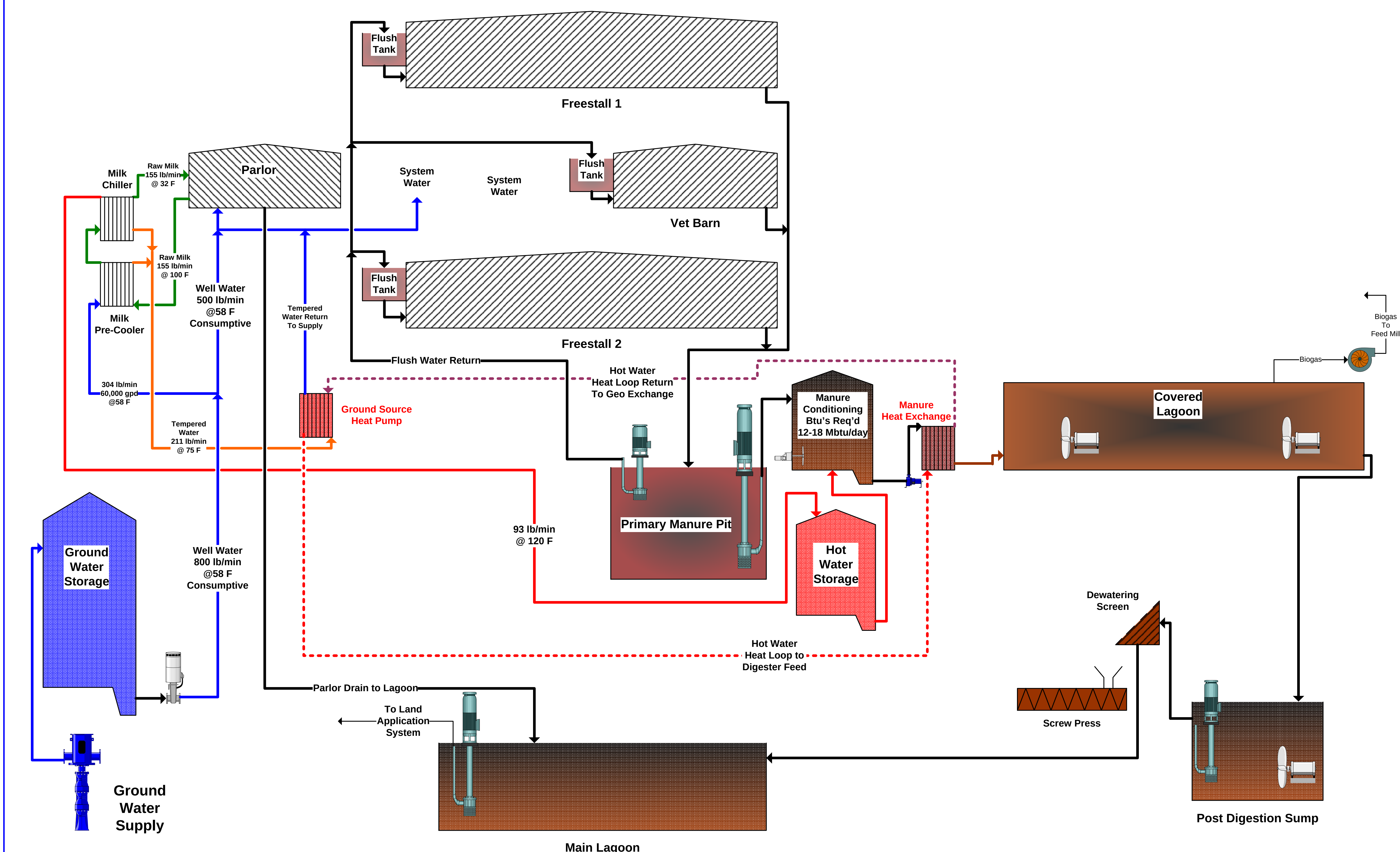

Figure 2 – Covered Lagoon Digester

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Manure Digester and Geothermal Energy Study

Covered Lagoon Digester Process Flow Diagram

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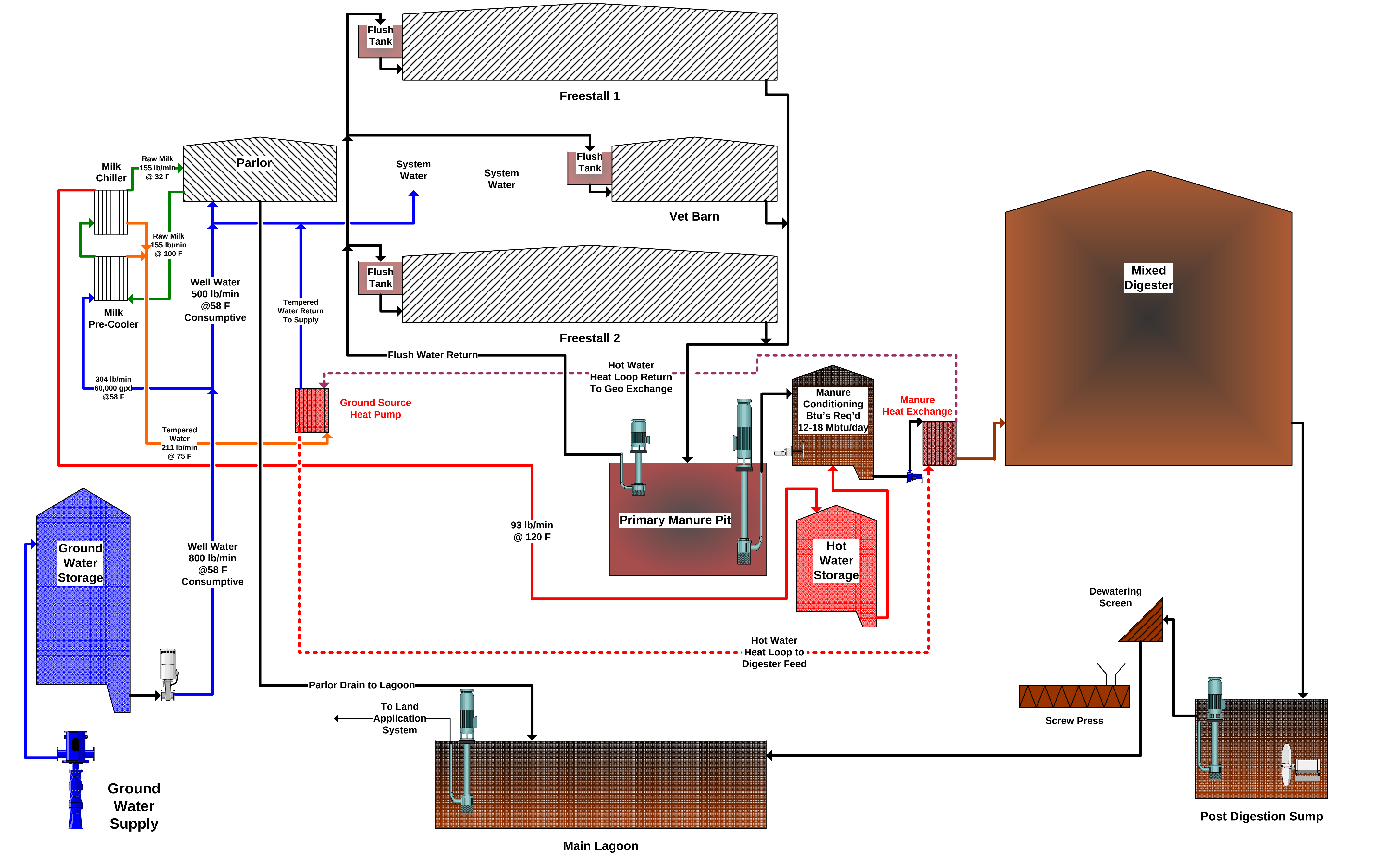

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Figure 3 – Complete Mix Digester

Springfield, Colorado
Manure Digester and Geothermal Energy Study
Complete Mixed Digester Conceptual Process Flow

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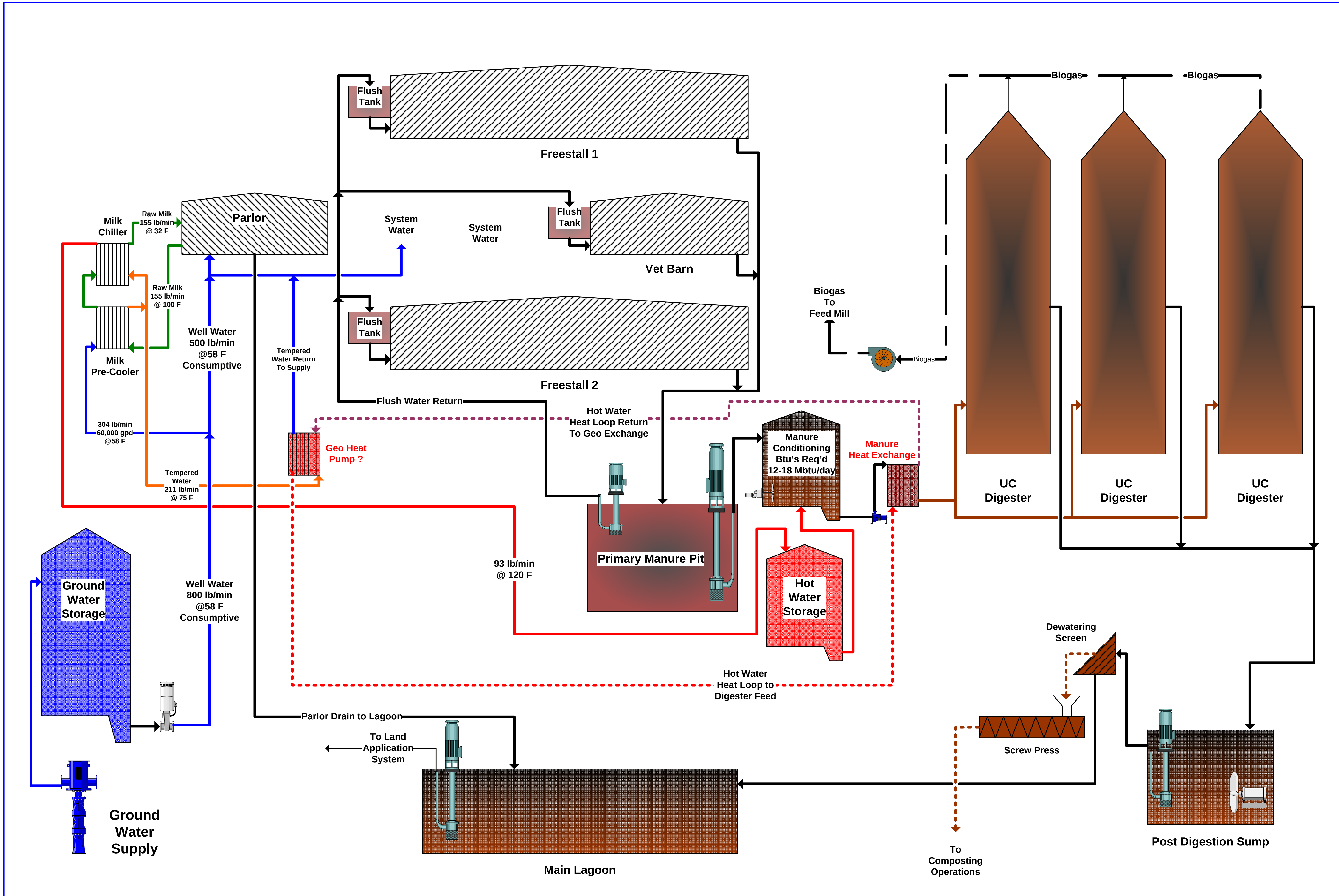

Figure 4 – Upright Cylinder Digester
Springfield, Colorado
Manure Digester and Geothermal Energy Study
Upright Cylinder Digester Process Flow Diagram

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include the costs for and electrical production system. Complete electrical production equipment is currently running at approximately $1,100/kw.

Table 5 – System Cost Estimates

Lusk Dairy Farm Digester System – 3,000 Head			
	Covered Lagoon	UC Digester	CM Digester
General Conditions	$ 22,000	$ 26,000	$ 33,500
Engineering	$ 43,100	$ 53,300	$ 51,575
Site Work	$ 349,250	$ 92,500	$ 79,500
Finishes	$ 3,500	$ 7,500	$ 5,000
Tanks & Metals	$ 57,630	$ 485,880	$ 931,630
Equipment	$ 97,800	$ 115,400	$ 89,400
Instrumentation	$ 30,200	$ 40,700	$ 30,200
Mechanical Systems	$ 78,000	$ 78,250	$ 62,750
Electrical Equipment	$ 74,250	$ 76,750	$ 74,250
Total	**$ 755,730**	**$ 965,780**	**$ 1,357,805**
Contingency	$ 188,933	$ 244,070	$ 339,451
Total – Biogas Only	**$ 906,876**	**$ 1,220,350**	**$ 1,629,366**
Cost Per Head – Biogas Only	**$ 315**	**$ 407**	**$ 566**
Engine Generator System	**$ 412,500**	**$ 412,500**	**$ 412,500**
Total	**$ 1,319,376**	**$ 1,632,850**	**$ 2,041,866**
Cost Per Head w/ Electricity	**$ 436**	**$ 544**	**$ 680**

Energy Potential

The only reason for considering a manure digester at this facility is the potential renewable energy available. The gross energy potential estimated from this facility is based upon an assessment of field results and literature review. The values are generally considered conservative in that some facilities with proactive and attentive manure management techniques have shown greater yield results than those projected here. The following excerpt from an agency review (The Minnesota Project 2002) of the Tom Haubenschilds dairy digestion project near Princeton, Minnesota illustrates the possible range; ***with 425 cows, the biogas output per cow was almost twice projections – with 750 cows, the output per cow has come down somewhat to about 40 percent above projections. Haubenschild's cows are producing about 50 percent more manure per cow than the digester was engineered for, which somewhat explains the high biogas production per cow.*** Also, only the production head numbers are used. If properly managed, dry and heifer cows can contribute up to 25% more production potential. Since dry and heifer cows are often managed in areas where manure handling is less frequent and much more labor and equipment intensive, that source often only goes to composting.

Based on general industry values, 1,000 lactating production cows will produce approximately 1,800 cubic feet of manure each day from which approximately 40 ft^3 of biogas per ft^3 of manure at 600/Btu/ft^3 can be expected. The daily Btu value per 1,000 cows is approximately 43.2 million Btu's (MBtu). On a 3,000 head dairy this will translate to approximately 130 MBtu's daily. At current natural gas equivalent pricing of $10/MBtu, an annual energy value of around $475,000 ($1,300/day) is possible. It is likely that this energy pricing will remain at or above this level for the foreseeable future at this location.

A very critical relationship to note at this point is that a digester facility on the Lusk farm has the potential manure energy capable of providing 100% of the raw energy required for the feed mill operation. This is in contrast to being utilized for electrical production at 15,000 BTU/kWh. The electrical value would be approximately 8,970 kWh/day ($807@$0.09/ kWh)) for an annual value of just over $295,000 or approximately 62% of the value potential of the energy when used directly in the feed mill. If actual production values approximate those achieved by the dairy experience from Minnesota, it may be possible to justify both direct biogas utilization and electrical production.

Chapter 2 AD Cost Benefit – Summary

Review of Potential Costs and Benefits

Overview

The costs provided represent general facility estimates and include a 25% contingency for this level of pre-design evaluation. The estimated energy values are based on current actual energy costs in this area. **Table 6 – Cost Benefit Summary** provides a general assessment of the economic value for an anaerobic digestion facility on the Lusk Dairy.

Table 6– Cost Benefit Summary

Digester Technology	Biogas MBTU/Day	Value		Simple ROI		Notes
		Gas ($/Day)	Electricity ($/Day)	Gas (Yrs)	Electricity* (Yrs)	
Covered Lagoon	130	$1,300	$807	1.91	4.47	ROI is overstated as gas production is unpredictable and seasonal which will greatly reduce energy value
Upright Cylinder	130	$1,300	$807	2.54	5.5	Multiple Tank System Provides Redundancy and Flexibility
Complete Mix	130	$1,300	$807	3.54	6.9	Mixing is difficult and one tank system decreases maintenance reliability

The above values clearly show that there is sound economic value to the digester systems considered for the Lusk Dairy and the direct use of biogas provides the greatest net value. This facility shows better economics than most historical assessments due to the fact that gas values are up to 2.5-3.0 times greater than historical values and the regional cost of electricity is 40-50% greater than many other regions.

Specific Site Considerations

During the course of reviewing the entire system operations and assessing the optimum energy recovery opportunities, a unique feature to the Lusk dairy project became apparent as compared to most facilities considering a digester. This feature is the incorporation of a Feed Mill operation into the integrated project and was mentioned briefly above. Typically, a dairy will produce more energy than it can use which requires benefit be gained from offsite energy sales to a local utility. Since the value of resale is generally less than half of the retail value, buyback programs commonly do not greatly improve the economic justification of an onsite generation facility. This would be the case here as there would be significant periods of excess power production that would have to be sold at the wholesale buyback rate or utilized for service elsewhere on the farm. Even if utilized for operation of the irrigation system and 100% of the electricity can be utilized, it is highly doubtful if the added capital cost can be justified for electrical production. When the additional operations costs are included, electrical production becomes even less attractive at this location.

In considering this option further, the feed mill as planned is to run 12 hours each day. This presents a significant storage challenge/requirement if all of the biogas is to be utilized for feed mill energy. To resolve this issue, the feed mill vendor was contacted relative to the 12 hour operations cycle. When questioned, the vendor indicated that the boiler, currently sized for approximately 250 horsepower could be downsized to run continuously at approximately 125 horsepower as could the material handling equipment. This will require that the feed mill run nearly continuously in order to optimally utilize the available biogas energy. Similarly, Reggie Lusk was contacted relative to this approach. It was felt that the continuous operation would be okay. From an industrial operations approach, continuous operation of this type of equipment can have a number of benefits resulting from lowered stresses by not starting and stopping the equipment as well as easier maintenance activities on the smaller equipment required for material handling. Also, continuous operations can lead to more predictable maintenance schedules and approaches.

Summary

The concept of anaerobic digestion of the manure produced on the Lusk Dairy appears to have considerable financial merit based upon the review of critical factors as they relate to this dairy location. The site combines a number of unique benefits that actually make anaerobic digestion more attractive here than at most dairy sites. The factors that stand out are:

1) Excellent site geography
2) Excellent location for feed delivery
3) Pending proximal (<80 miles) location of milk processing facilities in Kansas and Texas
4) High power costs (> $0.085/kWh)
5) High natural gas costs (>$10.00/mmbtu)
6) Onsite demand for 100% of energy produced at the optimum offset value
7) Temporal location through integrated site design to minimize parasitic losses by integrating feed mill, digestion system and milk cooling and heat transfer systems.

With the above factors and the relatively attractive rate of return on the digestion systems, anaerobic digestion at this facility appears feasible due to both financial and technical factors. Also as stated earlier, production values well in excess of those projected here may be possible with acute attention to the system details. In the second portion of this study (Chapter 3), the potential for enhancing this value further through the incorporation of ground source heat exchange will be considered.

Chapter 3 Ground Source Heat System

Project Overview

The potential for this site to integrate ground source heating/cooling technology with the anaerobic digestion facility is being considered due to;

1) The large volumes of water commonly used on a dairy operation for cleaning, animal consumption and irrigation.

2) The relatively shallow and stable ground water table which can be easily used for ground source heat exchange.

3) Potential net value of ground source heat recovery technology to offset typical parasitic demands for initial and maintenance digester heating demands.

Ground water and soils (ground source) can be used efficiently through the use of integrated ground source heat pumps. Typical ground source heat pump systems use a recirculating coolant similar to automotive cooling systems but take advantage of the tremendous heat sink capacity of natural earth environments. In the case of the Lusk dairy, both ground source loops and direct use of pumped ground water will be assessed for potential application to enhance the planned dairy project's energy efficiency.

Heating and Cooling Demands

Ground source geothermal systems can provide both heating and cooling functions depending on the system need. Typical systems operate on the heat pump principle where the mechanical energy of the electrically driven heat pump compressor can channel heat either from the ground source or back to the ground source. At the Lusk dairy, an extensive review of the facility heating and cooling demands lead to the following general evaluation:

1) Very few general facility (HVAC) cooling and heating demands exist.

2) Parlor heating is only performed when outside temperatures are less than 32 F and is provided by gas fired radiant heaters.

3) No active heat exchange is used for parlor cooling as it is provided by circulating fans only.

4) Cow cooling is a substantial demand but is only accomplished by large 1 HP fans distributed throughout the parlor and freestall barns.

5) Preparing milk for storage and shipping represents the single largest cooling demand.

6) The potential cooling demand for milk is approximately 14 MBtu/day.

7) Depending on the season, preparing manure for digestion represents a heat demand very similar to the milk cooling demand.

8) The potential heat demand for manure will range from approximately 7-20 MBTU/day or 5-15% of the expected energy production.

Milk Cooling

Milk enters the piping systems at approximately 100 F and must be cooled to 32 F prior to storage. Milk is shipped from the farm at no more than 34 F. A 3,000 head dairy is expected to produce an average milk flow of approximately 18 gpm of milk that must be chilled. This heat can be removed by the following means:

1) Traditional refrigerated chillers and plate heat exchangers.

2) Staged chilling using ground water for pre-chilling followed by mechanical chilling in two stage plate heat exchangers.

3) Ground water cooled mechanical chillers that use water for a heat sink as compared to air coils.

4) Ground source heat pumps that pass the milk heat to the ground water used for normal consumption.

5) Ground source heat pumps that utilize ground loops as a heat sink.

After considerable review with the Dairy contractor, it is clear that ground water is an excellent and energy efficient method for both pre-cooling the milk and has become a standard feature in modern large dairy design. Ground water as a heat sink for mechanical chilling is desirable where power costs are above $0.05/ kWh such as the Lusk Dairy.

Based on comparing general cooling demands with normal consumptive water use by a dairy this large, the facility can pass normal consumptive water flowing at approximately twice the rate of flow of the milk to provide the pre-cooling at virtually no net increase in operations cost. This water must be pumped and delivered under pressure as part of normal operations and can readily be utilized as a ground water heat sink. In addition, approximately ½ of the ground water used in the pre-cooling heat exchanger can flow to the mechanical chiller and provide an additional heat sink. This combined heat collecting effort then allows that water and heat to be reused in the general operations as shown below:

1) Tempered water for cow sanitation

2) Warm/Tempered water for manure wash down

3) Warm/Tempered water for manure dilution

4) Warm/Tempered water for ground source heat pumping to heat the manure

Using normal ground water flows for milk cooling has been determined as a clear energy benefit to the Lusk dairy operation and will be included in the facility plans. The value of extracting heat back out of the flow for manure heating is reviewed and discussed below. In rough terms, the cost of the parasitic demands for manure heating ranges from $70 - $200 per day equivalent depending on the raw manure temperatures against a normal biogas production value of $1,300/day.

Ground Source Heat Exchange System Options

Based upon the features of the Lusk Dairy and a basic heating and cooling energy demand analysis, it was determined that between the heat available from milk and normal consumptive ground water flows there is little reason to consider a classic ground source loop system and the following ground source heat pump system alternatives can be considered appropriate.

1) Full Milk Cooling and Slurry Heating with Ground Source Heat Pumps (GSHP)

2) Partial Milk Cooling and Full Slurry Heating with GSHP

3) Slurry Heating Only with GSHP

Alternative 1: Full Milk Cooling and Slurry Heating

This GSHP system utilizes water-to-water units to cool the milk from 100°F to 32°F while using the heat rejection side of the heat pumps to raise the temperature of the manure slurry from 60°F up to 115°F before it goes into the manure digesters.

This configuration would replace the chiller plant and pre-cooler heat exchanger, simplify some of the piping in the system, and provide the most energy savings. In order to meet the 260 MBH cooling capacity requirements, the system requires four water-to-water units for a water/glycol piping loop at a flow rate of 45 gpm with two additional heat pump units for standby/backup for a total of 6 units. The cooling side of the heat pumps will provide approximately 28°F fluid to the heat exchanger for the milk process cooling. The leaving temperature of the fluid is approximately 58°F. A series of one or more thermal ice storage tanks will provide a buffer between the heat pumps and the milk heat exchanger for better temperature control during varying modes of operation either due to temperature fluctuations or the rate of milk cooling required. **Figure 5 – Alternative 1 Flow Diagram** depicts a schematic layout of the intended operation for this alternative.

The heating side of the heat pumps has sufficient capacity to heat the manure slurry from 60°F to 115°F and there is approximately 300 MBH of excess heating capacity due to the amount of heat rejection from the heat pump units. The additional heat can be utilized through a ground water heat exchanger to warm the ground water for tempered water applications within the parlor and freestall areas.

Table 7 – Alternative 1 Performance Information, summarizes the system performance characteristics of this alternative's process. The energy consumption includes the heat pumps, associated circulating pumps, and both primary and secondary pumps at estimated horse power requirements. The total annual energy consumption for Alternative 1 is 413,000 kWh/yr at an annual cost of $37,200 at $0.09/kWh. This does not include energy consumption and implementation cost for the rest of the dairy facility.

Reggie Lusk Diary & Feed Lot - Ground Source Energy Evaluation

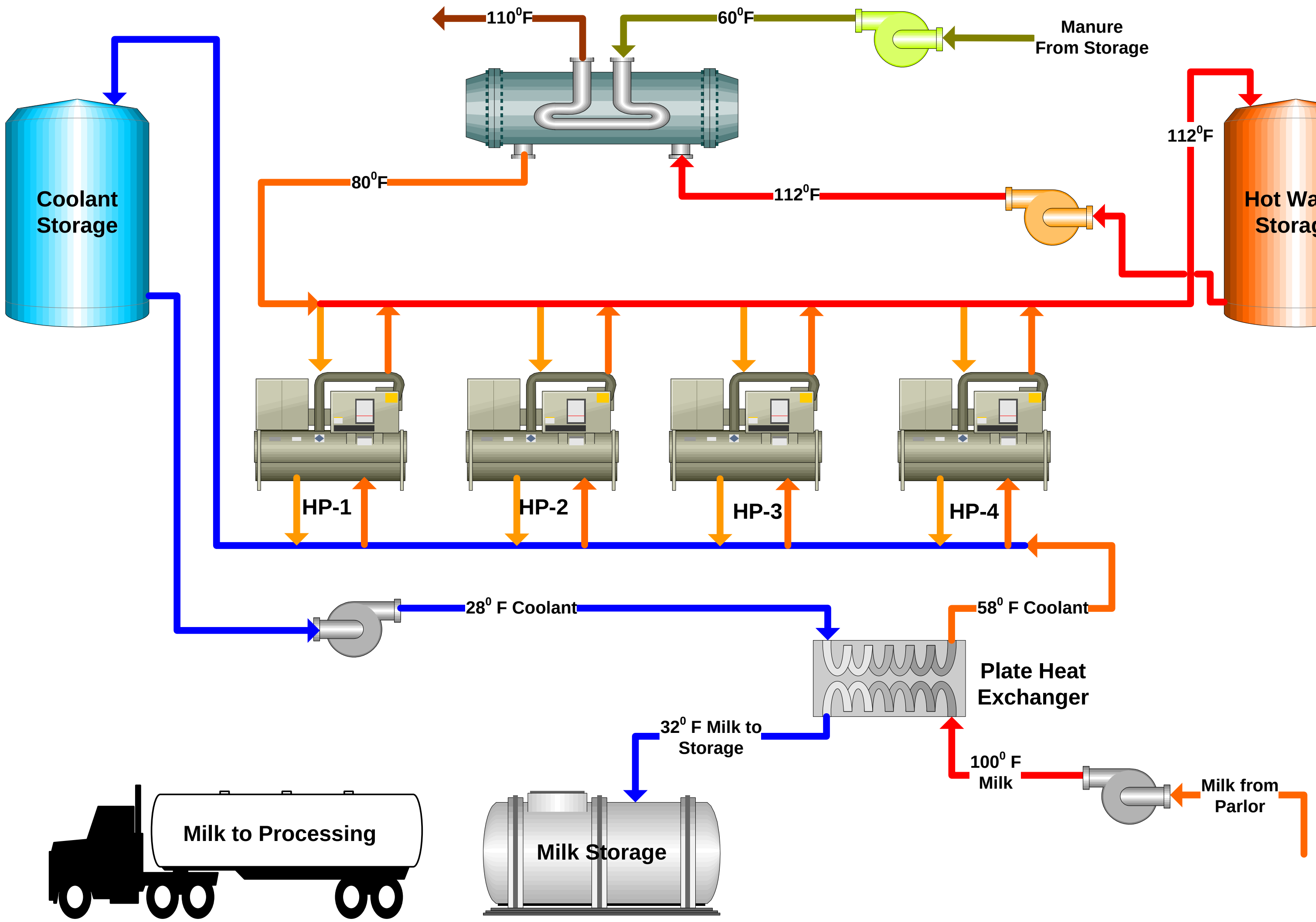

Figure – 5 GSHP Alternative 1 – Full Milk Cooling and Slurry Heating

Table 7 – Alternative 1 Performance Information

System Factor	Value
Total Required Cooling Capacity (Btu/hr)	632,400
Total Required Heating Capacity (Btu/hr)	567,600
Excess Cooling Capacity (Btu/hr)	31,000
Excess Heating Capacity (Btu/hr)	308,200
Annual Energy Consumption (kWh/yr)	413,000
Estimated Total Peak Demand (kW)	54
Annual Operating Cost (@ 0.09/kWhr)	$37,200
Estimated Implementation Cost for Alternative	$180,000
Internal Rate of Return (20-year study)	5.3%

The Internal Rate of Return (IRR) assumes the incremental difference between the baseline system and Alternative 1 as the estimated implementation cost for the alternative, based on the estimated operating cost difference (no chiller and no parasitic gas consumption). The actual cost difference will probably improve the IRR. It should also be noted that interest and inflation rates were not considered for calculating the IRR.

Alternative 2: Partial Milk Cooling and Full Slurry Heating

This GSHP system utilizes water-to-water units to cool the milk from 60°F to 32°F after passing through the 58°F ground water plate exchanger while using the heat rejection side of the heat pumps to raise the temperature of the manure slurry from 60°F up to 115°F before it goes into the manure digesters.

This configuration would replace the chiller plant but not the pre-cooler heat exchanger. It still takes advantage of the cooling available from the groundwater and provides slurry heating without large excess heat to be shed in another process. In order to meet the cooling capacity requirements of approximately 260 mbh, the system requires two water-to-water units for a water/glycol piping loop at a flow rate of 45 gpm. The cooling side of the heat pumps will provide approximately 28°F fluid to the heat exchanger for the milk process cooling. The leaving temperature of the fluid is approximately 40°F.

A series of one or more thermal ice storage tanks will provide a buffer between the two heat pumps and the milk heat exchanger for better temperature control during varying modes of operation either due to temperature fluctuations or the rate of milk cooling required. **Figure 6 – Alternative 2 Flow Diagram** depicts a schematic layout of the intended operation for Alternative 2.

Table 8 – Alternative 2 Performance Information, summarizes the system performance characteristics of this alternative's process. The energy consumption includes the heat pumps, associated circulating pumps, and both primary and secondary pumps at estimated horse power requirements. The total annual energy consumption for Alternative 2 is 316,500 kWh/yr at an annual cost of $28,500 at $0.09/kWh. This does not include energy consumption and implementation cost for the rest of the dairy facility. The Internal Rate of Return (IRR) assumes the incremental difference between the baseline system and Alternative 2 as the estimated implementation cost for the alternative and is based on the estimated operating cost difference (no chiller and reduced parasitic gas

Reggie Lusk Dairy & Feed Lot - Ground Source Energy Evaluation

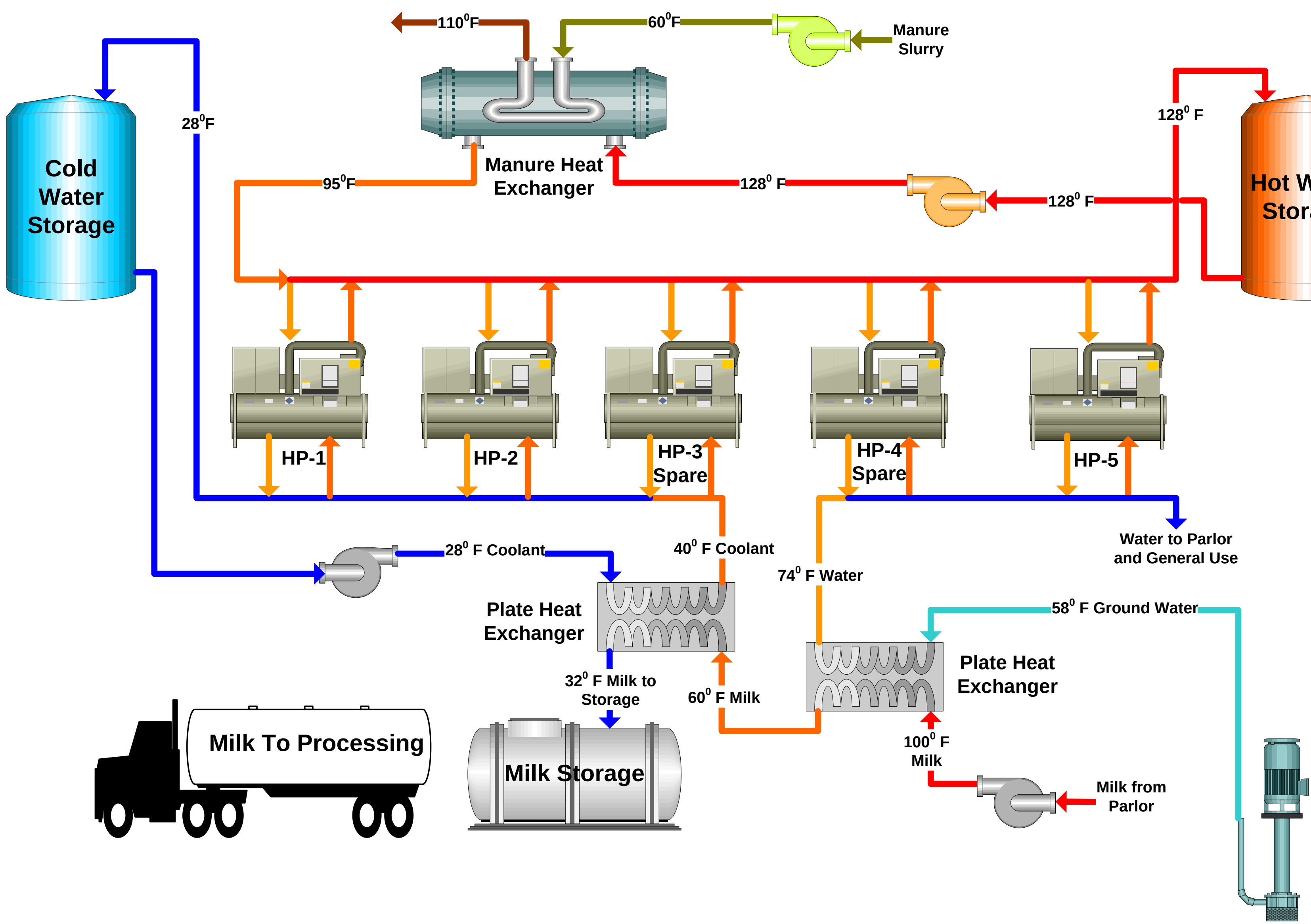

Figure – 6 GSHP Alternative 2 – Partial Milk Cooling and Full Slurry Heating

consumption). The actual cost difference will probably improve the IRR. It should also be noted that interest and inflation rates were not considered for calculating the IRR. This alternative appears to be the most attractive resulting in the smallest overall system that is more flexible in both cooling and heating modes.

Table 8 – Alternative 2 Performance Information

System Factor	Value
Total Required Cooling Capacity (Btu/hr)	260,400
Total Required Heating Capacity (Btu/hr)	567,600
Excess Cooling Capacity (Btu/hr)	5,200
Excess Heating Capacity (Btu/hr)	59,500
Annual Energy Consumption (kWh/yr)	316,525
Estimated Total Peak Demand (kW)	42
Annual Operating Cost (@ 0.09/kWhr)	$28,500
Estimated Implementation Cost for Alternative	$150,000
Internal Rate of Return (20-year study)	**7.9%**

Alternative 3: Slurry Heating Only

This GSHP system configuration uses water-to-water heat pump units to take consumptive use 58°F well water direct from the consumption storage to just boost the manure slurry temperature from 60°F to 105°F. The chiller and pre-cool heat exchangers and processes remain unchanged from the original design. **Figure 7 – Alternative 3 Flow Diagram** depicts a schematic layout of the intended operation for Alternative 2. This configuration requires 2 heat pumps and a third heat pump is suggested for standby/backup to the other units. If the heating capacity is exactly matched on the manure slurry heat exchanger, the outlet temperature of the manure slurry mixture will approach 108°F. The cold side of the heat pumps will cool the well water from 58°F down to 37°F and require a flow rate of 45 gpm. This 37°F water can then be fed to the pre-cooler to significantly improve its efficiency and reduce mechanical chiller energy requirements by up to 50%.

Table 9 – Alternative 3 Performance Information summarizes the system performance characteristics of this alternative's process. The energy consumption includes the heat pumps, associated circulating pumps, and both primary and secondary pumps at estimated horse power requirements. The total annual energy consumption for Alternative 1 is 218,800 kWh/yr at an annual cost of $19,700 at $0.09/kWh. This does not include energy consumption and implementation cost for the rest of the dairy facility. The Internal Rate of Return (IRR) assumes the incremental difference between the baseline system and Alternative 3 as the estimated implementation cost for the alternative, based on the estimated operating cost difference (parasitic gas consumption value). The actual cost difference will probably improve the IRR. It should also be noted that interest and inflation rates were not considered for calculating the IRR.

Reggie Lusk Diary & Feed Lot - Ground Source Energy Evaluation

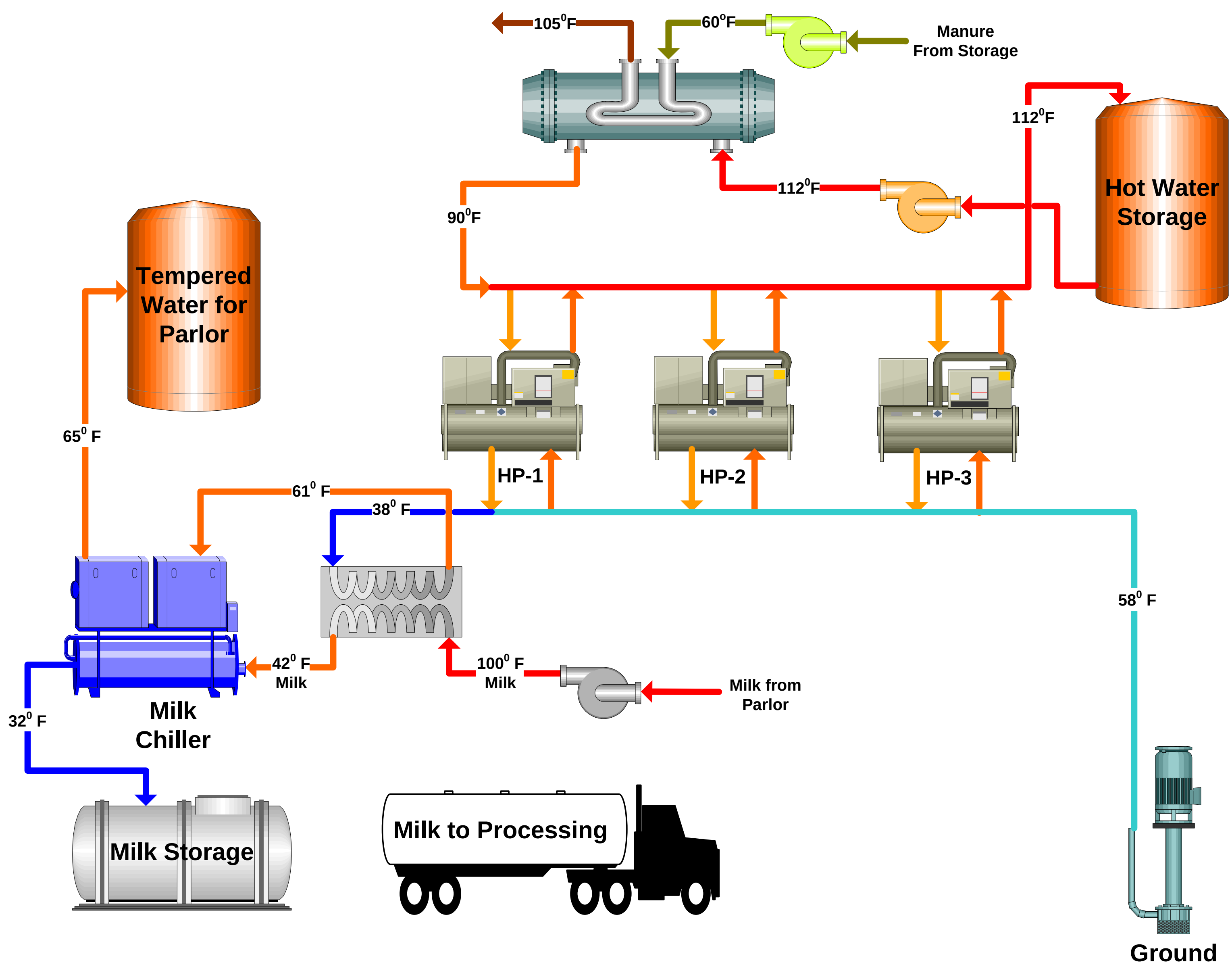

Figure – 7 GSHP Alternative 3 - Slurry Heating Only

Table 9 – Alternative 3 Performance Information

System Factor	Value
Total Required Cooling Capacity (Btu/hr)	260,400
Total Required Heating Capacity (Btu/hr)	495,400
Excess Cooling Capacity (Btu/hr)	129,000
Excess Heating Capacity (Btu/hr)	5,900
Annual Energy Consumption (kWh/yr)	218,800
Estimated Total Peak Demand (kW)	29
Annual Operating Cost (@ 0.09/kWhr)	$19,700
Estimated Implementation Cost for Alternative	$90,000
Internal Rate of Return (20-year study)	**8.9%**

GSHP Application Summary

The three alternatives described above represent a novel approach to energy management on a modern dairy farm in that GSHP technology has only recently been considered in modern dairy farm design. Some facilities in colder climates than southeast Colorado have utilized GSHP technology to provide milk cooling, slab heating to eliminate ice and parlor air conditioning during humid summer months. At this time, use of GSHP technology to eliminate parasitic demands for manure digestion has not been documented.

The application of ground source heat pumps (GSHP) for this project offers a very unique solution to biomass energy production. After evaluating three different alternatives of utilizing water-to-water ground source heat pumps to provide a heating source to a manure slurry for digestion that creates electricity from the methane created from biomass, it is determined that all three alternatives can meet the goal of removing a gas-fired heating system (parasitic consumption of methane) for biomass energy production, but two of the alternatives can also provide cooling to the milk process load. Each alternative requires different integration requirements.

Alternative 1 replaces the gas-fired heating source, the chiller, and the pre-cooler heat exchanger with well water, and has an excessive amount of additional heat that must be rejected to another process load, ground heat exchanger, or space heating. The electrical consumption for this Alternative has been estimated to be 413,000 kWh/yr.

Alternative 2 replaces the gas-fired heating source and the chiller but requires additional piping configurations. The electrical consumption for this Alternative has been estimated to be 316,525 kWh/yr.

Alternative 3 replaces only the gas-fired heating source with minimal impact to the rest of the milk dairy process and is the smallest system. The electrical consumption has been estimated to be 218,800 kWh/yr and the energy required for complete milk cooling is reduced by about 60%.

Alternative 2 is the recommended alternative if the project proceeds to the design phase. It is suggested that thermal ice and hot water storage tanks be considered to act as a buffer between the heat pumps and the respective process loads so that varying load conditions, such as temperature, can be satisfied.

However; it is important to consider with any of the geothermal heat pump alternatives, each one is scalable with the addition of more GSHP units. In the event production requirements increase in the future, the geothermal heat pump system will only require bringing online the number of heat pumps units that are necessary to meet the new capacity requirements. However, there will be a need to address the increase in electrical load required by the additional heat pump units.

Final Analysis Pending

Due to a lack of detailed cost information from the project contractor, Mason Dairy Contractors (MDC) relative to component costs for the milk cooling operation planned at the Lusk Dairy it has not been possible to fully confirm the relative cost-benefits of a GSHP system. At this point and based upon conversations with GSHP vendors, the capital cost of GSHP equipment for milk cooling is typically lower that standard mechanical chilling equipment and there is a substantial energy savings as well. Based upon this knowledge, it appears that ground source milk cooling should be considered for this facility along with the recovery of this heat for manure heating.

Chapter 4 AD and GSHP Energy Systems Summary

The primary focus of this feasibility study has been to assess the value of integrating anaerobic manure digestion and GSHP technologies to enhance the energy efficiency of a large modern dairy operation planned for the Lusk Feed Lot location near Springfield, Colorado. Based upon extensive research relative to this integration, if this combination is utilized at the Lusk Farm, it may be the first full integration of the two technologies.

Anaerobic Digestion Technology Application

Three AD system alternatives were considered and the mixed multiple above ground tank approach appears to provide the best overall system economics and reliability. This approach provides redundancy and reliability that are critical to full realization of the renewable energy economic benefit. A common challenge for this type of facility is to balance production rates with usage/demands. Biogas storage is generally a mechanical challenge and typically adds a substantial cost and complexity to an operation. Eliminating the need for storage and providing a consistent supply provides a key element in the design approach on this project because the biogas produced can be fully utilized by the feed lot operation in the flake drying facility. Similar to the overall integration of AD and GSHP technologies, this integration appears to be a unique application as the majority of modern dairies can not fully utilize the energy potential provided by the biogas. The projected natural gas demand of the feed mill very closely approaches the projected production from the digestion facility. A further benefit is that the feed mill capital cost can be reduced and efficiency increased by operating on a continuous basis. The estimated value of this energy at current rates is $1,300/day or $475,000 annually. When considered in conjunction with the lowered capital of the feed mill equipment the cost benefit of the digestion system becomes even better than that projected. Furthermore, and as noted in the text, it is likely that the production values used can be significantly improved above historical standards through proper system design and management

GSHP Technology Application

The application of GSHP system(s) for the Lusk project presents an interesting opportunity to leverage an additional energy efficient technology to the Lusk project. GSHP systems were considered for application on the entire project. During the preliminary evaluation, it became evident that general space and facility demands were limited and that the primary GSHP application was for providing a medium to transfer milk or ground water heat to the manure and thereby minimize parasitic energy losses related to the heating the manure prior to feeding into the digester. Through the systems reviewed it was found that GSHP technology could be beneficially applied to a variety of applications. Each system was found capable of providing adequate ground source and/or milk source heat for heating the manure.

Based upon vendor conversations, GSHP technology is often found less capital intensive than standard milk chilling systems. When considered in conjunction with the core energy savings as well as parasitic heat savings for digestion, GSHP technology at the proposed Lusk Dairy facility becomes an attractive option.

Attachment 1 – AD Project Cost Details

Covered Lagoon

Lusk Dairy Farm Digester System - 3,000 Head							
	Notes	Unit Cost	Units	Cost	Margin	Total	Total
General Conditions							
Administrative		$ 8,500	1	$ 8,500		$ 8,500	
Travel		$ 2,500	1	$ 2,500		$ 2,500	
Subsistance		$ 1,000	1	$ 1,000		$ 1,000	
Permits & Fees		$ 2,500	1	$ 2,500		$ 2,500	
Startup Services				$ -		$ -	
Proj. Management		$ 7,500	1	$ 7,500		$ 7,500	
Office and Storage Facilities		$ 2,500		$ -		$ -	
							$ 22,000.00
Engineering							
Civil Engineering-Site		$ 85	120	$ 10,200		$ 10,200	
Civil Engineering-Struct		$ 95	60	$ 5,700		$ 5,700	
Process Engineering		$ 120	100	$ 12,000		$ 12,000	
Electrical Engineering		$ 95	80	$ 7,600		$ 7,600	
Mechanical Engineering		$ 95	80	$ 7,600		$ 7,600	
							$ 43,100.00
Site Work							
Excavation	Cu. Yds.	$ 2.00	12,000	$ 24,000		$ 24,000	
Fill	Cu. Yds.	$ 3.50	12,500	$ 43,750		$ 43,750	
Liner	Sq. Ft	$ 0.95	60,000	$ 57,000		$ 57,000	
Cover	Sq. Ft	$ 4.50	40,000	$ 180,000		$ 180,000	
Misc. Concrete	Equipment Pads 100 Sq. Ft @ $10/sq. Ft.	$ 10	100	$ 1,000		$ 1,000	
Tank Foundation	Ring Foundation	$ 35,000		$ -		$ -	
Piping	Process Piping - 100 Ft. 2-3" PVC @ $30/ft	$ 30	200	$ 6,000		$ 6,000	
	Biogas Piping - 200 Ft 2" Steel @ $25/ft.	$ 25	300	$ 7,500		$ 7,500	
	General Water Piping - 100 Ft. of 1" @ $10/ft	$ 10	300	$ 3,000		$ 3,000	
	Chemical and Misc. 100 Ft. @ $20/ft	$ 20	200	$ 4,000		$ 4,000	
Site Prep	Sub-base for tanks & building - $2/sqft @ 300 sqft	$ 2	1,500	$ 3,000		$ 3,000	
Site Work	Site Filling, Grading, Finish site - 5$/cu.yd.	$ 5	1,000	$ 5,000		$ 5,000	
Accessways	Roads & Misc. Site @ $15/sq.ft.	$ 15	1,000	$ 15,000		$ 15,000	
							$ 349,250.00
Finishes	Misc. Painting	$ 10	350	$ 3,500		$ 3,500	
							$ 3,500.00
Tanks & Metals							
Bolted Steel	NA	$ 0.75		$ -		$ -	
	Holding Tank	$ 0.59	62,000	$ 36,580		$ 36,580	
	Clarifier	$ 2.50		$ -		$ -	
	Preheat	$ 2.50		$ -		$ -	
Building	200 sq. ft.	$ 65	200	$ 13,000		$ 13,000	
	Ribbon Drains	$ 50	50	$ 2,500		$ 2,500	
	Pump Stands	$ 250	6	$ 1,500		$ 1,500	
	Doors	$ 1,200	1	$ 1,200		$ 1,200	
	Windows	$ 350	1	$ 350		$ 350	
	Rollup Door	$ 2,500	1	$ 2,500		$ 2,500	
							$ 57,630.00
Equipment							
Chopper Pump	Vaughan- Feed from pit to Conditioning	$ 4,500	1	$ 4,500		$ 4,500	
Blowers	Rotron	$ 6,500	2	$ 13,000		$ 13,000	
FEB Pumps	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Chopper Pump	Vaughan	$ 4,200	1	$ 4,200		$ 4,200	
Screen	Basket Strainer	$ 500	1	$ 500		$ 500	
Heat Mix Pump	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Scrubber	ESS	$ 4,500	1	$ 4,500		$ 4,500	
Heat Ex	ESS	$ 3,500	2	$ 7,000		$ 7,000	
Boiler	Hurst	$ 56,000		$ -		$ -	
Hot Water Pumps	Bell&Gosset	$ 400		$ -		$ -	
Chem Pumps	LMI	$ 2,500	2	$ 5,000		$ 5,000	
Digester Feed Pump	Wilden/Vogelsang	$ 1,500		$ -		$ -	
Bottom Mixer	ABS	$ 4,500	3	$ 13,500		$ 13,500	
Recirculation Pumps	Vaughan	$ 4,500	4	$ 18,000		$ 18,000	
Flare	S&J	$ 3,500	1	$ 3,500		$ 3,500	
Pressure Regulator/Flame Trap	S&J	$ 4,500	1	$ 4,500		$ 4,500	
Breather Flame Arrestor	S&J	$ 4,500	2	$ 9,000		$ 9,000	
Pressure Relief	Fisher	$ 3,100	1	$ 3,100		$ 3,100	
Digester Recirc Pump	Goulds	$ 1,500	3	$ 4,500		$ 4,500	
							$ 97,800.00
Instrumentation							
Magmeters	2 inch units	$ 2,800		$ -		$ -	
				$ -		$ -	
Gas Flow Meters-FCI	2 inch units	$ 3,000	3	$ 9,000		$ 9,000	
				$ -		$ -	
pH meters	Rosemount	$ 1,500	1	$ 1,500		$ 1,500	
Conductivity Meters				$ -		$ -	
Alkalinity Meters				$ -		$ -	
Level	Krohne	$ 3,000	3	$ 9,000		$ 9,000	
Level	Miltronics	$ 3,000	2	$ 6,000		$ 6,000	
RTD's	Rosemount	$ 400	8	$ 3,200		$ 3,200	
Misc. Lab & Handhelds		$ 1,500	1	$ 1,500		$ 1,500	
							$ 30,200.00
Mechanical Systems							
Digester Feed Piping	Valves, Pipe and Fittings	$ 30	700	$ 21,000		$ 21,000	
Digester Recirc Piping	Valves, Pipe and Fittings	$ 30	600	$ 18,000		$ 18,000	
Transfer Piping	Valves, Pipe and Fittings	$ 30	250	$ 7,500		$ 7,500	
Internal Mechanical & Fab	Valves, Pipe and Fittings	$ 4,500	1	$ 4,500		$ 4,500	
Hot Water Piping	Valves, Pipe and Fittings	$ 3,500		$ -		$ -	
HVAC Systems	Fans, Filters, Etc.	$ 2,500	1	$ 2,500		$ 2,500	
Tank Insulation	$8.50/sq.ft.	$ 9		$ -		$ -	
Piping Insulation	$10/ft.	$ 10	300	$ 3,000		$ 3,000	
Misc. Valves & Fittings		$ 75	20	$ 1,500		$ 1,500	
Chemical Piping		$ 20	150	$ 3,000		$ 3,000	
HVAC Systems Install		$ 3,500	1	$ 3,500		$ 3,500	
Misc. Equipment Install	3 men 10 days @ $250/day/man	$ 250	20	$ 5,000		$ 5,000	
Misc. Mechanical Labor	3 men 10 days @ $250/day/man	$ 250	20	$ 5,000		$ 5,000	
Misc. Piping Supplies	Equipment, Tools, supplies & misc.	$ 3,500	1	$ 3,500		$ 3,500	
							$ 78,000.00

Electrical Equipment							
Power Supply	Transformers, Main Power to Facility	$ 4,500	1	$ 4,500		$ 4,500	
MCC's	Starters, Power Dist. Lighting	$ 12,500	1	$ 12,500		$ 12,500	
Controls	PLC Panel	$ 17,500	1	$ 17,500		$ 17,500	
Controls	Numatics	$ 6,500	1	$ 6,500		$ 6,500	
Misc. Electrical	Plugs, Cords, switches, fixtures, hangars etc	$ 7,500	1	$ 7,500		$ 7,500	
Underground Electrical	Site and underslab	$ 7,500	1	$ 7,500		$ 7,500	
MCC	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Instruments	$250/day/man	$ 250	5	$ 1,250		$ 1,250	
Equipment Electrical	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Site Electrical	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Lighting	$250/day/man	$ 250	8	$ 2,000		$ 2,000	
Controls	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Misc. Electrical Supplies	Conduit,Wire, Hangars, junction boxes	$ 5,000	1	$ 5,000		$ 5,000	
							$ 74,250.00
Totals				$ 755,730		$ 755,730	**$ 755,730.00**
	Contingency	25%		**188,933**			**$ 188,932.50**
	Total			**$ 944,663**			**$ 944,662.50**
	Cost per Head			**$ 314.89**			**$ 314.89**

Complete Mix

Lusk Dairy Farm Digester System - 3,000 Head							
	Notes	Unit Cost	Units	Cost	Margin	Total	Total
General Conditions							
Administrative		$ 12,500	1	$ 12,500		$ 12,500	
Travel		$ 2,500	1	$ 2,500		$ 2,500	
Subsistance		$ 1,000	1	$ 1,000		$ 1,000	
Permits & Fees		$ 2,500	1	$ 2,500		$ 2,500	
Startup Services				$ -		$ -	
Proj. Management		$ 7,500	2	$ 15,000		$ 15,000	
Office and Storage Facilities		$ 2,500		$ -		$ -	
							$ 33,500.00
Engineering							
Civil Engineering-Site		$ 85	95	$ 8,075		$ 8,075	
Civil Engineering-Struct		$ 95	100	$ 9,500		$ 9,500	
Process Engineering		$ 120	125	$ 15,000		$ 15,000	
Electrical Engineering		$ 95	120	$ 11,400		$ 11,400	
Mechanical Engineering		$ 95	80	$ 7,600		$ 7,600	
							$ 51,575.00
Site Work							
Misc. Concrete	Equipment Pads 100 Sq. Ft @ $10/sq. Ft.	$ 10	100	$ 1,000		$ 1,000	
Tank Foundation	Ring Foundation	$ 35,000	1	$ 35,000		$ 35,000	
Piping	Process Piping - 100 Ft. 2-3" PVC @ $30/ft	$ 30	200	$ 6,000		$ 6,000	
	Biogas Piping - 200 Ft 2" Steel @ $25/ft.	$ 25	300	$ 7,500		$ 7,500	
	General Water Piping - 100 Ft. of 1" @ $10/ft	$ 10	300	$ 3,000		$ 3,000	
	Chemical and Misc. 100 Ft. @ $20/ft	$ 20	200	$ 4,000		$ 4,000	
Site Prep	Sub-base for tanks & building - $2/sqft @ 300 sqft	$ 2	1500	$ 3,000		$ 3,000	
Site Work	Site Filling, Grading, Finish site - 5$/cu.yd.	$ 5	1000	$ 5,000		$ 5,000	
Accessways	Roads & Misc. Site @ $15/sq.ft.	$ 15	1000	$ 15,000		$ 15,000	
							$ 79,500.00
Finishes	Misc. Painting	$ 10	500	$ 5,000		$ 5,000	
							$ 5,000.00
Tanks & Metals							
Bolted Steel	1 - 950,000 gallon digester	$ 0.75	1,000,000	$ 750,000		$ 750,000	
	Insulation	$ 8.50	12,500	$ 106,250		$ 106,250	
	Holding Tank	$ 0.59	62,000	$ 36,580		$ 36,580	
	Clarifier	$ 2.50		$ -		$ -	
	Preheat	$ 2.50		$ -		$ -	
Building	400 sq. ft.	$ 65	400	$ 26,000		$ 26,000	
	Ribbon Drains	$ 50	100	$ 5,000		$ 5,000	
	Pump Stands	$ 250	6	$ 1,500		$ 1,500	
	Doors	$ 1,200	2	$ 2,400		$ 2,400	
	Windows	$ 350	4	$ 1,400		$ 1,400	
	Rollup Door	$ 2,500	1	$ 2,500		$ 2,500	
							$ 931,630.00
Equipment							
Chopper Pump	Vaughan- Feed from pit to Conditioning	$ 4,500	1	$ 4,500		$ 4,500	
Blowers	Rotron	$ 6,500	2	$ 13,000		$ 13,000	
FEB Pumps	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Chopper Pump	Vaughan	$ 4,200	1	$ 4,200		$ 4,200	
Screen	Basket Strainer	$ 500	1	$ 500		$ 500	
Heat Mix Pump	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Scrubber	ESS	$ 4,500	1	$ 4,500		$ 4,500	
Heat Ex	ESS	$ 3,500	2	$ 7,000		$ 7,000	
Boiler	Hurst	$ 56,000		$ -		$ -	
Hot Water Pumps	Bell&Gosset	$ 400	4	$ 1,600		$ 1,600	
Chem Pumps	LMI	$ 2,500	4	$ 10,000		$ 10,000	
Digester Feed Pump	Wilden/Vogelsang	$ 1,500	2	$ 3,000		$ 3,000	
Top Mixer	Ligtnin	$ 4,500	3	$ 13,500		$ 13,500	
Flare	S&J	$ 3,500	1	$ 3,500		$ 3,500	
Pressure Regulator/Flame Trap	S&J	$ 4,500	1	$ 4,500		$ 4,500	
Breather Flame Arrestor	S&J	$ 4,500	2	$ 9,000		$ 9,000	
Pressure Relief	Fisher	$ 3,100	1	$ 3,100		$ 3,100	
Digester Recirc Pump	Goulds	$ 1,500	3	$ 4,500		$ 4,500	
							$ 89,400.00
Instrumentation							
Magmeters	2 inch units	$ 2,800		$ -		$ -	
				$ -		$ -	
Gas Flow Meters-FCI	2 inch units	$ 3,000	3	$ 9,000		$ 9,000	
				$ -		$ -	
pH meters	Rosemount	$ 1,500	1	$ 1,500		$ 1,500	
Conductivity Meters				$ -		$ -	
Alkalinity Meters				$ -		$ -	
Level	Krohne	$ 3,000	3	$ 9,000		$ 9,000	
Level	Miltronics	$ 3,000	2	$ 6,000		$ 6,000	
RTD's	Rosemount	$ 400	8	$ 3,200		$ 3,200	
Misc. Lab & Handhelds		$ 1,500	1	$ 1,500		$ 1,500	
							$ 30,200.00
Mechanical Systems							
Digester Feed Piping	Valves, Pipe and Fittings	$ 30	300	$ 9,000		$ 9,000	
Digester Recirc Piping	Valves, Pipe and Fittings	$ 30	100	$ 3,000		$ 3,000	
Transfer Piping	Valves, Pipe and Fittings	$ 30	75	$ 2,250		$ 2,250	
Internal Mechanical & Fab	Valves, Pipe and Fittings	$ 4,500	1	$ 4,500		$ 4,500	
Hot Water Piping	Valves, Pipe and Fittings	$ 3,500	2	$ 7,000		$ 7,000	
HVAC Systems	Fans, Filters, Etc.	$ 2,500	3	$ 7,500		$ 7,500	
Piping Insulation	$10/ft.	$ 10	300	$ 3,000		$ 3,000	
Misc. Valves & Fittings		$ 75	20	$ 1,500		$ 1,500	
Chemical Piping		$ 20	150	$ 3,000		$ 3,000	
HVAC Systems Install		$ 3,500	1	$ 3,500		$ 3,500	
Misc. Equipment Install	3 men 10 days @ $250/day/man	$ 250	30	$ 7,500		$ 7,500	
Misc. Mechanical Labor	3 men 10 days @ $250/day/man	$ 250	30	$ 7,500		$ 7,500	
Misc. Piping Supplies	Equipment, Tools, supplies & misc.	$ 3,500	1	$ 3,500		$ 3,500	
							$ 62,750.00

Electrical Equipment							
Power Supply	Transformers, Main Power to Facility	$ 4,500	1	$ 4,500		$ 4,500	
MCC's	Starters, Power Dist. Lighting	$ 12,500	1	$ 12,500		$ 12,500	
Controls	PLC Panel	$ 17,500	1	$ 17,500		$ 17,500	
Controls	Numatics	$ 6,500	1	$ 6,500		$ 6,500	
Misc. Electrical	Plugs, Cords, switches, fixtures, hangars etc	$ 7,500	1	$ 7,500		$ 7,500	
Underground Electrical	Site and underslab	$ 7,500	1	$ 7,500		$ 7,500	
MCC	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Instruments	$250/day/man	$ 250	5	$ 1,250		$ 1,250	
Equipment Electrical	$250/day/man	$ 250	12	$ 3,000		$ 3,000	
Site Electrical	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Lighting	$250/day/man	$ 250	8	$ 2,000		$ 2,000	
Controls	$250/day/man	$ 250	8	$ 2,000		$ 2,000	
Misc. Electrical Supplies	Conduit,Wire, Hangars, junction boxes	$ 5,000	1	$ 5,000		$ 5,000	
							$ 74,250.00
Totals				$ 1,357,805		$ 1,357,805	**$ 1,357,805.00**
	Contingency	25%		**339,451**			**$ 339,451.25**
	Total			**$ 1,697,256**			**$ 1,697,256.25**
	Cost per Head			**$ 565.75**			**$ 565.75**

UCD Bolted

Lusk Dairy Farm Digester System - 3,000 Head							
	Notes	**Unit Cost**	**Units**	**Cost**	**Margin**	**Total**	**Total**
General Conditions							
Administrative		$ 10,000	1	$ 10,000		$ 10,000	
Travel		$ 2,500	1	$ 2,500		$ 2,500	
Subsistance		$ 1,000	1	$ 1,000		$ 1,000	
Permits & Fees		$ 2,500	1	$ 2,500		$ 2,500	
Startup Services				$ -		$ -	
Proj. Management		$ 7,500	1	$ 7,500		$ 7,500	
Office and Storage Facilities		$ 2,500	1	$ 2,500		$ 2,500	
							$ 26,000.00
Engineering							
Civil Engineering-Site		$ 85	80	$ 6,800		$ 6,800	
Civil Engineering-Struct		$ 95	100	$ 9,500		$ 9,500	
Process Engineering		$ 120	150	$ 18,000		$ 18,000	
Electrical Engineering		$ 95	100	$ 9,500		$ 9,500	
Mechanical Engineering		$ 95	100	$ 9,500		$ 9,500	
							$ 53,300.00
Site Work							
Misc. Concrete	Equipment Pads 100 Sq. Ft @ $10/sq. Ft.	$ 10	100	$ 1,000		$ 1,000	
Tank Foundation	Ring Foundation	$ 12,000	4	$ 48,000		$ 48,000	
Piping	Process Piping - 100 Ft. 2-3" PVC @ $30/ft	$ 30	200	$ 6,000		$ 6,000	
	Biogas Piping - 200 Ft 2" Steel @ $25/ft.	$ 25	300	$ 7,500		$ 7,500	
	General Water Piping - 100 Ft. of 1" @ $10/ft	$ 10	300	$ 3,000		$ 3,000	
	Chemical and Misc. 100 Ft. @ $20/ft	$ 20	200	$ 4,000		$ 4,000	
Site Prep	Sub-base for tanks & building - $2/sqft @ 300 sqft	$ 2	1500	$ 3,000		$ 3,000	
Site Work	Site Filling, Grading, Finish site - 5$/cu.yd.	$ 5	1000	$ 5,000		$ 5,000	
Accessways	Roads & Misc. Site @ $15/sq.ft.	$ 15	1000	$ 15,000		$ 15,000	
							$ 92,500.00
Finishes	Misc. Painting	$ 10	750	$ 7,500		$ 7,500	
							$ 7,500.00
Tanks & Metals							
Bolted Steel	4 - 100,000 gal. Digesters	$ 0.75	400,000	$ 300,000		$ 300,000	
	Insulation Sq.ft.	$ 8.50	13,000	$ 110,500		$ 110,500	
	Holding Tank	$ 0.59	62,000	$ 36,580		$ 36,580	
	Clarifier	$ 2.50		$ -		$ -	
	Preheat	$ 2.50		$ -		$ -	
Building	400 sq. ft.	$ 65	400	$ 26,000		$ 26,000	
	Ribbon Drains	$ 50	100	$ 5,000		$ 5,000	
	Pump Stands	$ 250	6	$ 1,500		$ 1,500	
	Doors	$ 1,200	2	$ 2,400		$ 2,400	
	Windows	$ 350	4	$ 1,400		$ 1,400	
	Rollup Door	$ 2,500	1	$ 2,500		$ 2,500	
							$ 485,880.00
Equipment							
Chopper Pump	Vaughan- Feed from pit to Conditioning	$ 4,500	1	$ 4,500		$ 4,500	
Blowers	Rotron	$ 6,500	3	$ 19,500		$ 19,500	
FEB Pumps	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Chopper Pump	Vaughan	$ 4,200	1	$ 4,200		$ 4,200	
Screen	Basket Strainer	$ 500	1	$ 500		$ 500	
Heat Mix Pump	Goulds	$ 1,500	1	$ 1,500		$ 1,500	
Scrubber	ESS	$ 15,000	1	$ 15,000		$ 15,000	
Heat Ex	ESS	$ 3,500	2	$ 7,000		$ 7,000	
Boiler	Hurst	$ 56,000		$ -		$ -	
Hot Water Pumps	Bell&Gosset	$ 400	4	$ 1,600		$ 1,600	
Chem Pumps	LMI	$ 2,500	4	$ 10,000		$ 10,000	
Digester Feed Pump	Wilden/Vogelsang	$ 1,500	4	$ 6,000		$ 6,000	
Mixer	Ligtnin	$ 4,500	4	$ 18,000		$ 18,000	
Flare	S&J	$ 3,500	1	$ 3,500		$ 3,500	
Pressure Regulator/Flame Trap	S&J	$ 4,500	1	$ 4,500		$ 4,500	
Breather Flame Arrestor	S&J	$ 4,500	2	$ 9,000		$ 9,000	
Pressure Relief	Fisher	$ 3,100	1	$ 3,100		$ 3,100	
Digester Recirc Pump	Goulds	$ 1,500	4	$ 6,000		$ 6,000	
							$ 115,400.00
Instrumentation							
Magmeters	2 inch units	$ 2,800		$ -		$ -	
				$ -		$ -	
Gas Flow Meters-FCI	2 inch units	$ 3,000	5	$ 15,000		$ 15,000	
				$ -		$ -	
pH meters	Rosemount	$ 1,500	2	$ 3,000		$ 3,000	
Conductivity Meters				$ -		$ -	
Alkalinity Meters				$ -		$ -	
Level	Krohne	$ 3,000	4	$ 12,000		$ 12,000	
Level	Miltronics	$ 3,000	2	$ 6,000		$ 6,000	
RTD's	Rosemount	$ 400	8	$ 3,200		$ 3,200	
Misc. Lab & Handhelds		$ 1,500	1	$ 1,500		$ 1,500	
							$ 40,700.00
Mechanical Systems							
Digester Feed Piping	Valves, Pipe and Fittings	$ 30	300	$ 9,000		$ 9,000	
Digester Recirc Piping	Valves, Pipe and Fittings	$ 30	100	$ 3,000		$ 3,000	
Transfer Piping	Valves, Pipe and Fittings	$ 30	75	$ 2,250		$ 2,250	
Internal Mechanical & Fab	Valves, Pipe and Fittings	$ 4,500	4	$ 18,000		$ 18,000	
Hot Water Piping	Valves, Pipe and Fittings	$ 3,500	4	$ 14,000		$ 14,000	
HVAC Systems	Fans, Filters, Etc.	$ 2,500	1	$ 2,500		$ 2,500	
Piping Insulation	$10/ft.	$ 10	300	$ 3,000		$ 3,000	
Misc. Valves & Fittings		$ 75	20	$ 1,500		$ 1,500	
Chemical Piping		$ 20	150	$ 3,000		$ 3,000	
HVAC Systems Install		$ 3,500	1	$ 3,500		$ 3,500	
Misc. Equipment Install	3 men 10 days @ $250/day/man	$ 250	30	$ 7,500		$ 7,500	
Misc. Mechanical Labor	3 men 10 days @ $250/day/man	$ 250	30	$ 7,500		$ 7,500	
Misc. Piping Supplies	Equipment, Tools, supplies & misc.	$ 3,500	1	$ 3,500		$ 3,500	
							$ 78,250.00

Electrical Equipment							
Power Supply	Transformers, Main Power to Facility	$ 4,500	1	$ 4,500		$ 4,500	
MCC's	Starters, Power Dist. Lighting	$ 12,500	1	$ 12,500		$ 12,500	
Controls	PLC Panel	$ 17,500	1	$ 17,500		$ 17,500	
Controls	Numatics	$ 6,500	1	$ 6,500		$ 6,500	
Misc. Electrical	Plugs, Cords, switches, fixtures, hangars etc	$ 7,500	1	$ 7,500		$ 7,500	
Underground Electrical	Site and underslab	$ 7,500	1	$ 7,500		$ 7,500	
MCC	$250/day/man	$ 250	15	$ 3,750		$ 3,750	
Instruments	$250/day/man	$ 250	5	$ 1,250		$ 1,250	
Equipment Electrical	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Site Electrical	$250/day/man	$ 250	15	$ 3,750		$ 3,750	
Lighting	$250/day/man	$ 250	8	$ 2,000		$ 2,000	
Controls	$250/day/man	$ 250	10	$ 2,500		$ 2,500	
Misc. Electrical Supplies	Conduit,Wire, Hangars, junction boxes	$ 5,000	1	$ 5,000		$ 5,000	
							$ 76,750.00
Totals				$ 976,280		$ 976,280	**$ 976,280.00**
	Contingency	25%		**244,070**			**$ 244,070.00**
	Total			**$ 1,220,350**			**$ 1,220,350.00**
	Cost per Head			**$ 406.78**			**$ 406.78**