From: Northeast Colorado Resource Conservation & Development

Date: November 24, 2010

To: Value-Added Board

RE: RC&D Thoughts of report and next steps;

On behalf of the Northeast Colorado RC&D Council we would like to acknowledge Symbios Technologies, LLC and Stewart Environmental Consultants, LLC for their expertise, knowledge and professionalism they brought to this grant. They did a very complete and thorough job investigating and fulfilling the grant requirements and writing the final report.

Northeast Colorado RC&D has discussed with Symbios Technologies, LLC and Stewart Environmental Consultants, LLC their interest in continuing to work together on the next steps and finding a way to complete construction of an anaerobic digester. All three parties are in favor of this.

The list below of next steps is taken from the final report which was compiled while meeting with the producers, RC&D Council members, Symbios Technologies, LLC and Stewart Environmental Consultants, LLC.

1) Detailed study of dryland application of effluent, pivot irrigation, or possible wetlands project on Tom Bornhoft II's land. Included in this should be investigation of whether existing lagoons on each farm could be used for liquid effluent storage, which would reduce the excavation and other lagoon construction costs included in the modeling for this report.
2) Investigation of windrow composting and sale of the organic residuals.
3) Permitting requirements definition.
4) Negotiation with HEA for higher electric rates and/or RECs.
5) Pursue grants and equity funds from a number of sources.
   a) USDA and other grants, with the help of NCRC&D.
   b) DOE grants, including GEO ARRA funding scheduled for release in 2010.
   c) Contact local, regional, and national investors.
6) Design and engineering.
7) Project construction and commissioning.

The following is a comment and or concern that was brought to me from the producers after the final report was submitted that relates to the payout schedule of the digester in relation to the current age of the barns. The feasibility study shows the payout of the digester is 17 years, the current age of the barns are 13-15 years, by the time the digester starts paying for itself the barns would be approximately 30 years old.

All three parties involved with this grant will continue to look for another funding source that would assist in studying the next steps along with funding for the construction of a digester. The producers are also very interested in continuing to move forward.

Haxtun Swine Manure Digester Project
ACRE Feasibility Study

DETERMINING FEASIBILITY OF A CENTRALIZED HOG WASTE DIGESTER NEAR HAXTUN, COLORADO

Final Report to
Northeast Colorado Resource Conservation and Development

Submitted by:
Symbios Technologies and Stewart Environmental Consultants

November 1, 2010

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1. PROJECT OVERVIEW

1.1. Executive Summary

This feasibility study determined the renewable energy production quantity and project size, appropriate technology, and economic feasibility of a hog manure biogas facility near Haxtun, Colorado in Logan County east of Sterling. The key finding of this study is that a 283 kilowatt (kW) biogas electric generating power station is possible combining the manure from all three hog farms investigated, and that if the electricity is sold to Highline Electric Association for $0.06/kilowatt-hour (kWh), solid residuals are composted and sold for $7.50 per cubic yard, and liquid effluent from the digester is land-applied during eligible months at no net cost and stored in a covered storage basin during the winter months, and if 30% of the $4.2 million capital cost is paid with equity and the other 70% paid through grants, the project yields an internal rate of return (IRR) to equity of 14%.

However, if debt is used to fund the project, interest costs make the project IRR negative in all cases. Regardless of whether a biogas production facility is built in Logan County, the intent is that findings from this study could assist in the development of other agricultural- and food processing-based regional biogas facilities. The significant challenges encountered in this project, necessitating the high level of grants or other public funding necessary to move the project forward, are discussed in Section 3. In particular, participation by the farmers is necessary to manage costs and potential revenues related to liquid effluent use, composting of solids and subsequent sale, and permitting in order to make the project viable.

The U.S. Department of Agriculture's (USDA) Resource Conservation and Development (RC&D) program helps communities plan and carry out projects that increase natural resources conservation, support economic development, and enhance the local environment and standard of living. The RC&D program is administered by USDA's Natural Resources Conservation Service (NRCS). The Northeast Colorado Resource Conservation & Development (NCRC&D) Council commissioned this report, and has the support of key industry partners as well as regional economic development entities and government officials, including producers Tom Wernsman, Tom Bornhoft II, and Rick Wernsman; Logan County Commissioners; GE Energy; The Climate Trust; Colorado Carbon Fund; Colorado Livestock Association; a major equity investor; and Highline Electric Association.

1.2. Abstract

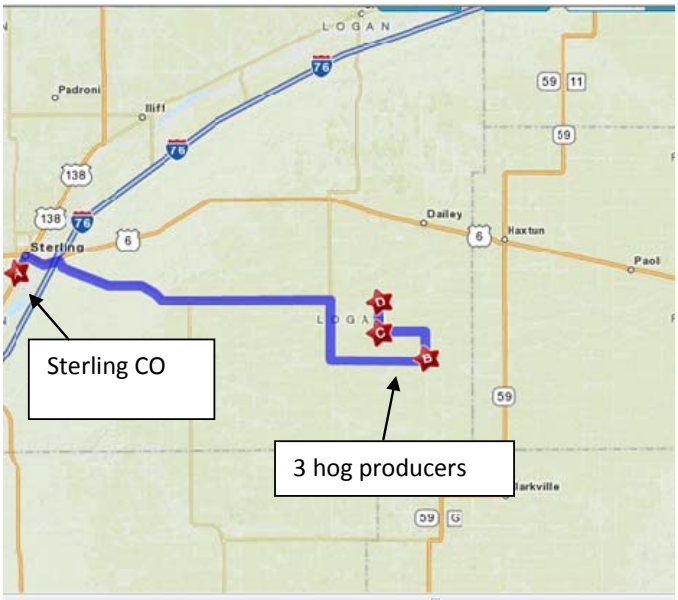
The objective of this study is to examine the feasibility of developing a regional anaerobic digester near Haxtun, Colorado to serve three significant hog feeding operations that supply Murphy-Brown, LLC, to utilize their manure to produce renewable energy and organic fertilizer. The digester would provide the collective operators with a waste management and renewable energy facility that can maintain itself financially, provide a consistent revenue stream, and provide primary and secondary rural employment. In addition to making a contribution to renewable energy, the anaerobic digester also would make a contribution to the low-carbon

economy through sustainable waste management, reduction of the uncontrolled emissions of methane, and through nutrient recycling via the replacement of fossil-fuel based fertilizers.

1.3. Project Description

The purpose of this project is to investigate the feasibility of developing the first waste-to-energy facility in Northeastern Colorado in order to reduce the carbon impacts, water pollution impacts, energy costs, and waste disposal costs of agribusiness in Logan County. There is a need for the farm economy of Logan County to prepare for climate change legislation and to assure that the impacts of such legislation, as well as increasing fossil fuel energy prices and increasingly strict water quality regulations, have a positive rather than a negative impact on agribusiness in the community. This proposal fulfills an urgent need to move a project forward in the best possible location and with the optimum project partners, infrastructure, and logistics in order to make a collaborative anaerobic digester project a reality for Northeastern Colorado. The project is important to the New Energy Economy of Colorado and to the economic growth and development of Logan County and Northeastern Colorado. It is believed that as many as 100 new jobs may be created during the construction period, with a number of those continuing into the operations phase as a result of this project. In addition, significant greenhouse gas reductions, improved water quality, organic fertilizer production, and renewable energy production and use are possible as a result of this project. This project will enable Northeast Colorado Resource Conservation & Development (NCRC&D) and the Colorado Department of Agriculture to:

- Examine the project thoroughly now, ahead of coming climate change legislation when carbon credits are expected to gain significant value.
- Establish project feasibility in time for American Recovery and Reinvestment Act (ARRA) funding to be available for the project (construction must start in 2010).
- Act now while partners are lined up and very interested in the project.
- Capitalize on a unique concentration of feedstocks and energy users.
- Examine this waste-to-energy project now when energy prices are low so the project is staged for construction as energy prices increase.



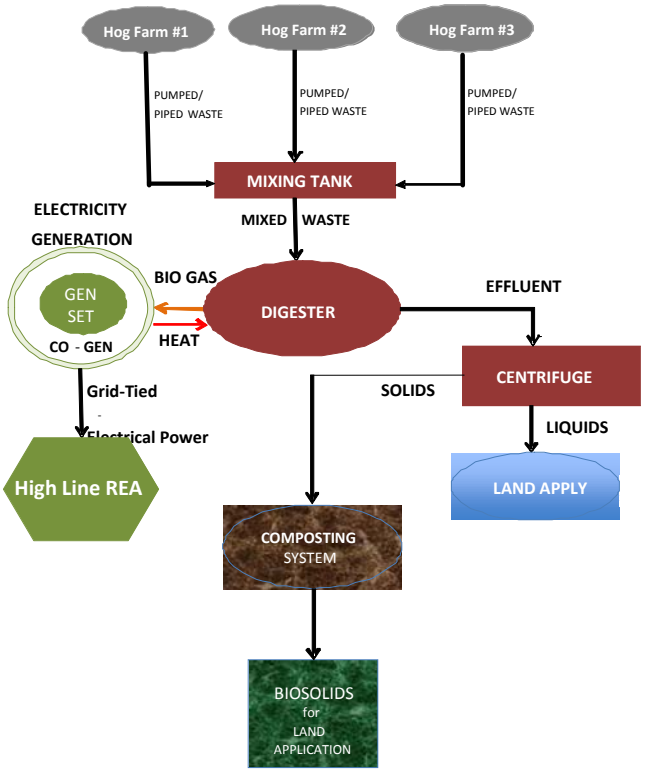
Electrical generation accounts for greater than 50 percent of total U.S. agriculture air emissions. Currently available renewable energy sources, such as wind and solar power, are expensive and unreliable for baseload power. Biogas can be generated from waste for use either as a natural gas substitute or for electrical power generation at more favorable economics than wind or solar power, and can provide reliable baseload power 24 hours a day.

In 2004, Colorado voters approved a referendum requiring that the state

source 10% of its electricity from renewable sources. In October of 2006, the state's largest utility, Xcel Energy, announced it would meet the 10 percent target by the end of 2007. Xcel's quick success reflects, in part, the abundance of solar power and wind in Colorado. Xcel, which serves 1.3 million customers in Colorado, is studying how it could attain a higher percentage of energy from renewable sources. An alternative that has not been investigated extensively in the Rocky Mountain region is the use of biogas. This feasibility study will examine all regionally relevant variables associated with using the waste products from large hog feeding operations as feedstocks for an energy-producing "community" anaerobic digester. The benefits from this project are not only quantitative in the form of energy production revenue, carbon credits, and rural economic development, but also qualitative in the form of increased environmental stewardship, decreased odors, and increased process efficiency. The proposed project site is on land in Logan County owned by one of the producers (see map above).

Symbios Technologies, Stewart Environmental Consultants, and NCRC&D have been developing this project since late 2009 and have worked with the producers, Highline Electric Association, and Colorado Livestock Association to establish interest and conduct the evaluation of the project. The producers are interested in providing waste feedstocks for the centralized digester as well as in using biogas or electricity from the project and solid and liquid fertilizers from the project on their farms. Symbios has identified private investors interested in providing equity funding and/or acting as owner/operator of the facility, and technology partners have been identified that could build the digester while American Recovery and Reinvestment Act (ARRA) funds are available.

Numerous hog manure digesters have been operated successfully in the U.S. Laboratory data and information from the scientific literature and the producers was used for developing the techno-economic model and conducting the first phase feasibility evaluation. The team has a plan to solve one of the most difficult hurdles of any digester project: an economically and environmentally feasible plan to dispose of digester effluent by using it as valuable nitrogen-, phosphorous-, and potassium rich fertilizer via land application on farmland in the area, with an alternative wetlands project that would provide natural treatment of the nutrient water. Symbios has completed a similar feasibility study previously, and applied its chemical engineering digester system model as well as its financial digester model



developed for the Greeley Clean Energy Park feasibility analysis funded by the Governor's Energy Office and other renewable energy project evaluation projects, in order to complete the Haxtun study.

This study evaluated the best business structure options. Project funding and ownership can be organized in many different ways in order to best serve the needs of the project stakeholders. One potential ownership model would be a joint venture between the developers, the financial partners, and the producers to build, own, and operate the plant.

The project evaluated in this study includes the following features (see provisional process flow diagram above).

- Digester to be located on one of the producer's sites.
- Pipe or truck hog manure to digester.
- Produce electricity or biogas.
- Provide electricity or biogas back to the producers or net meter to the grid.
- Store liquid effluent in retention ponds onsite that have sufficient capacity to store all effluent in between the periods in the spring and fall when land application of effluent would be acceptable, or treat the effluent in a wetlands project.
- Biosolids generated by the project will be composted onsite and sold.

2. KEY FINDINGS AND RECOMMENDATIONS

2.1. Engineering Summary

2.1.1. Waste Quantification

The USDA's *Agricultural Waste Management Field Handbook* Part 651, used to design agricultural waste treatment systems, was used as a reference for the solids composition and chemical makeup of swine manure in conjunction with the results of the three samples analyzed.

An additional factor considered is manure collection. A common process for gathering and storing swine waste is under slatted floors in tanks, which may be allowed to overflow into lagoons. With an anaerobic digestion system, spilled food and water can have a large effect on the solids content and the chemical makeup of the manure.

Waste Solids and Chemical Makeup

Table 1, below, is based on data from the *Agricultural Waste Management Field Handbook*. This data is representative for manure as excreted.

Table 1: Solids and Chemical Makeup of Swine Waste as Excreted

Component	Units	Sow				Boar	Nursery
		Grower	Gilt	Gestation	Lactation		Nursery Pigs
		40-220 lbs					0-40 lbs
Weight	lb/d/1000#	63.4	32.8	27.2	60	20.5	106
Volume	ft^3/d/1000#	1	0.53	0.44	0.96	0.33	1.7
Moisture	%	90	90	90.8	90	90.7	90
Total Solids	% w.b.	10%	10%	10%	10%	10%	10%
Total Solids	lb/d/1000#	6.34	3.28	2.5	6	1.9	10.6
Volatile Solids (VS)	lb/d/1000#	5.4	2.92	2.13	5.4	1.7	8.8
Fixed Solids (FS)	lb/d/1000#	0.94	0.36	0.37	0.6	0.3	1.8
Chemical Oxygen Demand (COD)	lb/d/1000#	6.06	3.12	2.37	5.73	1.37	9.8
Biochemical Oxygen Demand (5 day) (BOD_5)	lb/d/1000#	2.08	1.08	0.83	2	0.65	3.4
Nitrogen (N)	lb/d/1000#	0.42	0.24	0.19	0.47	0.15	0.6
Phosphorus (P)	lb/d/1000#	0.16	0.08	0.06	0.15	0.05	0.25
Potassium (K)	lb/d/1000#	0.22	0.13	0.12	0.3	0.1	0.35
Dissolved Solids (TDS)	lb/d/1000#	1.29					
C:N Ratio		7:1	7:1	6:1	6:1	8:1	8:1

Below is Table 2 containing data from the USDA's *Agricultural Waste Management Field Handbook* for manure from storage tanks under slats.

Table 2: Solids and Chemical Makeup of Swine Waste from Storage Tanks

Component	Units	Farrow	Nursery	Grow/ Finish	Breeding/ Gestation
Moisture	%	96.5	96	91	97
Total Solids	% w.b.	4%	4%	9%	3%
Volatile Solids (VS)	lb/d/1000gal	199.85	233.27	562.35	149.96
Fixed Solids (FS)	lb/d/1000gal	101.64	99.97	187.45	99.97
Nitrogen (N)	lb/d/1000gal	29.16	40.00	52.48	25.00
Ammonia (NH4-N)	lb/d/1000gal	23.32	33.32		
Phosphorus (P)	lb/d/1000gal	15.00	13.32	22.50	10.00
Potassium (K)	lb/d/1000gal	23.32	13.32	18.33	17.50
C:N Ratio	lb/d/1000gal	4:1	3:1	6:1	3:1

Solids

The main difference between the two tables, other than the sampling location, is the shear volume of waste per hog and the amount of solids. The manure from the storage tanks is considerably more diluted, likely due to water spilled or rain migrating into the basins. Prior to proceeding with a full-scale design of an anaerobic system, a series of samples should be taken from various pits to better determine the solids concentration. This is a critical point because the majority of the energy stored in the manure is in the volatile portion of the solids. The ideal solids concentration for anaerobic digestion is approximately 8 percent with greater than 70 percent of the solids being volatile. The more diluted the solution, the larger the system needs to be for the same amount of gas production, so the capital costs are driven up. As the solids increase above 8 percent, it becomes harder to pump and mix the digester.

According to the USDA, total solids are typically 10 percent as excreted from swine and can be as low as 3 percent when taken from storage tanks under slats. For the purpose of this report, the data from Mr. Wernsman's farm were used. The data from Mr. Tom Wernsman's farm samples showed solids range from 4 to 10.9 percent. Two of the samples reported had 8.6 percent solids with 70 percent volatile; the other sample reported 10.9 percent solids with 76 percent volatile. This variability in the sample data is expected given the characteristics of the manure slurry; both of these samples are consistent with the data report by the USDA.

Carbon to Nitrogen Ratio

The ideal carbon to nitrogen ratio for anaerobic digestion is approximately 30:1. Swine manure characteristically is high in nitrogen with a carbon to nitrogen ratio ranging from 6:1 to 8:1. Nitrogen is necessary in only sparing amounts for the growth of anaerobic bacteria. Even though swine manure has a high ratio of nitrogen in proportion to carbon, anaerobic digestion will work well if additional carbon sources are added to the anaerobic digestion system to aid the process. Nevertheless, it is imperative that excess nitrogen is consistently removed, either mechanically or chemically, from the system to prevent ammonia buildup in the digester. Excess nitrogen is passed through the process and discharged in the liquid effluent as ammonia (NH_4), which can be land-applied as a fertilizer.

Ammonia can become toxic to anaerobic systems at concentrations above 4,000 ppm of ammonia. To maintain a consistent level of nitrogen in the system the supernatant recycle will have to be carefully monitored and it is possible, but unlikely, that from time to time the digester may need to be diluted with some fresh water. What is more likely is that there will be a consistent amount of liquid effluent that will need to be disposed of through land application.

The laboratory data reports from samples taken at Mr. Wernsman's farm had a carbon to nitrogen ratio of 4:1 and 8:1, which is also comparable with data reported in the USDA handbook.

Volume Assumptions and Calculations

Volumetric data was used as reported by the farmers. Table 3, below, shows the assumptions used for the annual manure volume calculations.

Table 3: Assumptions of Annual Manure Volume

Number of producers	3
Buildings per site	4
Pits/building/site	4
Pit capacity (gal)	12,000
Settling tank capacity (gal)	50,000
No. times settling tank pumped per year	1
Times pits cleaned per year	26

Table 4, below, shows the calculation of the volume of manure available for digestion.

Table 4: Manure Available For Digestion

Volume of all pits	576,000	Gal
Volume of all settling tanks	150,000	Gal
Annual volume from pits	14,976,000	gal/year
Annual volume from settling tanks	150,000	gal/year
Annual manure volume	15,126,000	gal/year
Daily manure volume	41,030	gal/day

Swine manure contains a tremendous amount of energy and can easily be digested anaerobically to produce biogas, which is very similar to natural gas. Estimates received from the farmers show the three farms combined produce approximately 15 million gallons of manure on an annual basis, which translates into approximately 16 thousand Million British Thermal Units (MMBTUs) of energy per year.

Below, Table 5 shows assumptions used for the model to predict the amount of biogas and methane production available based on the volumetric data and chemical constituents listed above.

Table 5: Manure Production

Description	Amount	Units
Animals	11,520	Hogs
Volume of Manure	5,471	ft^3/day
Volatile Solids (VS)	9%	
Volatile Solids (lb/day)	29,542	
Volatile Solids destruction	50%	
Projected Gas Production	9.0	ft^3/lb of VS
Concentration of Methane	60.0%	

Based on the above assumptions, the projected gas and energy production is shown in the two tables below.

Table 6: Gas Production

Description	Amount	Units
Biogas	132,938	ft^3 biogas/day
Methane	79,763	ft^3 CH_4/day

Table 7: Energy Production

Description	Amount	Units
Electrical Generation	0.0245	kW/hog
Electrical power output	0.2826	MW

The tables below identify the projected plant inputs and outputs on an annual basis.

Table 8: Plant Input

Description	Amount	Units
Animals	11,520	Hogs
Mass of Manure	173	ton/day
Volume of Manure	5,471	ft^3/day
	28	gal/min
	41,030	gal/day
	14,976,000	gal/year
Nitrogen	1,504	lbs/day
Phosphorus	624	lbs/day
Potassium	743	lbs/day

Table 9: Plant Output

Description	Amount	Units
Biogas	132,938	ft^3 biogas/day
Methane	79,763	ft^3 CH_4/day
Methane	2	tons/day
Solids	10	ton/day
Fixed (inorganic)	3	ton/day
Organic	7	ton/day
Total Solids	17	yds/day
Liquids (re-use or discharge)	37,882	gal/day
Nitrogen (95%)	1,429	lbs/day
Phosphorus (95%)	593	lbs/day
Potassium (95%)	706	lbs/day

2.1.2. Anaerobic Digestion Technology

Anaerobic digesters are engineered containment vessels designed to exclude air and promote the growth of anaerobic bacteria. While there are many different configurations of anaerobic digesters, only two configurations are considered suitable for use with swine manure because of the high solids loading. The configurations considered suitable are plug flow and completely mixed systems.

Plug Flow Anaerobic Digester

Plug flow digesters are a very simple type of system to operate and maintain, so there is very little special training and oversight required to operate a plug flow digester. Given the simple operation, these systems are very well-suited for farm operation.

The feedstock flows through the digester in a large plug with very little mixing and exits after the waste has been stabilized. Plug flow systems are ideal for very high solids feedstock with a typical suspended solids concentration of 11 to 13 percent, such as manure. Additionally, manure contains a population of methanogens when it is excreted. This consortium of microorganisms provides a constant inoculum of anaerobic bacteria replacing the population that is steadily removed with the plug at the tail end of the digester. Since the solids flow through a plug, the methanogens are constantly being removed from the digester, and given the slow growth rate of methanogens, it is imperative that new methanogens are constantly reintroduced to maintain the process. This is why plug flow is so well-suited to manure digestion.

Completely Mixed Digesters

Swine manure, when excreted, is typically 10 percent suspended solids; however, after it is diluted while being gathered in the pits, the solids concentration is typically reduced to 4 to 5 percent, which makes the swine manure well-suited to completely mixed systems. The completely mixed system is more technologically advanced than a plug flow system and operates on a more dilute feed stream with a solids concentration of 3 to 10 percent suspended solids. Completely mixed systems provide the best solids digestion and, as a result, the best gas production. Because of the superior solids reduction, higher gas production, and ability to handle a varying feedstock, a completely mixed system will be best suited for the Haxtun swine manure application.

Typically, a complete mixed digester is either a steel or concrete tank located above or in the ground and can be either circular or rectangular in shape. For the purpose of this feasibility study, a 900,000 gallon above-ground rectangular concrete tank was specified for the digester. This provides a 22-day hydraulic retention time, which is typical for a mesophilic system. The digester will be fitted with four submersible mixers, a three-phase separator, and an emergency gas flare. The mixers will be used to maintain a completely mixed condition within the tank. The three-phase separator is used to separate gas, liquid, and solids. The gas will be recovered for use in the combined heat and power (CHP) unit for electrical power generation and heat recovery to maintain the temperature in the digester. There is no gas storage included in this proposal, so the CHP unit will be matched to the gas flow from the digester and in situations where excess gas is produced, the waste gas flare will be run. If gas storage is desired, an additional cost of $150K to $200K should be included in the capital costs. This will provide an above-ground, double-walled, low-pressure gas storage balloon.

Vendors

Given the density of population in Europe and the need to address waste stabilization in a space efficient fashion, anaerobic technology has been seen as a viable solution for the past few decades. Additionally, most European countries have offered preferential pricing for electricity generated with biogas, so this has made the economics very favorable for anaerobic digestion projects. As a result, there is a tremendous amount of experience in anaerobic digestion among European engineering firms, which supply leading anaerobic technology. Only recently the interest has flowed over to the United States with many of these European engineering firms forming partnerships or opening offices in the United States to promote their technology.

There are numerous anaerobic technology vendors with many different solutions; however, there are only a handful of technology providers that have been in business for more than a decade with several installations still operating. Many vendors supply a completely mixed system all with very subtle differences to set them apart from their competitors. All have experience in mixed feedstock digester systems, and all have successful systems currently operating. For the purpose of this project, all of the vendors listed below are considered leaders in the field of anaerobic technology, and all are capable of providing a digester technology that would work for the purpose of this project. There are three large international companies, which are considered leaders in the industry for completely mixed systems, including ADI, Biothane,

and Global Water and Energy. Combined, these companies have several thousands of wastewater and chemical process plant installations with several hundred anaerobic installations around the world. Any one of them is capable of supplying an excellent turnkey package.

The purpose of this report was to determine the feasibility of an anaerobic digester to process manure from the three Haxtun swine facilities, so rather than select a particular vendor, information was used from several different vendors to assemble the most representative model for a combined completely mixed anaerobic system to treat swine waste, including provide equipment and technology pricing information. Below is a list of vendors that supplied information for this report.

Plug Flow System Vendors

GHD
Chilton, Wisconsin

RCM Digesters
Berkeley, California

Completely Mixed System Vendors

ADI Systems, Inc.
Wolfeboro, New Hampshire

Biothane, LLC
Camden, New Jersey

Global Water & Energy
Austin, Texas 78758

2.1.3. Design Considerations

Facility Layout

The facility will require at least 3 acres and as much as 7 acres, depending upon solids composting and liquid effluent handling. The process will consist of several unit operations: receiving, anaerobic digester, solids separation and handling, and digestate handling.

Receiving

Feed stocks for the anaerobic digester will be swine waste from the three hog farms all located near Haxtun, Colorado within a 2-mile radius of each other. Two cost estimates were produced: one based on trucked waste, and the other based on pumping the waste. For both scenarios, it was assumed that the digester would be located on one of the three farms, so transportation and pumping costs were adjusted accordingly.

The feed stock is projected to be 41,000 gallons per day, which will require six to seven truck loads per day, or alternatively the manure can be pumped. Pumping may reduce the size of the influent storage tank required, since the manure can be pumped as needed. For the purpose of this study, pumping rate was not a factor and a fixed flow rate was used for pump sizing. When the detailed engineering is performed, this will need to be evaluated and precisely sized; however, this will have little to no effect on the capital costs. Pipeline costs were based on pumping the manure 2 miles from two farms to the third farm where the digester will be located. Underground pipeline installations in Northern Colorado cost between $5 to $9 per inch of pipe diameter and foot of installed length. For the purpose of this report a 10-inch diameter pipe for 4 miles at a value of $5 per inch-foot was used; however, this can vary depending upon the complexity of the installation and the level of ground water in the area.

All manure will arrive to an influent holding tank where it will be fed at a steady state into the digester by one of two redundant chopper pumps both controlled by variable frequency drives (VFDs).

The level of the digester at the pump station will be monitored electronically. For the trucked system, the level will need to be controlled by the truckers and operators, while for the pumped system the influent pump station level will be controlled electronically based on the pumping feed rate from all three farms.

Anaerobic Digester

The digester design used for this analysis is a completely mixed mesophilic anaerobic digester with a 20-day hydraulic retention (HRT) time and consisting of a 900,000-gallon above-ground insulated concrete tank. The system will be heated by waste heat from the CHP engine that is included in the proposal and operate with biogas produced by the digester. The CHP will produce 283 kilowatt hours (kWh) of electrical energy and 346 kWh of thermal energy. This will maintain an operating temperature of approximately 36 degrees Celsius (98 degrees Fahrenheit), which is in the mesophilic temperature range. The digester will be supplied with four submersible mixers to maintain a completely mixed system. A three-phase separator has also been included in the digester budget to provide separation of gas, solids, and liquids. This is important in a completely mixed system as the retention of anaerobic microbes is critical to the healthy operation of the system. There will be limited gas storage, approximately 50,000 gallons, in the digester head; this will be enough for buffering and constant operation of the CHP. The gas space of the digester will be coated with a corrosion-resistant epoxy coating to prevent concrete corrosion from hydrogen sulfide gas. Finally, solids will be removed on a regular basis with a pump operated periodically to pump solids to a centrifuge, which is included in the cost estimate for dewatering solids.

Solids Separation

The centrifuge will be housed in an odor-controlled area of the building with a truck loading bay. The centrifuge is sized so that it can be operated two to three days a week and provide enough solids removal for consistent operation of the digester. The anticipated amount of solids is 10 tons a day at 22 percent dry solids. These solids will not be completely stabilized,

but can be directly land applied to one of the farms or further composting will be necessary to stabilize the solids for sale outside of the three farms participating in the digester project. The system will be designed with a truck loading area for solids loading and transport to land application or a further composting area.

Digestate Treatment

The liquid effluent will still contain high levels of organic pollutants and cannot be discharged directly to any water shed. Given the high nutrient content of this liquid effluent, it will make a good liquid fertilizer product with an estimated nitrogen-to-phosphorus-to-potassium ratio of 2.5:1:1.2. This nutrient ratio is based upon estimates made from chemical concentration data for swine manure from USDA's documentation. For complete verification, a pilot test could be run to explicitly determine the exact chemical makeup of the effluent.

There are several possibilities for treatment and disposal of the nutrient-rich liquid effluent:

1. It can be treated for discharge or reuse;
2. It can be filtered to reduce the volume and concentrate the nutrients creating a high-strength fertilizer; or
3. It can be land-applied with no further treatment.

Any further treatment will require an investment of capital, which will likely be difficult to recover. Typically, the best use of the effluent is to land-apply the liquid as it is discharged either with tanker trucks or through a central pivot system. For the purpose of this model, land application via a tanker truck at a cost of $15 per 1,000 gallons applied was used. However, a central pivot application system should be significantly more cost efficient over trucking. Typically, a land application permit from the state will be required. The cost for permitting has not been included in this study since it is unknown if there will be one or several sites requiring permitting. The cost of the permitting process can range from $4,000 to $25,000 depending on the amount of sampling required and the complexity of the permit application based on the site. Additionally, the permitting process can take 180 days. In negotiating and planning for a future project, permitting should be included in the final package to control costs and ensure a successful project.

There was no cash value given to the nutrient-rich water, so there is a potential to sell this liquid and recover some of those costs, which would improve project economics.

For the purpose of this study, a rudimentary unlined effluent lagoon with a six-month storage capacity of approximately 7.5 million gallons was included. This can be used to hold the effluent during the winter when the ground is frozen and the effluent can not be discharged

2.1.4. System Costs

Capital Costs

Two capital models were created for this model; one for a trucked system, and one for a pumped system. The basic process is the same for both systems with the feedstock transport being the only real difference.

Table 10: Trucked Effluent

Description	Construction Cost
Building	$ 735,569
Influent Pump Station	$ 225,637
Anaerobic Digester	$ 1,092,482
Transportation of Feed Stock	$ 108,000
Effluent Storage Basins	$ 671,402
Subtotal	***$ 2,833,090***
Contingency (10%)	$ 283,309
Estimated TOTAL Capital Costs	**$ 3,116,399**

Table 11: Pumped Effluent

Description	Construction Cost
Building	$ 735,569
Influent Pump Station	$ 225,637
Anaerobic Digester	$ 1,092,482
Lift Stations and Piping	$ 1,119,000
Effluent Storage Basins	$ 671,402
Subtotal	***$ 3,844,090***
Contingency (10%)	$ 384,409
Estimated TOTAL Capital Costs	**$ 4,228,499**

Below is a table showing the assumptions and costs for the piping installation.

Table 12: Piping Installation

Description	Qty	Unit	Amount	Total
Lift Station Costs				
Lift Station	3	ea.	$10,000	$30,000
Excavation	3	ea.	$ 6,000	$18,000
Pumps/piping	3	ea.	$ 5,000	$15,000
Pipe Line				
Length of Pipe	4	Miles		
Pipe Diameter	10	Inch		
Cost pipe installed	5	$/foot/in dia		$1,056,000
Total Capital Costs				**$1,119,000**

For trucking system a capital cost for three trucks at $30,000/ea was added to the budget.

The capital costs for the pumped system are approximately $400,000 higher; however, the operational costs are $87,000 less per year. Based on this the payback for the pumped system will be between four and five years.

Operational Costs

Below are two tables showing the weekly operational costs for the pumped and trucked systems, respectively.

Table 13: Pumped System Weekly Operating Costs

Description	Qty		Amt	Unit	$/Unit	Total
Operators	1.5		40	hours/week	$ 30.00	$1,800.00
Electrical			168	hours/week		
Chopper Pumps	5	hp	626	kWh/week	$ 0.07	$ 41.93
Mixers	10	hp	1252	kWh/week	$ 0.07	$ 87.61
Circulation Pumps	10	hp	1252	kWh/week	$ 0.07	$ 87.61
Centrifuge	20	hp	596	kWh/week	$ 0.07	$ 41.72
Controls & Lighting	12	hp	125	kWh/week	$ 0.07	$ 8.75
Pumping Costs						$1,239.94
Chemicals				weekly	$ 100.00	$ 100.00
Lab Testing				weekly	$ 100.00	$ 100.00
Total Weekly Operational Costs						**$3,507.56**

Table 14: Trucked System Weekly Operating Costs

Description	Qty		Amount		$/Unit	Total
Operators	1.5		40	hours/week	$ 30.00	$1,800.00
Electrical			168	hours/week		
Chopper Pumps	5	hp	626	kWh/week	$ 0.07	$ 41.93
Mixers	20	hp	2,503	kWh/week	$ 0.07	$ 175.22
Circulation Pumps	20	hp	2,503	kWh/week	$ 0.07	$ 175.22
Centrifuge	20	hp	2,503	kWh/week	$ 0.07	$ 175.22
Controls & Lighting	1	hp	125	kWh/week	$ 0.07	$ 8.75
Transportation						$5,692.87
Chemicals				weekly	$ 100.00	$ 100.00
Lab Testing				weekly	$ 100.00	$ 100.00
Total Weekly Operational Costs						**$8,269.21**

2.1.5. Conclusions

Typical swine manure is high in nitrogen, so it is very important that the biogas process is designed to prevent a toxic build-up of ammonia in the system as this can inhibit gas production, solids digestion and in extreme cases even cause the digester to upset. The toxic buildup of ammonia can easily be prevented if the system is well-designed with the proper process controls in place such as precise dilution, nutrient removal, and balanced supernatant recycling.

Supernatant recycling will retain a large amount of the alkalinity in the system, which is very important for the healthy operation of the system. Anaerobic bacteria grow within a very tight pH range, so buffering is very important to prevent pH swings, which can easily kill methanogenic microorganisms. However, supernatant recycling can lead to a buildup of ammonia in the system, so this needs to be carefully considered.

The model used for this study was based on a typical completely mixed anaerobic digester. Rather than selecting a particular vendor and using their equipment, we used costs and information from several vendors, as well as local construction costs to estimate the costs for installing this system. We purposefully used conservative costs for this proposal rather than provide a very tightly designed system with a narrow operating range and a low price that may not be reproducible when the final engineering is done. Based on the fact that this is a very conservative estimate, we feel that there is potential for a 10 to 20 percent savings from the projected cost, during the detailed engineering phase. As an example, if the digester is very conservatively designed, there may be a significant cost savings by using lined steel tanks as opposed to pour in place concrete tanks. Additionally, there may be equipment on the farms that can be used as part of the process to provide buffering. Stewart Environmental has the in-house

expertise to refine this design and minimize the capital costs while providing a system that is capable of safe efficient operation.

Swine manure is well-suited to anaerobic digestion and will provide a long-term energy supply for a low cost provided the system is well thought out and properly designed. It can be hard, if not impossible, to recover from early design flaws, which can effect the system cost and operation dramatically. The system laid out in this feasibility study will be robust and relatively simple to operate, so it is well-suited to on-farm operation; however, there is a tremendous amount of design work that needs to be done before a system can be installed with a high probability of long term successful operation. It is our opinion that the process is technically feasible as noted. It is our recommendation that this potential operation be more thoroughly analyzed under a Phase 2 feasibility study and that a business plan be commissioned to explore the economics in further detail.

2.2. Carbon Market Benefits

The Haxtun project has the potential to provide carbon market benefits to participating partners. Generally, the types of benefits able to be realized depend on two factors. The first is the end use of the energy produced by the project, and the second is the type of greenhouse gas (GHG) regulation in place. Understanding these benefits within the context of possible greenhouse gas regulation is important for partners. Given current market conditions and government regulation, the only potential benefit that has been identified is the creation of a revenue stream from the sale of carbon credits.

2.2.1. Overview of Carbon Markets

Carbon markets are being developed around the world as a means to allay concerns over environmental, and ultimately societal, costs of global climate change. The goal of carbon markets is to create an incentive for the reduction of GHGs by putting a price on the emissions of these gases, such as carbon dioxide or methane. Essentially, carbon markets are an attempt to internalize the otherwise external costs to society of GHG emissions.

These markets function by trading either allowances or carbon credits. Allowances, which are also called pollution permits, are distributed to regulated emitters by governments or other regulatory bodies and act as tradable currency for emitters to reach their emissions restrictions under cap-and-trade systems. Carbon credits are tradable securities created by projects outside of cap-and-trade systems that either reduce or sequester GHG emissions. Both allowances and credits are measured as one metric ton of GHG emissions, and standardized to a carbon dioxide equivalent, or CO_{2e}. For example, methane, or CH_4, is considered 21 times more powerful than carbon dioxide; therefore, one metric ton of methane equals 21 metric tons of CO_2e. The forms of these markets fall into two general categories: allowances are traded in cap-and-trade regimes, also called emissions trading markets, while credits are traded on carbon credit markets.

Cap-and-trade regimes are characterized by GHG emission targets for regulated emitters, which most current policy options limiting regulation to entities emitting over 25,000 metric tons

of CO_2e per year. Regulated entities are given an allowance that limits the amount GHGs they can emit. If they emit below their limit they are allowed to sell those unused allowances to others whose emissions exceed their allowed limit. If they emit above their limit they can either purchase unused allowances from other regulated entities and/or carbon credits generated from projects outside the scope of the cap-and-trade system.

Entities regulated in a cap-and-trade system have three main options to ensure they do not surpass their GHG emissions limit. First, they can abate, or reduce, emissions, via a number of avenues that include switching to less GHG-intensive fuels. Second, they can reduce production output. Third, they can purchase unused allowances from other regulated entities, and/or carbon credits generated from projects outside the scope of the cap-and-trade system.

Carbon credit systems are based on projects that reduce the amount of GHGs emitted from "business-as-usual", or normal, activities. Depending on the type of market, these credits can be used in a number of ways. First, they can be bought by individuals and businesses to voluntarily meet their own emissions reduction goals. Second, they can be sold to entities that are regulated, or "capped", in a cap-and-trade system to meet their emissions targets. Third, they can be saved by the project implementer to meet their own GHG emissions goals or sold at a later date.

Another aspect of carbon markets has been the rapidly growing trend in the business community to estimate the GHG emissions associated with a company's business activities. This is usually called corporate GHG accounting, and measures a company's "carbon footprint". The process entails measuring a company's direct GHG emissions, such as from fuel combusted at their facilities. However, they also measure GHG emissions associated with their electricity consumption and parts of their supply chain, such as product distribution.

2.2.2. Carbon Credit Revenue Stream

Currently, there is no cap-and-trade system or other regulation that would not permit the Haxtun project farmers from generating carbon credits. For the Haxtun project, the only way for carbon credits to be generated would be to substitute the biogas generated by the project for current fossil fuel consumption. The most likely scenario is that the biogas could be substituted for natural gas on the farms. However, biogas can also be used in natural gas vehicles, as well.

The estimated amount of carbon credits that could be generated annually is about 6,000 metric tons of CO_2e. The sale of these credits could bring in revenues up to about $30,000 annually for five to 10 years. To estimate the carbon credit generation potential of the Haxtun project, the "Livestock Project Protocol: Capturing and Destroying Methane from Manure Management Systems Version 2.2" from the Climate Action Reserve was used.

Given the multi-partner aspect of Haxtun project one issue with a carbon credit project would be ownership rights of the credits that are generated. Ownership rights can be given to anyone of the partners involved in Haxtun project, or to the project financier if the financier is not one of the partners.

2.2.3. Disincentives

The partners need to be aware that given the current lack of GHG regulation at the federal and state level, that there is currently a disincentive for them to implement clean energy projects. Most types of regulation will encourage regulated entities to reduce their emissions from the entity's established emissions baseline. Therefore, until an entity is regulated there is an incentive to be "dirty", so that when they are regulated their baseline emissions level is high. However, there very well may be "early-action" benefits to entities that pursue GHG reduction activities before regulation is in place.

There is also a disincentive related to carbon credit generation. Carbon credits that are approved to be sold into a cap-and-trade system will generally be able to demand a higher price than credits sold in voluntary markets. Therefore, it may prove to be in the partner's best interest to wait until a cap-and-trade system is implemented to pursue carbon credit projects. However, carbon credits that are generated before the establishment of a cap-and-trade system that are accredited by certain carbon credit standards have a good possibility of being allowed into the system.

2.3. Financial Summary

2.3.1. Attributes of Economic Model

Financial Model Scenarios Evaluated

A financial model was created to determine project revenues, costs, and financial metrics and to evaluate different financing scenarios to help determine the most optimal project design and mix of funding sources for the proposed project. This included scenarios, for example, that considered the production and use of biogas as the final energy fuel, versus using biogas to produce electricity. Reasonable efforts were taken to support the assumptions employed in the financial model and these assumptions were based on the best information available as of the date of this report.

Project Capitalization and Critical Assumptions

The project's capitalization will likely include a combination of equity, public financing, and debt (whether in the form of public bonds or bank debt). The exact mix among these components will be determined by a number of variables beyond the purview of this report. However, the base case evaluated in this report makes a core assumption that a joint venture of the three swine farmers that generate the waste or an as yet unidentified private investor can serve as the project owner and consider funding anywhere from 10% to 30% of the capital expenditures required by the project. Several scenarios were evaluated (see Appendix A for the list of the initial set of scenarios) to determine this range of equity. Thus, additional project capitalization scenarios were modeled to evaluate their feasibility.

For purposes of this report, "Equity" refers to a monetary investment by the owner of the project. The ability of the project to generate a profitable return will be of importance to the

project and will most likely be the primary motivation of a third-party investor or equity partner. This equity partner will evaluate the equity required, term to payback, and Internal Rate of Return (IRR) of the respective scenarios to determine the most favorable project capitalization mix and its total equity commitment.

For purposes of this report, "Public Financing" includes all bond issues, tax increment financing, treasury direct payments, and other publicly issued finance programs, including grants, whether they are originated by the Cities of Sterling or Haxtun or a county, state or federal government agency or carbon financing entity. However, for modeling purposes, no interest or payback timeline was assumed for any public financing components. **The exact character of funds from Public Financing sources may be materially different from the assumptions herein. This could materially affect the forecasted results presented herein.**

For purposes of this report, "Debt" refers to all loans with a corresponding interest rate whereby the entity owning the project would be deemed the borrower. Given the current condition of the credit markets, each scenario evaluated herein assumes that no bank debt will be available. **The availability of Debt for the project could materially affect the forecasted results presented herein.**

It should be noted that a total of 32 initial scenarios were evaluated with the following primary variables:

- **Equity** of either 30% or 100% of total project costs.
- **Debt** of either 70% or 0% of total project costs.
- **Producing** either electricity or gas.
- **Residual solids** are either sold or not sold.
- **Transportation** of feed stock is either pumped or trucked to the digester site.
- **Effluent water** is either land applied by a truck or a pivot.

Regardless of the variables above chosen for a given scenario analysis, the following assumptions remained static throughout all scenario evaluations:

- U.S. Treasury Direct Payments equal to approximately 30% of the total qualifying project costs are paid to the project within 60 days of commissioning of the project.
    - It is further assumed that qualifying project costs are equal to the total project costs.
    - All treasury direct payments are distributed to the project's ownership.
- Operating days per calendar year: 360.
- Tipping fees paid: $0.00.
- No effluent treatment was considered as the effluent is expected to be land applied at zero cost.
- Organic residuals revenue: $7.50 per cubic yard; 17 cubic yards produced per day.
- No renewable energy credits were assumed to be sold as they are not currently offered by the local rural electric association, Highline Electric Association.
- Electricity sale price: $0.06 per kWh (only available if gas is not produced).
- Gas sale price: $5.00 per MMBTU (only available if electricity is not produced).

- Inflation factor: 3.00% per year.
- Annual interest rate used in debt scenarios: 6.5%.
- IRR is calculated using Years 1-20 of cash flows and assumes no project sale.

In consideration of all of the comments above, the results of the 32 scenarios were evaluated and one of the scenarios (Scenario 15 in Appendix A) was chosen as the base case scenario (see below for description) as it was the only scenario that resulted in any significant cumulative net cash flow from operations over the 20 year life of the project. This report then evaluated three additional sub-scenarios (Scenarios 2-4 below) using all of the same assumptions with adjustments to the project capitalization mix. The project capitalization mixes for these four scenarios, each of which assumes (a) electricity is produced; (b) residual solids are sold; (c) feedstocks are piped to the digester site; and (d) effluent water is land-applied through a pivot, are as follows:

- **Base case scenario** – 100% of project costs are funded by an equity source; debt and public financing are assumed to fund 0% of the project costs.
- **Scenario 2** – 30% of project costs are funded by an equity source; 70% of project costs are funded through public financing; and 0% of project costs are funded by debt.
- **Scenario 3** – 10% of project costs are funded by an equity source; 70% of project costs are funded through public financing; and 20% of project costs are funded by debt.
- **Scenario 4** – 10% of project costs are funded by an equity source; 90% of project costs are funded through public financing; and 0% of project costs are funded by debt.

Below are key results of each of the scenarios:

							Year 3				
Scenario #	IRR	Equity $	Debt $	Grants $	Total Project Costs	Cumulative Net Cash Flow from Operations	Revenues	Op Ex	EBITDA	Cash Flow	Cash on Cash Yield
Base Case	-13.39%	$4,228,499	$ -	$ -	$ 4,228,499	$ 1,727,676	$ 204,021	$184,640	$19,381	$ 19,381	0.46%
2	14.11%	$1,268,550	$ -	$2,959,949	$ 4,228,499	$ 1,727,676	$ 204,021	$184,640	$19,381	$ 19,381	1.53%
3	-39.12%	$ 422,850	$ 845,700	$2,959,949	$ 4,228,499	$ (775,983)	$ 204,021	$184,640	$19,381	$ (43,629)	-10.32%
4	219.70%	$ 422,850	$ -	$3,805,649	$ 4,228,499	$ 1,727,676	$ 204,021	$184,640	$19,381	$ 19,381	4.58%

2.3.2. Summary

The two most profitable scenarios above are scenarios 2 and 4. However, these scenarios both assume that significant grant funding is available (see partial list of available grants below). The award of enough grant funding to fund the project to the extent required in the scenarios above is highly speculative given the uncertainty as to whether grant funding will continue after the November 2010 mid-term elections. However, the goal of this feasibility study was to determine if (a) a project is financially feasible and (b) under what conditions said project is financially feasible. Based on the financial modeling performed, subject to the assumptions noted throughout this section, at least two scenarios exist under which this project is financially feasible. In later phases of the project, additional scenarios would be explored based on then-current market conditions in order to determine whether a project can be funded.

2.3.3. Availability of Public Funding Options

There are several public financing options available to this project given the cooperation of private, for-profit entities and public entities in the development of this project. While detailed evaluation of the different mechanisms and programs available to provide funding for this project are beyond the scope of this report, there are several notable agencies and programs which may provide funding in the future. A partial list of these programs appears below:

- American Recovery and Reinvestment Act of 2009 (ARRA);
- U.S. Department of Energy (DOE);
- Colorado Governor's Energy Office (GEO);
- U.S. Department of Agriculture (USDA);
- Tax Increment Financing district (TIF) funding;
- Build America Bonds;
- Qualified Energy Conservation Bonds;
- New Clean Renewable Energy Bonds; and
- Private Activity Bonds.

3. PROBLEMS ENCOUNTERED AND MITIGATING CIRCUMSTANCES

Many groups have invested significant time and resources into attempting to develop commercial-scale anaerobic digester projects for energy generation in Colorado over the past several years in various locations, and all have failed or decided not to proceed with their projects, including prominent, large food processing companies and municipalities. The reasons for this lack of success include feedstock transportation costs, liquid effluent treatment or land application costs, technological limitations, lack of available financing, low electricity and gas prices in Colorado, and lack of regulatory support or state and local incentives. A few of these problems and their possible solutions specific to this project are discussed here.

3.1. Manure Transportation Costs

Two scenarios for manure transportation were modeled for this report. One entailed trucking the manure from two of the farms to a central digester on the third farm. The cost of the trucking was greater than the revenues that result from sale of the electricity and compost from the project, and thus when taken with digester operating costs, led to severely negative IRRs in all scenarios. Thus, pumping of manure via pipes was modeled as an alternative to trucking. Despite high capital cost of building more than four miles of pipelines between farms, this solution yields positive IRRs in the case of no debt being used to finance the project and if there is no cost to land-apply the effluent (other than covered storage lagoon capital cost), as discussed in Section 2.3.1.

3.2. Digestate Land Application Costs

The completion of this feasibility study was delayed for a number of weeks by the challenge of modeling liquid effluent treatment. As discussed in Section 2.1.3. under "Digestate Treatment," the handling of the liquid digestate effluent from the digester is non-trivial, and

likely represents a cost center. Although there is a possibility to generate revenue from the nutrient-rich digestate, there are sufficient regulatory and logistical unknowns to this scenario that Stewart Environmental Consultants advised taking a conservative approach rather than assuming revenues would be generated from the liquids as fertilizer.

The liquid effluent will still contain high levels of organic pollutants and cannot be discharged directly to any water shed. Given the high nutrient content of this liquid effluent, it will make a good liquid fertilizer product with an estimated nitrogen-to-phosphorus-to-potassium ratio of 2.5:1:1.2. There are several possibilities for treatment and disposal of the nutrient-rich liquid effluent, including building a wastewater treatment facility onsite and treating the effluent for discharge to the watershed or reuse, filtering and concentrating to create a high-strength fertilizer, or land-applying with no further treatment. The first two scenarios would require significant investment of capital and are considered to be prohibitive for a project of this size. Typically, the best use of the effluent is to land-apply the liquid as it is discharged either with tanker trucks or through a central pivot system. For the purpose of this model, land application via tanker trucks at a cost of $15 per 1,000 gallons applied was initially used in the model, as discussed in Section 2.1.3. This scenario resulted in more than $200,000 per year of operating cost just for the land application, exceeding the electricity revenue from the project and resulting in severely negative IRRs in the financial model. However, a central pivot application system should be significantly more cost efficient over trucking. Typically, a land application permit from the state will be required. The cost for permitting has not been included in this study since it is unknown if there will be one or several sites requiring permitting. The cost of the permitting process can range from $4,000 to $25,000 depending on the amount of sampling required and the complexity of the permit application based on the site. Additionally, the permitting process can take 180 days. In negotiating and planning for a future project, permitting should be included in the final package to control costs and ensure a successful project. Approximately 2,000 acres under pivot irrigation would be needed to land-apply the effluent from this project.

Since all of the farmland cultivated by the three producers is dryland, pivot application would require transportation of the effluent to nearby farms under irrigation. Thus, the possibility was discussed of using a sprayer to apply the effluent to the producers' own farms at their own cost, to recover the nutrient value on their farms. The possibility was also discussed of using the producers' existing storage lagoons for wintertime storage of the effluent, when it cannot be land applied. In this case, additional piping cost would need to be included since manure would be piped one way from two of the farms, and digestate piped back for lagoon storage and land application on that farm. Although these solutions hold promise, additional diligence would need to be conducted regarding state and local permitting, including the producers' well permits that restrict land application of liquid from the settling ponds. If the effluent in the lagoons was re-classified as fertilizer, these permitting issues may be mitigated. Odor issues would need to be taken into consideration in the permitting diligence, and it would need to be assured that application of the liquid was done in the appropriate months in order to not violate Amendment 14 to the State Constitution, which prohibits application of hog manure liquids in the winter. Approximately 8,000 acres of dryland farmland would be needed to land apply the digestate, which could mostly be provided by the three producers.

3.3. Windrow Composting

Composting of the solid residuals from the digester would be necessary in order to reduce pathogens in the solids sufficiently to achieve the $7.50/cubic yard (approximately $15/ton) revenues from the solids that were modeled for this report. There are two possibilities for composting: 1) installing composting equipment, or 2) composting the solids in windrows on the producers' land. The second option is recommended due to the capital and operating costs involved in installing a composter. Although the demand and price points were confirmed via discussions with producers, further study of this option, as well as establishment of sufficient markets for the compost, is necessary. Stewart Environmental estimates that three weeks to one month (1-2 weeks more in winter) would be necessary to complete the composting process, and a minimum of 45 to 60 days' worth of storage for the compost would need to be added. The hog manure compost may be higher in value vs. cattle manure compost, due to its higher level of nitrogen. To verify this, a solids nutrient profile would need to be established via laboratory analysis.

3.4. Pig Mortality

The producers indicated that they would be interested in including their mortality as feed stock for the digester. Currently, pig mortalities are buried in pits on-farm. However, changes in regulation by the Colorado Department of Health and Environment (CDPHE) are expected by the producers, which would require them to incur expense to have rendering companies take the mortality for offsite processing rather than burying them onsite. Thus, there is motivation to investigate the possibility of grinding the mortalities and feeding them into the digester for conversion into biogas and usable nutrients. This option could provide a financial advantage to the producers, but would need further diligence regarding permitting, land application regulatory issues, costs of installing a hopper and grinder, and determining if bones would break down sufficiently in the process.

3.5. Low Electricity Revenues

None of the scenarios modeled where biogas from the digester was sold directly yielded positive IRRs, due to low gas sale values, so installation of a CHP (combined heat and power generation unit) is recommended despite the additional capital cost. Highline Electric Association management indicated that they would purchase electricity from this project at between $0.05 and $0.06 per kilowatt-hour (kWh). For purposes of this study, $0.06 was used, which is a comparatively low electric rate that inhibits project feasibility. Although management indicated that HEA does purchase Renewable Energy Certificates (RECs) at various times for renewable electricity production, they indicated at this time that it would be unlikely they would purchase RECs from this project. If a higher electric rate, and/or the purchase of RECs could be negotiated with HEA, the economics of this project would improve significantly, as the electricity revenue is a key driver in the calculation of key financial metrics including IRR and cash-on-cash return. Therefore, it is recommended that discussions continue with HEA to obtain improved pricing for the renewable electricity, as this project would improve the sustainability profile of HEA's power portfolio.

3.6. Need for Public Funding

As discussed in Section 2.3, of the 35 scenarios modeled for this study, only two produce positive returns. No scenario evaluated that includes debt financing as a component of the project capitalization structure was found to be feasible, as all scenarios that included interest expense had negative IRRs. The two scenarios that produced positive IRRs both included only equity and public funding in their capitalization mixes. Of the total $4.2 million estimated project capital costs, one scenario would require $3.0 million in grants or other public funding and the other would require $3.8 million in grants or other public funding. Therefore, if investigation of the other issues summarized in this section such as permitting, land application of the digestate, and composting proves them to be feasible, it is the recommendation of this report that funding be pursued from the Governor's Energy Office, USDA, DOE, and other sources in order to obtain this needed public funding of between $3.0 and $3.8 million. If project capital costs can be reduced e.g. via use of the producers' existing lagoons, these amounts may be able to be reduced.

3.7. Walmart as a Driver

Walmart has announced an initiative to encourage all of its suppliers to account for their carbon emissions and implement sustainability improvements. All three feedlots evaluated in this study are custom feedlots for Murphy-Brown, LLC, a subsidiary of Smithfield Foods, Inc. the world's largest producer and processor of pork. Since 70% of the pork sold at Walmart originates from Smithfield Foods, it is possible that this project could be viewed favorably by Smithfield and Murphy-Brown as a supplier to Walmart, as part of an effort to reduce its corporate greenhouse gas emissions, since this project would reduce Murphy-Brown's supply chain and pork product life cycle emissions. This may provide the producers with an advantage in future contract negotiations with Murphy-Brown.

3.8. Conclusions

In order to move this project to the execution stage, a number of challenges would need to be overcome, as well as opportunities for mitigating circumstances pursued and exploited. Some of these problems and mitigating opportunities are listed below. A Phase 2 study or more detailed evaluation of digestate application costs and permitting issues would need to be completed with participation of the producers in order to proceed. In addition, project economics would improve if RECs could be sold to Highline Electric Association. Even with these improvements, significant public (non-interest bearing and non-dilutive) funding such as grants would be necessary to complete a profitable project. **It is a key finding of this report that a partnership with the producers, and using their equipment and land to handle solids and liquids and recover their nutrients to extract greatest value, will greatly increase chances of project success.**

The following will require further investigation and action in order to pursue a commercial project:

- Manure transportation costs.
- Effluent treatment/land application costs.

    - Dryland application through a sprayer.
    - Pivot application would need other farmers.
    - Wetlands project may mitigate costs.
- Well permitting issues and other permitting.
- Composting costs and logistics.
- Need to add costs of hopper and grinder for pig mortality and conduct further diligence.
- Low electricity revenues need to be mitigated.
- Interest expense is prohibitive; need a $3MM to $3.8MM in grants to be feasible.
- Need to identify $425K to $1.3MM equity financing.

4. RECOMMENDED NEXT STEPS

Next steps to be taken based on findings and recommendations from completion of the project include:

4.1 Detailed study of dryland application of effluent, pivot irrigation, or possible wetlands project on Tom Bornhoft II's land. Included in this should be investigation of whether existing lagoons on each farm could be used for liquid effluent storage, which would reduce the excavation and other lagoon construction costs included in the modeling for this report.
4.2 Investigation of windrow composting and sale of the organic residuals.
4.3 Permitting requirements definition.
4.4 Negotiation with HEA for higher electric rates and/or RECs.
4.5 Pursue grants and equity funds from a number of sources.
    4.5.1 USDA and other grants, with the help of NCRC&D.
    4.5.2 DOE grants, including GEO ARRA funding scheduled for release in 2010.
    4.5.3 Contact local, regional, and national investors.
4.6 Design and engineering.
4.7 Project construction and commissioning.

5. NOTABLE ACCOMPLISHMENTS

Key accomplishments of this feasibility study include obtaining cooperation from three swine producers interested in moving a project forward, and then determining that a 283 kW power station creating electricity from swine waste is feasible in the case of up to 30% of project capital costs being funded by equity and the remainder funded by grants or other public funding. In addition, it was determined that if composted in windrows, the solid residuals from the digestion process would be valuable and able to be sold as fertilizer for farms. Third, solutions for extracting value from the liquid effluent include land application either in dryland or irrigated scenarios, possibly using existing large lagoons on each farm for storage, assuming regulatory and permitting barriers could be overcome. Finally, Highline Electric Association indicated willingness to purchase the renewable electricity generated by the project.

6. ACCOUNTING OF PROJECT EXPENDITURES

This $50,000 study was funded by a $25,000 grant from the ACRE program and $25,000 in cost share from Symbios Technologies. Project expenses included contract engineering fees paid to Stewart Environmental Consultants, carbon markets analysis fees paid to Trebol Consulting, and project management, project outputs market evaluation, risk evaluation, financial modeling, and report writing fees paid to Symbios Technologies.

APPENDIX A FINANCIAL SCENARIOS EVALUATED

Symbios Technologies, LLC

Haxtun Financial Scenarios Run

Pivot Application Assumption - 20 year ownership

Scenario #	Equity %	Sale of Residual Solids?	Sale of Carbon Credits?	Power Produced
Trucked				
1	100%	No	Yes	Gas
2	30%	No	Yes	Gas
3	100%	No	No	Elec
4	30%	No	No	Elec
5	100%	Yes	Yes	Gas
6	30%	Yes	Yes	Gas
7	100%	Yes	No	Elec
8	30%	Yes	No	Elec
Pumped				
9	100%	No	Yes	Gas
10	30%	No	Yes	Gas
11	100%	No	No	Elec
12	30%	No	No	Elec
13	100%	Yes	Yes	Gas
14	30%	Yes	Yes	Gas
15	100%	Yes	No	Elec
16	30%	Yes	No	Elec

Liquid Spreading Assumption - 20 year ownership

Scenario #	Equity %	Sale of Residual Solids?	Sale of Carbon Credits?	Power Produced
Trucked				
17	100%	No	Yes	Gas
18	30%	No	Yes	Gas
19	100%	No	No	Elec
20	30%	No	No	Elec
21	100%	Yes	Yes	Gas
22	30%	Yes	Yes	Gas
23	100%	Yes	No	Elec
24	30%	Yes	No	Elec
Pumped				
25	100%	No	Yes	Gas
26	30%	No	Yes	Gas
27	100%	No	No	Elec
28	30%	No	No	Elec
29	100%	Yes	Yes	Gas
30	30%	Yes	Yes	Gas
31	100%	Yes	No	Elec
32	30%	Yes	No	Elec

APPENDIX B INCOME STATEMENT – SCENARIO 2 (30% EQUITY, 70% PUBLIC FUNDING) – YEARS 1-10

	Year									
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Revenues										
Organic residual	$ 44,805	$ 46,149	$ 47,533	$ 48,959	$ 50,428	$ 51,941	$ 53,499	$ 55,104	$ 56,757	$ 58,460
Electricity produced from gas	$ 146,707	$ 151,597	$ 156,488	$ 161,378	$ 166,268	$ 171,158	$ 176,049	$ 180,939	$ 185,829	$ 190,719
Total revenues	$ 191,512	$ 197,746	$ 204,021	$ 210,337	$ 216,696	$ 223,099	$ 229,548	$ 236,043	$ 242,586	$ 249,179
Operating expenses										
Digester operations	$ 168,784	$ 173,848	$ 179,063	$ 184,435	$ 189,968	$ 195,667	$ 201,537	$ 207,583	$ 213,810	$ 220,224
Electricity generation	$ 5,257	$ 5,416	$ 5,577	$ 5,744	$ 5,915	$ 6,093	$ 6,277	$ 6,465	$ 6,658	$ 6,859
Total operating expenses	$ 174,041	$ 179,264	$ 184,640	$ 190,179	$ 195,883	$ 201,760	$ 207,814	$ 214,048	$ 220,468	$ 227,083
EBITDA	$ 17,471	$ 18,482	$ 19,381	$ 20,158	$ 20,813	$ 21,339	$ 21,734	$ 21,995	$ 22,118	$ 22,096
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Depreciation	$ 479,336	$ 833,999	$ 619,353	$ 463,731	$ 350,712	$ 341,011	$ 336,863	$ 207,954	$ 79,468	$ 79,334
Amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net income (loss) before income taxes	$ (461,865)	$ (815,517)	$ (599,972)	$ (443,573)	$ (329,899)	$ (319,672)	$ (315,129)	$ (185,959)	$ (57,350)	$ (57,238)
Income tax (expense) benefit	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net income (loss)	$ (461,865)	$ (815,517)	$ (599,972)	$ (443,573)	$ (329,899)	$ (319,672)	$ (315,129)	$ (185,959)	$ (57,350)	$ (57,238)

APPENDIX C INCOME STATEMENT – SCENARIO 2 (30% EQUITY, 70% PUBLIC FUNDING) – YEARS 2-20

	Year									
	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Revenues										
Organic residual	$ 60,214	$ 62,020	$ 63,881	$ 65,797	$ 67,771	$ 69,804	$ 71,898	$ 74,055	$ 76,277	$ 78,565
Electricity produced from gas	$ 195,610	$ 200,500	$ 205,390	$ 212,725	$ 220,061	$ 227,396	$ 234,732	$ 242,067	$ 249,402	$ 256,738
Total revenues	$ 255,824	$ 262,520	$ 269,271	$ 278,522	$ 287,832	$ 297,200	$ 306,630	$ 316,122	$ 325,679	$ 335,303
Operating expenses										
Digester operations	$ 226,831	$ 233,636	$ 240,645	$ 247,864	$ 255,300	$ 262,959	$ 270,848	$ 278,973	$ 287,342	$ 295,962
Electricity generation	$ 7,064	$ 7,277	$ 7,494	$ 7,719	$ 7,952	$ 8,191	$ 8,438	$ 8,692	$ 8,954	$ 9,223
Total operating expenses	$ 233,895	$ 240,913	$ 248,139	$ 255,583	$ 263,252	$ 271,150	$ 279,286	$ 287,665	$ 296,296	$ 305,185
EBITDA	$ 21,929	$ 21,607	$ 21,132	$ 22,939	$ 24,580	$ 26,050	$ 27,344	$ 28,457	$ 29,383	$ 30,118
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Depreciation	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 40,068	$ -	$ -	$ -	$ -
Amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net income (loss) before income taxes	$ (57,405)	$ (57,727)	$ (58,202)	$ (56,395)	$ (54,754)	$ (14,018)	$ 27,344	$ 28,457	$ 29,383	$ 30,118
Income tax (expense) benefit	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net income (loss)	$ (57,405)	$ (57,727)	$ (58,202)	$ (56,395)	$ (54,754)	$ (14,018)	$ 27,344	$ 28,457	$ 29,383	$ 30,118

APPENDIX D CASH FLOW STATEMENT – SCENARIO 2 (30% EQUITY, 70% PUBLIC FUNDING) – YEARS 1-10

	Year									
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Net income (loss)	$ (461,865)	$ (815,517)	$ (599,972)	$ (443,573)	$ (329,899)	$ (319,672)	$ (315,129)	$ (185,959)	$ (57,350)	$ (57,238)
Increases to compute cash flow										
Depreciation	$ 479,336	$ 833,999	$ 619,353	$ 463,731	$ 350,712	$ 341,011	$ 336,863	$ 207,954	$ 79,468	$ 79,334
Amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Equity contributions	$ 1,268,550	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Principal advances	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Public financing	$ 2,959,949	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treasury direct payments	$ -	$ 1,268,550	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income tax expense (benefit)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total increases to compute cash flow	$ 4,707,835	$ 2,102,549	$ 619,353	$ 463,731	$ 350,712	$ 341,011	$ 336,863	$ 207,954	$ 79,468	$ 79,334
Decreases to compute cash flow										
Capital expenditures	$ (4,228,499)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt service principal payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income tax payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total decreases to compute cash flow	$ (4,228,499)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net cash flow (deficit) available for distribution	$ 17,471	$ 1,287,032	$ 19,381	$ 20,158	$ 20,813	$ 21,339	$ 21,734	$ 21,995	$ 22,118	$ 22,096
Cumulative net cash flow (deficit) available for distribution	$ 17,471	$ 1,304,503	$ 1,323,884	$ 1,344,042	$ 1,364,855	$ 1,386,194	$ 1,407,928	$ 1,429,923	$ 1,452,041	$ 1,474,137
Annual cash on cash yield	1.38%	101.46%	1.53%	1.59%	1.64%	1.68%	1.71%	1.73%	1.74%	1.74%

APPENDIX E CASH FLOW STATEMENT – SCENARIO 2 (30% EQUITY, 70% PUBLIC FUNDING) – YEARS 2-20

	Year									
	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Net income (loss)	$ (57,405)	$ (57,727)	$ (58,202)	$ (56,395)	$ (54,754)	$ (14,018)	$ 27,344	$ 28,457	$ 29,383	$ 30,118
Increases to compute cash flow										
Depreciation	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 40,068	$ -	$ -	$ -	$ -
Amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Equity contributions	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Principal advances	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Public financing	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treasury direct payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income tax expense (benefit)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total increases to compute cash flow	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 79,334	$ 40,068	$ -	$ -	$ -	$ -
Decreases to compute cash flow										
Capital expenditures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt service principal payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Income tax payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total decreases to compute cash flow	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net cash flow (deficit) available for distribution	$ 21,929	$ 21,607	$ 21,132	$ 22,939	$ 24,580	$ 26,050	$ 27,344	$ 28,457	$ 29,383	$ 30,118
Cumulative net cash flow (deficit) available for distribution	$ 1,496,066	$ 1,517,673	$ 1,538,805	$ 1,561,744	$ 1,586,324	$ 1,612,374	$ 1,639,718	$ 1,668,175	$ 1,697,558	$ 1,727,676
Annual cash on cash yield	1.73%	1.70%	1.67%	1.81%	1.94%	2.05%	2.16%	2.24%	2.32%	2.37%