PSC REF#:295459

Feasibility Study

PROJECT PHOENIX

Prepared for:
Kewaunee County
810 Lincoln Street
Kewaunee, WI 54216

Prepared by:
Dynamic Concepts, LLC
PO Box 436
Waukesha, WI 53187

June 30th, 2016

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE EE0006222"

Table of Contents

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

1.0 Executive Summary

There were (3) three primary objectives outlined by Kewaunee County for feasibility analysis: energy production, nutrient concentration, and the creation of clean water. Dynamic Concepts has proposed a county wide community biogas agglomeration project by integrating a network of ten proposed community anaerobic digestion facilities through 66 miles of gas piping to a centralized biogas processing facility strategically located along an existing natural gas transmission line. The project, with an estimated $188 million capital cost, would produce in excess of 7,000 standard cubic feet per minute (scfm) of renewable biogas, by harvesting methane gas from the manure of more than 58,000 equivalent cows across county and reduce manure volumes applied to the land by more than 300 million gallons annually. If realized, this project would be largest of its kind in North America and establish Kewaunee County as a global leader in sustainability, setting a precedent for responsible agriculture for future generations.

Kewaunee County is one of Wisconsin's premier dairy counties with 95,000 cows and replacement young stock producing over 1.1 billion pound of milk annually. One in five jobs in Kewaunee County is associated with the dairy industry. The county has 16 permitted CAFOs, 15 dairy and 1 beef. These animals produce some 650 million gallons of liquid manure each year.

The management of this manure is one of the most difficult, expensive, and potentially limiting problems facing the dairy industry today. Traditionally, manure is stored in earthen ponds or lagoons and then land applied at a later date. The construction cost of the lagoons or other storage facilities require large capital investments and provide limited benefits to the environment or the farming operations. The average cost to land apply manure is 1.5-2.0 cents per gallon which results in an estimated $10-$15 million dollars annually spent hauling and spreading manure on crop land by farms in Kewaunee County.

Manure produced by the dairy industry in Kewaunee County only supplies 50-60% of the nutrient demand in the county. The issues facing Kewaunee County are more directly related to nutrient distribution and the timing of application than a surplus of nutrients.

This feasibility study evaluates the opportunities in Kewaunee County for both biogas generation and utilization as well nutrient concentration and water treatment from both a technical and financial focus. Nutrient concentration and water treatment produce value added nutrient products that can be better utilized to deliver the nutrients where and when they are needed and best utilized.

The proposed project will be the first community system of this scale to include a viable nutrient concentration system (NCS) to reduce the adverse environmental impacts of nutrient loading to ground and surface waters. The integration of nutrient concentration and biogas production on a county wide scale allows for the economically feasible redistribution of nutrients through the reduction of the water in the manure. When implemented, this project will provide water quality protection, agricultural viability, and economic sustainability to the county.

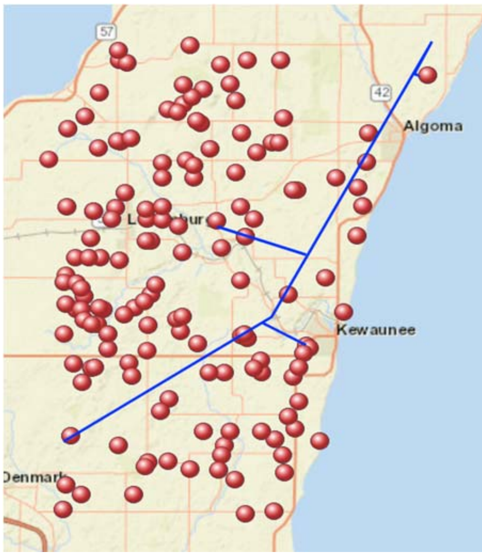


Figure 1.1 Dairy Farms in Kewaunee County

Our initial study efforts determined that Kewaunee County has substantial feed stock from manure and off farm organic waste to support a large methane recovery system. An estimated 86% of the manure produced in Kewaunee County could feasibly be collected and processed. The potential exists in Kewaunee County to produce 286,452 megawatt hours per year of electrical generation through processing manure and other organic waste products. The Wisconsin Public Service Corporation is currently paying $.04 per kilowatt hour (kWh) for renewable electricity. A project producing electricity is not feasible at this level of power purchase. A project of this scale would require a power purchase price of $0.13 to $0.18 per kWh to make the project economically viable and comparative to the current market rates for gas utilization in the form of renewable natural gas (RNG).

Fortunately, there is an interstate natural gas pipeline running through the county (blue line on the map to the right, red dots are dairies). The current market price for renewable natural gas is in the range of $15 to $31 per MMBtu. This price can be obtained by utilizing the Renewable Fuel Standard. D3 of the Renewable Fuel Standard is the renewable code for cellulosic biofuel, which includes ethanol, renewable diesel, and now, renewable natural gas.

In summary, our findings indicate that integrating anaerobic digestion (AD), nutrient concentration systems (NCS), and solids processing can accomplish the goals of improving the economics of manure handling while have positive effects on the environment. The system includes ten manure hub and spoke systems and two renewable natural gas conditioning and injection points with the following key highlights:

- **Estimated project capital cost of $188 Million**
- **Internal rate of return of 18.5%**
- **Production of over 7,000 SCFM biogas or 2,000,000 MMBTU/yr of Renewable Natural Gas *(equivalent to 16.6M gallons of gasoline or 344,828 barrels of crude oil)***
- **338,147,110 gallons of clean water produced annually**
- **60,000 less trucks on the county's roads annually**
- **75 new permanent fulltime jobs created**
- **Greenhouse gas reduction over 200,000 tons annually by anaerobic digestion of dairy manure *(equivalent to 38,326 passenger vehicles driven for one year)***

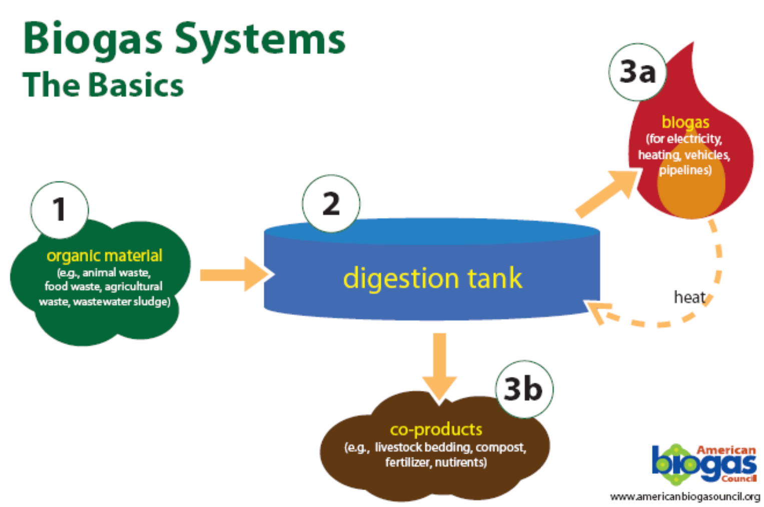
2.0 Project Description

The purpose of this study was to determine if a fully integrated hub and spoke manure processing system can be established in Kewaunee County. This report is the result of our technological, environmental, and economic evaluation of proven technology solutions available to meet the needs of a hub and spoke concept. Our findings indicated that integrating anaerobic digestion (AD), nutrient concentration systems (NCS), and renewable natural gas (RNG) can accomplish the goals of improving the economics of manure handling while having positive effects on the environment. The study evaluates ten hub and spoke systems and two renewable natural gas conditioning and injection points that were conceptualized by Dynamic. This section provides an overview of how all of the components are integrated together to create a $188,000,000 project that creates 7,219 standard cubic feet of biogas per minute and 338,147,110 gallons of clean water annually.

AD is a waste treatment process which manages and treats animal wastes reducing pathogens and odor prior to introduction on farm lands. The methane generated is used to create renewable power (RP) or renewable natural gas (RNG). We have developed economic models that predict the financial returns of both RP into the grid and RNG injected into the interstate pipeline. With the current market environment, RNG is a viable option while RP is not economically feasible at this time.

When discussing manure management with dairy farms, the main concerns are overwhelmingly:

- Volume of manure
- Nutrient management limitations



On multi-generational farms, manure has been applied near the main farm for years, causing a buildup of nutrients in the soils. As the farm grows and is required to follow a nutrient management plan that limits the amount of manure that can be applied due to the nutrient levels of the soils, they need to haul the manure further from the main farm, increasing their operating costs. The manure is nutrient rich in nitrogen, phosphorus, potassium, and other micro nutrients, providing fertilizer for crop production. The application rates run from 7,000-15,000 gallons per acre. Sometimes the over application of nutrients happens due to the expense of hauling further away from the livestock production facility causing a buildup of nutrients in the soils.

Some farms have considered installing digesters to help with manure management. Most digesters installed nationwide to date have not addressed the volume or nutrient issues. They mainly focus on energy production with the farm benefits of pathogen and odor reduction and possibly a source of bedding. Given the high capital cost of digestion systems, a relatively high energy value is required to justify the investment. Even with a high power purchase rate, systems require extensive maintenance and oversight to achieve the projected financial returns. Very few of the installed systems produce a positive cash flow for the farm.

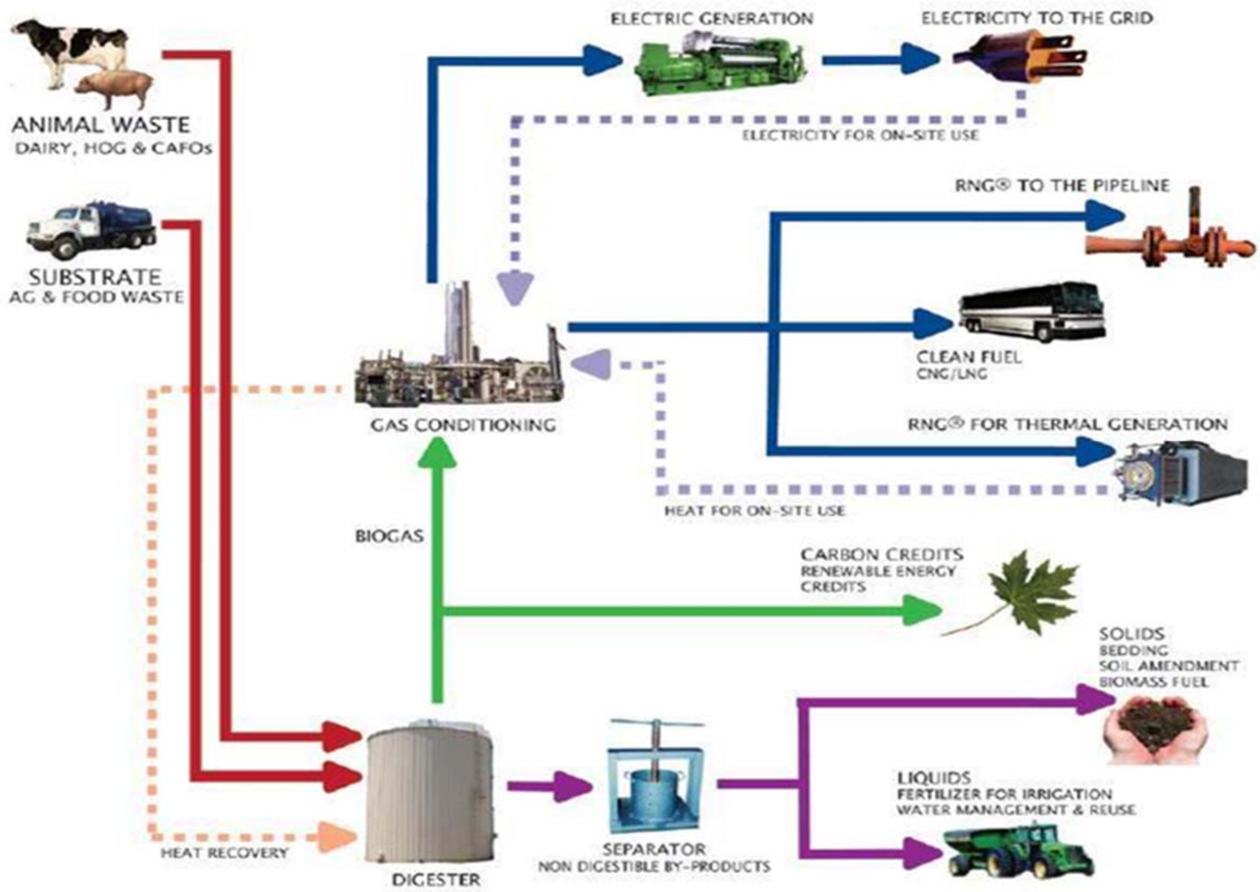
In order to improve the financial returns of digestion systems, many system providers are turning to co-digestion of food processing by-products or substrates. This significantly increases the amount of energy produced from the system. The challenges with these systems are high utility interconnect costs due to larger generator sizing, the added volume and nutrients brought onto the farm, and the operational issues that come with operating at increased organic loading rates. Until digestion systems address the issues of volume reduction and nutrient management, their development will remain limited to high energy off-takes or odor issues. *Anaerobic digesters generate renewable biogas energy and help with manure management by reducing odors and pathogens but digesters alone don't solve the volume or nutrient management problems.*

The objectives of installing NCS are to improve the economic efficiencies of manure handling, improve flexibility of the timing of manure application, and reduce the adverse environmental impact of nutrient loading to ground and surface waters by making the redistribution of nutrients economically feasible.

We have evaluated several nutrient concentration systems that are technically capable of successfully decreasing volume of manure land applied by 50-60%. This reduction is accomplished through suspended solids separation, ultrafiltration, and reverse osmosis. Stated simply, the NCS system "dewaters or removes water" from the manure. Removing over half of the volume as clean water allows the strategic management of nutrients because of the improved economic feasible of hauling further distances. The volume reduction provides more flexibility in the timing of manure field applications. The dairies will have an increased ability to apply manure during low risk time periods and avoid applications during in-climactic conditions. The simple explanation of how a NCS works is first separating the suspended particles in the manure, then separating the nutrients, salts, and minerals from the water. By combining these technologies, ultimately, the farm becomes a mini organic fertilizer plant. This allows for the reallocation of the nutrients from where it is causing water quality issues and economically redistributes it to land that is in need of nutrients for crop production. The nitrogen and potassium can be applied at more precise times when the crop needs the nutrients (i.e.: split applications or prior to planting)

Photo 2.1: Reverse Osmosis System

instead of applying manure when the crops are not able to utilize the nutrients such as fall applications. Operating these systems in series will create an overall volume reduction of 70%. Additional benefits to reducing the manure volumes include less wear and tear on



town and county roads as the volume needed to apply nutrients has been reduced. This means 60,000 fewer trucks on the roads and the loads within the weight limits of the roads. It also means the manure can be stored more cost effectively for longer periods of time ensuring the application of the nutrients takes place when the crops can utilize them and avoiding the time of the year that has the highest likelihood of a run-off event.

3.0 Geographic Analysis

The geographic analysis and strategic division of the county began by first categorically understanding the locations and volumes of the manure produced by each farm within the county. After reviewing the farm data supplied by Kewaunee County, we decided to convert all the cow, heifer, and calf data to equivalent cows. The milk cows were assumed to have an average weight of 1,400 lbs. The heifers were assumed to have an average weight of 850 lbs. and were multiplied by 0.6 to get equivalent milk cows. The calves were assumed to have an average weight of 150 lbs. and were multiplied by 0.11 to get equivalent milk cows.

The next step in the analysis was to plot all the dairy farms in Kewaunee County as shown in Figure 3.1. The concentrated animal feeding operations (CAFOs) were plotted as gold squares, the CAFOs with digesters were plotted as red triangles, all the farms with more than 200 cows were plotted as blue circles, and all dairy farms with less than 200 equivalent dairy cows were plotted as green circles. Based on past experiences with these types of projects, we added the natural gas transmission lines to the map since that could influence the possible locations of the hubs.

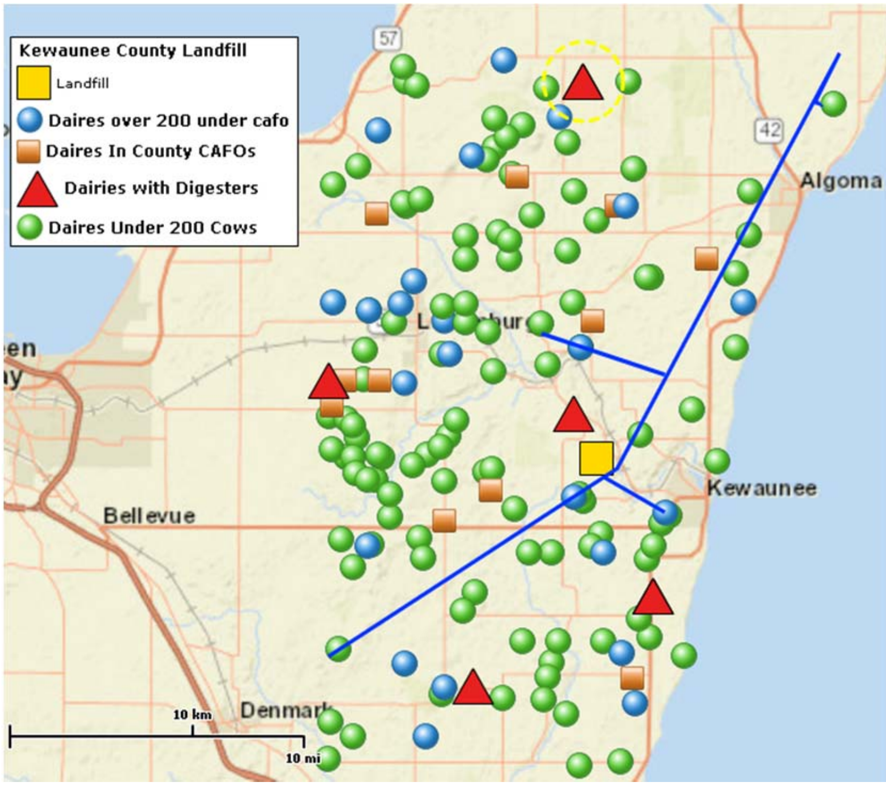


Figure 3.1 Dairy Farm Locations within Kewaunee County

With all the farms on the map, the concept of using the larger CAFO farms as the manure processing hubs with the smaller surrounding farms as the spokes was evaluated. Initially, a 5 mile radius was drawn around each CAFO. These boundaries were further refined until we established the ten hubs shown in Figure 3.2

With the hubs and boundaries established, farms were all grouped by hub. With the total equivalent milk cows for each hub, the total amount of manure that would have to be processed by each hub system was estimated. It was assumed that each cow produces 23.5 gallons of manure per day and the farm uses an additional 8 gallons of water per cow per day for a total of 31.5 gallons of liquid manure per equivalent milk cow per day processed through the system. These values are based on flow meter data collected by Dynamic at numerous farms over the past 10 years. The total amount of manure for each hub is listed in Table 3.1.

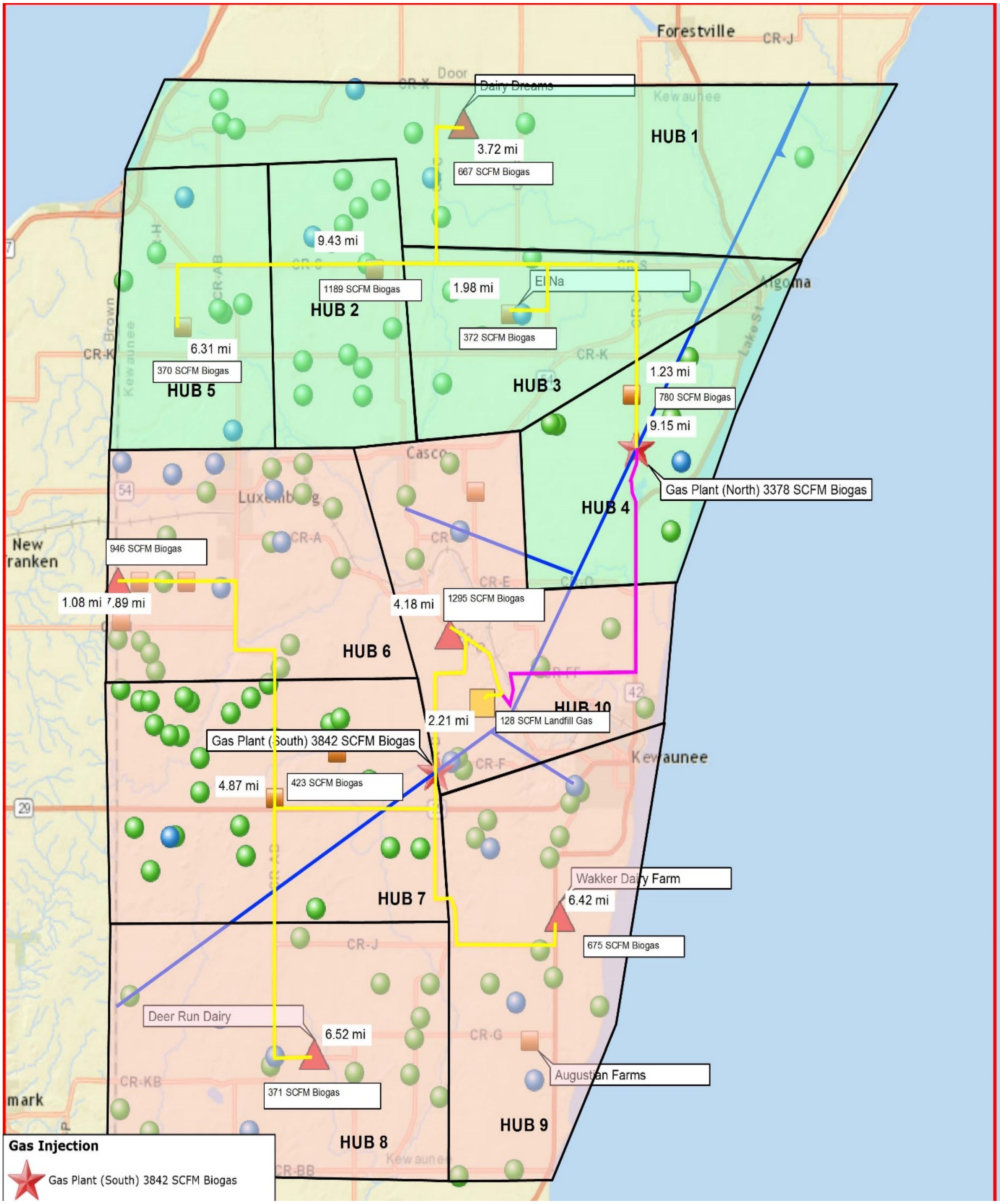
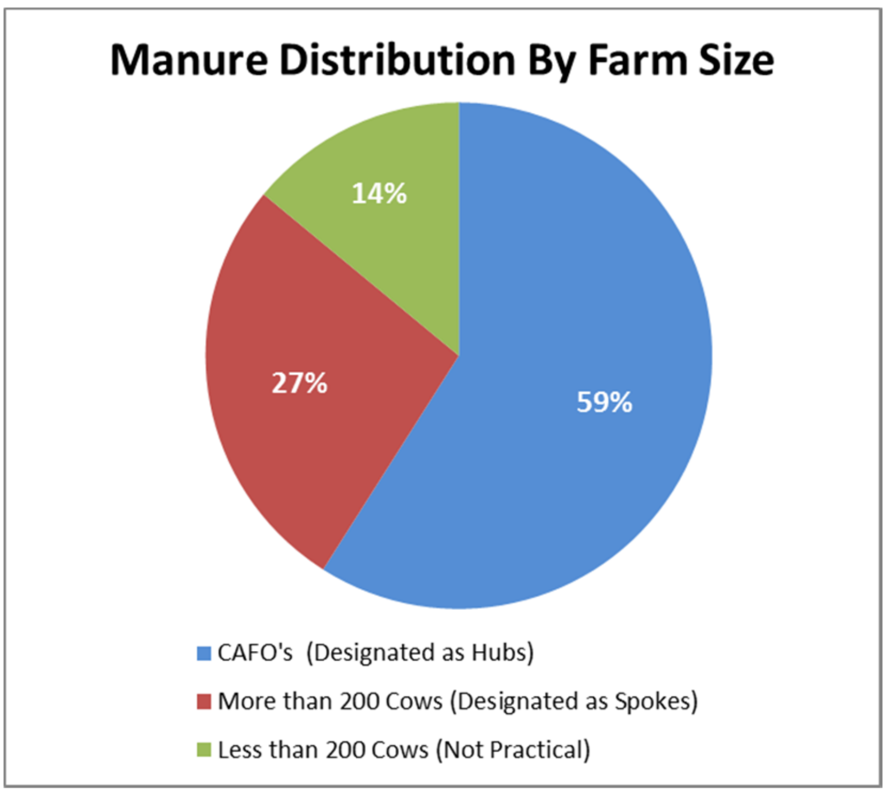


Figure 3.2: Kewaunee County Anaerobic Digestion Hub Division

Total Manure Volume in Kewaunee County		
Hub No.	**Total Cow Equivalents**	**Total Manure (gal/day)**
Hub #1	5,414	170,835
Hub #2	9,293	292,233
Hub #3	2,772	85,891
Hub #4	5,837	184,182
Hub #5	2,921	92,170
Hub #6	7,950	250,856
Hub #7	5,008	158,024
Hub #8	3,569	112,617
Hub #9	5,602	176,767
Hub #10	10,059	317,404
Total	**58,375**	**1,840,978**

Table 3.1: Total Manure Volume in Kewaunee County

The next step in the evaluation was to determine how much of the total amount of manure could practically be collected and brought to each hub for processing. Using the map, we estimated the distance from each of the spoke farms to the hub. Based on our experience hauling manure to a community digester facility on a daily basis, we eliminated all farms further than 5 miles from each hub. Next, we eliminated all farms less than 200 equivalent milk cows based on the assumption that many smaller farms handle their manure as a solid versus a liquid. Finally, we eliminated all farms that were primarily a calf raising facility since they typically have pack manure rather than liquid manure. Filtering the data based on these criteria, we developed a manure volume estimation based on the practical milk cow equivalents as shown in Table 3.2. Finally, we looked at the amount of manure generated by each hub farm without any spoke farms and



this data is summarized in Table 3.

Total Manure Volume Practical to Capture through Hub & Spoke System		
Hub No.	**Practical Cow Equivalents**	**Total Manure (gal/day)**
Hub #1	4,721	148,967
Hub #2	8,418	265,623
Hub #3	2,635	83,145
Hub #4	5,523	174,274
Hub #5	2,619	82,640
Hub #6	6,700	211,413
Hub #7	2,994	94,473
Hub #8	2,624	82,798
Hub #9	4,809	151,744
Hub #10	9,167	289,258
Total	**50,210**	**1584,337**

Table 3.2: Total Volume of Manure that is Practical to Capture through a Hub & Spoke method

The practical manure generation is 86% of the total manure generation and the hub only manure generation is 59% of the total manure generation in Kewaunee County.

Total Manure Volume Available at Hubs Only		
Hub No.	**Total Cow Equivalents**	**Total Manure (gal/day)**
Hub #1	4020	126,848
Hub #2	7,644	241,200
Hub #3	1,798	56,734
Hub #4	4,773	150,608
Hub #5	1,470	46,385
Hub #6	2,265	71,470
Hub #7	1,762	55,599
Hub #8	1,365	43,072
Hub #9	2,250	70,997
Hub #10	6,847	216,052
Total	**34,194**	**1,078,965**

Table 3.3: Total Manure volume of the main hub farms only

4.0 Biogas Production

With the amount of manure generation calculated for each of the 10 hubs, the amount of biogas potential for each hub was then calculated. The biogas production for each hub was based on the following assumptions: 9.6% volatile solids in the manure, 40% volatile solids destruction rate through the digestion process, 9 cubic feet of methane produced per pound of volatile solids destroyed, and 60% methane content of the biogas. These values represent the average values from the data we have collected operating manure digestion systems over the last 10 years. The energy value of the biogas was calculated by using the lower heating value of methane at 900 Btu/cubic foot[1]. The biogas potential and energy potential was determined using the three manure distribution categories from the previous section; Total Manure, Practical Manure, and Hub Only Manure. This data is summarized in Table 41.

Hub No.	Biogas from Total Manure (cu.ft./day)	Energy Value Total Manure (Btu/day)	Biogas from Practical Manure (cu.ft./day)	Energy Value Practical Manure (Btu/day)	Biogas from Hub Only Manure (cu.ft./day)	Energy Value Hub Only Manure (Btu/day)
Hub #1	584,257	315,498,901	509,471	275,114,575	433,822	234,264,053
Hub #2	1,002,863	541,546,230	908,437	490,555,920	824,910	445,451,349
Hub #3	293,747	158,623,570	284,359	153,553,676	194,033	104,777,803
Hub #4	629,906	340,149,074	596,020	321,850,837	515,083	278,144,857
Hub #5	315,223	170,220,223	282,632	152,621,282	158,637	85,663,725
Hub #6	857,932	463,283,388	723,037	390,440,088	244,430	131,992,060
Hub #7	540,443	291,839,397	323,101	174,474,272	190,148	102,679,916
Hub #8	385,152	207,982,190	283,172	152,912,655	147,305	79,544,884
Hub #9	604,545	326,454,533	518,968	280,242,744	242,811	131,117,941
Hub #10	1,085,527	586,184,604	989,266	534,203,625	738,901	399,006,467
Total	**6,299,597**	**3,401,782,110**	**5,418,462**	**2,925,969,674**	**3,690,080**	**1,992,643,055**

Table 4.1: Biogas Production from Manure in Kewaunee County

The total amount of manure in Kewaunee County has the potential for over 19 MW of electrical generation or over 4,300 scfm of renewable biogas. The practical amount of manure has the potential to generate over 17 MW of power or 3,700 scfm of renewable biogas and the manure from just the hubs has the potential for more than 11 MW of electrical generation and 2,500 scfm of renewable biogas.

The potential amount of biogas production was also evaluated by adding off-farm organic waste or substrates to the system. It was assumed that 20% substrates were added to each hub and the substrates had an average chemical oxygen demand of 180,000 mg/L. The amount of biogas potential by adding substrates to the practical manure volume and hub only manure volume for each hub is summarized in Table 4.1.

Hub No.	Biogas from Practical Manure w/ Substrates (cu.ft./day)	Energy Value Practical Manure w/ Substrates (Btu/day)	Biogas from Hub Only Manure w/ Substrates (cu.ft./day)	Energy Value Hub Only Manure w/ Substrates (Btu/day)
Hub #1	960,152	518,481,958	817,582	441,494,235
Hub #2	1,712,042	924,502,926	1,554,624	839,497,135
Hub #3	535,898	289,385,115	365,679	197,466,782
Hub #4	1,123,266	606,563,621	970,725	524,191,490
Hub #5	532,647	287,629,341	298,964	161,440,754
Hub #6	1,362,632	735,821,547	458,418	247,545,535
Hub #7	608,911	328,812,139	358,357	193,513,024
Hub #8	533,671	288,182,105	277,613	149,911,136
Hub #9	978,047	528,145,247	457,599	247,103,324
Hub #10	1,864,379	1,006,764,505	1,392,534	751,968,236
Total	**10,211,645**	**5,514,288,505**	**6,952,096**	**3,754,131,651**

Table 4.2: Biogas & Energy potential from manure in Kewaunee County when combined with 20% substrates

Adding substrates to the manure has the potential to double biogas production. By adding 20% substrates to the practical manure scenario, the electrical generation potential increased from 17 MW to 32 MW. Likewise, the hub only scenario increased from 11 MW to over 21 MW. Adding substrates to the manure can significantly improve the financial feasibility of the project by doubling the revenue potential without a significant increase in capital and operating expenses.

5.0 Nutrient Management Analysis

The core of the feasibility report focuses on technology and the feasibility of various approaches to manure management. The true core of the issue in Kewaunee County revolves more about agronomy issues as it relates to manure management and the technology components are simply the tools to help better manage this resource. The 4R's of the nutrient stewardship concept involves applying the right fertilizer source at the right rate, at the right time, and in the right place[2]. By utilizing the various manure processing technologies currently available, the farms would have more tools to help them optimize their application to the 4R's while protecting ground and surface waters.

In order to estimate the nutrient content of the various products produced by the advanced separation processes, we developed a model that would track the nitrogen, phosphorus, and potassium through the steps of separation. This model was based on our experience in the industry and input from various equipment suppliers. We started the analysis by assuming the nutrient content of the manure and water prior to separation has a total nitrogen content of 26 lbs./1,000 gallons, a P_2O_5 content of 11 lbs./1,000 gallons, and a K_2O content of 20 lbs./1,000 gallons and a total dry matter content of 9%. This assumption is based on test data from farms with mechanical scrape manure collection systems and includes the parlor wash water. With the estimated total manure volume in the county, there are 17.6 million lbs. of total nitrogen, 7.5 million lbs. of P_2O_5, and 13.6 million lbs. of K_2O produced annually. Using the estimated 1st year availability of the nutrients at 40% for nitrogen (assuming incorporated within 3 days), 60% for P_2O_5, and 80% for K_2O, yields 7.0 million lbs. of nitrogen, 4.5 million lbs. of P_2O_5, and 10.8 million lbs. of K_2O[3].

In an attempt to put the amount of nutrients produced annually into perspective, we reviewed the data from the 2014 Wisconsin Agricultural Statics[4] to determine the number of harvested acres in Kewaunee County and the type of crops grown on those acres. In summary for the 2013 crop year, Kewaunee County had 130,228 harvested acres comprised of corn for silage, corn for grain, soybeans, oats, winter wheat, and forage crops. Based on this data and making some assumptions on soil test levels and yields, an approximation of the total fertilizer requirements for growing these crops was 10.7 million lbs. of nitrogen, 8.2 million lbs. of P_2O_5, and 24.7 million lbs. of K_2O[5].

	Annual Crop Usage (lbs.)	Nutrients in Manure (lbs.)	% of Nutrients Supplied by Manure	Nutrient Balance (lbs.)
Nitrogen	10,709,500	7,026,104	65.6%	**-3,683,396**
Phosphorus	8,226,820	4,516,875	54.9%	**-3,709,945**
Potash	24,693,900	10,840,208	43.9%	**-13,853,692**

Table 5.1: Total Manure Nutrient Supply & Demand in Kewaunee County

At a very high level, it appears that there are almost twice as many nutrients required for crop production as the nutrients from manure in the county. This data would suggest that the issue with manure application is more related to the principals of right rate, right time, and right place than simply the farms producing more manure than the crops can utilize.

Manure has significant value as a crop fertilizer, but unlike commercial fertilizers, the nitrogen-phosphorus-potassium ratios are a function of the manure and the ratios typically don't match up with the crop uptake needs. In many cases, application to meet the nitrogen needs of a crop will lead to the over application of phosphorus or application to the phosphorus needs will require a commercial nitrogen fertilizer application in addition to the manure. These issues create challenges when trying to adhere to the principals of the right rate and the right place.

Another challenge with manure as a fertilizer is that it is 90-95% water. This leads to significant volume challenges in trying to distribute this volume across the acres in short windows of time. Due to the solids in manure and form of the nutrients, application typically only occurs in the spring of the year prior to planting and the fall following harvest to avoid spreading manure on growing crops other than fresh cut alfalfa fields. In order to meet the fertilization needs of the crop, 15,000-20,000 gallons per acre are applied. Depending on the soil saturation and soil temperature, this volume has the potential to make the nutrients more mobile than commercial fertilizers, especially when applied in the fall of the year. It also stresses the local roads with significant amounts of truck traffic. Assuming half the manure in the county had to be trucked to the desired fields, that would put over 60,000 semi-trucks on the roads or about 30,000 semi-trucks on the roads for the first few weeks of spring and another 30,000 semi-trucks in the late fall. These issues create challenges when trying to adhere to the principals of right time and right place.

The first goal of an advanced separation system is to separate the phosphorus from the nitrogen and potassium to allow the nutrients to get applied at ratios that better match the crop uptake needs. Since a majority of the phosphorus stays with the suspended solids, by separating them from the liquid stream, the phosphorus can be separated from the nitrogen and potassium. Once separated, these nutrients can potentially be applied at the rates required for crop uptake, limiting the amounts of excess nutrients in the soils that can lead to ground and surface water contamination. By separating the nutrients, the farm has a tool to assist in applying the nutrients to the right place and at the desired rate for each of the key nutrients.

The second goal of an advanced separation system is to allow lower application rates at more frequent intervals throughout the growing season and eliminate the need for fall application of manure. Once the suspended solids are removed from the manure, the manure is easier to irrigate if irrigation infrastructure exists. This allows application at several intervals throughout the growing season to allow the crops to take up the nutrients as they are needed and eliminate the need for fall application. The manure stream can also be further processed to remove much of the water from the manure stream. This concentrates the nutrients to allow for lower application rates per acre and fewer trucks required to deliver these nutrients to the correct fields. This assists in applying the nutrients at the right time and at the right place.

Advanced separation provides greater options of how, when, and where to apply the manure to maximize the agronomic benefits of manure while trying to protect the ground and surface waters.

5.1 Anaerobic Digestion

The anaerobic digestion step does not reduce or segregate any of the nutrients that were initially introduced into the system. The value of anaerobic digestion is as a pre-treatment step for advanced separation by converting a majority of the organic nitrogen to an inorganic form (making the nitrogen more available to the plants), homogenizing the manure by mixing it for an extended period of time, breaking down the volatile organics which increases the efficiency of membrane systems and reduces cleaning cycles, reducing the pathogens in the manure, and providing a constant elevated temperature which increases the efficiency of separation of the suspended solids.

5.2 Coarse Solids Separation

The first stage in the separation process removes the coarse suspended solids from the manure stream. These coarse solids are typically separated through a mechanical screw press and produce a stackable product with about 70% moisture. This product contains about 25% of the phosphorus from the manure stream and is the first step in starting to segregate the phosphorus from the nitrogen and potassium. Options for use of the coarse separated solids are typically cow bedding, land application, or composting.

The challenges with using the 70% moisture solids as bedding in barns with deep bedded stalls is it has a tendency to create higher somatic cell counts than sand or sawdust. The advantages of using the solids as bedding is that it recycles a product on the farm and no longer requires the farm to purchase their bedding. It is also easier on the manure handling equipment and lagoons than sand.

With a projected nutrient value of 2.0-1.5-0.8, it has a relatively low value as a fertilizer for land application. The value of this product for land application is the organic matter and micronutrients it provides to the soil. The challenges with this product is that it can typically only be applied in the spring and fall and needs to be stored extended periods of time.

For this project, it was assumed that a natural gas fired drying system would be installed at each hub to dry the coarse fiber from 70% moisture to about 50% moisture. The highest value use for the dried coarse solids is as cow bedding. At 50-55% moisture, this product overcomes most of the herd health issues associated with the 70% moisture bedding. With the cow numbers in northeastern Wisconsin, there is a large enough market to support the production volume. At 50% moisture, it also opens up this product to be shipped to horticultural wholesales for incorporation into their soil amendment products as an alternative to peat moss. By reducing the moisture content, it cuts the weight of the product by about 60%; improving the economics of trucking it to these locations. This provides a secondary market for this product in the event there are more coarse solids produced than can be sold as bedding.

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

5.3 Fine Solids Separation

Fine solids separation is the second step in the process. By removing the fine solids from the manure stream, up to 95% of the phosphorus contained in the manure stream can be segregated from the nitrogen and potassium. This step creates a phosphorus rich cake product and a nitrogen and potassium liquid product typically referred to as "tea water". If the farm is set up for irrigation, the tea water can be run through the irrigation system to add nitrogen and potassium to the crops as they are needed. This step is also used to reduce the amount of suspended solids in the manure stream to below 1% if the goal of the farm is to separate the clean water from the nutrient rich liquid. Fine solids separation systems often use polymers and sometimes coagulants to bind together the finest particles into a larger particle to allow it to be separated. Options for use of the fine separated solids are land application, blend back with the nutrient rich water prior to land application, or processing into a pelleted product.

The fine solids come out of the process at about 90% moisture and are run through a press to reduce the moisture to about 75-80%. At 90% moisture, the fines are in a slurry, but at 75-80%, it is a stackable cake. Again, the cake product has a relatively low fertilizer value of 2.5-2.5-1.0, but contains about 70% of the phosphorus in the manure stream. The challenge with utilizing the cake product for land application is in the storage requirements. The system produces a significant amount of cake on a daily basis which takes up a considerable amount of space when piled and stored. It can also create leachate problems if not stored under a roof. If the farm wants to keep this product for land application, it would be easier to handle as a slurry and build a liquid storage structure to hold the slurry between land application intervals.

Another concept that was explored is taking the cake to a centralized pelleting plant that would allow this product to be dried, pelleted, and stored until it could be land applied. Once processed into a pellet, this product could be classified as a fertilizer and be used as a solid fertilizer product that could be applied to cropland with shallow soils. Since it is in the form of a pellet, it will act as a slow release fertilizer and limit the potential for the nutrients to leach into the ground water. Also, the pathogens in the manure would be destroyed in the drying and pelleting process, reducing the risk of pathogen contamination of groundwater. This concept is explored in further detail in the next section.

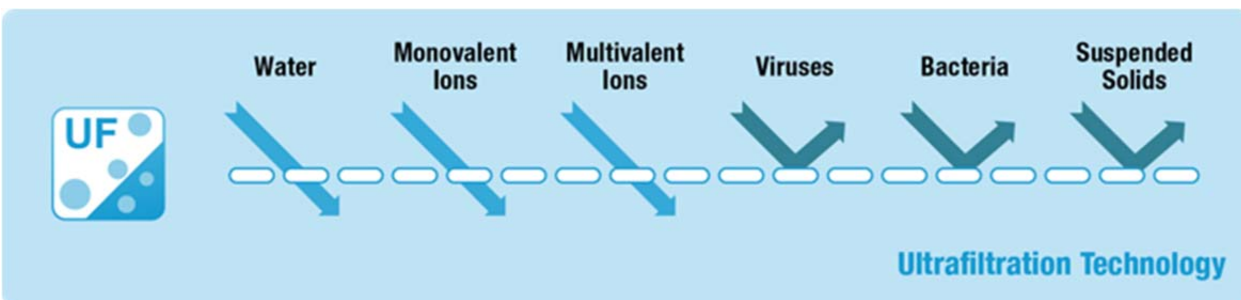
The liquids produced from this step or "tea water" can be stored for land application or further processed to separate a majority of the water from the nutrients. If a farm has the infrastructure to irrigate the tea water on acres close to the farm, this is a cost effective way to apply both the volume and nutrients at times when the crops can utilize them. The tea water represents about 75% of the original manure volume and primarily contains the nitrogen and potassium. The majority of the nitrogen in the tea water is also in an inorganic form which allows the crops to utilize it more readily. Irrigation of tea water is best suited to forage crops since they typically have a high demand for potassium and can use the nitrogen that is applied. If all the tea water produced in the county were irrigated, that would eliminate up to 60,000 semi-trucks from the roads. Additional information regarding manure irrigation can be obtained through the Wisconsin Manure Irrigation Workgroup Report "Considerations for the Use of Manure Irrigation Practices".

One of the drawbacks to irrigating the tea water is the infrastructure required for irrigation. Most farms in the county do not have irrigation equipment in place. Also, many fields are too small or have too much slope for irrigation. Another challenge is the current limitations placed on irrigation by some of the towns.

Another option for the tea water is to further process it to separate the water from the nutrient stream. This is typically done through multiple filtration steps such as ultrafiltration and reverse osmosis. It is recommended that each hub be further evaluated to determine if it is more cost effective and advantageous to irrigate the tea water or to process it further.

5.4 Suspended Solids Removal

The third stage of advanced separation is the removal of the very fine suspended solids from the manure stream. This step is typically utilized as a preparatory step prior to reverse osmosis when the goal of the farm is to separate the water from the nutrient stream. There are multiple technologies that can perform this function such as bag filters, sand filters, and ultrafiltration (UF). These systems are designed to remove particles 0.1 to 0.01 micron in size.



Picture 5.4.1: Ultrafiltration Technology courtesy of aqua innovations

The suspended solids removal process rejects the remaining suspended solids from the tea water. This product can be recycled back to the start of the fine solids separation process or put directly into storage for land application. If a mechanical separation system is utilized for fine solids separation, it would be recommended to put this product directly into storage. If a polymer based system is utilized for fine solids separation, this product can be recycled back to the start of that process to maximize the percentage of clean water that can be produced by the system. Once the suspended solids are removed from the liquid stream, it is ready to be processed through a reverse osmosis system to remove the dissolved solids from the water.

5.5 Dissolved Solids Removal

The final stage in advanced separation is the separation of the dissolved solids from the clean water. This is typically done with a reverse osmosis (RO) system. An RO system uses membranes to filter out salts and particles down to 0.001 micron. Most RO systems in this application use brackish water membranes operating between 200-400 psi. They are typically designed to provide 70-80% clean water recovery of the incoming stream. This yields 50-65% clean water of the original manure stream sent to the first separation stage.

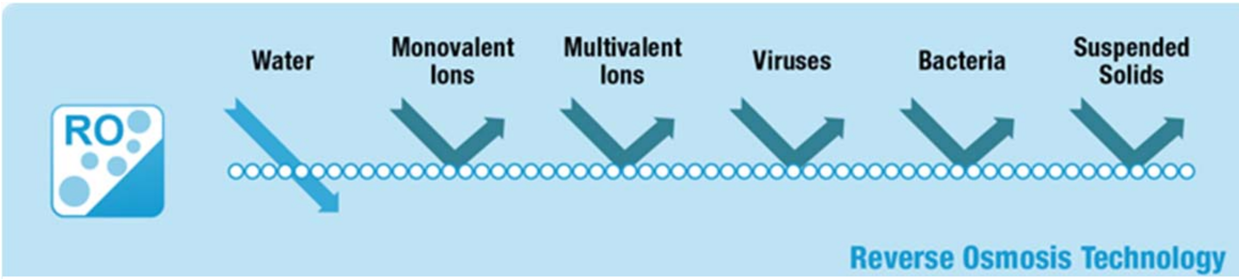


Figure 5.5.1: Reverse Osmosis Technology courtesy of Aqua Innovations

The RO system uses a high pressure pump on the feed side of the membrane system. As the feed material is pressurized on the outside of the membranes, the clean water is able flow to the center of the membrane tube and out of the system. The clean water is referred to as the permeate. The remaining dissolved solids that don't pass through the membranes are rejected from the system as the concentrate. The concentrate contains the soluble nitrogen and potassium. Most suppliers also inject an acid prior to or in one of the stages of the RO to convert the ammonia-nitrogen to a more stable ammonium-nitrogen. By converting the ammonia-nitrogen to ammonium-nitrogen, it is less likely to volatize in storage or after land application, making a higher percentage of the nitrogen plant available.

The concentrate typically contains 2-3 times the concentration of nitrogen and potassium as the original manure stream. If the product is hauled and applied through traditional application methods, it can be applied at significantly lower volumes per acre to achieve the desired fertilization levels. It can also be applied to meet the nitrogen needs of the crop since it does not contain phosphorus. If the typical application rate of raw manure was 15,000 gallons per acre, the concentrated nutrient liquid could be applied at 5,000 gallons per acre and meet the nitrogen requirements of corn silage. This helps prevent the nutrients from leaching further in the soil. This also has the ability to take about 40,000 trucks off the roads for manure application. Also, by concentrating the nutrients and reducing the volume, the concentrate can be spring applied and applied through the growing season, eliminating the need for fall application.

The remaining clean water generated by the process could be re-used by the farming operations, irrigated on acres close the farm, or discharged to surface waters. Since the water is a valuable resource, re-using it on farm or irrigating it would be preferred options. Irrigating the clean water avoids many of the concerns associated with manure irrigation since it is almost nutrient and mineral free and pathogen free.

Advanced separation systems help improve the ability to achieve the 4R's of agronomy by segregating the phosphorus from the nitrogen and potassium, separating the solids from the liquids, and reducing the volume of manure that needs to be applied. These help by applying the nutrients in the correct rate to the correct place at the correct time to maximize nutrient uptake by the crops. Combining these practices can also eliminate the need for fall application of manure. Adding irrigation of either the tea water or the RO water provides another significant impact by taking 40,000-60,000 manure trucks off the roads and fields.

Reduced application rates and loads per acre will also reduce soil compaction on the fields which will lead to increased yields. Also, by irrigating the water to the growing crops, yields will be increased and the need for crop insurance will be reduced. By increasing yields, more nutrients are consumed by the crops. All these factors help to reduce the ability of the nutrients to find their way to surface and ground water sources.

6.0 Technology Review

6.1 Anaerobic Digestion

An anaerobic digester is a waste treatment facility which manages and treats animal wastes prior to introduction on farm lands. By-products of the process, such as methane and heat, can be utilized on-site to reduce energy costs.

This technology is proven and well understood among various livestock and human waste handling systems.

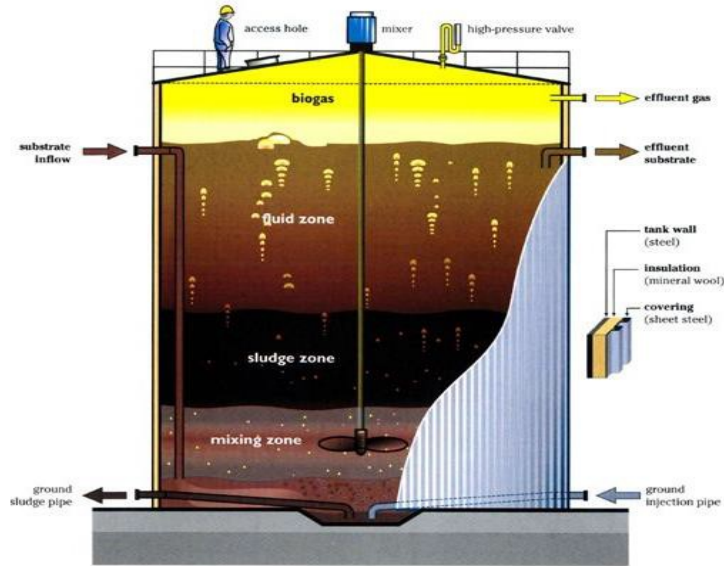
- Over 7,500 plants in Germany alone *(source: German Biogas Association)*
- 16,000 Wastewater Treatment Plants in the U.S. 3,500 of these employ anaerobic digestion *(source: U.S. Department of Energy).*
- 192 Ag based operational systems in the U.S. *(source EPAgstar)*
- 29 Systems in the state of WI, all located on dairy farms *(source EPAstar).*
- 28 Of these systems operate CHPs *(source EPAstar).*

The process utilizes bacteria in the absence of oxygen to break down organic materials. As organic material breaks down, it generates biogas with 60-65% methane content. Under controlled conditions, anaerobic digestion is a holistic treatment solution that stabilizes the nutrient stream. In addition, it also produces a significant amount of energy in the form of biogas, while controlling odors, reducing pathogens, minimizing environmental impact from waste emissions, and maximizing fertilizer nutrient and water recovery.

Controlled anaerobic digestion requires an airtight chamber called a digester. To promote bacterial activity, the digester must maintain a temperature of at least 68° F. Using higher temperatures up to 150° F shortens processing time and reduces the required volume of the tank by 25 percent to 40 percent. However, there are more species of anaerobic bacteria that thrive in the temperature range of a standard design (mesophilic bacteria) than there are species that thrive at higher temperatures (thermophilic bacteria). High-temperature digesters are also more prone to upset because of temperature fluctuations and their successful operation requires close monitoring and diligent maintenance.

Dynamic has evaluated many types of anaerobic digesters in projects across the United States, including Complete Stirred Tank Reactor (CSTR), Covered Lagoon, Batch Digester, Plug-Flow Digester, Up flow Anaerobic Sludge Blanket (UASB), Anaerobic Sequencing Batch Reactor (ASBR), and others. The complete stirred, plug-flow, and covered anaerobic lagoon are three types of digesters recognized by USDA's Natural Resource Conservation Service (NRCS) in the form of "National Guidance provided to States." Examination of four anaerobic alternatives is included in the following breakdown.

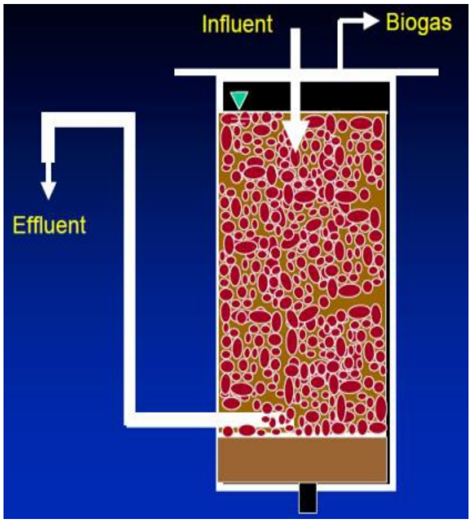
6.1.1 Complete Stirred Anaerobic Digester



The Complete-Stirred Digester (also referred to as Complete Mix) is a large, concrete or steel circular container. Today's complete-mix digester can handle organic wastes with total solid concentration of 3% to 10%. Complete-mix digesters can be operated at either the mesophilic or thermophilic temperature range with a hydraulic retention time (HRT) as brief as 10-20 days. This technology type is mature with a well understood economic and investment profile. The figure to the right represents general configuration of a complete mix approach.

6.1.2 Fixed Film Digester

Flushed dairy nutrient water defined as the liquid fraction after particulate solids are removed is usually too dilute for conventional anaerobic digestion systems. One practical alternative is to apply high-rate anaerobic digestion technology, such as fixed-film digestion, to recover energy and treat the flushed dairy nutrient wastewater at much shorter residence times (less than 3 days) than that allowed by conventional technologies.

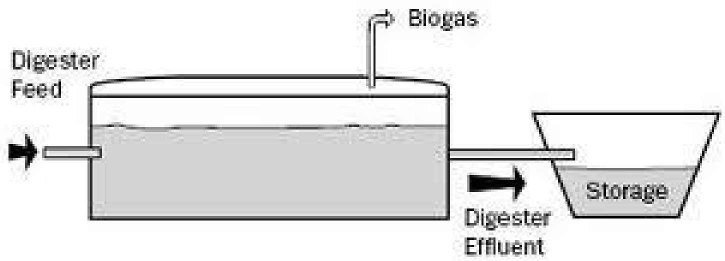


The basic fixed-film digester design consists of a tank packed with inert media on which a consortia or colony of bacteria attach and grow as a stable, robust biofilm. As influent passes through the high surface area, high bioavailability and media-filled reactor, the anaerobic biomass converts/ metabolizes organic matter in the nutrient water to biogas. Immobilization of bacteria as a biofilm prevents washout of slower growing cells and provides biomass retention independent of hydraulic retention time. Fixed-film digesters are well suited for treating large volumes of dilute wastewater because large numbers of bacteria can be concentrated inside smaller digesters operating at shorter hydraulic retention times than would be needed to achieve the same degree of treatment with conventional suspended- growth anaerobic reactors.

Generally, the fixed-film design is suitable for any livestock waste that is subject to dilution with water for transport or processing, or the liquid fractions from physical separation processes. Also, fixed-film reactors have a smaller footprint than conventional designs, an important factor where land availability is limited.

6.1.3 Plug Flow Digester

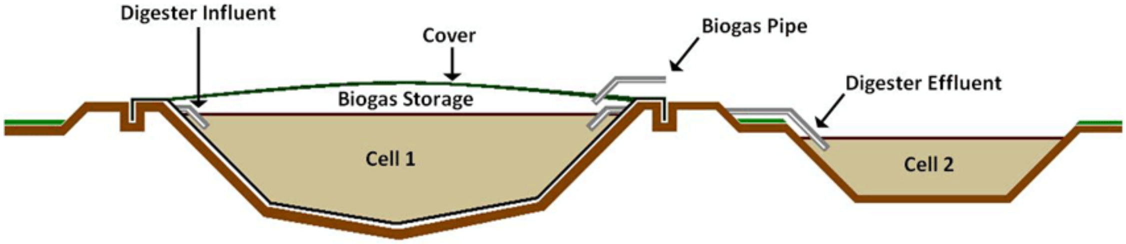
A typical plug-flow digester design consists of a covered reactor where the material to be digested enters at one end of the tank and exits at the opposite. The nutrient stream is added daily to one end of the digester and equal volume of digested nutrients are forced out the other end. Plug-flow digesters work best for dairy manure with 11-14% total solids.



6.1.4 Covered Lagoon Digester

A covered lagoon digester is a large anaerobic holding pond (not a storage pond or basin) with a long retention time and a high dilution factor.

Typically covered lagoons are used with flush manure collection systems that discharge manure at 0.5-2% total solids. The in-ground, earth or lined lagoon is covered with a flexible or floating gas tight cover generally made of geosynthetic material. These geomembranes allow them to conform to most any size and shape. They are not heated and considered ambient temperature digesters. Retention time is usually 30– 45 days or longer depending on lagoon size. In climates that have elevated year round temperatures, such as southern and western U.S., these digesters can produce stable, reduced odor, nutrient rich effluent for application on fields and crops; pathogen and weed seed reduction, and biogas for farm energy use. Very large lagoons in hot climates may produce sufficient quantity, quality, and consistency of gas to justify use in an engine generator. In areas with cooler climates, waste digestion, odor control, and gas production will be less consistent and the low quality gas may need to be flared off much of the year for odor control and greenhouse gas reduction.

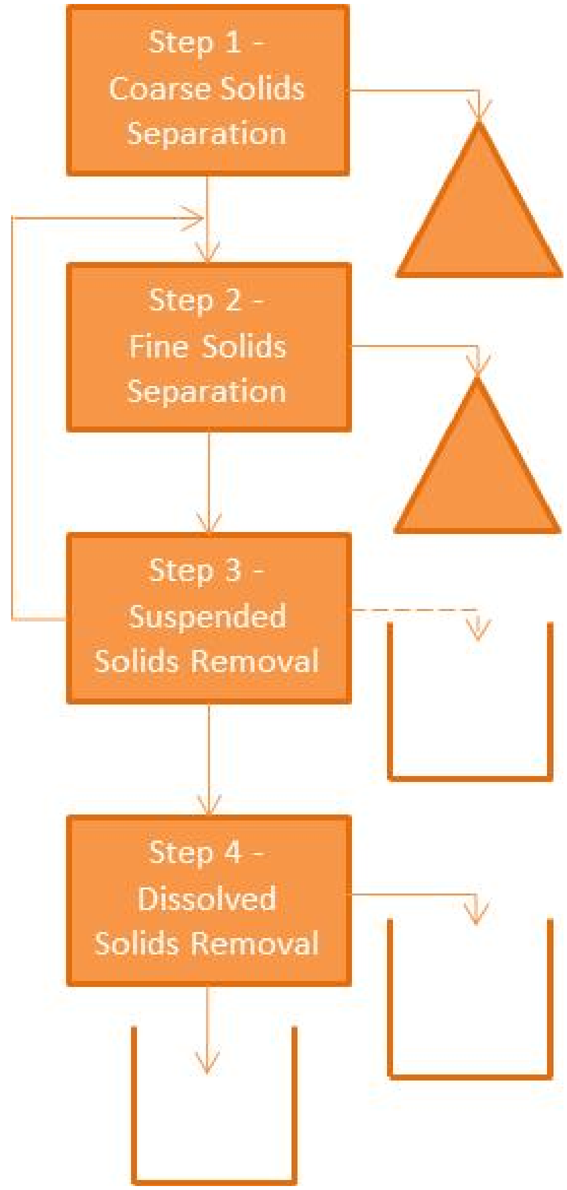


Due to the seasonality of weather and cooler climate, the Covered Lagoon Digester is not a viable option to optimize biogas production in Kewaunee County.

The Plug Flow, Fixed Film and Complete Stirred Systems will perform well when matched with the type of manure the dairies are creating. However, the Fixed Film system has not been well commercialized utilizing dairy manure. The two options that fit the total solid content of the dairies' manure stream are Plug Flow and Complete Stirred. Both of these systems are specifically designed to maximize methane output utilizing a standard mesophilic digester.

6.2 Advanced Separation Technology

The challenge as stated earlier is to separate the nutrients from the water to create economically usable products and clean water. In many cases, this is accomplished through a four step process. The first three steps are focused on suspended solids removal while the final step is focused on dissolved solids removal as illustrated above.



6.2.1 Coarse Solids Separation

Coarse solids separation is the first step in the process. As the name implies, the first step removes the largest particles, typically about 1/8" and larger. Many different types of equipment can be used for this step including static slope screens, drum screens, screw presses, and different combinations of these pieces of equipment. With each of these pieces of equipment, there are trade-offs between ease of use, cost to operate, and labor required for operation.

Picture 6.2.1.1: Bauer Screw Press

From our perspective, screw presses are the most effective means of capturing coarse solids and reducing their moisture content for use as bedding or sending them to a drying system to further reduce their moisture content. The lower the moisture content of the solids sent to the drying operation, greater throughput and less energy consumption is required by the dryer. A screw press can typically achieve about 68-72% moisture solids.

6.2.2 Fine Solids Separation

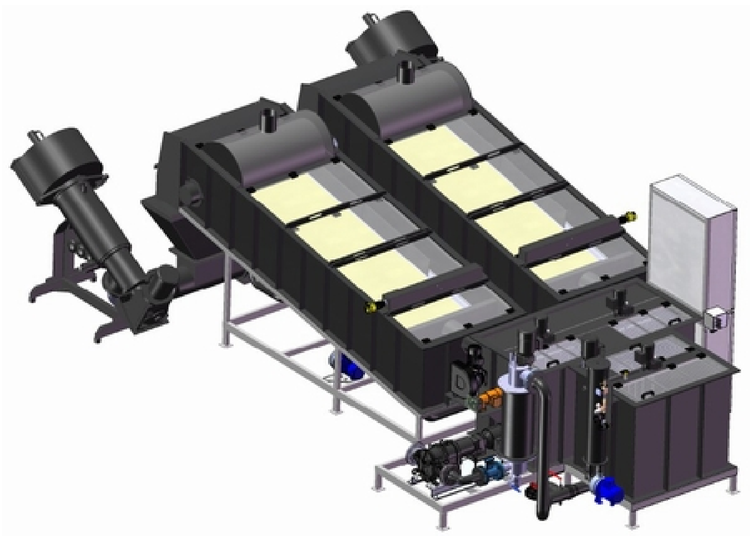
Fine solids separation is the second step in the process. By removing the fine solids from the manure stream, up to 95% of the phosphorus contained in the manure stream can be segregated from the nitrogen and potassium. This step creates a phosphorus rich cake product and a nitrogen and potassium liquid product typically referred to as "tea water". If the farm is set up for irrigation, the tea water can be run through the irrigation system to add nitrogen and potassium to the crops as they are needed. This step is also used to reduce the amount of suspended solids in the manure stream to below 1% if the goal of the farm is to separate the clean water from the nutrient rich liquid. Fine solids separation systems often use polymers and sometimes coagulants to bind together the finest particles into a larger particle to allow it to be separated.

Picture 6.2.2.1: Trident DAF System

Based on current technology in the marketplace, there are three systems that would be considered commercially available solutions for this step of the process: Trident Nutrient Recovery System, AL-2 Belt Filter System, and centrifugal separation systems.

The Trident system utilizes dissolved air floatation (DAF) tank to float the fine particles to the surface after they have been mixed with the polymer. There are a series of skimmers that continuously skim the solids off of the surface of the tank. The liquids from the tank overflow a weir wall at one end of the tank while the solids are skimmed into a collection trough at the other end of the tank. The solids come off the system at about 90% moisture. These solids typically contain 70-90% of the phosphorus that was originally in the manure. These solids can be pumped into a storage tank and blended with the concentrate from the next steps of separation for land application or pressed into a cake. Trident also provides their proprietary polymers for the system and the polymer make-down unit.

Another option for this application is the AL-2 system. This system blends the polymer and coagulant with the manure in mixing chambers and then they overflow into a tank with an inclined filter belt. This belt is typically supplied with 300 to 500 micron openings. As the belt slowly rises out of the water, the floating solids adhere to the belt and the liquids drain through the belt. At the top of the belt is a roller that gently squeezes the free water out of the solids before they fall into an auger or pump. Like the Trident system, the solids can be pumped into storage or pressed into a cake. On the bottom side of the belt is a spray bar that uses the liquids that just passed through the belt to spray it off to keep it clean.



Picture 6.2.2.2: AL2 Separation System

Centrifuges use centrifugal force to separate the fine particles from the liquids. They typically spin at speeds of 1,800 to 3,600 rpm. The material enters one end of the spinning bowl assembly and the force pushes the solids to the outside of the bowl assembly. Inside the bowl assembly a scroll is turning at a few rpm differential than the bowl to scrape the solids from the sidewall of the bowl and convey them to the solids discharge end of the bowl. As the liquids travel down the other end of the machine, they exit out ports that control the pool depth inside the bowl. In many cases, polymers and coagulants are added to the feed stream to achieve higher levels of solids capture to prevent premature fouling of the next stage of separation.

Picture 6.2.2.3: Centrisys Centrifuge Equipment

6.2.3 Fiber Drying System

When using solids for bedding, our experience has been that there is a direct link between moisture content and somatic cell counts. Mechanical separation systems typically don't get the coarse fiber any drier than 65% moisture. From our experience, most farms that are having success with solids as bedding are drying it to 50-60% moisture. Drying much lower than 50% typically creates dust problems in the barns. Once the material has been dried sufficiently to 55-60% the reduction in somatic cell reaches a point of diminishing marginal return where additional drying no longer reduces the somatic cell counts.

In addition to drying the coarse fiber for bedding, the fine solids can also be processed through the dryer to reduce the moisture content to make transporting the cake off the farm more economical. This option is often selected when the farm is limited by phosphorus in their nutrient management plan. By drying the fine solids to about 50% moisture, a typical semi-trailer will be full and near its maximum weight/volume ratio.

There are numerous dryer manufacturers in the area including Baker-Rullman in Watertown, WI, Uzelac Industries in Milwaukee, WI, FEECO in Green Bay WI, and Innovative Environmental Companies (IEC) in Rockford IL. All of these suppliers have multiple years of experience in drying products such as wood chips, sawdust, or municipal bio-solids. Currently, only Baker-Rullman and IEC have dryers installed that are drying dairy solids. FEECO has a system that is scheduled to be installed on a farm in the second half of 2016.

The Baker-Rullman system uses a natural gas burner and furnace unit that creates the heat for drying. The solids enter the system prior to a rotary drum that is flipping the material as it is progressing along the length of the drum. A large blower is pulling the heated air from the furnace through the drum to dry the material. The moisture content of the material is controlled by the burner setting on the furnace, the feed rate of the solids, and the speed of the fan pulling the air through the material. After the material exits the drum, it goes through an air separator where the steam is exhausted up through the roof and the dried fiber drops to the bottom and is conveyed away from the air separator and piled.

Picture 6.2.3.1: IEC Dryer System

The IEC system also uses a natural gas burner and furnace that creates the heat for drying. The IEC system feeds the solids through a hammer mill to break up any clumps and then the material goes into vacuum tower. A large blower pulls the air from the furnace through the tower to dry the material. As the material dries, it is light enough to escape out of the tower and is transferred to an air separator where the steam is exhausted up through the roof and the solids fall to the bottom and are conveyed away and piled. The moisture level of the solids is controlled by the feed rate into the system, the speed of the blower, and the burner setting on the furnace.

6.2.4 Suspended Solids Removal System

The third stage of advanced separation is the removal of the very fine suspended solids from the manure stream. This step is typically utilized as a preparatory step prior to reverse osmosis when the goal of the farm is to create clean water. There are multiple technologies that can perform this function such as bag filters, sand filters, membrane bioreactors (MBR), and ultrafiltration (UF). From our experience, UF systems provide the best operational results since they typically have a lower operating cost although they have a higher capital costs and operate at a higher efficiency which allows for a greater percentage of clean water recovery. UF systems are designed to remove particles down to 0.1 to 0.01 microns in size.

A UF system consists of multiple housings with a membrane in each housing. A pump either pushes or pulls the process water through the membrane. The solids are trapped on the outside of the membrane and the water without the suspended solids is allowed to pass through the membrane. The water that passes through the UF membrane is called permeate. Once the differential pressure across the membrane reaches a certain point, the UF system backwashes the membranes with the permeate that it created to wash the particles off of the membrane surface. This backwash water is called the UF concentrate. The UF membrane system continually repeats this process. The UF concentrate can be recycled back to the start of the fine solids separation process or sent directly to storage for land application. If the goal of the

Picture 6.2.4.1: Aqua Innovations UF Equipment

advanced separation system is to maximize the clean water produced, the UF stream is typically recycled.

There are numerous suppliers that supply equipment for fine suspended solids removal as a part of their entire package but don't manufacture this equipment or sell this equipment independently of their package. Manufacturers of this equipment such as GE, Dow, Evoqua, and Xylem have considerable experience in municipal or industrial applications with this technology, but limited experience with manure. Aqua Innovations out of Beloit, WI is a supplier that is currently in this space that manufactures the ultrafiltration and reverse osmosis systems and has multiple years of experience processing dairy manure.

6.2.5 Dissolved Solids Removal System

The final stage in advanced separation is the separation of the dissolved solids from the clean water. This is typically done with a reverse osmosis (RO) system. An RO system uses membranes to filter out salts and particles less than 0.001 microns. Most RO systems in this application use brackish water membranes operating between 200-400 psi. They are typically designed to provide 70-80% clean water recovery of the incoming stream. This yields 50-65% clean water of the original manure stream sent to the first separation stage.

The RO system uses a high pressure pump on the feed side of the membrane system. As the feed material is pressurized on the outside of the membranes, the clean water is able flow to the center of the membrane tube and out of the system. The clean water is referred to as the permeate. The remaining dissolved solids that don't pass through the membranes are rejected from the system as the concentrate. The concentrate contains the soluble nitrogen and potassium. Most suppliers also inject an acid prior to or in one of the stages of the RO to tie up the ammonia that may be present and convert it to a stabilized ammonium. The concentrate typically contains 2-3 times the concentration of nitrogen and potassium as the original manure stream, is readily available to crops, and can easily be irrigated since it doesn't contain any suspended solids.

Picture 6.2.5.1: Aqua Innovation Reverse Osmosis System

Again, RO systems are typically packaged by suppliers as part of a complete system, but typically not manufactured by them. Aqua Innovations also makes their own RO systems and has experience operating these systems on dairy manure.

7.0 Market Analysis

7.1 Renewable Natural Gas (RNG)

RINs are the renewable identification numbers used to identify and track biofuel production that obligated parties need to demonstrate blending for compliance with the renewable fuel standard (RFS). D3 of the renewable fuel standard is the RIN code for cellulosic biofuel, which includes ethanol, renewable diesel, and now, renewable natural gas.

Removing CO2 and impurities to bring the methane content up to the same specifications required of fossil-based natural gas results high-Btu biogas is pipeline quality and can be used for transportation fuel when compressed (CNG) or liquefied (LNG). CNG has been the most common fuel used by fleets where medium-duty trucks are close to the fueling station, such as city fleets, local delivery trucks and waste haulers. LNG is typically used for heavy-duty trucks traveling along the growing network of LNG fueling stations. CNG currently sells at premiums over traditional natural gas due to the value of the environmental credits (RINs) produced through the use of renewable fuels.

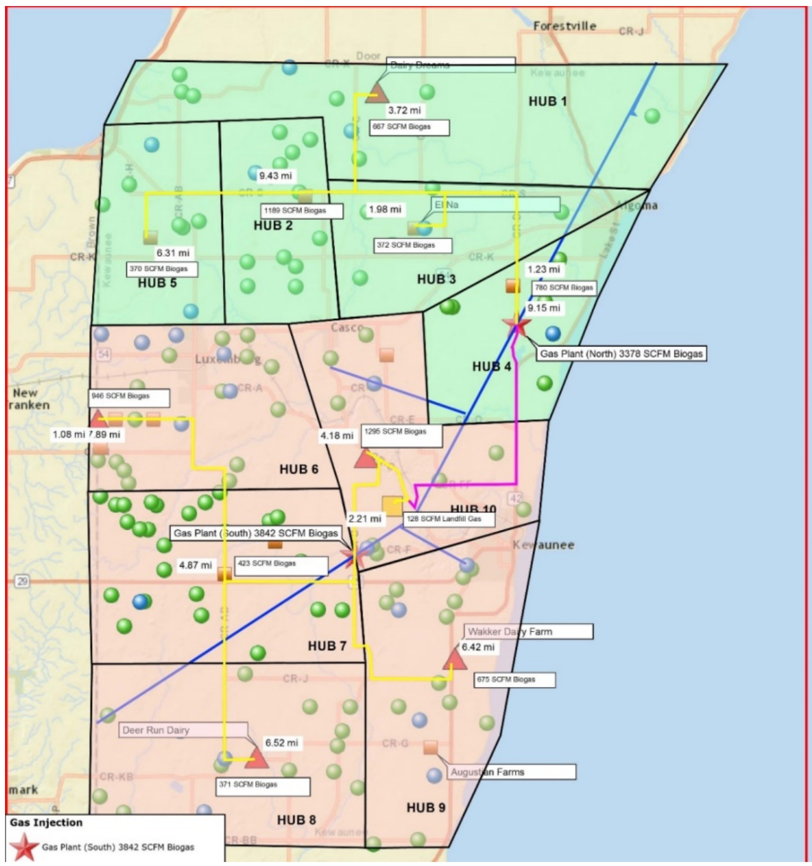


Figure 7.1.1: Map showing proposed gas pipeline in Kewaunee County (yellow lines) Existing main distribution lines (blue lines)

Kewaunee County has a unique opportunity to capitalize on the heavy concentration of dairy animals. This opportunity is to create renewable natural gas and inject into the interstate pipeline that already exists in the county. We are proposing to install 10 manure hubs with spokes to other farms. Each hub consists of anaerobic digestion, solids separation, nutrient concentration, and solids drying equipment.

The biogas generated by the anaerobic digesters will piped to a centralized cleanup and compression system to generate natural gas (see illustration right and below).

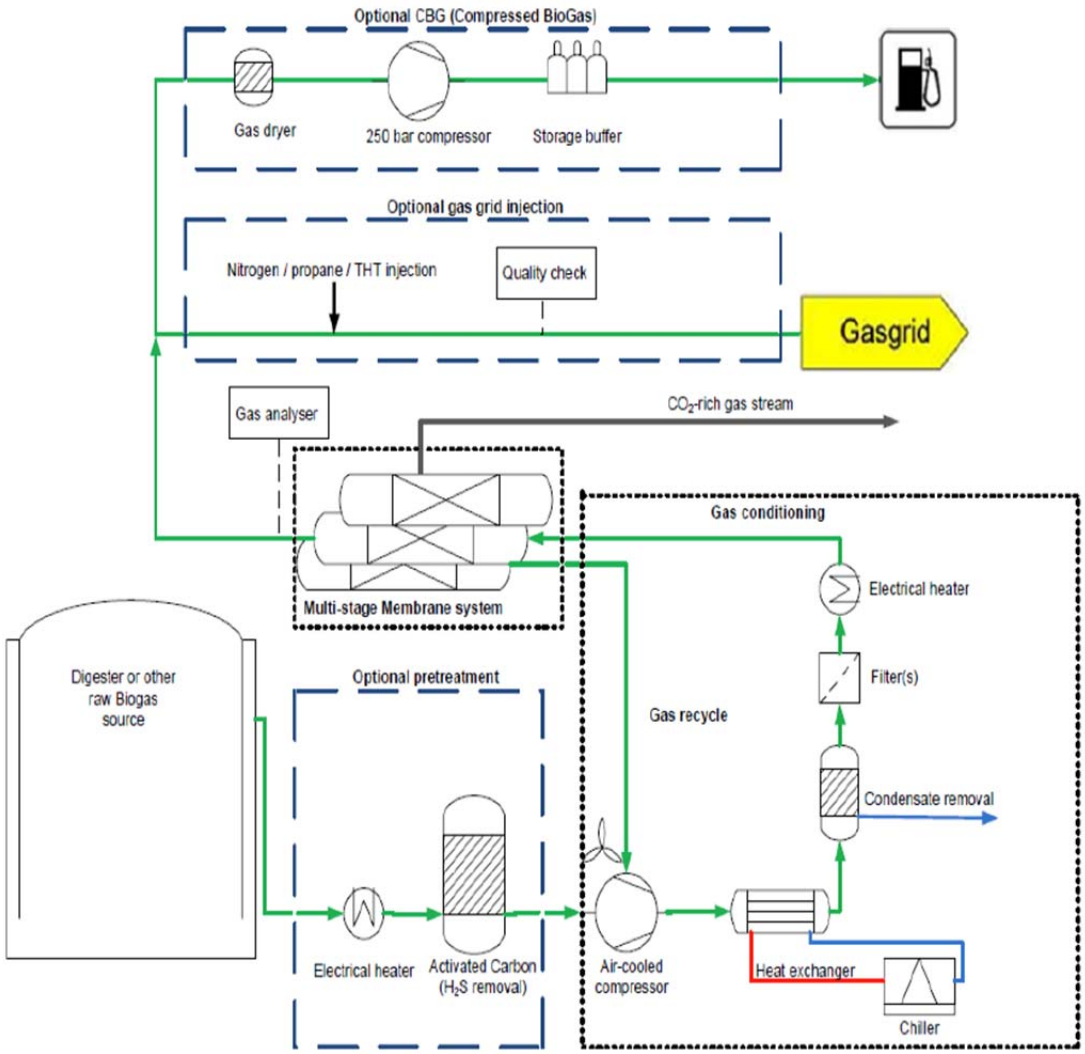


Figure 7.1.2: Process Flow Diagram depicting the improvement of biogas to RNG renewable natural gas courtesy of Clean Methane Systems, LLC.

The value of D3-qualified biogas fluctuates based on the trading prices of three primary revenue components.

1. Commodity Gas Price – Natural Gas Intelligence charts indicate that natural gas has generally traded between \$2.00 and \$3.00 per MMBtu over the past few months, with recent trading at about \$2.25. For our own modeling purposes, we assume 100% of the traded value of this component, and it accounts for roughly 12% of our total calculated value.

2. RIN Credit – D3 RIN credits have risen from roughly \$1.00 per MMBtu a year ago to current levels at about \$1.70, with fluctuation in 2016 generally between \$1.65 and \$1.81. Much of the increase occurred concurrent with new quotas issued by the EPA late in 2015. For calculating purposes, there are

approximately 11.72 RINs applicable to a single MMBtu. For our own modeling purposes, we assume that we receive about 70% of the traded value, meaning this component of revenue will represent about 67% of the total projected.

3. California LCFS Credit – We expect to receive roughly 50% of the traded value of the California Low Carbon Fuel Standards ("LCFS") credits related to applicable biogas. Those credits have traded Calculation of Gross & Net Biogas Values between $100 and $126 per MT in 2016 with recent figures at about $115. For purposes of our own projection models, we use an assumed trading value of $100, meaning that this component of revenue represents about 21% of the net.

At current trading prices for these components and given assumptions stated above, we believe that there is a strong potential to sell D3-qualified biogas into the California market in a variably-priced contract at a current price of about $21 per MMBtu at the point of injection. Fixed price contracts are likely also available, though most are substantially below the variably priced options.[1]

7.2 Renewable Electricity

Most of the digesters that have been built over the last 10 years have used the biogas to produce renewable electricity. At the time, the utilities were willing to pay a premium rate for the renewable electricity. In the last few years, the utilities have met their renewable standards and are no longer willing to pay a premium. Currently, the local utility is offering to purchase the power at $0.04/kWh which does not create a favorable economic return on investment.

7.3 Direct Use

Direct use is typically the lowest capital cost use for the biogas. The challenge in the current market environment with low natural gas costs is that direct use does not provide a significant payback on the investment. Another challenge is that the proposed biogas system will produce significantly more biogas than the most industrial users can utilize to offset natural gas loads. Typically, the most feasible direct use of biogas is to co-locate the biogas plant with a large industrial natural gas user that also is willing to pay a premium to offset their natural gas usage with renewable biogas.

7.4 Off Farm Feed Stock

It is our experience that to make methane recovery projects financially attractive to the investment community, off farm organic waste or substrates, need to be considered. Tipping fees in exchange for offering waste disposal alternatives to private industry can provide an alternative revenue stream for a project and supplemental biogas production. This increases revenue in multiple aspects of the facility but there are other strategic opportunities observable through proper waste accumulation and management. It is not uncommon to see a negative opinion with regards to importing substrates or outside waste into a facility. In the overwhelmingly majority of cases, organic waste we process was previously being disposed of in a landfill, municipal waste water treatment plant, or directly land applied. These options are all less desirable as they are indirectly generating more pollution in their untreated state and contributing to costs and issues to the local government and community in perhaps less visible ways. Our strategic approach allows for energy to be harnessed from waste that otherwise would not have, reducing volume, environmental impact of the waste products, and further subsidizing the true importation of commercial fertilizers commonly used in agriculture to supplement plant nutrient needs. All locations and operations are unique and we have experience with facilities located in nutrient rich environments whose concern is nutrient capture and reduction to facilities which have no livestock and use anaerobic digestion and strategic substrate accumulation solely as a means to amass nutrients to supplement the crop demands of their crop growing business to reduce their cost of purchasing chemical fertilizers. There are near endless options with waste product opportunities that are geographical and facility specific, and through our experience and extensive database of lab analysis and strategic selection program, we customize the needs on a case by case basis.

8.0 Economic Analysis

8.1 Capital Cost

We analyzed the impact of capital cost as related to gas production in SCFM evaluating multiple scenarios for both gas production and gas utilization. Capital cost estimates were compiled based on the best available data.

Conceptually, we took a two-tiered approach to project scale and development, both with a similar element of hub and spoke structure. The first-tier focused on biogas production evaluating multiple scenarios and opportunities related to the production of biogas from available animal waste in Kewaunee County. The second-tier focused on biogas utilization evaluating both centralized and decentralized use of the biogas and electrical production and sales compared with RNG production and sales. This approach allowed us to generate capital cost estimates that could be used to evaluate the economics of incorporating animal waste from multiple satellite farms into one centralized community anaerobic digestion facility, impact of processing off farm organic waste products, and centralized vs. decentralized biogas production for RNG or electrical generation.

Two different approaches were evaluated for biogas production, each under two different scenarios of operation with and without the use of organic feedstocks to augment biogas production. The county was divided into 10 regions, each of which included a centralized anaerobic digestion facility geographically located at or near the farm with the largest manure volume in their respective region. Our base capital evaluation, Scenario 1, took into account only manure collected from these 10 farms without the addition of any substrates. Scenario 2 included additional infrastructure to collect manure from smaller satellite farms in close proximity to the centralized anaerobic digestion facility that were substantially sized to justify the added capital cost of manure collection. Smaller satellite farms with more than 200 cow equivalents were included in this scenario and manure was assumed to be hauled into the centralized facility from each satellite location. Scenario 3 was analogous to Scenario 1 with the only difference being the addition of off farm organic feedstocks. Similarly, Scenario 4 was analogous to Scenario 2 with the only difference being the addition of off farm organic feedstocks.

Gas utilization was evaluated at multiple scaled intervals for decentralization and centralized use as well as utilization as a fuel for electrical power generation and compression for sale directly as natural gas. A network of natural gas pipelines were proposed that would link multiple centralized anaerobic digestion facilities together, collecting the gas for transportation to a centralized gas compression and conditioning plant where gas would be injected into the transmission pipeline that is currently running through Kewaunee County. There was a natural division of the 10 regions into north and south projects based on the assumption that the new gas pipeline had to run down county roads. The north hub included 5 of the proposed regions, while the south hub was comprised of the remaining 5 regions and the existing Kewaunee County Landfill which is currently producing and flaring biogas.

In addition to the equipment necessary for feedstock collection, anaerobic digestion, gas production, collection, conditioning, and utilization, we made assumptions and included equipment costs for the processing and treatment of the post digestion effluent. It was assumed that every facility would include a complete dewatering and water treatment system which processed effluent waste stream to clean water to identify and demonstrate the maximum feasible environmental impact to Kewaunee County should a complete county wide system be constructed. Each of the 10 anaerobic digestion sites is separating coarse fiber and included drying technology to create a saleable product in the form of dairy bedding. After coarse fiber separation, fine fiber and suspended solids are removed to produce a solid cake product which is available for export and utilization in a centralized fertilizer facility. Finally, the effluent is processed by a combination of ultrafiltration (UF) and reverse osmosis (RO) technology that creates clean water and concentrated nutrient water suitable for land application with a variety of technologies.

It was assumed that all equipment was new and there was no credit given at any location for existing infrastructure that could be utilized or incorporated into the proposed facility as discounted costs.

	Manure Only		**20% Substrates**	
	Hub Only	**Hub & Spoke**	**Hub Only**	**Hub & Spoke**
Cap Ex [$]	$115,757,824.99	$158,552,166.03	$140,827,654.21	$188,770,919.25
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$43,023.76	$40,750.90	$28,416.48	$26,147.66

Table 8.1.1: Capital cost estimates of projects with multiple inclusion scenarios for single large county wide project

It becomes immediately apparent from Table 1.1 that the inclusion of other organic feedstocks has the most significant impact of the cost/SCFM biogas production. The inclusion of satellite farms and organization of multiple community digesters is also advantageous exhibiting lower costs/SCFM in both scenarios when compared with collection and utilization of waste from the largest single farms only when evaluating the composite of all the 10 anaerobic digestion locations. On a case by case basis, this does not always hold true and is dependent on the combination of factors including the number of satellite locations, their manure volume contribution, distance from the home site, proportion of trucked vs. pumped or centrally collected manure. Additional analysis on a case by case basis would be required to evaluate the economics of each proposed satellite location with regards to additional cost/SCFM of biogas produced and their relative value to project incorporation.

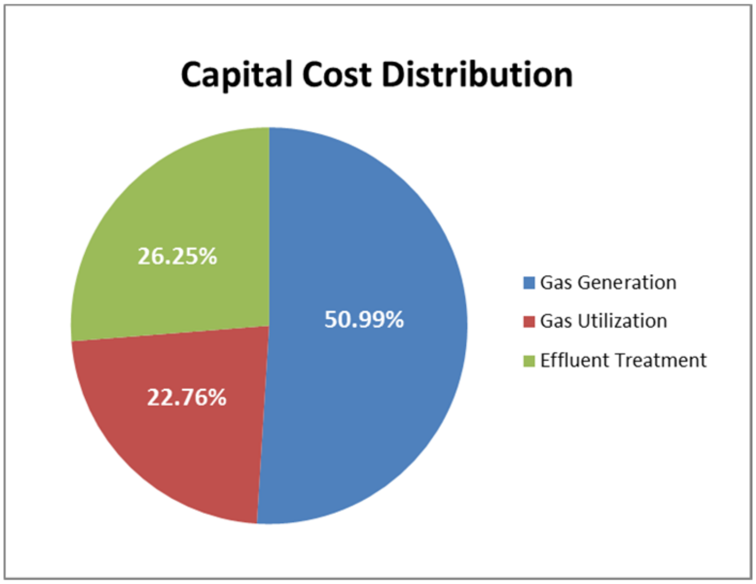
Capital cost estimates were constructed by dividing each individual centralized anaerobic digestion location into 20 unique sub-systems of the project. Each of these categories was assigned a unit cost that was derived utilizing historical operating data and/or current budgetary quotations from equipment vendors.

The capital cost of the project can be divided into three main general categories, gas production, gas utilization, and effluent treatment. The proportional division of these general categories compared between scenarios is outlined in Table 2.1 below.

	Manure Only		**20% Substrates**	
	Hub Only	**Hub & Spoke**	**Hub Only**	**Hub & Spoke**
Gas Production	41.04%	48.23%	45.07%	50.99%
Gas Utilization	33.53%	25.87%	29.50%	22.76%
Effluent Treatment	25.43%	25.91%	25.43%	26.25%

Table 8.1.2: Proportional breakdown of capital investment into single county wide project

The data illustrates that the largest percentage of capital cost is involved with gas generation. This includes the cost of all equipment and infrastructure necessary to collect and process all of the feedstocks and process it utilizing anaerobic digestion technology to create raw biogas. In both cases, the addition of spokes or satellite farms increase the cost of gas production as there is additional capital required to accept manure from satellite farms. This in turn leads to higher processing cost/unit for satellite locations than that from the host farm location. The variation in the proportion of capital used for gas production is not a function of the gas production capital cost but related to efficiencies and lower unit costs for gas utilization and effluent treatment. In both scenarios, the capital cost of the gas production infrastructure had a less than $57/cow equivalent variation between hub and hub and spoke scenarios and in both cases the cost when evaluated on a per cow equivalent basis the hub only without spokes was the lowest unit cost option.



Two independent potential projects were identified within Kewaunee County that also have potential to be combined into one large gas collection and utilization project that is county wide. We also compared the use of biogas as a fuel for internal combustion engines (ICE) and electricity production vs. compression and sale as RNG. The capital cost is very similar for both options.

The electrical generation capital estimate was developed assuming that the biogas was consumed and electricity generated at each anaerobic digestion facility located within each of the 10 regions outlined. At face value, the cost of CHP's and the gas conditioning required to combust biogas is slightly higher than that of conditioning and compression. In order for the conditioning and compression project to work, a private gas pipeline needs to be constructed to channel the biogas to a centralized compression and injection gas plant located adjacent to a transmission line already passing through Kewaunee County. Another larger scale option for utilization of the gas to produce electricity would be to maintain the private gas pipeline and funnel all the gas produced to a centralized electrical power generation plant that could take advantage of scale and employ fewer but significantly larger gas engines that could combust either biogas or natural gas as a fuel.

The North Gas Hub project incorporates regions 1-5 into one project across the northern third of Kewaunee County. Biogas generated at the anaerobic digestion sites is compressed and piped to a centralized compression and injection plant with a proposed location near County Road D and Shady Lane.

North Gas Hub	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$61,363,518.59	$75,546,611.90	$76,452,592.11	$89,404,343.39
Biogas [SCFM]	1,477	1,792	2,738	3,378
Cost/SCFM [$/SCFM]	$41,553.77	$42,150.54	$27,470.92	$26,468.36

Table 8.1.3: North project capital cost estimates

The South Gas Hub project incorporates regions 6-10 into one project across the south of Kewaunee County. Biogas produced at the anaerobic digestion sites is compressed and piped to a centralized compression and injection plant with a proposed location near the intersection of County Road B and County Road F. The South Gas Hub project exhibits slightly better capital cost rates per SCFM of biogas production. This is in part due to the incorporation of the biogas currently being generated and flared the Kewaunee County Landfill that is not being utilized. The cost per SCFM of biogas produced at the landfill is significantly less than any of the 10 regions evaluated as gas is already being generated and the only new infrastructure needed would be gas conditioning and compression boosting along with a short 2.2 mile section of gas pipe to link the landfill with the primary collection pipeline.

South Gas Hub	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$55,532,032.99	$82,393,280.73	$65,512,788.70	$100,083,174.71
Biogas [SCFM]	1,214	2,099	2,173	3,842
Cost/SCFM [$/SCFM]	$45,749.44	$39,262.63	$30,151.23	$26,052.21

Table 8.1.4: South Project capital cost estimates

A third project option combines both the North and South projects/regions together to create one large integrated county wide project. This would require the construction of an additional 9.2 miles of gas piping to link the north and south facilities together. The advantage is seen in reduced capital cost of the construction of a single large gas compression and injection plant vs. two smaller independent facilities as well as a reduction in initial investment in interconnection costs for a single interconnection point as compared to two individual interconnection points and associated infrastructure.

Mega Gas Hub	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$115,757,824.99	$158,552,166.03	$140,827,654.21	$188,199,623.84
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$43,023.76	$40,750.31	$28,416.48	$26,068.52

Table 8.1.5: County wide project with single gas injection plant capital cost estimates

The final project option was evaluated only on a county wide basis. It involves the same construction of 10 localized community digestion facilities which would each have their own on site CHP's and independently product electricity.

All CHP Systems	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$107,444,813.01	$151,837,794.70	$137,048,273.04	$192,355,930.60
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$39,934.06	$39,024.61	$27,653.87	$26,644.24

Table 8.1.6: County wide project with CHP's for electrical production capital cost estimates

In all of the conceptualized projects, the hub and spoke model which incorporates the largest volume of manure when combined with other off farm organic feedstocks is the most advantageous, exhibiting the lowest capital cost per SCFM produced.

The largest use of the capital investment is in the gas conditioning, compression and utilization equipment. This holds true for both RNG and electrical power generation projects. The table below shows the proportion of funds associated with the various aspects of the overall capital investment.

Mega Gas Hub 20% Substrate Hub & Spoke Scenario		
Description	Capital Cost Estimate	Percent of Total
Remote Farm Manure Reception	$8,553,156.25	4.54%
Anaerobic Digesters	$35,982,420.00	19.12%
Substrate Reception	$3,240,077.74	1.72%
Site Manure Collection	$6,716,675.07	3.57%
Site Material Transfer/Hydronic Heating	$2,759,983.33	1.47%
Natural Gas Boiler	$680,117.65	0.36%
Instrumentation	$1,577,502.33	0.84%
Electrical Subcontractor	$14,629,428.31	7.77%
Mechanical/Plumbing Subcontractor	$2,428,348.00	1.29%
Civil/Excavation Subcontractor	$6,659,876.00	3.54%
Engineering/Development Costs	$8,254,929.09	4.39%
Coarse Fiber Separation	$3,396,857.90	1.80%
Fine Solids Separation	$14,767,444.34	7.85%
Water Treatment	$21,331,486.44	11.33%
Effluent Loading	$1,015,235.00	0.54%
Drying System	$7,675,000.00	4.08%
Local Hub Gas Chilling & Compression	$16,500,000.00	8.77%
Semi-Truck & Tanker	$1,660,733.65	0.88%
Rolling Stock Equipment	$2,700,000.00	1.43%
Lagoon Effluent Storage Space	$3,422,163.60	1.82%
Biogas Gas Pipe Line	$5,848,190.14	3.11%
Centralized Gas Conditioning/Injection	$18,400,000.00	9.78%
Total Capital Cost	$188,199,623.84	

Table 8.1.7: Itemized capital cost estimate for substrate hub and spoke system county wide project.

Given the high density of farms and close proximity to one another in Kewaunee County the inclusion of multiple satellite farms or "spokes" into a centralized anaerobic digestion facility displays an improved feasibility. In practice, each spoke or participating satellite farm would have to be individually evaluated for compatibility with the project as well an evaluation of their existing infrastructure to develop detailed capital estimates allowing a case by case analysis to be conducted. For the purpose of this feasibility study, we made the assumption that all satellite farms located within a 5 mile radius of the proposed anaerobic digestion facility were compatible and all farms were considered to be in compliance with required manure storage requirements. It was also assumed that the same set of improvements were required at each satellite site including modification to a centralized manure collection pit, manure loading pump and load stand, unloading and effluent reception system and concrete truck containment pad. Satellite farms of sufficient sizes that were less than ½ mile from the host site were assumed to be able to pump their manure to the centralized digestion facility.

The cost of effluent treatment is significant representing more than 25% of the total capital cost of the project. The capital and operating cost of effluent treatment are both high cost and do not produce revenue streams equivalent to the gas production and utilization capital investment, however they do yield undeniable environmental benefits to the community.

Mega Gas Hub No E	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$83,968,282.17	$115,692,713.40	$104,555,202.84	$139,328,835.17
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$31,208.53	$29,734.78	$21,097.36	$19,299.17

Table 8.1.8: Capital estimate county wide project with NO nutrient concentration or water treatment equipment included.

Satellite farms in a community anaerobic digestion system can be of economic benefit to the project; however this is dependent on the quantity of satellites, size, distance, and existing infrastructure as well as a well-structured and planned community system/project. In some scenarios, it makes economic sense to combine satellites into a project while others may have negligible value or even strain the economics. Taking a look at the county wide scenario, for instance, the capital cost per SCFM of biogas produced is 5.28% lower with a community system that includes 10 host farms and 36 satellite locations where manure is hauled by semi to the anaerobic digestion plants. Looking deeper and comparing the North Project and the South Project a slightly different situation is observed. In the North Project, the capital cost per SCFM of biogas produced is actually 1.14% higher than if no satellite farms were included. This is because in in the (5) five proposed project regions included in the north hub, there are only 11 satellite farms contributing an additional 17.61% of the total manure. In the South Project, the capital cost per SCFM of biogas produced is 14.18% less than if no satellite farms were included in the projects. This cluster includes 25 satellite farms which contribute an additional 44.90% of the manure to the anaerobic digestion facility. In all cases, the capital cost per SCFM of biogas generated was lower for the hub and spoke model than the hub only model when substrates are added to the equation. The addition of substrates has a larger economic impact that in most cases will outweigh that of the inclusions of satellite farms.

8.2 Operating Cost

We analyzed the impact of operating cost as related to biogas production in SCFM evaluating multiple scenarios for both gas production and gas utilization. Operating costs estimates were generated based on historically documented data and experience operating anaerobic digestion facilities. Data for equipment that Dynamic does not directly have operating experience with was provided by manufacturers. Individual operating cost estimates were built for each individual anaerobic digestion hub and gas injection location which was then combined to form composite operations cost estimates. The operating estimate for each anaerobic digestion system was broken down into 33 individual operating expenses. Each one was based on historical operational data from multiple anaerobic digestion systems and scaled using multiple techniques based on a variety of plant inputs and operating points that best relate to each criterion.

The trucking analysis was unique in this study give the high density and close proximity of satellite farms to proposed anaerobic digestion sites. A weighted average trip distance was calculated based on the fraction of total manure from the satellite farms and their distance to the anaerobic digestion site. Data used in the analysis was based on historical data collected by Dynamic. Dynamic currently owns and operates a semi tanker which hauls manure to and from satellite farms to a community digester. The short trips and frequent stops and starts and excessive turning changes the unit rates from more readily available over the road trucking projections. In our model, the trucking is shared between sites with a single truck able to successfully haul manure to and from multiple anaerobic digestion sites in a single day. The cost of trucking manure varies dependent on distance between satellite and anaerobic digester sites. On average, every additional mile adds an additional half-tenth of a cent/gallon of hauling cost. The cost of trucking manure even 1 mile by road is approximately 4-6 times more costly than that of pumping equivalent manure ½ mile as the crow flies when comparing variable costs.

Mega Gas Hub	Manure Only		20% Substrates	
	Hub Only	**Hub & Spoke**	**Hub Only**	**Hub & Spoke**
Cap Ex [$]	$115,757,824.99	$158,552,166.03	$140,827,654.21	$188,199,623.84
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$43,023.76	$40,750.31	$28,416.48	$26,068.52
Op Ex [$]	$15,192,319.65	$22,181,176.39	$17,766,590.31	$25,385,685.78
Cost/SCFM [$/SCFM]	$5,646.54	$5,700.90	$3,584.98	$3,516.31

Table 8.2.1: Operating Costs County Wide RNG project

North Gas Hub	Manure Only		20% Substrates	
	Hub Only	**Hub & Spoke**	**Hub Only**	**Hub & Spoke**
Cap Ex [$]	$61,363,518.59	$75,546,611.90	$76,452,592.11	$89,404,343.39
Biogas [SCFM]	1,477	1,792	2,738	3,378
Cost/SCFM [$/SCFM]	$41,553.77	$42,150.54	$27,470.92	$26,468.36
OP Ex [$]	$8,356,894.78	$10,477,328.33	$9,897,598.35	$11,921,915.46
Cost/SCFM [$/SCFM]	$5,659.07	$5,845.73	$3,556.40	$3,529.51

Table 8.2.2: Operating costs North RNG project

South Gas Hub	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$55,532,032.99	$82,393,280.73	$65,512,788.70	$100,083,174.71
Biogas [SCFM]	1,214	2,099	2,173	3,842
Cost/SCFM [$/SCFM]	$45,749.44	$39,262.63	$30,151.23	$26,052.21
OP Ex [$]	$6,835,424.87	$11,703,848.05	$7,868,991.97	$13,418,770.32
Cost/SCFM [$/SCFM]	$5,631.29	$5,577.20	$3,621.58	$3,492.98

Table 8.2.3: Operating costs South RNG project

All CHP Systems	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$107,444,813.01	$151,837,794.70	$137,048,273.04	$192,355,930.60
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$39,934.06	$39,024.61	$27,653.87	$26,644.24
OP Ex [$]	$13,557,030.42	$19,905,214.30	$16,203,727.60	$23,592,279.75
Cost/SCFM [$/SCFM]	$5,038.75	$5,115.94	$3,269.62	$3,267.89

Table 8.2.4: Operating costs county wide CHP electrical generation project

Mega Gas Hub No E	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Cap Ex [$]	$83,968,282.17	$115,692,713.40	$104,555,202.84	$139,328,835.17
Biogas [SCFM]	2,691	3,891	4,956	7,219
Cost/SCFM [$/SCFM]	$31,208.53	$29,734.78	$21,097.36	$19,299.17
OP Ex [$]	$10,178,450.80	$14,813,384.01	$11,752,447.70	$16,546,834.93
Cost/SCFM [$/SCFM]	$3,783.03	$3,807.26	$2,371.43	$2,291.99

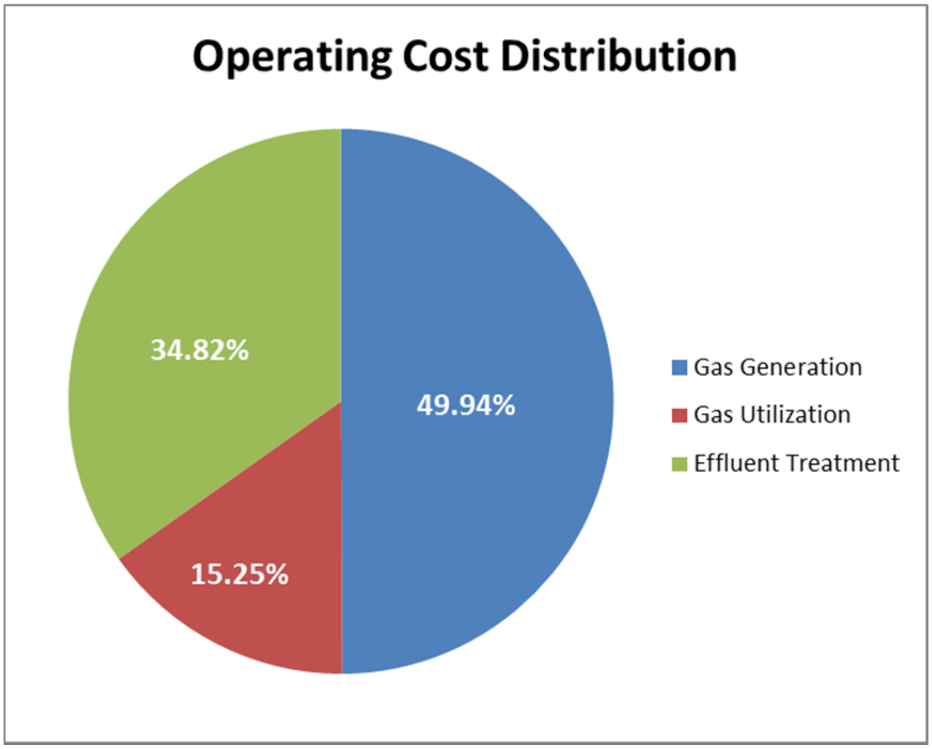
Table 8.2.5: Operating costs county wide project with NO nutrient concentration or water treatment equipment included

Comparing the hub and spoke with and without substrates illustrates that the addition of substrates to the anaerobic digestion system results in a 14.44% increase in the overall annual operating cost while also increasing biogas yields by 85.55% resulting in a 38.83% reduction in operating cost per SCFM produced. Comparing the hub only scenarios with and without substrates, illustrates the addition of substrates to the anaerobic digestion system results in a 16.94% increase in the overall annual operating budget while also increasing biogas yield by 84.19% resulting in a 36.51% reduction in operating cost per SCFM. The operating cost associated with the

Operating Cost Distribution				
	Manure Only		20% Substrates	
	Hub Only	Hub & Spoke	Hub Only	Hub & Spoke
Gas Production	53.32%	54.34%	49.10%	49.94%
Gas Utilization	13.68%	12.45%	17.05%	15.25%
Effluent Treatment	33.00%	33.21%	33.85%	34.82%

Table 8.2.6: Proportional operating cost distribution

addition of substrates to the system is minimal when compared to the benefit and value associated with higher gas yields. This is due in part to two reasons. First, the cost of processing organic food waste products is generally less than that of manure; it costs and estimated 15% less per gallon to process organic food waste than dairy manure. Second, the energy content of the organic feedstock is significantly higher than that of dairy manure. Lower costs of processing combined with higher biogas yields per gallon contribute to the reduced operating cost per SCFM rate when evaluating the addition of substrate to the anaerobic digestion facility.



Hub and spoke compared to hub only projects is more difficult to analyze of a general basis as it is a function of multiple variables that need to be evaluated on a site by site basis. However, when looking at Kewaunee County as a whole, the addition of spokes to all of the hubs has a minimal effect on operating costs. The hub only approach processes manure from 34,183 cows. Adding spokes to all of the hubs increases this number substantially by 46.88% to 50,210 cows. The operating cost/SCFM generated increases less than 1% with the hub and spoke model exhibiting a slightly higher operating cost compared to the hub only model on manure only. There is a less than 3.6% deviation across all models for the North and South projects as well as the single large project. This demonstrates that hauling manure from satellite farms to a centralized anaerobic digestion facility is negligible from a variable operating cost perspective for a project of this proposed scale.

Mega Gas Hub 20% Substrate Hub & Spoke Scenario				
	RNG Natural Gas Use		**Electricity Production Use**	
Description	**Op Ex Estimate**	**% of Total**	**Op Ex Est.**	**% of Total**
Utilities – Gas & Electric	$9,098,781.96	35.19%	$5,041,211.68	21.37%
Parts, Materials, Lubricants	$6,428,810.57	24.87%	$8,225,116.43	34.85%
Labor & Management	$4,985,326.80	19.28%	$4,985,326.80	21.23%
Chemicals/Polymers	$2,564,797.55	9.92%	$2,564,797.55	10.87%
Subcontractors/Services	$1,495,887.89	5.79%	$1,495,887.89	6.34%
Testing & Consulting	$398,736.70	1.54%	$398,736.70	1.69%
Safety/Tools/Housekeeping	$394,498.83	1.53%	$394,498.83	1.67%
Fuel & Truck Expenses	$326,493.79	1.26%	$326,493.79	1.38%
Communications	$161,176.02	0.62%	$161,176.02	0.68%
Total	**$25,854,510.11**		**$23,593,245.69**	

Table 8.2.7: Operating cost comparison between RNG and CHP RE project

Parts and Utilities make up more than 50% of the operating cost of an anaerobic digestion project's operating cost regardless of biogas usage. As is evident in the table above, the power consumption is significantly higher in a project going to RNG vs. generating electricity because of the high power requirement needed to compress the gas prior to injection into a pipe line. Conversely, the equipment required to produce RNG consumes a fraction of the parts that internal combustion gensets which produce electricity. In general, the operating cost of CHP's to produce electricity compares quite closely to the compression and conditioning to RNG quality gas which can be observed in the above table.

8.3 Financial Modeling

All of the projections in this section are based on a county wide system including ten manure processing hubs with the spoke farm's manure being trucked or pumped to the hub site. Each hub is an integrated site with anaerobic digestion, solids separation, solids drying, and NCS. The system includes 66 miles of dedicated gas pipeline, two centralized gas conditioning and injection points on the interstate transmission pipeline. For the modeling, it was assumed that a separate business enterprise provides all funding for construction and ongoing operations.

Project revenue has been categorized into RNG sales, processing fees, and fiber sales totaling $57,273,910 annually.

Base Revenue Source Description	Annual Revenue
Tipping Fee's	$6,708,074
Fiber Sales	$4,613,600
RNG Gas Sales	$45,952,236
Sub-Total Revenue	**$57,273,910**

Table 8.3.1: County Wide RNG Project Revenue Summary

The total operating costs are $25,181,703 per year. The operating cost is decreased by $5,504,536 which represents the reduction in land application cost due to the reduction of volume. This was done because in this evaluation the enterprise supplies all of the capital and the operating costs.

Operating Expense Description	Annual Expense
Labor /Staff	$4,985,326
Material Processing	$9,015,596
Gas Conditioning & Compression	$3,372,209
UF RO	$2,564,797
Solids Separation	$3,236,529
Land Application Cost	($5,504,537)
Fiber Drying	$2,007,246
Sub-Total Expenses	**$19,677,166**

Table 8.3.2: County wide RNG project Operating Cost Summary

In the table below, the CHP Mega Hub illustrates the capital required to install the system to create renewable power for the grid. As stated earlier in this report, WPS's current purchase rate is $.04 per kWh. At this rate, renewable power is not a viable alternative.

The Gas Mega Hub covers the entire county with 10 manure processing sites and two gas conditioning and injection points. The cost of installing the equipment to process at the hubs only is $115,757,824 creating and internal rate of return (IRR) of 2.49%. Installing enough capacity to process the manure from the spoke farms and trucking the manure to the hub requires an investment of $158,552,166 creating an IRR of 2.0%. Increasing the operating capacity to process all of the manure from the hubs, spokes, and add 20% by volume of off farm waste (substrates) requires an additional $30,218,753 in capital investment bringing the total project capital estimate to $188,770,919, creating an IRR of 18.52%. This level of return would be of interest to the financial community.

	Manure Hub Only		Manure Hub & Spoke		Substrate Hub & Spoke	
	Cap Ex	**Pre Tax IRR**	**Cap Ex**	**Pre Tax IRR**	**Cap Ex**	**Pre Tax IRR**
CHP Mega Hub	$107,444,813	NA	$151,837,795	NA	$192,355,931	NA
RNG Mega Hub	$115,757,824	2.49%	$158,552,166	2.00%	$188,770,919	18.52%

Table 8.3.3: Pre tax IRR comparison of county wide RNG & NCS project scenarios

The next table illustrates the financial returns of the enterprise if were installed as a biogas production system only without any of the nutrient concentration or clean water equipment. The total capital requirements of the manure hub and spoke system would be decreased by $42,859,453 and the IRR would increase to 3.90%. Similarly, the required capital investment of the substrate hub and spoke system would be decreased by $49,442,084 and the IRR would increase to 24.77%.

Manure Hub & Spoke		Substrate Hub & Spoke	
Cap Ex	**Pre Tax IRR**	**Cap Ex**	**Pre Tax IRR**
$115,692,713	3.90%	$139,328,835	$24.77%

Table 8.3.4: Pre tax IRR comparison of county wide RNG project scenarios with NO nutrient concentration or water treatment equipment included.

While both options for an integrated county wide RNG system with and without nutrient concentration and clean water generation technology produce a level of return that would be of interest to the financial community, the integration of NCS with biogas dilutes the returns. *Another way of looking at it is that the sale of renewable natural gas (RNG) is funding the nutrient concentration and clean water technology that provides that produces the environmental benefits.*

9.0 Job Creation

All major capital investment projects require the expertise and support of a broad variety of disciplines from engineers and construction workers to restaurant and hotel staff that support the construction project to manufacturing and logistics to manufacture materials and transport them to the site. There are many different ways to estimate the overall impact of large capital projects to the community and the amount of jobs that are created or supported as a result of the investment. Job creation can be grouped into three categories; direct, indirect, and induced jobs.

- Direct Jobs are categorized as occupations that work directly on the development and construction of the project i.e. developers, engineers, construction workers, equipment operators, etc.
- Indirect Jobs are positions at the various materials suppliers and vendors that support the project by providing the materials for construction. These types of jobs include people at manufacturing facilities, concrete plants, and equipment factories both who are involved in the manufacturing process and those in the office such as engineers, designers, and administration that support these positions.
- Induced Jobs are created in support of the direct jobs. They are created to support the demand of workers on the project and include staff at hotels, restaurants, gas stations, grocery stores, bars, etc.

We utilized ARRA methodology, which was developed to estimate job creation resulting from the American Recovery and Reinvestment Act based on capital investment into infrastructure to estimate job creation. The Council of Economic Advisors (CEA) for job creation potential developed a formula to estimate job creation. It assumes that $92,000 of capital investment creates one job year. The job creation is then divided between direct and indirect jobs and induced jobs with 64% being accounted for as direct and indirect jobs and 35% being classified as induced jobs.

Applying the ARRA formula to the proposed Kewaunee County community renewable natural gas project estimated capital cost budget results in the following job estimates:

- $188 million project generates a total estimated 2,044 job years
- 1,308 direct and indirect job years created
- 716 induced job years created

The long term job creation would not end with construction as the gas conditioning and anaerobic digestions facilities will require full time staffing as well as a significant annual operating expense which will generate additional direct, indirect and induced jobs.

It is estimated that the ongoing operations of the facility would have an annual operating expense budget of $25 million dollars and require an estimated 74 new full time permanent skilled positions.

Of the estimated $25 million annual operating budget $9 million would be spent on local subcontractors and service providers, spare parts, tools and equipment to sustain operations. This would result in the creation of an additional 63 direct and indirect jobs on a reoccurring annual basis, not including induced jobs.

The project has the potential to be one of the largest single investments and job creation opportunities in Kewaunee County.

10.0 Ownership Structure

The project that has been proposed is a large-scale value added manure management business in Kewaunee County. This new enterprise will require $180 million dollars of capital investment and will generate over $57 million dollars a year in gross revenue. The annual operating cost will be over of $25 million dollars per year. The company will employ 70-75 full time employees.

This new business will require a unique set of professionals with a command of multiple different disciplines. These disciplines include: manure handling, biogas production, water treatment, transportation logistics, gas pipeline management, gas conditioning, gas injection, nutrient management, financial management, and human resource management. These professionals will focus on maximizing the renewable energy and the environmental attributes of the project allowing the dairy producer to stay focused on dairying.

There proposed project and resulting business in Kewaunee County will be multi-faceted and closely integrated with the dairy producers. There are multiple different ways to structure this business depending on the ownership and capital investment options; however, in each case is paramount to develop a business structure that provides benefits to all parties' involved.

10.1 Value Added Cooperative

If the project were formed as a value-added co-op, it would be eligible for additional grants and government support. According to USDA Rural Development, value added products must meet one of the following criteria:

1. The changing of the physical state or form of the product. Examples include: processing wheat into flour, corn into ethanol, slaughtering livestock or poultry, or slicing tomatoes.
2. A product produced in a manner that enhances its value, as demonstrated through a business plan. An example is organically produced products.
3. The physical segregation of an agricultural commodity or product in a manner that results in the enhancement of the value of that commodity or product. Examples: include an identity preservation system for a variety or quality of grain desired by an identified end-user or the traceability of hormone-free livestock to the retailer.
4. The term "value-added agricultural product" includes any agricultural commodity or product that is used to produce renewable energy on a farm or ranch. *Examples: collecting and converting methane from animal waste to generate energy.*
5. Locally produced and marketed farm products are those that are grown on your own farm and are sold within a 400 mile radius of your farm or within the state in which it is produced.
6. USDA Rural Development offers Value-Added Producer Grants with four eligible entities: Independent Producers, Farmer or Rancher Cooperative, Agricultural Producer Groups and Majority-Controlled Producer Based Business Ventures.

10.2 Limited Liability Company (LLC)

A limited liability company (LLC) is created for a special purpose which allows for multiple members. Members should have the same common goals (production Agriculture) and is a pass through entity for tax purposes.

Each farm entity could be a member of the LLC. The LLC will provide limited liability protection to the owners (members) who are typically not personally responsible for the business debts and liabilities of the LLC. Creditors cannot pursue the personal assets (house, savings accounts, etc.) of the owners to pay business debts.

All LLCs should have a written operating agreement that defines the basic rights and responsibilities of the members (and managers, if you have them). In a member-managed LLC, this would include things like member voting rights, additional capital contributions, buy-out provisions, and other important management and operational issues for the owners.

10.3 Third Part Ownership/Investment

Third party investment capital could be available for the project. The returns created by the project would support the investment. The environmental benefits would also be appealing to the corporate investor.

All three of these ownership structures touched on here would need a professional staff to manage and operate the project. The same basic concept of having the dairy producer pay for services works in all three scenarios. These professionals will focus on maximizing the renewable energy and environmental attributes of the project. The dairy producer can remain focused on dairying. Funding of the enterprise as charge for services has merit in either structure.

11.0 Centralized Fertilizer Plant

The concept of a centralized fertilizer plant was evaluated for this study. It is assumed the plant will process the fine separated solids post -digestion into a pelleted product. Based on the nutrient balance, of the practical manure total, the centralized fertilizer plant can expect to receive approximately 1,020 wet tons per day of fine separated solids or cake. Using a 70% capacity factor, the plant will need to process about 60 tons/hr. of cake at 75% moisture.

A drying and pelleting companies were contacted to get equipment and operating costs. It was assumed the drying and pelleting portion of this plant would represent about 25% of the capital required to build this facility. In addition to the drying and pelleting equipment, there will be considerable amounts of material handling and storage.

Picture 11.1: Pelleting & fertilizer facility courtesy of FEECO international

Based on the production rate of 1,020 tons per day of cake, the plant will need to receive and unload 6-9 semi loads per hour. In order to continue processing over weekends and holidays, the plant will require 4,000 to 5,000 tons of storage to feed the plant. Following the drying and pelleting process, it is estimated that about 28% of the original mass will remain or 286 tons per day at 10% moisture content. Assuming the pelleted product is 35 lbs./cubic foot[6], the plant will produce about 600 cubic yards of pelleted product per day. Assuming the pelleted fertilizer cannot be land applied for 6 months of the year; the plant will need over 100,000 cubic yards of storage or need a significant off-take for the pelleted product throughout the winter months.

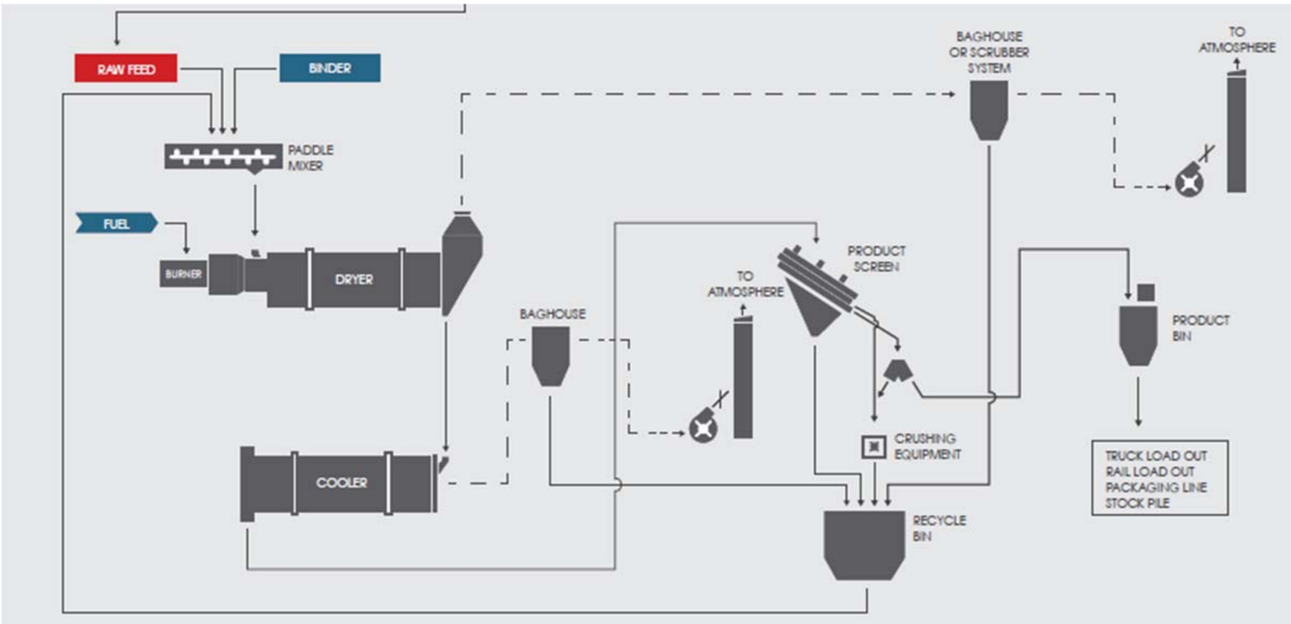


Figure 11.1: Process flow diagram of a pelleting operation courtesy of FEECO International

Based on these assumptions, the capital cost estimate for the centralized fertilizer plant is $45 million and the annual operating cost of the plant is $9.75 million. The plant is capable of producing just over 100,000 tons per year of pellets. Assuming a 5 year simple payback on the investment, the plant will need revenue of $18.75 million per year. Dividing this by the 100,000 tons of pellets provides a pellet price of $188/ton

Site Improvement/Utilities	$1,000,000
Material Receiving Estimate	$1,500,000
Drier System Estimate	$10,000,000
Pellet System Estimate	$5,000,000
Pellet Storage Estimate	$12,500,000
Installation Estimate	$15,000,000
Total Capital Estimate	**$45,000,000**

Table 11.1: Budgetary capital estimates of pelleting facility

Natural Gas Cost Estimate	$5,250,000
Electricity Estimate	$830,000
Parts Cost Estimate	$1,450,000
Labor Cost Estimate	$450,000
Subcontractor Estimate	$870,000
Trucking Estimate	$900,000
Total Annual Operating Cost Estimate	**$9,750,000**

Table 11.2: Budgetary operating estimates of pelleting facility

Based on only manure as the feed stock for digestion, it is anticipated that the pelleted fine solids will have a N-P-K nutrient content of 2.5-2.5-1.0. This equates to about $50/ton in fertilizer value[7] of the pellets. In order to achieve the needed $188/ton, the micronutrient, pH, and organic matter value will have to be realized in addition to the fertilizer value. The pelleted product could also be blended with other micronutrients to develop a value added micronutrient package.

The next challenge with the centralized fertilizer plant concept is the distribution of the pellets on the crop land. As a high level analysis to determine acres required per year for land application, we assumed the limiting nutrient for land application of the pellets is phosphorus. The plant is anticipated to generate about 3,760,000 lbs. of P_2O_5 annually. Assuming 50% of the pellets could be applied to corn silage acres at 80 lbs./acre of P_2O_5 and 50% of the pellets could be applied on forage crop acres at 65 lbs./acre of P_2O_5 and the 1st year availability of the phosphorus is 80%[8], the plant would require about 18,800 acres of corn silage and 23,140 acres of forage for distribution. According to the 2014 Wisconsin Agricultural Statistics, Kewaunee County has 35,600 corn silage acres and 49,728 forage acres[9].

Based on these numbers, the County has the land base demand for the nutrients produced by the centralized fertilizer plant. The challenge with this concept will be developing a pellet product that can be economically justified by the market.

12.0 Conclusion

In summary, our findings indicate that the integration of anaerobic digestion and production of renewable natural gas can successfully be coupled with nutrient concentration and clean water generation on a county wide scale in Kewanee County. A project that achieves the goals of improving the economics of manure handling, having positive environmental benefits, and generating renewable energy is feasible in Kewaunee County.

Dynamic has conceptualized and outlined a county wide project which included 10 community anaerobic digestion systems that process 86% of the total manure produced in the county and producing 7,219 standard cubic feet per minute of biogas. The anaerobic digestion systems are linked together by a 66 mile network of private gas pipeline transferring biogas to a centralized gas conditioning and compression facility to improve the biogas to natural gas quality and inject it into an existing national transportation pipeline. The project also incorporates nutrient concentration technology which will produce an estimated 338,147,110 gallons of clean water, reducing transportation demands of manure hauling, and taking 60,000 semi-trucks off the roads annually. The proposed project has an estimated capital cost of $188 million which would generate an estimated 2,044 jobs during the execution of the project. The resulting manure management agri-business would employ 75 permanent full time skilled workers and have an annual operating budget in excess of $25 million creating additional local direct and indirect/induced jobs annually in Kewaunee County.

If realized, a project of this magnitude would be largest of its kind in North America and establish Kewaunee County as a global leader in sustainability, setting a precedent for responsible agriculture, and establishing a repeatable road map for other neighboring communities across the country.

The development of a project has to be a living and fluid process that adjusts in real time to technical details and changes, logistical material transfer analysis, capital cost, off take and feedstock contracts, operating expense, financing and ownership structure, environmental demand, permitting requirements, and community/local government relations and concerns.

Getting the farms involved in the planning process and understanding of their operations and goals is an extremely important and undervalued aspect of project development which only becomes amplified when developing a community system.

Overall, there still exists a lack of public education as it relates to large farming operations, anaerobic digestion, and nutrient management. The partnership with the community cannot be underestimated during the development of a project of this nature and is an important aspect to successful project development/design that must be proactively managed. Public safety, pollution risks, local economic impact, contamination, odor, and traffic concerns are always addressed with each project. Transparent, frequent communication and cooperation with local governances is the preferred approach to addressing public concern, the earlier the better in many cases.

Preliminary review and evaluation has indicated that a project as described is feasible in Kewaunee County justifying additional evaluation and development. The following are recommended next steps in development and evaluation of the project opportunity in Kewaunee County that should be worked on in parallel.

1. Host a county wide meeting for farmers to discuss the project, define the project goals, and create a shared vision to generate project support.
2. Conduct a county wide survey to get a better understanding of each of the farms current status including and addressing items such as the following:
   - Current manure management practices and application methods
   - Overall nutrient management situation, issues, problems, etc.
   - Land application capabilities and limitations
   - Manure and nutrient operational challenges
   - Existing infrastructure and manure collection/storage capacities
   - Manure volumes and types

2. Evaluate funding sources and possible business ownership structures:
   - Public
   - Public / Private
   - Private

13.0 Sources

[1] Avallone, Eugene A. and Baumeister III, Theodore . 1996. *Marks' Standard Handbook for Mechanical Engineers*. Tenth Addition. 4-26.

[2] The Fertilizer Institute. http://www.nutrientstewardship.com/4rs/4r-principles.

[3] Madison, Fred, Kelling, Keith, Massie, Leonard, Ward Good, Laura. *Guidelines for Applying Manure to Cropland and Pasture in Wisconsin*. University of Wisconsin – Extension. A3392.

[4] Unites States Department of Agriculture National Agriculture Statistics Service. *2014 Wisconsin Agriculture Statistics.* Produced in cooperation with the Wisconsin Department of Agriculture, Trade, and Consumer Protection and complied by the USDA NASS, Wisconsin Field Office.

[5] Laboski, Carrie A. M., and Peters, John B. 2012. *Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin.* University of Wisconsin – Extension. A2809.

[6] Hoffman, Lee and Reckinger, Nick. FEECO International.

[7] Knorr, Bryce. 2016. *Weekly Fertilizer Review*. Farm Futures. http://farmfutures.com/story-weekly-fertilizer-review-0-30765.

[8] Madison, Fred, Kelling, Keith, Massie, Leonard, Ward Good, Laura. *Guidelines for Applying Manure to Cropland and Pasture in Wisconsin*. University of Wisconsin – Extension. A3392.

[9] Unites States Department of Agriculture National Agriculture Statistics Service. *2014 Wisconsin Agriculture Statistics.* Produced in cooperation with the Wisconsin Department of Agriculture, Trade, and Consumer Protection and complied by the USDA NASS, Wisconsin Field Office.

[10] Information provided by Clean Methane Systems LLC . June 27th, 2016.

14.0 Appendix 1: Mass & Energy Balance

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #1 - Total**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5414	0	0	170,835	709.0	121,720	97,376	
Substrate				0	0.0	0	0	180,000
Totals				170,835	709	121,720	97,376	

Biogas Production

Methane Content	60%	
Methane Generation	350,554	cubic ft/day
Energy Value of Biogas	315,498,901	Btu/day
Biogas Production	584,257	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,553	kW
CHP Capacity Factor	90.0%	
Electricity Produced	33,538	kWh/day
Plant Parasitic Load	3,354	kWh/day
Electricity for Export	30,184	kWh/day

Thermal Energy Production

Plant Thermal Needs	99	MMBtu/day
Excess Thermal Energy	27	MMBtu/day
Excess Thermal Energy	1.1	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #2 - Total**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	9293	0	0	293,233	1,216.9	208,930	167,144	
Substrate				0	0.0	0	0	180,000
Totals				293,233	1,217	208,930	167,144	

Biogas Production

Methane Content	60%	
Methane Generation	601,718	cubic ft/day
Energy Value of Biogas	541,546,230	Btu/day
Biogas Production	1,002,863	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,665	kW
CHP Capacity Factor	90.0%	
Electricity Produced	57,567	kWh/day
Plant Parasitic Load	5,757	kWh/day
Electricity for Export	51,810	kWh/day

Thermal Energy Production

Plant Thermal Needs	170	MMBtu/day
Excess Thermal Energy	46	MMBtu/day
Excess Thermal Energy	1.9	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #3 - Total**
Date: June 7, 2016

Inputs

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2722	0	0	85,891	356.4	61,197	48,958	
Substrate				0	0.0	0	0	180,000
Totals				85,891	356	61,197	48,958	

Biogas Production

Methane Content	60%	
Methane Generation	176,248	cubic ft/day
Energy Value of Biogas	158,623,570	Btu/day
Biogas Production	293,747	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	781	kW
CHP Capacity Factor	90.0%	
Electricity Produced	16,862	kWh/day
Plant Parasitic Load	1,686	kWh/day
Electricity for Export	15,176	kWh/day

Thermal Energy Production

Plant Thermal Needs	50	MMBtu/day
Excess Thermal Energy	14	MMBtu/day
Excess Thermal Energy	0.6	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #4 - Total**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5837	0	0	184,182	764.4	131,230	104,984	
Substrate				0	0.0	0	0	180,000
Totals				184,182	764	131,230	104,984	

Biogas Production

Methane Content	60%	
Methane Generation	377,943	cubic ft/day
Energy Value of Biogas	340,149,074	Btu/day
Biogas Production	629,906	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,674	kW
CHP Capacity Factor	90.0%	
Electricity Produced	36,158	kWh/day
Plant Parasitic Load	3,616	kWh/day
Electricity for Export	32,542	kWh/day

Thermal Energy Production

Plant Thermal Needs	107	MMBtu/day
Excess Thermal Energy	29	MMBtu/day
Excess Thermal Energy	1.2	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #5 - Total**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2921	0	0	92,170	382.5	65,671	52,537	
Substrate				0	0.0	0	0	180,000
Totals				92,170	383	65,671	52,537	

Biogas Production

Methane Content	60%	
Methane Generation	189,134	cubic ft/day
Energy Value of Biogas	170,220,223	Btu/day
Biogas Production	315,223	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	838	kW
CHP Capacity Factor	90.0%	
Electricity Produced	18,095	kWh/day
Plant Parasitic Load	1,809	kWh/day
Electricity for Export	16,285	kWh/day

Thermal Energy Production

Plant Thermal Needs	54	MMBtu/day
Excess Thermal Energy	15	MMBtu/day
Excess Thermal Energy	0.6	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #6 - Total**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	7950	0	0	250,856	1,041.1	178,736	142,989	
Substrate				0	0.0	0	0	180,000
Totals				250,856	1,041	178,736	142,989	

Biogas Production

Methane Content	60%	
Methane Generation	514,759	cubic ft/day
Energy Value of Biogas	463,283,388	Btu/day
Biogas Production	857,932	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,280	kW
CHP Capacity Factor	90.0%	
Electricity Produced	49,248	kWh/day
Plant Parasitic Load	4,925	kWh/day
Electricity for Export	44,323	kWh/day

Thermal Energy Production

Plant Thermal Needs	146	MMBtu/day
Excess Thermal Energy	40	MMBtu/day
Excess Thermal Energy	1.6	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #7 - Total**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5008	0	0	158,024	655.8	112,592	90,074	
Substrate				0	0.0	0	0	180,000
Totals				158,024	656	112,592	90,074	

Biogas Production

Methane Content	60%	
Methane Generation	324,266	cubic ft/day
Energy Value of Biogas	291,839,397	Btu/day
Biogas Production	540,443	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,436	kW
CHP Capacity Factor	90.0%	
Electricity Produced	31,023	kWh/day
Plant Parasitic Load	3,102	kWh/day
Electricity for Export	27,921	kWh/day

Thermal Energy Production

Plant Thermal Needs	92	MMBtu/day
Excess Thermal Energy	25	MMBtu/day
Excess Thermal Energy	1.0	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #8 - Total Cows**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	3569	0	0	112,617	467.4	80,240	64,192	
Substrate				0	0.0	0	0	180,000
Totals				112,617	467	80,240	64,192	

Biogas Production

Methane Content	60%	
Methane Generation	231,091	cubic ft/day
Energy Value of Biogas	207,982,190	Btu/day
Biogas Production	385,152	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,024	kW
CHP Capacity Factor	90.0%	
Electricity Produced	22,109	kWh/day
Plant Parasitic Load	2,211	kWh/day
Electricity for Export	19,898	kWh/day

Thermal Energy Production

Plant Thermal Needs	65	MMBtu/day
Excess Thermal Energy	18	MMBtu/day
Excess Thermal Energy	0.7	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #9 - Total**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5602	0	0	176,767	733.6	125,947	100,758	
Substrate				0	0.0	0	0	180,000
Totals				176,767	734	125,947	100,758	

Biogas Production

Methane Content	60%	
Methane Generation	362,727	cubic ft/day
Energy Value of Biogas	326,454,533	Btu/day
Biogas Production	604,545	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,607	kW
CHP Capacity Factor	90.0%	
Electricity Produced	34,703	kWh/day
Plant Parasitic Load	3,470	kWh/day
Electricity for Export	31,232	kWh/day

Thermal Energy Production

Plant Thermal Needs	103	MMBtu/day
Excess Thermal Energy	28	MMBtu/day
Excess Thermal Energy	1.2	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #10 - Total**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	10059	0	0	317,404	1,317.2	226,151	180,921	
Substrate				0	0.0	0	0	180,000
Totals				317,404	1,317	226,151	180,921	

Biogas Production

Methane Content	60%	
Methane Generation	651,316	cubic ft/day
Energy Value of Biogas	586,184,604	Btu/day
Biogas Production	1,085,527	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,885	kW
CHP Capacity Factor	90.0%	
Electricity Produced	62,312	kWh/day
Plant Parasitic Load	6,231	kWh/day
Electricity for Export	56,081	kWh/day

Thermal Energy Production

Plant Thermal Needs	184	MMBtu/day
Excess Thermal Energy	50	MMBtu/day
Excess Thermal Energy	2.1	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Total Hubs**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	58375	0	0	1,841,977	7,644.2	1,312,416	1,049,933	
Substrate				0	0.0	0	0	180,000
Totals				1,841,977	7,644	1,312,416	1,049,933	

Biogas Production

Methane Content	60%	
Methane Generation	3,779,758	cubic ft/day
Energy Value of Biogas	3,401,782,110	Btu/day
Biogas Production	6,299,597	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	16,741	kW
CHP Capacity Factor	90.0%	
Electricity Produced	361,614	kWh/day
Plant Parasitic Load	36,161	kWh/day
Electricity for Export	325,452	kWh/day

Thermal Energy Production

Plant Thermal Needs	1,070	MMBtu/day
Excess Thermal Energy	291	MMBtu/day
Excess Thermal Energy	12.1	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #1 - Feasible**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4721	0	0	148,967	618.2	106,140	84,912	
Substrate				0	0.0	0	0	180,000
Totals				148,967	618	106,140	84,912	

Biogas Production

Methane Content	60%	
Methane Generation	305,683	cubic ft/day
Energy Value of Biogas	275,114,575	Btu/day
Biogas Production	509,471	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,354	kW
CHP Capacity Factor	90.0%	
Electricity Produced	29,245	kWh/day
Plant Parasitic Load	2,925	kWh/day
Electricity for Export	26,321	kWh/day

Thermal Energy Production

Plant Thermal Needs	87	MMBtu/day
Excess Thermal Energy	23	MMBtu/day
Excess Thermal Energy	1.0	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #2 - Feasible**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	8418	0	0	265,623	1,102.3	189,258	151,406	
Substrate				0	0.0	0	0	180,000
Totals				265,623	1,102	189,258	151,406	

Biogas Production

Methane Content	60%	
Methane Generation	545,062	cubic ft/day
Energy Value of Biogas	490,555,920	Btu/day
Biogas Production	908,437	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,414	kW
CHP Capacity Factor	90.0%	
Electricity Produced	52,147	kWh/day
Plant Parasitic Load	5,215	kWh/day
Electricity for Export	46,932	kWh/day

Thermal Energy Production

Plant Thermal Needs	154	MMBtu/day
Excess Thermal Energy	42	MMBtu/day
Excess Thermal Energy	1.7	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #3 - Feasible**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2635	0	0	83,145	345.1	59,241	47,393	
Substrate				0	0.0	0	0	180,000
Totals				83,145	345	59,241	47,393	

Biogas Production

Methane Content	60%	
Methane Generation	170,615	cubic ft/day
Energy Value of Biogas	153,553,676	Btu/day
Biogas Production	284,359	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	756	kW
CHP Capacity Factor	90.0%	
Electricity Produced	16,323	kWh/day
Plant Parasitic Load	1,632	kWh/day
Electricity for Export	14,691	kWh/day

Thermal Energy Production

Plant Thermal Needs	48	MMBtu/day
Excess Thermal Energy	13	MMBtu/day
Excess Thermal Energy	0.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #4 - Feasible**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5523	0	0	174,274	723.2	124,171	99,337	
Substrate				0	0.0	0	0	180,000
Totals				174,274	723	124,171	99,337	

Biogas Production

Methane Content	60%	
Methane Generation	357,612	cubic ft/day
Energy Value of Biogas	321,850,837	Btu/day
Biogas Production	596,020	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,584	kW
CHP Capacity Factor	90.0%	
Electricity Produced	34,213	kWh/day
Plant Parasitic Load	3,421	kWh/day
Electricity for Export	30,792	kWh/day

Thermal Energy Production

Plant Thermal Needs	101	MMBtu/day
Excess Thermal Energy	27	MMBtu/day
Excess Thermal Energy	1.1	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #5 - Feasible**
Date: June 7, 2016

Inputs

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2619	0	0	82,640	343.0	58,882	47,105	
Substrate				0	0.0	0	0	180,000
Totals				82,640	343	58,882	47,105	

Biogas Production

Methane Content	60%	
Methane Generation	169,579	cubic ft/day
Energy Value of Biogas	152,621,282	Btu/day
Biogas Production	282,632	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	751	kW
CHP Capacity Factor	90.0%	
Electricity Produced	16,224	kWh/day
Plant Parasitic Load	1,622	kWh/day
Electricity for Export	14,601	kWh/day

Thermal Energy Production

Plant Thermal Needs	48	MMBtu/day
Excess Thermal Energy	13	MMBtu/day
Excess Thermal Energy	0.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #6 - Feasible**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	6700	0	0	211,413	877.4	150,633	120,506	
Substrate				0	0.0	0	0	180,000
Totals				211,413	877	150,633	120,506	

Biogas Production

Methane Content	60%	
Methane Generation	433,822	cubic ft/day
Energy Value of Biogas	390,440,088	Btu/day
Biogas Production	723,037	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,921	kW
CHP Capacity Factor	90.0%	
Electricity Produced	41,504	kWh/day
Plant Parasitic Load	4,150	kWh/day
Electricity for Export	37,354	kWh/day

Thermal Energy Production

Plant Thermal Needs	123	MMBtu/day
Excess Thermal Energy	33	MMBtu/day
Excess Thermal Energy	1.4	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #7 - Feasible**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	2994	0	0	94,473	392.1	67,313	53,850	
Substrate				0	0.0	0	0	180,000
Totals				94,473	392	67,313	53,850	

Biogas Production

Methane Content	60%	
Methane Generation	193,860	cubic ft/day
Energy Value of Biogas	174,474,272	Btu/day
Biogas Production	323,101	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	859	kW
CHP Capacity Factor	90.0%	
Electricity Produced	18,547	kWh/day
Plant Parasitic Load	1,855	kWh/day
Electricity for Export	16,692	kWh/day

Thermal Energy Production

Plant Thermal Needs	55	MMBtu/day
Excess Thermal Energy	15	MMBtu/day
Excess Thermal Energy	0.6	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #8 - Feasible**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2624	0	0	82,798	343.6	58,994	47,195	
Substrate				0	0.0	0	0	180,000
Totals				82,798	344	58,994	47,195	

Biogas Production

Methane Content	60%	
Methane Generation	169,903	cubic ft/day
Energy Value of Biogas	152,912,655	Btu/day
Biogas Production	283,172	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	753	kW
CHP Capacity Factor	90.0%	
Electricity Produced	16,255	kWh/day
Plant Parasitic Load	1,625	kWh/day
Electricity for Export	14,629	kWh/day

Thermal Energy Production

Plant Thermal Needs	48	MMBtu/day
Excess Thermal Energy	13	MMBtu/day
Excess Thermal Energy	0.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #9 - Feasible**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4809	0	0	151,744	629.7	108,118	86,495	
Substrate				0	0.0	0	0	180,000
Totals				151,744	630	108,118	86,495	

Biogas Production

Methane Content	60%	
Methane Generation	311,381	cubic ft/day
Energy Value of Biogas	280,242,744	Btu/day
Biogas Production	518,968	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,379	kW
CHP Capacity Factor	90.0%	
Electricity Produced	29,790	kWh/day
Plant Parasitic Load	2,979	kWh/day
Electricity for Export	26,811	kWh/day

Thermal Energy Production

Plant Thermal Needs	88	MMBtu/day
Excess Thermal Energy	24	MMBtu/day
Excess Thermal Energy	1.0	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #10 - Feasible**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	9167	0	0	289,258	1,200.4	206,097	164,878	
Substrate				0	0.0	0	0	180,000
Totals				289,258	1,200	206,097	164,878	

Biogas Production

Methane Content	60%	
Methane Generation	593,560	cubic ft/day
Energy Value of Biogas	534,203,625	Btu/day
Biogas Production	989,266	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,629	kW
CHP Capacity Factor	90.0%	
Electricity Produced	56,787	kWh/day
Plant Parasitic Load	5,679	kWh/day
Electricity for Export	51,108	kWh/day

Thermal Energy Production

Plant Thermal Needs	168	MMBtu/day
Excess Thermal Energy	46	MMBtu/day
Excess Thermal Energy	1.9	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Total Hubs - Practical**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	50210	0	0	1,584,337	6,575.0	1,128,846	903,077	
Substrate				0	0.0	0	0	180,000
Totals				1,584,337	6,575	1,128,846	903,077	

Biogas Production

Methane Content	60%	
Methane Generation	3,251,077	cubic ft/day
Energy Value of Biogas	2,925,969,674	Btu/day
Biogas Production	5,418,462	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	14,400	kW
CHP Capacity Factor	90.0%	
Electricity Produced	311,034	kWh/day
Plant Parasitic Load	31,103	kWh/day
Electricity for Export	279,931	kWh/day

Thermal Energy Production

Plant Thermal Needs	920	MMBtu/day
Excess Thermal Energy	250	MMBtu/day
Excess Thermal Energy	10.4	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #1 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4721	0	0	148,967	618.2	106,140	84,912	
Substrate				37,242	154.6	92,733	83,459	180,000
Totals				186,209	773	198,872	168,371	

Biogas Production

Methane Content	60%		
Methane Generation	576,091	cubic ft/day	
Energy Value of Biogas	518,481,958	Btu/day	
Biogas Production	960,152	cubic ft/day	666.772066

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,552	kW
CHP Capacity Factor	90.0%	
Electricity Produced	55,115	kWh/day
Plant Parasitic Load	5,512	kWh/day
Electricity for Export	49,604	kWh/day

Thermal Energy Production

Plant Thermal Needs	108	MMBtu/day
Excess Thermal Energy	99	MMBtu/day
Excess Thermal Energy	4.1	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #2 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	8418	0	0	265,623	1,102.3	189,258	151,406	
Substrate				66,406	275.6	165,351	148,816	180,000
Totals				332,029	1,378	354,609	300,222	

Biogas Production

Methane Content	60%	
Methane Generation	1,027,225	cubic ft/day
Energy Value of Biogas	924,502,926	Btu/day
Biogas Production	1,712,042	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	4,550	kW
CHP Capacity Factor	90.0%	
Electricity Produced	98,276	kWh/day
Plant Parasitic Load	9,828	kWh/day
Electricity for Export	88,448	kWh/day

Thermal Energy Production

Plant Thermal Needs	193	MMBtu/day
Excess Thermal Energy	177	MMBtu/day
Excess Thermal Energy	7.4	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #3 - Feasible w/ Substrates**

Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	2635	0	0	83,145	345.1	59,241	47,393	
Substrate				20,786	86.3	51,757	46,581	180,000
Totals				103,931	431	110,999	93,975	

Biogas Production

Methane Content	60%	
Methane Generation	321,539	cubic ft/day
Energy Value of Biogas	289,385,115	Btu/day
Biogas Production	535,898	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,424	kW
CHP Capacity Factor	90.0%	
Electricity Produced	30,762	kWh/day
Plant Parasitic Load	3,076	kWh/day
Electricity for Export	27,686	kWh/day

Thermal Energy Production

Plant Thermal Needs	60	MMBtu/day
Excess Thermal Energy	55	MMBtu/day
Excess Thermal Energy	2.3	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #4 - Feasible w/ Substrates**

Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	5523	0	0	174,274	723.2	124,171	99,337	
Substrate				43,569	180.8	108,487	97,638	180,000
Totals				217,843	904	232,658	196,975	

Biogas Production

Methane Content	60%	
Methane Generation	673,960	cubic ft/day
Energy Value of Biogas	606,563,621	Btu/day
Biogas Production	1,123,266	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,985	kW
CHP Capacity Factor	90.0%	
Electricity Produced	64,478	kWh/day
Plant Parasitic Load	6,448	kWh/day
Electricity for Export	58,031	kWh/day

Thermal Energy Production

Plant Thermal Needs	127	MMBtu/day
Excess Thermal Energy	116	MMBtu/day
Excess Thermal Energy	4.8	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #5 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	2619	0	0	82,640	343.0	58,882	47,105	
Substrate				20,660	85.7	51,443	46,299	180,000
Totals				103,300	429	110,325	93,404	

Biogas Production

Methane Content	60%	
Methane Generation	319,588	cubic ft/day
Energy Value of Biogas	287,629,341	Btu/day
Biogas Production	532,647	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,416	kW
CHP Capacity Factor	90.0%	
Electricity Produced	30,575	kWh/day
Plant Parasitic Load	3,058	kWh/day
Electricity for Export	27,518	kWh/day

Thermal Energy Production

Plant Thermal Needs	60	MMBtu/day
Excess Thermal Energy	55	MMBtu/day
Excess Thermal Energy	2.3	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #6 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	6700	0	0	211,413	877.4	150,633	120,506	
Substrate				52,853	219.3	131,604	118,444	180,000
Totals				264,266	1,097	282,237	238,950	

Biogas Production

Methane Content	60%	
Methane Generation	817,579	cubic ft/day
Energy Value of Biogas	735,821,547	Btu/day
Biogas Production	1,362,632	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	3,621	kW
CHP Capacity Factor	90.0%	
Electricity Produced	78,219	kWh/day
Plant Parasitic Load	7,822	kWh/day
Electricity for Export	70,397	kWh/day

Thermal Energy Production

Plant Thermal Needs	154	MMBtu/day
Excess Thermal Energy	141	MMBtu/day
Excess Thermal Energy	5.9	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #7 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	2994	0	0	94,473	392.1	67,313	53,850	
Substrate				23,618	98.0	58,809	52,928	180,000
Totals				118,091	490	126,121	106,778	

Biogas Production

Methane Content	60%	
Methane Generation	365,347	cubic ft/day
Energy Value of Biogas	328,812,139	Btu/day
Biogas Production	608,911	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,618	kW
CHP Capacity Factor	90.0%	
Electricity Produced	34,953	kWh/day
Plant Parasitic Load	3,495	kWh/day
Electricity for Export	31,458	kWh/day

Thermal Energy Production

Plant Thermal Needs	69	MMBtu/day
Excess Thermal Energy	63	MMBtu/day
Excess Thermal Energy	2.6	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #8 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2624	0	0	82,798	343.6	58,994	47,195	
Substrate				20,700	85.9	51,543	46,389	180,000
Totals				103,498	430	110,537	93,584	

Biogas Production

Methane Content	60%	
Methane Generation	320,202	cubic ft/day
Energy Value of Biogas	288,182,105	Btu/day
Biogas Production	533,671	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,418	kW
CHP Capacity Factor	90.0%	
Electricity Produced	30,634	kWh/day
Plant Parasitic Load	3,063	kWh/day
Electricity for Export	27,571	kWh/day

Thermal Energy Production

Plant Thermal Needs	60	MMBtu/day
Excess Thermal Energy	55	MMBtu/day
Excess Thermal Energy	2.3	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #9 - Feasible w/ Subs**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4809	0	0	151,744	629.7	108,118	86,495	
Substrate				37,936	157.4	94,461	85,015	180,000
Totals				189,680	787	202,579	171,509	

Biogas Production

Methane Content	60%	
Methane Generation	586,828	cubic ft/day
Energy Value of Biogas	528,145,247	Btu/day
Biogas Production	978,047	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,599	kW
CHP Capacity Factor	90.0%	
Electricity Produced	56,143	kWh/day
Plant Parasitic Load	5,614	kWh/day
Electricity for Export	50,528	kWh/day

Thermal Energy Production

Plant Thermal Needs	110	MMBtu/day
Excess Thermal Energy	101	MMBtu/day
Excess Thermal Energy	4.2	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #10 - Feasible w/ Substrates**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	9167	0	0	289,258	1,200.4	206,097	164,878	
Substrate				72,315	300.1	180,064	162,058	180,000
Totals				361,573	1,501	386,161	326,936	

Biogas Production

Methane Content	60%	
Methane Generation	1,118,627	cubic ft/day
Energy Value of Biogas	1,006,764,505	Btu/day
Biogas Production	1,864,379	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	4,955	kW
CHP Capacity Factor	90.0%	
Electricity Produced	107,020	kWh/day
Plant Parasitic Load	10,702	kWh/day
Electricity for Export	96,318	kWh/day

Thermal Energy Production

Plant Thermal Needs	210	MMBtu/day
Excess Thermal Energy	193	MMBtu/day
Excess Thermal Energy	8.0	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #1 - Hub Only**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	4020	0	0	126,848	526.4	90,380	72,304	
Substrate				0	0.0	0	0	180,000
Totals				126,848	526	90,380	72,304	

Biogas Production

Methane Content	60%		
Methane Generation	260,293	cubic ft/day	
Energy Value of Biogas	234,264,053	Btu/day	
Biogas Production	433,822	cubic ft/day	301.265501

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,153	kW
CHP Capacity Factor	90.0%	
Electricity Produced	24,903	kWh/day
Plant Parasitic Load	2,490	kWh/day
Electricity for Export	22,412	kWh/day

Thermal Energy Production

Plant Thermal Needs	74	MMBtu/day
Excess Thermal Energy	20	MMBtu/day
Excess Thermal Energy	0.8	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #2 - Hub Only**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	7644	0	0	241,200	1,001.0	171,856	137,485	
Substrate				0	0.0	0	0	180,000
Totals				241,200	1,001	171,856	137,485	

Biogas Production

Methane Content	60%	
Methane Generation	494,946	cubic ft/day
Energy Value of Biogas	445,451,349	Btu/day
Biogas Production	824,910	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,192	kW
CHP Capacity Factor	90.0%	
Electricity Produced	47,352	kWh/day
Plant Parasitic Load	4,735	kWh/day
Electricity for Export	42,617	kWh/day

Thermal Energy Production

Plant Thermal Needs	140	MMBtu/day
Excess Thermal Energy	38	MMBtu/day
Excess Thermal Energy	1.6	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #3 - Hub Cows Only**
Date: June 7, 2016

Inputs

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1798	0	0	56,734	235.4	40,424	32,339	
Substrate				0	0.0	0	0	180,000
Totals				56,734	235	40,424	32,339	

Biogas Production

Methane Content	60%	
Methane Generation	116,420	cubic ft/day
Energy Value of Biogas	104,777,803	Btu/day
Biogas Production	194,033	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	516	kW
CHP Capacity Factor	90.0%	
Electricity Produced	11,138	kWh/day
Plant Parasitic Load	1,114	kWh/day
Electricity for Export	10,024	kWh/day

Thermal Energy Production

Plant Thermal Needs	33	MMBtu/day
Excess Thermal Energy	9	MMBtu/day
Excess Thermal Energy	0.4	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #4 - Hub Only**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	4773	0	0	150,608	625.0	107,309	85,847	
Substrate				0	0.0	0	0	180,000
Totals				150,608	625	107,309	85,847	

Biogas Production

Methane Content	60%	
Methane Generation	309,050	cubic ft/day
Energy Value of Biogas	278,144,857	Btu/day
Biogas Production	515,083	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,369	kW
CHP Capacity Factor	90.0%	
Electricity Produced	29,567	kWh/day
Plant Parasitic Load	2,957	kWh/day
Electricity for Export	26,610	kWh/day

Thermal Energy Production

Plant Thermal Needs	88	MMBtu/day
Excess Thermal Energy	24	MMBtu/day
Excess Thermal Energy	1.0	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #5 - Hub Cows Only**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1470	0	0	46,385	192.5	33,049	26,439	
Substrate				0	0.0	0	0	152,727
Totals				46,385	192	33,049	26,439	

Biogas Production

Methane Content	60%	
Methane Generation	95,182	cubic ft/day
Energy Value of Biogas	85,663,725	Btu/day
Biogas Production	158,637	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	422	kW
CHP Capacity Factor	90.0%	
Electricity Produced	9,106	kWh/day
Plant Parasitic Load	911	kWh/day
Electricity for Export	8,196	kWh/day

Thermal Energy Production

Plant Thermal Needs	27	MMBtu/day
Excess Thermal Energy	7	MMBtu/day
Excess Thermal Energy	0.3	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #6 - Hub Cows Only**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2265	0	0	71,470	296.6	50,923	40,738	
Substrate				0	0.0	0	0	180,000
Totals				71,470	297	50,923	40,738	

Biogas Production

Methane Content	60%	
Methane Generation	146,658	cubic ft/day
Energy Value of Biogas	131,992,060	Btu/day
Biogas Production	244,430	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	650	kW
CHP Capacity Factor	90.0%	
Electricity Produced	14,031	kWh/day
Plant Parasitic Load	1,403	kWh/day
Electricity for Export	12,628	kWh/day

Thermal Energy Production

Plant Thermal Needs	42	MMBtu/day
Excess Thermal Energy	11	MMBtu/day
Excess Thermal Energy	0.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #7 - Hub Cows Only**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1762	0	0	55,599	230.7	39,614	31,691	
Substrate				0	0.0	0	0	180,000
Totals				55,599	231	39,614	31,691	

Biogas Production

Methane Content	60%	
Methane Generation	114,089	cubic ft/day
Energy Value of Biogas	102,679,916	Btu/day
Biogas Production	190,148	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	505	kW
CHP Capacity Factor	90.0%	
Electricity Produced	10,915	kWh/day
Plant Parasitic Load	1,092	kWh/day
Electricity for Export	9,824	kWh/day

Thermal Energy Production

Plant Thermal Needs	32	MMBtu/day
Excess Thermal Energy	9	MMBtu/day
Excess Thermal Energy	0.4	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #8 - Hub Cows Only**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1365	0	0	43,072	178.7	30,689	24,551	
Substrate				0	0.0	0	0	180,000
Totals				43,072	179	30,689	24,551	

Biogas Production

Methane Content	60%	
Methane Generation	88,383	cubic ft/day
Energy Value of Biogas	79,544,884	Btu/day
Biogas Production	147,305	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	391	kW
CHP Capacity Factor	90.0%	
Electricity Produced	8,456	kWh/day
Plant Parasitic Load	846	kWh/day
Electricity for Export	7,610	kWh/day

Thermal Energy Production

Plant Thermal Needs	25	MMBtu/day
Excess Thermal Energy	7	MMBtu/day
Excess Thermal Energy	0.3	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #9 - Hub Cows Only**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2250	0	0	70,997	294.6	50,586	40,469	
Substrate				0	0.0	0	0	180,000
Totals				70,997	295	50,586	40,469	

Biogas Production

Methane Content	60%	
Methane Generation	145,687	cubic ft/day
Energy Value of Biogas	131,117,941	Btu/day
Biogas Production	242,811	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	645	kW
CHP Capacity Factor	90.0%	
Electricity Produced	13,938	kWh/day
Plant Parasitic Load	1,394	kWh/day
Electricity for Export	12,544	kWh/day

Thermal Energy Production

Plant Thermal Needs	41	MMBtu/day
Excess Thermal Energy	11	MMBtu/day
Excess Thermal Energy	0.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #10 - Hub Cows Only**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	6847	0	0	216,052	896.6	153,938	123,150	
Substrate				0	0.0	0	0	180,000
Totals				216,052	897	153,938	123,150	

Biogas Production

Methane Content	60%	
Methane Generation	443,341	cubic ft/day
Energy Value of Biogas	399,006,467	Btu/day
Biogas Production	738,901	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,964	kW
CHP Capacity Factor	90.0%	
Electricity Produced	42,415	kWh/day
Plant Parasitic Load	4,241	kWh/day
Electricity for Export	38,173	kWh/day

Thermal Energy Production

Plant Thermal Needs	126	MMBtu/day
Excess Thermal Energy	34	MMBtu/day
Excess Thermal Energy	1.4	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #1 - Hub Only w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4020	0	0	126,848	526.4	90,380	72,304	
Substrate				31,712	131.6	78,963	71,067	180,000
Totals				158,560	658	169,343	143,370	

Biogas Production

Methane Content	60%		
Methane Generation	490,549	cubic ft/day	
Energy Value of Biogas	441,494,235	Btu/day	
Biogas Production	817,582	cubic ft/day	567.76522

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,173	kW
CHP Capacity Factor	90.0%	
Electricity Produced	46,931	kWh/day
Plant Parasitic Load	4,693	kWh/day
Electricity for Export	42,238	kWh/day

Thermal Energy Production

Plant Thermal Needs	92	MMBtu/day
Excess Thermal Energy	84	MMBtu/day
Excess Thermal Energy	3.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #2 - Hub w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	7644	0	0	241,200	1,001.0	171,856	137,485	
Substrate				60,300	250.2	150,147	135,132	180,000
Totals				301,500	1,251	322,003	272,617	

Biogas Production

Methane Content	60%	
Methane Generation	932,775	cubic ft/day
Energy Value of Biogas	839,497,135	Btu/day
Biogas Production	1,554,624	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	4,131	kW
CHP Capacity Factor	90.0%	
Electricity Produced	89,240	kWh/day
Plant Parasitic Load	8,924	kWh/day
Electricity for Export	80,316	kWh/day

Thermal Energy Production

Plant Thermal Needs	175	MMBtu/day
Excess Thermal Energy	161	MMBtu/day
Excess Thermal Energy	6.7	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #3 - Hub Cows Only w/ Substrates**
Date: June 7, 2016

Inputs

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1798	0	0	56,734	235.4	40,424	32,339	
Substrate				14,184	58.9	35,318	31,786	180,000
Totals				70,918	294	75,742	64,125	

Biogas Production

Methane Content	60%	
Methane Generation	219,408	cubic ft/day
Energy Value of Biogas	197,466,782	Btu/day
Biogas Production	365,679	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	972	kW
CHP Capacity Factor	90.0%	
Electricity Produced	20,991	kWh/day
Plant Parasitic Load	2,099	kWh/day
Electricity for Export	18,892	kWh/day

Thermal Energy Production

Plant Thermal Needs	41	MMBtu/day
Excess Thermal Energy	38	MMBtu/day
Excess Thermal Energy	1.6	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #4 - Hub Only w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	4773	0	0	150,608	625.0	107,309	85,847	
Substrate				37,652	156.3	93,753	84,378	180,000
Totals				188,260	781	201,062	170,225	

Biogas Production

Methane Content	60%	
Methane Generation	582,435	cubic ft/day
Energy Value of Biogas	524,191,490	Btu/day
Biogas Production	970,725	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	2,580	kW
CHP Capacity Factor	90.0%	
Electricity Produced	55,722	kWh/day
Plant Parasitic Load	5,572	kWh/day
Electricity for Export	50,150	kWh/day

Thermal Energy Production

Plant Thermal Needs	109	MMBtu/day
Excess Thermal Energy	100	MMBtu/day
Excess Thermal Energy	4.2	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #5 - Hub Cows Only w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1470	0	0	46,385	192.5	33,049	26,439	
Substrate				11,596	48.1	28,874	25,987	180,000
Totals				57,981	241	61,923	52,426	

Biogas Production

Methane Content	60%	
Methane Generation	179,379	cubic ft/day
Energy Value of Biogas	161,440,754	Btu/day
Biogas Production	298,964	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	795	kW
CHP Capacity Factor	90.0%	
Electricity Produced	17,161	kWh/day
Plant Parasitic Load	1,716	kWh/day
Electricity for Export	15,445	kWh/day

Thermal Energy Production

Plant Thermal Needs	34	MMBtu/day
Excess Thermal Energy	31	MMBtu/day
Excess Thermal Energy	1.3	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #6 - Hub Only w/ Substrates**
Date: June 7, 2016

Inputs

	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2254	0	0	71,123	295.2	50,676	40,540	
Substrate				17,781	73.8	44,275	39,847	180,000
Totals				88,904	369	94,950	80,388	

Biogas Production

Methane Content	60%	
Methane Generation	275,051	cubic ft/day
Energy Value of Biogas	247,545,535	Btu/day
Biogas Production	458,418	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,218	kW
CHP Capacity Factor	90.0%	
Electricity Produced	26,314	kWh/day
Plant Parasitic Load	2,631	kWh/day
Electricity for Export	23,683	kWh/day

Thermal Energy Production

Plant Thermal Needs	52	MMBtu/day
Excess Thermal Energy	47	MMBtu/day
Excess Thermal Energy	2.0	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #7 - Hub Cows Only w/ Substrates**

Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1762	0	0	55,599	230.7	39,614	31,691	
Substrate				13,900	57.7	34,611	31,150	180,000
Totals				69,499	288	74,225	62,841	

Biogas Production

Methane Content	60%	
Methane Generation	215,014	cubic ft/day
Energy Value of Biogas	193,513,024	Btu/day
Biogas Production	358,357	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	952	kW
CHP Capacity Factor	90.0%	
Electricity Produced	20,571	kWh/day
Plant Parasitic Load	2,057	kWh/day
Electricity for Export	18,514	kWh/day

Thermal Energy Production

Plant Thermal Needs	40	MMBtu/day
Excess Thermal Energy	37	MMBtu/day
Excess Thermal Energy	1.5	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #8 - Hub Cows Only w/ Substrates**
Date: June 7, 2016

Inputs

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	1365	0	0	43,072	178.7	30,689	24,551	
Substrate				10,768	44.7	26,812	24,131	180,000
Totals				53,840	223	57,501	48,682	

Biogas Production

Methane Content	60%	
Methane Generation	166,568	cubic ft/day
Energy Value of Biogas	149,911,136	Btu/day
Biogas Production	277,613	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	738	kW
CHP Capacity Factor	90.0%	
Electricity Produced	15,936	kWh/day
Plant Parasitic Load	1,594	kWh/day
Electricity for Export	14,342	kWh/day

Thermal Energy Production

Plant Thermal Needs	31	MMBtu/day
Excess Thermal Energy	29	MMBtu/day
Excess Thermal Energy	1.2	MMBtu/hour

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #9 - Hub Cows Only w/ Substrates**
Date: June 7, 2016

Inputs	Cows - Scrape	Cows - Flush	Heifers	Gallons/Day	Tons/day	TS (lbs/day)	VS (lbs/day)	COD (mg/L)
Manure	2250	0	0	70,997	294.6	50,586	40,469	
Substrate				17,749	73.7	44,195	39,776	180,000
Totals				88,746	368	94,781	80,244	

Biogas Production

Methane Content	60%	
Methane Generation	274,559	cubic ft/day
Energy Value of Biogas	247,103,324	Btu/day
Biogas Production	457,599	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	1,216	kW
CHP Capacity Factor	90.0%	
Electricity Produced	26,267	kWh/day
Plant Parasitic Load	2,627	kWh/day
Electricity for Export	23,641	kWh/day

Thermal Energy Production

Plant Thermal Needs	52	MMBtu/day
Excess Thermal Energy	47	MMBtu/day
Excess Thermal Energy	2.0	MMBtu/hour

DYNAMIC

Project Mass and Energy Balance

Project Name: **Kewaunee County Hub #10 - Hub Cows Only w/ Substrates**
Date: June 7, 2016

Inputs	**Cows - Scrape**	**Cows - Flush**	**Heifers**	**Gallons/Day**	**Tons/day**	**TS (lbs/day)**	**VS (lbs/day)**	**COD (mg/L)**
Manure	6847	0	0	216,052	896.6	153,938	123,150	
Substrate				54,013	224.2	134,492	121,043	180,000
Totals				270,065	1,121	288,430	244,193	

Biogas Production

Methane Content	60%	
Methane Generation	835,520	cubic ft/day
Energy Value of Biogas	751,968,236	Btu/day
Biogas Production	1,392,534	cubic ft/day

Electrical Energy Production

Electrical Efficiency	40.3%	
Gross kW Potential	3,701	kW
CHP Capacity Factor	90.0%	
Electricity Produced	79,935	kWh/day
Plant Parasitic Load	7,994	kWh/day
Electricity for Export	71,942	kWh/day

Thermal Energy Production

Plant Thermal Needs	157	MMBtu/day
Excess Thermal Energy	144	MMBtu/day
Excess Thermal Energy	6.0	MMBtu/hour

15.0 Appendix 2: Nutrient Balance

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #1 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 105,639 gal/day

Manure		
% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
3697	1585	2852

Water Volume 35,880 gal/day

Water		
% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 141,519 gal/day

Manure & Water		
% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
3697	1585	2852

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	24,535
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	35,095
Volume of Water	58%	81,889
Total	100%	141,519

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 25,902 lbs/day
Solids Recovered - Wet Basis 86,341 lbs/day
Solids Recovered - Wet Basis 43 tons/day
Solids Recovered - Wet Basis 133 cu.yds./day
Volume of Solids 7,247 gal/day

Volume of Liquids 134,272 gal/day

Liquids		
% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
3180	1204	2653

Solids		
% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
518	380	200

Volume of Concentrate 38,995 gal/day

Concentrate Returned		
% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
386	61	438

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 48,062 lbs/day
Solids Recovered - Wet Basis 192,247 lbs/day
Solids Recovered - Wet Basis 96 tons/day
Solids Recovered - Wet Basis 178 cu.yds./day
Volume of Solids 17,288 gal/day

Volume of Liquids 155,978 gal/day

Liquids		
% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1932	66	2189

Solids		
% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
1248	1139	464

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 116,984 gal/day 82.7%

Permeate		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
1545	5	1751

Volume of Concentrate 0 gal/day 25.0%

Concentrate		
% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 81,889 gal/day 57.9%

Water		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
8	0	2

Volume of Concentrate 35,095 gal/day 30.0%

RO Concentrate		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
1538	5	1749

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #2 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 188,365 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
6593	2825	5086

Water Volume 63,977 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 252,342 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
6593	2825	5086

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	43,749
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	62,578
Volume of Water	58%	146,015
Total	100%	252,342

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 46,186 lbs/day
Solids Recovered - Wet Basis 153,954 lbs/day
Solids Recovered - Wet Basis 77 tons/day
Solids Recovered - Wet Basis 238 cu.yds./day
Volume of Solids 12,922 gal/day

Volume of Liquids 239,420 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
5670	2147	4730

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
923	678	356

Volume of Concentrate 69,531 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
689	109	781

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 85,699 lbs/day
Solids Recovered - Wet Basis 342,796 lbs/day
Solids Recovered - Wet Basis 171 tons/day
Solids Recovered - Wet Basis 317 cu.yds./day
Volume of Solids 30,827 gal/day

Volume of Liquids 278,124 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
3444	117	3903

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
2226	2030	827

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 208,593 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
2755	8	3123

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 146,015 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
14	0	3

Volume of Concentrate 62,578 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
2742	8	3119

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #3 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 58,962 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
2064	884	1592

Water Volume 20,026 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 78,988 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
2064	884	1592

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	13,694
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	19,588
Volume of Water	58%	45,706
Total	100%	78,988

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 14,457 lbs/day
Solids Recovered - Wet Basis 48,191 lbs/day
Solids Recovered - Wet Basis 24 tons/day
Solids Recovered - Wet Basis 74 cu.yds./day

Volume of Liquids 74,943 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
1775	672	1481

Volume of Solids 4,045 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
289	212	111

Volume of Concentrate 21,765 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
216	34	244

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 26,825 lbs/day
Solids Recovered - Wet Basis 107,302 lbs/day
Solids Recovered - Wet Basis 54 tons/day
Solids Recovered - Wet Basis 99 cu.yds./day

Volume of Liquids 87,058 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1078	37	1222

Volume of Solids 9,649 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
697	636	259

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 65,294 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
862	3	977

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 45,706 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
4	0	1

Volume of Concentrate 19,588 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
858	3	976

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #4 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 123,585 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
4325	1854	3337

Water Volume 41,975 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 165,560 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
4325	1854	3337

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	28,703
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	41,057
Volume of Water	58%	95,800
Total	100%	165,560

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 30,303 lbs/day
Solids Recovered - Wet Basis 101,008 lbs/day
Solids Recovered - Wet Basis 51 tons/day
Solids Recovered - Wet Basis 156 cu.yds./day

Volume of Liquids 157,082 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
3720	1409	3103

Volume of Solids 8,478 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
606	445	234

Volume of Concentrate 45,619 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
452	71	512

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 56,227 lbs/day
Solids Recovered - Wet Basis 224,906 lbs/day
Solids Recovered - Wet Basis 112 tons/day
Solids Recovered - Wet Basis 208 cu.yds./day

Volume of Liquids 182,476 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
2260	77	2561

Volume of Solids 20,225 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
1460	1332	542

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 136,857 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
1808	5	2049

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 95,800 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
9	0	2

Volume of Concentrate 41,057 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
1799	5	2047

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #5 - Practical Cows

Date: June 13, 2016

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 58,604 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
2051	879	1582

Water Volume 19,904 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 78,508 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
2051	879	1582

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	13,611
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	19,469
Volume of Water	58%	45,428
Total	100%	78,508

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 14,369 lbs/day
Solids Recovered - Wet Basis 47,898 lbs/day
Solids Recovered - Wet Basis 24 tons/day
Solids Recovered - Wet Basis 74 cu.yds./day

Volume of Liquids 74,488 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
1764	668	1472

Volume of Solids 4,020 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
287	211	111

Volume of Concentrate 21,632 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
214	34	243

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 26,663 lbs/day
Solids Recovered - Wet Basis 106,650 lbs/day
Solids Recovered - Wet Basis 53 tons/day
Solids Recovered - Wet Basis 99 cu.yds./day

Volume of Liquids 86,529 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1072	36	1214

Volume of Solids 9,591 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
692	632	257

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 64,897 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
857	3	972

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 45,428 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
4	0	1

Volume of Concentrate 19,469 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
853	3	971

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #6 - Practical Cows

Date: June 13, 2016

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 149,922 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
5247	2249	4048

Water Volume 50,920 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 200,842 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
5247	2249	4048

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	34,820
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	49,807
Volume of Water	58%	116,215
Total	100%	200,842

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 36,760 lbs/day
Solids Recovered - Wet Basis 122,534 lbs/day
Solids Recovered - Wet Basis 61 tons/day
Solids Recovered - Wet Basis 189 cu.yds./day

Volume of Liquids 190,557 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
4513	1709	3765

Volume of Solids 10,285 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
735	540	283

Volume of Concentrate 55,341 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
548	87	621

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 68,209 lbs/day
Solids Recovered - Wet Basis 272,836 lbs/day
Solids Recovered - Wet Basis 136 tons/day
Solids Recovered - Wet Basis 253 cu.yds./day

Volume of Liquids 221,362 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
2741	93	3107

Volume of Solids 24,536 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
1771	1616	658

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 166,022 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
2193	7	2485

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 116,215 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
11	0	2

Volume of Concentrate 49,807 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
2182	7	2483

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #7 - Practical Cows

Date: June 13, 2016

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 66,995 gal/day

Manure		
% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
2345	1005	1809

Water Volume 22,754 gal/day

Water		
% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 89,749 gal/day

Manure & Water		
% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
2345	1005	1809

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	15,560
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	22,257
Volume of Water	58%	51,932
Total	100%	89,749

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 16,427 lbs/day
Solids Recovered - Wet Basis 54,756 lbs/day
Solids Recovered - Wet Basis 27 tons/day
Solids Recovered - Wet Basis 85 cu.yds./day

Volume of Liquids 85,153 gal/day

Liquids		
% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
2017	764	1682

Volume of Solids 4,596 gal/day

Solids		
% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
328	241	127

Volume of Concentrate 24,730 gal/day

Concentrate Returned		
% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
245	39	278

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 30,480 lbs/day
Solids Recovered - Wet Basis 121,921 lbs/day
Solids Recovered - Wet Basis 61 tons/day
Solids Recovered - Wet Basis 113 cu.yds./day

Volume of Liquids 98,919 gal/day

Liquids		
% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1225	42	1388

Volume of Solids 10,964 gal/day

Solids		
% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
792	722	294

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 74,189 gal/day 82.7%

Permeate		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
980	3	1111

Volume of Concentrate 0 gal/day 25.0%

Concentrate		
% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 51,932 gal/day 57.9%

Water		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
5	0	1

Volume of Concentrate 22,257 gal/day 30.0%

RO Concentrate		
% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
975	3	1109

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #8 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 58,716 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
2055	881	1585

Water Volume 19,942 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 78,658 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
2055	881	1585

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	13,637
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	19,506
Volume of Water	58%	45,515
Total	100%	78,658

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 14,397 lbs/day
Solids Recovered - Wet Basis 47,990 lbs/day
Solids Recovered - Wet Basis 24 tons/day
Solids Recovered - Wet Basis 74 cu.yds./day
Volume of Solids 4,028 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
288	211	111

Volume of Liquids 74,630 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
1767	669	1474

Volume of Concentrate 21,674 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
215	34	243

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 26,714 lbs/day
Solids Recovered - Wet Basis 106,854 lbs/day
Solids Recovered - Wet Basis 53 tons/day
Solids Recovered - Wet Basis 99 cu.yds./day
Volume of Solids 9,609 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
694	633	258

Volume of Liquids 86,694 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1074	36	1217

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 65,021 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
859	3	973

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 45,515 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
4	0	1

Volume of Concentrate 19,506 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
855	3	972

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #9 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 107,609 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
3766	1614	2905

Water Volume 36,548 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 144,157 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
3766	1614	2905

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	24,993
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	35,749
Volume of Water	58%	83,415
Total	100%	144,157

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis	26,385	lbs/day
Solids Recovered - Wet Basis	87,951	lbs/day
Solids Recovered - Wet Basis	44	tons/day
Solids Recovered - Wet Basis	136	cu.yds./day
Volume of Solids	7,382	gal/day

Volume of Liquids 136,775 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
3239	1227	2702

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
527	387	203

Volume of Concentrate 39,721 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
394	62	446

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis	48,958	lbs/day
Solids Recovered - Wet Basis	195,832	lbs/day
Solids Recovered - Wet Basis	98	tons/day
Solids Recovered - Wet Basis	181	cu.yds./day
Volume of Solids	17,611	gal/day

Volume of Liquids 158,886 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
1968	67	2230

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
1271	1160	472

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 119,164 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
1574	5	1784

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 83,415 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
8	0	2

Volume of Concentrate 35,749 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
1566	5	1782

Mass and Nutrient Balance

Project Name: Project Phoenix - Hub #10 - Practical Cows

Date: June 13, 2016

DYNAMIC

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 205,126 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
7179	3077	5538

Water Volume 69,669 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 274,795 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
7179	3077	5538

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	47,642
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	68,146
Volume of Water	58%	159,007
Total	100%	274,795

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 50,296 lbs/day
Solids Recovered - Wet Basis 167,654 lbs/day
Solids Recovered - Wet Basis 84 tons/day
Solids Recovered - Wet Basis 259 cu.yds./day
Volume of Solids 14,072 gal/day

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
1005	738	388

Volume of Liquids 260,723 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
6174	2338	5151

Volume of Concentrate 75,718 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
750	118	850

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 93,325 lbs/day
Solids Recovered - Wet Basis 373,299 lbs/day
Solids Recovered - Wet Basis 187 tons/day
Solids Recovered - Wet Basis 346 cu.yds./day
Volume of Solids 33,570 gal/day

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
2424	2211	900

Volume of Liquids 302,871 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
3751	127	4251

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 227,153 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
3001	9	3400

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 159,007 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
15	0	3

Volume of Concentrate 68,146 gal/day 30.0%

RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
2986	9	3397

Mass and Nutrient Balance

Project Name: Project Phoenix - Total Practical Cows

Date: June 13, 2016

Manure Collection System - 100% UF Concentrate Recycled

Manure Volume 1,123,524 gal/day

Manure

% DM	12.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
35	15	27
Nutrients (lbs/day		
N	P2O5	K2O
39323	16853	30335

Water Volume 381,594 gal/day

Water

% DM	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day		
N	P2O5	K2O
0	0	0

Combined Volume 1,505,118 gal/day

Manure & Water

% DM	8.96%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
26	11	20
Nutrients (lbs/day		
N	P2O5	K2O
39323	16853	30335

Summary of NCS Products

Distribution of Manure	Percent	Gallons
Volume of Solids	17%	260,945
Volume of UF Concentrate	0%	0
Volume of RO Concentrate	25%	373,252
Volume of Water	58%	870,921
Total	100%	1,505,118

Coarse Solids Separation System - Step 1

Solids Recovered - Dry Basis 275,484 lbs/day
Solids Recovered - Wet Basis 918,279 lbs/day
Solids Recovered - Wet Basis 459 tons/day
Solids Recovered - Wet Basis 1,417 cu.yds./day
Volume of Solids 77,074 gal/day

Volume of Liquids 1,428,044 gal/day

Liquids

% TSS	4.30%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
23.7	9.0	19.8
Nutrients (lbs/day)		
N	P2O5	K2O
33818	12808	28212

Solids

% TS	30.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
12.0	8.8	4.6
Nutrients (lbs/day)		
N	P2O5	K2O
5505	4045	2123

Volume of Concentrate 414,724 gal/day

Concentrate Returned

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
4109	648	4656

Fine Solids Separation System - Step 2

Solids Recovered - Dry Basis 511,161 lbs/day
Solids Recovered - Wet Basis 2,044,645 lbs/day
Solids Recovered - Wet Basis 1,022 tons/day
Solids Recovered - Wet Basis 1,893 cu.yds./day
Volume of Solids 183,871 gal/day

Volume of Liquids 1,658,897 gal/day

Liquids

% TSS	0.65%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
12	0	14
Nutrients (lbs/day)		
N	P2O5	K2O
20544	697	23281

Solids

% TS	25.0%	
Nutrients (lbs/ton)		
N	P2O5	K2O
13	12	5
Nutrients (lbs/day)		
N	P2O5	K2O
13274	12111	4930

Fine Suspended Solids Removal System - Step 3

Volume of Permeate 1,244,173 gal/day 82.7%

Permeate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
13	0	15
Nutrients (lbs/day)		
N	P2O5	K2O
16435	49	18625

Volume of Concentrate 0 gal/day 25.0%

Concentrate

% TSS	2.6%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
10	2	11
Nutrients (lbs/day)		
N	P2O5	K2O
0	0	0

Dissolved Solids Removal System - Step 4

Volume of Permeate 870,921 gal/day 57.9%

Water

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
0	0	0
Nutrients (lbs/day)		
N	P2O5	K2O
82	0	19

Volume of Concentrate 373,252 gal/day 30.0%

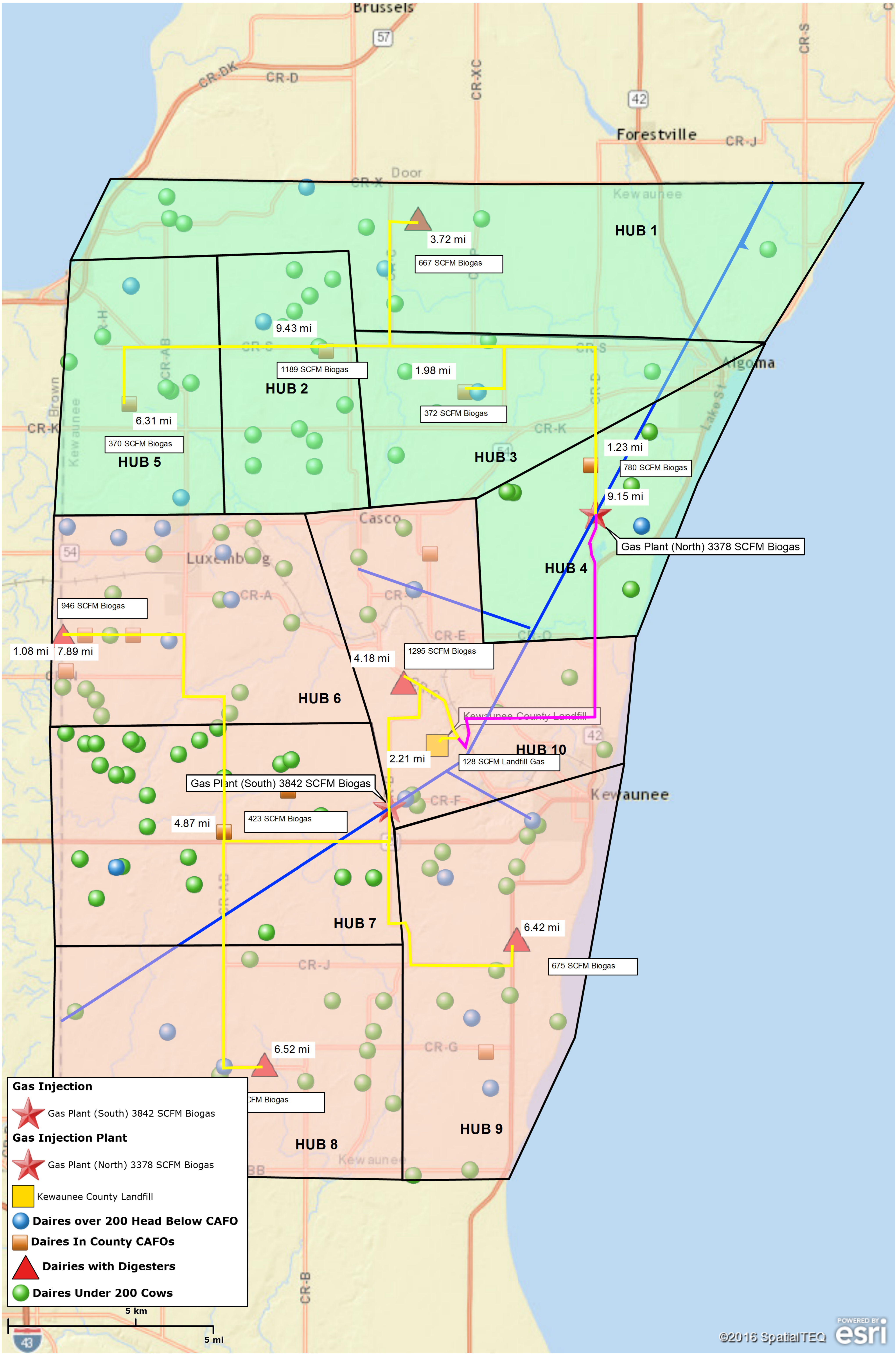
RO Concentrate

% TSS	0.00%	
Nutrients (lbs/1,000 gallons)		
N	P2O5	K2O
44	0	50
Nutrients (lbs/day)		
N	P2O5	K2O
16353	49	18607

16.0 Appendix 3: Maps

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

Kewaunee County Hub Divisions



17.0 Appendix 4: Capital & Operating Cost Detail

Dynamic Concepts, LLC
PO Box 436 | Waukesha, WI 53187

GAS DYNAMIC

North Hub	MANURE ONLY		20% SUBSTRATE		
	Hub & Spoke	Hub Only	Hub & Spoke	Hub Only	
CapEx	$ 75,546,611.90	$ 61,363,518.59	$ 89,404,343.39	$ 76,452,592.11	
OpEx	$ 10,477,328.33	$ 8,356,894.78	$ 11,921,915.46	$ 9,897,598.35	
Cost/SCFM CapEx	$ 42,150.54	$ 41,553.77	$ 26,468.36	$ 27,470.92	
Cost/SCFM OpEx	$ 5,845.73	$ 5,659.07	$ 3,529.51	$ 3,556.40	
Substrate Volume	0	0	150,930	124,355	gal/day
Manure Volume	754,649	621,775	754,649	621,775	gal/day
Biogas Production	1,792	1,477	3,378	2,783	SCFM
Dried Bedding Tons	137	113	165	136	ton/day
Fine Cake Tons	511	421	613	505	ton/day
Electrical Output	8.1	6.7	15.3	12.6	MW
Digesters	18	14	20	18	
Cow Eq.	23,916	19,705	23,916	19,705	
Participating Farms	16	5	16	5	
Skilled Operators	24.3	19.3	27.7	24.2	
Truck Drivers	2.1	0.0	2.1	0.0	
Management Staff	2.1	1.7	2.4	2.0	
Administrative Staff	1.0	0.8	1.2	1.0	
Total Employees	29.5	21.8	33.4	27.2	

GAS

DYNAMIC

South Hub	MANURE ONLY		20% SUBSTRATE		
	Hub & Spoke	Hub Only	Hub & Spoke	Hub Only	
CapEx	$ 82,393,280.73	$ 55,532,032.99	$ 100,504,302.45	$ 79,424,238.47	
OpEx	$ 11,703,848.05	$ 6,835,424.87	$ 13,418,770.32	$ 7,868,991.97	
Cost/SCFM CapEx	$ 39,262.63	$ 45,749.44	$ 26,161.83	$ 36,553.76	
Cost/SCFM OpEx	$ 5,577.20	$ 5,631.29	$ 3,492.98	$ 3,621.58	
Substrate Volume	0	0	165,937	91,438	gal/day
Manure Volume	829,686	457,190	829,686	457,190	gal/day
Biogas Production	2,099	1,214	3,842	2,173	SCFM
Dried Bedding Tons	151	83	181	100	ton/day
Fine Cake Tons	563	310	676	372	ton/day
Electrical Output	9.5	5.5	17.4	9.8	MW
Digesters	18	12	21	13	
Cow Eq.	26,294	14,478	26,294	14,478	
Participating Farms	30	5	30	5	
Skilled Operators	25.1	15.7	29.6	17.6	
Truck Drivers	6.6	0.0	6.6	0.0	
Management Staff	2.3	1.4	2.7	1.6	
Administrative Staff	1.2	0.7	1.3	0.8	
Total Employees	35.2	17.7	40.1	19.9	

GAS

DYNAMIC

MEGA HUB	MANURE ONLY		20% SUBSTRATE		
	Hub & Spoke	Hub Only	Hub & Spoke	Hub Only	
CapEx	$ 158,552,166.034	$ 115,757,824.989	$ 188,770,919.249	$ 140,827,654.215	
OpEx	$ 22,181,176.39	$ 15,192,319.65	$ 25,385,685.78	$ 17,766,590.31	
Cost/SCFM CapEx	$ 40,750.31	$ 43,023.76	$ 26,147.66	$ 28,416.48	
Cost/SCFM OpEx	$ 5,700.90	$ 5,646.54	$ 3,516.31	$ 3,584.98	
Substrate Volume	0	0	316,867	215,793	gal/day
Manure Volume	1,584,335	1,078,965	1,584,335	1,078,965	gal/day
Biogas Production	3,891	2,691	7,219	4,956	SCFM
Dried Bedding Tons	289	197	346	236	ton/day
Fine Cake Tons	1,074	731	1,289	877	ton/day
Electrical Output	17.6	12.2	32.7	22.4	MW
Digesters	36	26	41	31	
Cow Eq.	50,210	34,183	50,210	34,183	
Participating Farms	46	10	46	10	
Skilled Operators	49.4	35.0	57.3	41.8	
Truck Drivers	8.7	0.0	8.7	0.0	
Management Staff	4.4	3.0	5.1	3.6	
Administrative Staff	2.2	1.5	2.5	1.8	
Total Employees	64.7	39.5	73.5	47.1	

DYNAMIC

GAS NO EFFLUENT

MEGA HUB	MANURE ONLY		20% SUBSTRATE		
	Hub & Spoke	Hub Only	Hub & Spoke	Hub Only	
CapEx	$ 115,692,713	$ 83,968,282	$ 139,328,835	$ 104,555,203	
OpEx	$ 14,813,384	$ 10,178,451	$ 16,546,835	$ 11,752,448	
Cost/SCFM CapEx	$ 29,734.78	$ 31,208.53	$ 19,299.17	$ 21,097.36	
Cost/SCFM OpEx	$ 3,807.26	$ 3,783.03	$ 2,291.99	$ 2,371.43	
Substrate Volume	0	0	316,867	215,793	gal/day
Manure Volume	1,584,335	1,078,965	1,584,335	1,078,965	gal/day
Biogas Production	3,891	2,691	7,219	4,956	SCFM
Dried Bedding Tons	0	0	0	0	ton/day
Fine Cake Tons	0	0	0	0	ton/day
Electrical Output	17.6	12.2	32.7	22.4	MW
Digesters	36	26	41	31	
Cow Eq.	50,210	34,183	50,210	34,183	
Participating Farms	46	10	46	10	
Skilled Operators	32.4	23.4	36.9	27.9	
Truck Drivers	12.0	0.0	12.0	0.0	
Management Staff	3.0	2.0	3.3	2.4	
Administrative Staff	1.5	1.0	1.7	1.2	
Total Employees	48.8	26.5	53.9	31.4	

CHP

DYNAMIC

MEGA HUB	MANURE ONLY		20% SUBSTRATE		
	Hub & Spoke	Hub Only	Hub & Spoke	Hub Only	
CapEx	$ 151,837,795	$ 107,444,813	$ 192,355,931	$ 137,048,273	
OpEx	$ 19,905,214	$ 13,557,030	$ 23,592,280	$ 16,203,728	
Cost/SCFM CapEx	$ 39,024.61	$ 39,934.06	$ 26,644.24	$ 27,653.87	
Cost/SCFM OpEx	$ 5,115.94	$ 5,038.75	$ 3,267.89	$ 3,269.62	
Substrate Volume	0	0	316,867	215,793	gal/day
Manure Volume	1,584,335	1,078,965	1,584,335	1,078,965	gal/day
Biogas Production	3,891	2,691	7,219	4,956	SCFM
Dried Bedding Tons	289	197	346	236	ton/day
Fine Cake Tons	1,074	731	1,289	877	ton/day
Electrical Output	17.6	12.2	32.7	22.4	MW
Digesters	36	26	41	31	
Cow Eq.	50,210	34,183	50,210	34,183	
Participating Farms	46	10	46	10	
Skilled Operators	49.4	35.0	57.3	41.8	
Truck Drivers	8.7	0.0	8.7	0.0	
Management Staff	4.0	2.7	4.7	3.2	
Administrative Staff	2.0	1.4	2.4	1.6	
Total Employees	64.0	39.0	73.0	46.6	

Operating Cost Summary

	Manure Hub	Substrate Hub	Manure Spoke	Substrate Spoke
Hub 1	$ 1,716,847.61	$ 2,119,738.17	$ 1,654,589.08	$ 2,406,113.11
Hub 2	$ 3,093,269.79	$ 3,736,125.49	$ 3,490,931.07	$ 4,185,019.36
Hub 3	$ 911,345.84	$ 1,031,700.76	$ 1,191,009.31	$ 1,367,387.51
Hub 4	$ 1,946,799.20	$ 2,399,719.08	$ 2,339,351.22	$ 2,841,932.14
Hub 5	$ 673,797.25	$ 909,156.07	$ 1,208,009.29	$ 1,383,432.39
Hub 6	$ 1,046,131.14	$ 1,195,077.10	$ 2,978,027.03	$ 3,421,188.16
Hub 7	$ 901,590.83	$ 1,019,800.80	$ 1,330,954.96	$ 1,668,709.50
Hub 8	$ 641,355.68	$ 732,767.52	$ 1,216,312.90	$ 1,392,037.62
Hub 9	$ 1,051,165.94	$ 1,201,906.42	$ 2,077,313.03	$ 2,536,394.68
Hub 10	$ 2,850,366.84	$ 3,440,367.13	$ 3,803,598.98	$ 4,547,128.93
Kewaunee LF	$ 104,200.77	$ 104,200.77	$ 104,200.77	$ 104,200.77
Total Op Ex	**$ 14,936,870.90**	**$ 17,890,559.31**	**$ 21,394,297.66**	**$ 25,853,544.17**
Total Biogas SCFM	**2,691**	**4,956**	**3,891**	**7,219**