Economic Feasibility of Co-Digestion of Manure and Food Waste on a Northern NY Dairy:

Scenario I Case Study

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Scenario I Overview

Scenario I of the Co-Digestion of Manure and Food Waste on a Northern NY Dairy Case Study focuses on the addition of liquid food waste to an existing dairy manure anaerobic digester system in an 80:20 percent volume ratio of manure to food waste. This case study provides an economic feasibility analysis of adding a local source of cheese whey to a manure anaerobic digester generating electricity and heat by comparing the annual benefits to the capital costs of needed system additions and operating costs.

Farm System

This case study is based on a dairy farm located in northern New York State with an existing anaerobic digester system. The farm's lactating cows and replacement heifers equal approximately 1,860 lactating cow equivalents (LCE) on a mass of volatile solids (VS) basis. The farm works over 3,500 acres of land, most of which is owned by the farm. Table 1 provides key information about the farm and anaerobic digester system.

Table 1. Case farm with existing anaerobic digester system information.

Number of cows (current)	1,860 lactating cow equivalents
Digester type	Complete mix
Digester age	<10 years
Digester volume	1.3 million gallons
Digester temperature	100 degrees F
Influent	Raw manure, milking parlor wash water, grease trap waste
Stall bedding material	Recycled manure solids
Solid-liquid separation	Screw press separators, post digestion
Biogas utilization	400 kW engine generator set with heat recovery

Anaerobic Digester System

The farm's anaerobic digester system is less than 10 years old and is a complete mix, mesophilic system with a flexible membrane cover and a volume of approximately 1.3 million gallons. Currently manure from the lactating cows and heifers is being added to the digester, along with a small amount of grease trap waste from local restaurants that acts as a defoaming agent. Waste and wash water from the milking parlor is combined with the lactating cow manure prior to being added to the digester. The daily average volumes of each feedstock currently added to the digester are shown below in Table 2. The digester's current hydraulic retention time (HRT) is estimated based on these volumes to be 37 days. This does not account for any buildup of solids in the digester that may lower HRT.

Table 2. Current daily digester feedstock volumes.

Current digester feedstock[a]	Daily volume (gal)
Manure	31,280
Grease trap waste	75
Wash water	5,010
Daily total	**36,365**
Estimated digester hydraulic retention time (HRT)	**37 days**

The digester system utilizes a 400-kilowatt (kW) engine generator set (EGS) to convert biogas into electricity. The EGS also functions as a combined heat and power (CHP) system which recovers engine combustion and cooling jacket heat to heat a closed water loop and maintain the digester temperature at 100 degrees Fahrenheit. The electricity produced by the EGS is used to power the farm's daily operations, with the net excess electricity exported to the local electricity utility.

The farm utilizes screw press solid-liquid separation of the digester's effluent and uses the separated solids as bedding for the lactating cows. A portion of the separated liquids are pumped back through the lactating cow and heifer barns to help with manure flow to the digester, while the majority goes to on-farm long-term storage.

Food Waste Sources, Selection, and Equipment

Food waste sources were identified in part by utilizing the New York State Pollution Prevention Institute's Organic Resource Locator[1], a web-based tool to aid organic waste producers in connecting with potential organic waste recyclers. A 60-mile radius around the farm location was established to eliminate food waste sources out of reasonable distance from the farm. The filter tool provided by the Organic Resource Locator was used to show only organic waste from food and beverage manufacturers to avoid post-consumer contamination issues as well as packaging. The Organic Resource Locator tool also provides the type of food waste at each source, as well as the volume of food waste.

[a] Manure volume estimated using ASABE Standard. Other feedstock volumes estimated by farm owner.

After applying the location and food waste filter, cheese whey from a local cheese plant was selected as the most rational food waste choice for scenario I. The cheese whey was a logical choice due to its liquid consistency that doesn't require de-packaging or grinding, as well as the cheese plant's proximity to the farm and digester system. The volume of the cheese whey available was estimated to be 8,700 gallons per day using data from a previous assessment by Clarkson University[2]. The addition of the cheese whey would lower the digester's HRT to approximately 30 days, which is still above the common mesophilic AD design range of 20 – 25 days.

It was assumed the cheese whey could be delivered every other day by truck to an inground concrete reception pit before being pumped into the anaerobic digester at a prescribed rate. There is currently a small reception pit used for the grease trap waste that is not large enough for the additional cheese whey, therefore a second reception pit with an agitator, pump, and 190 ft of piping to the digester was factored into the cost analysis. The new reception pit will have a capacity of 4,000 cu-ft, which is approximately 30,000 gallons. Drive-over truck scales with a new 500 ft access road were also included in the cost analysis to measure the weight of cheese whey on each truck load.

Biogas Production and Energy Generation

Co-digesting food waste with manure has been known to improve digester performance, resulting in more complete digestion of digester contents and increased biogas production. Current biogas production from the existing digester and feedstocks was estimated in a couple of ways. Hourly electricity generation data from the EGS was analyzed for the past four complete years of operation and a representative year was selected. Biogas flow to the EGS was estimated each hour using the assumption that the engine was operating at 30% average electrical efficiency and the biogas methane content was approximately 60% (i.e., higher heating value was taken as 600 BTU/cf). The annual average estimated biogas flow during EGS operation was 94 cfm, and the average EGS power output was 300 kW. Biogas production from anaerobic digestion of raw manure is estimated at 79 cf/LCE in the Technical Reference Guide for Dairy-Derived Biogas Production, Treatment, and Utilization[3], which equates to 102 cfm for the 1,860 LCEs of the case farm and is within 10% of the operating data-based estimate.

The Technical Reference Guide includes the estimated biogas production from the anaerobic digestion of dairy manure with whey in different ratios on a VS mass basis. The cheese whey was reported to have 5% VS by mass and the VS content from the lactating cow manure and heifer manure was computed using ASABE[4] values (11.33% and 14.79%, respectively), resulting in an overall VS ratio of about 10.5% cheese whey to 89.5% manure. The estimated biogas production from this VS ratio of manure to whey is 10% more than the manure alone, assuming the whey VS is digested at the same rate as manure. Additional hourly biogas production was estimated by applying this 10% increase to the representative operating year data and computing the resulting additional electricity generation. Hours where electricity generation potential from the additional biogas production exceeded the 400 kW EGS rated power output were limited to that maximum capacity and accounted for less than 1% of the total electricity generation potential. An additional 226,750-kilowatt hour (kWh) of exportable electricity generation was calculated utilizing the existing EGS capacity, a 9% increase from the representative year's total electricity generation.

While the food waste selection of 20% by volume of cheese whey did not justify the need for additional electricity generation capacity to fully-utilize the additional biogas, it should be noted that the local utility distributed generation hosting capacity map was investigated and there was no additional capacity available on the utility grid beyond the current interconnection agreement of 400 kW for this location. A request for increased generation capacity to the utility would likely result in significant cost for required utility infrastructure upgrades.

Nutrient Management and Storage Impacts

The farm currently operates over 3,500 acres of crop land and applies separated liquid from digested effluent to all but 495 acres at an average rate of 7,000 gallons per acre for forage ground and between 8,000 and 10,000 gallons per acre for corn ground. The 495 acres that do not receive on-farm nutrients receive purchased urea fertilizer at an average rate of 122 pounds of nitrogen per acre. The nitrogen, phosphorus, and potassium values of the 80:20 manure and food waste digested effluent were calculated using values provided by previous Cornell PRO-DAIRY fact sheets for cheese whey[5] and dairy manure[6]. Table 3 shows the total nutrient contents in pounds per 1000 gallons of effluent.

Table 3. Anaerobic digester effluent nutrient contents.

Nutrient	Lbs/1000 gallons of effluent
Total Nitrogen	17.83
Phosphorus as P_2O_5	8.39
Potassium as K_2O	20.15

Based on the values in Table 3, the volume of effluent needed to reach the nitrogen requirements of 122 pounds of nitrogen per acre was calculated to be 6,800 gallons per acre. The additional effluent provided by the cheese whey would therefore cover 465 of the 495 acres that currently receive urea fertilizer, leaving only 30 acres that would still require urea fertilizer.

The farm currently utilizes roughly nine million gallons of on-farm manure storage, with five million gallons of additional remote storage. We assumed that there would not be enough existing storage volume to hold the additional effluent that would be produced from the cheese whey and a new on-farm manure storage pit was included in the capital costs. The new storage was designed using the downloadable Animal Waste Management (AWM) tool created by the NRCS[7]. The tool considers manually entered information on animal numbers and weights, bedding types and other waste additions, as well as precipitation data for the climate and region selected in the tool to calculate the storage dimensions and volume. The AWM tool also takes withdrawal events into account, which were assumed to happen twice a year for this scenario, once in May and again in October. The AWM tool estimated a storage measuring 106 ft by 335 ft with a depth of 14 ft for a volume of 277,000 cu-ft, which is roughly two million gallons. We assumed 1,300 ft of new piping with a new pump would be needed to transfer the additional effluent from the solid liquid separator to the new storage. We also included 1,200 ft of fence to surround the storage.

Economics

Capital Costs

The capital costs were calculated using the USDA Environmental Quality Incentives Program cost list[8] and other references. The list provides the cost per unit for many services and materials used in various agriculture systems. Table 4 summarizes the capital costs of the added infrastructure and equipment needed to take in the cheese whey.

Table 4. Capital costs to accept cheese whey to the existing digester system.

Capital costs	Cost ($)
Reception tank system	$56,772
Truck scales and access road	$135,120
Pipes and pump for new storage	$40,902
New storage	$70,172
Total investment	**$302,966**

The reception tank system includes the reception tank as well as the associated agitator, pump, and piping to the digester. The USDA cost list[8] gave a price of $10/cu-ft for an inground concrete reception pit, $9,927 for an agitator specifically for tanks 10-15 feet deep, $4,050 for a 3-10 horsepower pump, and $17.57/ft for 190 ft of 6–8-inch pipe running from the reception pit to the digester. The new 500 ft access road was priced at $30.24/ft for a constructed road with a heavy stone base and geotextile. The USDA cost list did not have a price for truck scales, so these were estimated to be $100,000 with a $20,000 installation cost. The additional pipes and pumps for the new storage were priced at $17.57/ft for 6–8-inch pipe, $12,269 for a 10-40 horsepower pump to pump the effluent across the road to the new storage, and $2,454 to install the pump. The cost for the 1,200 ft fence around the new storage was $1.00/ft and is included in the new storage cost. The new 277,000 cu-ft manure storage was priced at $0.25/cu-ft, which includes construction costs.

Operating Costs

Changes to operating costs are also expected from the addition of food waste to the existing digester system and are shown below in Table 5.

Table 5. Operating costs.

Annual operating costs	Cost ($)
Additional spreading	$71,994
Additional bedding costs	$63,839
Additional maintenance	$4,600
Additional labor	$3,380
Total	**$143,813**

A cost of $0.02 per gallon was used for the additional 3.6 million gallons of effluent that will require field spreading. This value includes fuel costs for equipment, as well as added labor. The need for supplementary bedding is possible as digesting food waste with manure often increases the performance of the digester bacteria, resulting in less solids in the effluent available for bedding recovery. For this scenario we assumed that 0.2 cubic feet of imported bedding per cow per day would be needed to supplement the digested separated solids. We used a price of $1,772/100 cu-yd, for kiln dried sawdust, equal to $0.66/cu-ft. Additional maintenance costs cover the cost of repairs that may be needed for the added equipment. Additional labor costs are associated with acquiring the food waste, managing the food waste contract(s), and labor for repairs. Two hours of additional labor per week are included in the estimate.

Annual Benefits

The annual benefits for scenario I include revenue from the food waste tipping fees, revenue from the additional electricity generated, and savings from reduced fertilizer purchases. The breakdown of the benefits for scenario I are shown below in Table 6.

Table 6. Annual benefits.

Annual benefits	Benefit ($)
Tipping fees	$221,727
Fertilizer savings	$19,813
Additional electricity revenue	$9,070
Additional revenue from carbon credits	$-
Total	**$250,610**

Payment for taking in food waste is made by the food waste producer in the form of tipping fees, the same type of payment that landfills would receive for taking food waste. The value of food waste tipping fees depends on the type of food waste and the region of the food waste disposal. In this case study, a tipping fee of $0.07/gallon was used for the cheese whey, which is an estimated tipping fee for liquid food waste in New York State.

The fertilizer savings were determined by calculating how many acres would no longer require the purchased urea fertilizer, using the average price of $700/ton for nitrogen fertilizer[9]. As stated above the additional effluent would provide nutrients for 465 of the 495 acres that were receiving urea fertilizer, which would save the farm roughly 28 tons of fertilizer per year.

The farm currently receives $0.04 per kilowatt hour (kWh) for the electricity produced by the digester system that is exported to the local electricity grid. With the additional biogas produced from adding food waste, we calculated the farm's added income from increased electricity exports to be $9,070 per year. Their average cost of imported electricity is $0.10/kWh, and this is already offset by the EGS that currently supplies about 80% more electricity than the farm uses.

The farm currently receives carbon credits for utilizing the anaerobic digester for their manure management, however we do not expect the farm to be able to receive additional carbon credits from adding food waste as carbon credits are awarded on a per cow basis. We were unable to confirm if adding food waste will impact the value of the carbon credits that the farm is currently receiving.

Economic Analysis

An economic analysis was performed to determine the gross profitability of adding food waste to the farm's existing digester system over the course of five years, considering the initial capital costs, and the additional operating costs and benefits. The undiscounted cash flow is shown in Table 7.

Table 7. Five-year cash flow.

Year	0	1	2	3	4	5
Investment	($302,966)					
Operating cost		($143,813)	($143,813)	($143,813)	($143,813)	($143,813)
Benefit		$250,610	$250,610	$250,610	$250,610	$250,610
Net annual benefit	($302,966)	$106,798	$106,799	$106,800	$106,801	$106,802

Year 0 can be considered the installation and transition period, where the additions and upgrades are being paid for and installed. Year one and on are the years that the digester system is operating with food waste being added. Operating costs and added benefits are considered for these years as the system is actively co-digesting food waste and impacting the farm's operations and income. The net annual benefit row shows the net benefit for each of the years starting at the installation period during year 0.

The net present value (NPV) and discounted benefit to cost ratio for scenario I were calculated to be $123,116 and 1.1 assuming a discount rate of 8%. No annual inflation or salvage value were considered in scenario I. The NPV is a method to determine the current value of future cash flows generated by a project or investment. An NPV of $123,116 indicates that the investment will have a positive return and a benefit to cost ratio greater than 1.0 is required for a positive return on investment.

Other Considerations

There are additional considerations that we took into account when planning scenario I of the case study, such as food waste contracts, contamination and quality assurance. A food waste contract is a contract between the food waste supplier and the digester operator stating the terms and conditions of the food waste agreement. Food waste contracts have become increasingly important considering the sizeable income that food waste can provide as well as the growing competition for food waste. Food waste contracts can vary in length, ranging from 1 to 3 years and up to 5 to 7 years. In this case study, we assumed the farm would be able to secure the cheese whey for a minimum of 5 years.

Food waste contracts can also help ensure the quality of the food waste and prevent serious contaminants that could potentially harm the digester system and reduce biogas production. Contaminants may include post-consumer items (e.g., eating utensils, plates, cookware, etc.) or unknown food wastes that contain high levels of elements that may cause digester upset, such as excessive salts or vitamins.

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