Northern NY Agricultural Development Program
2022 Project Final Report

Economic Feasibility Case Study of Co-Digestion of Manure and Food Waste on a Northern New York Dairy Farm

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Cooperating Producer:

- St. Lawrence County dairy farm

Background:

The US dairy industry has collectively set a goal to be carbon neutral or better by 2050. Anaerobic digestion (AD) and co-digestion are identified as manure management systems that can achieve net negative GHG emissions and are believed to be important in reaching the US dairy industry goal. Anaerobic digestion is a sequence of processes where microorganisms break down biodegradable material in the absence of oxygen producing biogas and digestate effluent. An anaerobic digester is designed to optimize this process through maintaining a mesophilic (typical) temperature of 100 degree-F and often mixing the contents to avoid solids settling. Co-digestion refers to the combined AD of multiple different biodegradable substrates, such as manure and food waste.

New York (NY) State has passed the Food Donation and Food Scrap Recycling Law, effective January 2022, that requires large food waste producers (more than 2 tons per week) to divert waste from landfills if accepted options are located within 25 miles for fees not exceeding 10% above the landfill tipping rate. This law will rely on and establish food waste recyclers, and farms are poised to participate given the need for recycling the nutrients and energy in food and manure. Dairy manure also provides a complementary balancing in the AD of food waste. However, processing food waste can require additional capital equipment and ongoing operating and maintenance costs that need to be carefully estimated to determine the economic feasibility of a co-digestion enterprise.

Methods:

The project team determined the research needs to include information on local regional food waste recycling opportunities, tipping fees for food waste, and on Clarkson University's research on micro-anaerobic co-digestion. Data was collected from the NYS Pollution Prevention Institute's Organic Resource Locator map[1] to identify food waste sources near the case study farm and in the northern New York region. A profile of the case study farm and its existing anaerobic digester system was developed, beginning on a June 2, 2022 visit to the farm.

Data collection and discussions identified two scenarios for investigation into the economic feasibility of the co-digestion of dairy manure and food waste:

- Scenario 1 would consider the case farm's existing digester-to-electrical generation system that had the capacity to add some food waste.
- Scenario 2 would consider installing a new anaerobic co-digestion system at the case farm to generate renewable natural gas (RNG), an energy source that has seen more recent development in NY and the U.S.

See additional information collected in **Results** section.

A webinar to disseminate the results as part of this NNYADP-funded project drew 185 attendees registering from 31 different NY counties produced insight into related on-farm digestion, emissions, and energy production interests by the agricultural and collateral industries. See the **Outreach** section.

Results:

Scenario 1

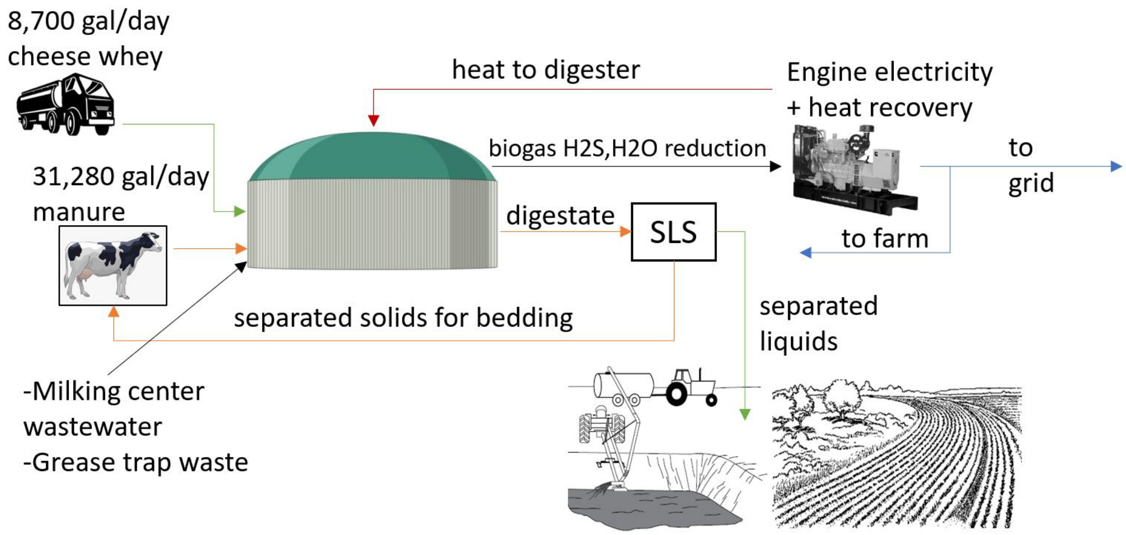

Figure 1. This flow diagram illustrates Scenario 1 analyzed by the Cornell PRO-Dairy Dairy Environmental Systems program for its case study of the economic feasibility of co-digestion of dairy manure and food waste on a northern New York dairy farm. Graphic: Cornell PRO-DAIRY.

Feedstock input included addition of a local manufacturer's cheese whey due to minimal pre-processing requirements and appropriate volume: 20% as digester feed to 80% manure. With the farm producing 31,280 gallons of manure, the food waste volume that could be accepted in the existing digester was estimated to be up to 25%.

Cost considerations included assessing the existing reception tank and farm access for accepting food waste, biogas and engine-generator set capacity, and in-ground storage capacity and land application requirements. An additional reception tank was required, as well as a new access road with truck scales dedicated to food waste reception. The biogas and electricity generation capacity including utility interconnection limit was just adequate for the estimated additional biogas produced from the cheese whey. A new in-ground storage for the added digestate was required, and the existing land base for application under the farm's nutrient management plan was adequate.

Capital costs associated with building the reception tank system and access road with truck scales was estimated at $191,890, while the new in-ground storage and piping and pump from the digester out to it was estimated at $111,075.

Operating costs were estimated to be $143,813 for the added equipment, food waste contract management, hauling, and spreading the additional effluent volume. The need to purchase some bedding to supplement the digested separated solids was included in the operating costs as well in the event that co-digesting whey reduced recovered solids.

Additional revenue-expense factors were driven primarily from the cheese whey tipping fee revenue estimated at about $220,000 annually, but also included avoided purchase of fertilizer for 460 acres operated by the farm due to the added digestate that could be spread and the additional exported electricity value at just $9,070 due to a $0.04/kWh export rate from the utility.

The economic feasibility analysis for Scenario 1: Net present value (NPV) over a short term of five years (given the existing digester's age of nearly 10 years) and the benefit-to-cost ratio were calculated at $123,116 and 1.1, respectively. The low revenue from electricity generation, approximately $0.10/kWh for imported farm usage offset and $0.04/kWh for exported excess, along with the limited utility grid capacity reinforced the decision to analyze RNG production instead of electricity for Scenario 2 (below).
See Appendix: Scenario 1 Case Study Report for more details on the analysis.

Scenario 2

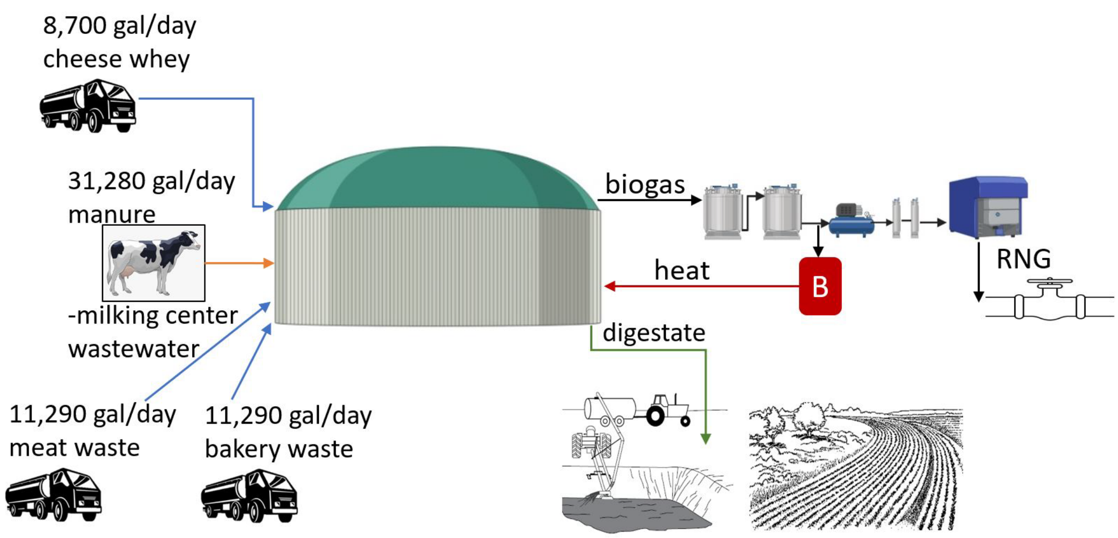

Figure 2. This flow diagram illustrates Scenario 2 analyzed by the Cornell PRO-Dairy Dairy Environmental Systems program for its case study of the economic feasibility of co-digestion of dairy manure and food waste on a northern New York dairy farm. RNG is renewable natural gas. Graphic: Cornell PRO-DAIRY.

Feedstock input required consideration of using food wastes in addition to the cheese whey source to analyze an equal volume with the case farm's manure (31,280 gal/day). Food manufacturer waste sources, specifically bakery and meat processing, were chosen to minimize pre-processing cost through avoiding significant contamination and de-packaging. Solids maceration was included to handle the higher solids content of the considered foods waste sources.

Sizing of the new anaerobic digester was modeled to accept about 65,000 gal/day of feedstock and maintain a 25-day hydraulic retention time. Sizing of two food waste reception tanks to accommodate at least 2 days of food deliveries totaled 75,000 gallons. The additional effluent long-term storage needed for the total volume considered the case study farm's existing manure storage capacity of approximately 13.5 million gallons, indicating 8.6 million gallons was needed.

Effluent nutrient value: Nutrient analysis of the digested food waste with manure was completed indicating a total nitrogen content of 38.42 lb per 1000 gallons, phosphorus (as P_2O_5) of 8.19 lb per 1000 gal, and Potassium (as K_2O) of 16.08 lb per 1000 gal. All the 3,500+ acres of the case farm's existing operated land could receive the on-farm nutrients based on their nutrient management plan average nitrogen application rate, with an additional opportunity for 3,100 acres to receive the same application rate of nutrients.

Operating costs associated with storing, hauling, and spreading the additional volume of effluent beyond the existing manure volume were computed and substantial cost ($328,150 annually) for application to the 3,100 acres beyond the farm's currently operated land was included, assuming the distance from the farm would be much greater.

Capital costs for Scenario 2 included the new anaerobic digester system, biogas upgrading to RNG system, and gas pipeline injection point were obtained using multiple inputs from project developers, New York farmers that have or are currently installing similar systems, and publication articles (**see Appendix:** Scenario 2 Case Study Report).

Biogas generation: The Cornell PRO-DAIRY Anaerobic Digester Simulation Tool was used to estimate:

1) biogas production from the selected digester feedstocks,
2) heating load of the digester to maintain 100ºF operating temperature, and
3) the net RNG production after utilizing some biogas for the digester heating and considering methane recovery efficiency and potential methane leakage.

Additional operating costs of an estimated $585,500 annually were included for the full operation and maintenance of the new digester-to-RNG production system and for the anticipated cost of imported utility grid electricity required to power the system.

Revenue from food waste tipping fees comprised an estimated $1.93 million per year using a $0.07/gal tip fee for the cheese whey and a $50/US ton equivalent for the bakery waste and meat waste that has more solids. Tipping fees can vary greatly, even from year to year for the same waste. It is likely that multiple sources of food waste (between 10 and 30) will be necessary to maintain the total volume considered in this analysis.

RNG production value was estimated at $10/MMBTU under this co-digestion model in NY state, assuming it would need to come from a third-party buyer or buyers at a minimum to no premium over current natural gas consumer costs[2]. Discussions with gas utilities, advisors from the non-profit Energy Vision, based in New York and Seattle, and those attending the Advanced Energy Conference in New York City in September 2022 informed the developing opportunity for RNG sale from institutions or corporations looking to achieve their own greenhouse gas (GHG) and carbon reduction goals. (An example of a co-digestion system that is selling RNG in this format to Middlebury College is located adjacent to Goodrich Dairy Farm in Salisbury, Vermont[3].)

Revenue from RNG: While the value per unit of energy used in this analysis is not substantial and is about 6 times lower than the potential value for RNG from dairy manure-only AD participating in the California Low Carbon Fuel Standard and US EPA Renewable Fuel Standard programs, it is the much larger volume of biogas energy derived from manure co-digested with food waste (6 times more than the manure alone in this analysis) that provides substantial total revenue, estimated at $1.85 million annually.

The economic feasibility analysis for Scenario 2 was evaluated over a 15-year term, typical for this type of project with an anaerobic digester having an expected life span of 20 to 30 years, and included the potential tax benefits that include tax depreciation on a MACRS (Modified Accelerated Cost Recovery System) schedule and the 2022 U.S. Inflation Reduction Act investment tax credit for anaerobic digesters and biogas upgrading capital investment. The NPV and benefit-to-cost ratio were computed at $19,922,594 and 2.1, respectively, including all capital expense, tax benefits, operating costs, and revenue.

Conclusions:

The economic feasibility of a new co-digestion system for the case analyzed of an 1,860 lactating cow equivalent dairy's manure combined with an equal volume of food waste was found to be a good investment with inclusion of the 30% federal investment tax credit and ability to sell the renewable natural gas (RNG) to a third party. Electricity generation and revenue continues to be challenged in New York due to low export value and extreme grid capacity limitations that present excessive upgrade costs to projects. Partnership with developers who can arrange for the AD project financing including tax appetite, construction, food waste sourcing and management, ongoing maintenance and energy sales can be a good option for dairies that wish to participate in this enterprise, designed to cut methane emissions from raw manure storage and landfilled food waste and produce useful energy, and continue their focus on dairy farming. Ongoing work by Cornell CALS PRO-DAIRY Dairy Environmental Systems will include additional economic feasibility analysis of smaller sized dairy farms and with consideration of different sources of food waste located across New York, as well as variable sensitivity.

Outreach:

- November 14, 2022: Cornell Cooperative Extension Agriculture In-Service webinar, 20 attendees
- December 1, 2022: PRO-DAIRY webinar on this project, 185 attendees registering from 31 different NY counties including NNY counties. Presented as part of this NNYADP-funded project. Recording is posted on the PRO-DAIRY website at https://cals.cornell.edu/co-digestion-webinar.
  Attendee breakout: 21 dairy producers/employees, 53 consultants, 39 government employees, 20 Extension/educators, 7 developers, 36 "other." Polling of 89 live attendees indicated interest in more information on anaerobic digestion: 50%,

biogas energy systems: 40%, nothing at this time: 10%. Interest in more information on GHS emissions related to: solid separation: 33%, manure storage covers and flares: 33%, composted or bedded pack barns: 30%, reduced summer storage or nothing at this time: 4%. Ninety-five percent of the live participants indicated that the webinar was very informative or informative with the remaining 5% indicating it was somewhat informative.

- January 17 and 18, 2023: North Country Regional Ag Team Dairy Days in-person presentations in Watertown and Lowville, respectively. Participants include 11 farmer/farmer advisors, FarmNet representatives, and CCE Extension staff.
- Written case studies: one for each Scenario are posted on the Cornell University eCommons repository. **See Appendix.**
- January 31, 2023: PRO-DAIRY e-Leader announcement of case studies.
- January 31, 2023: Morning Ag Clips and Cornell social media announcement of case studies.
- Progressive Dairy summary of case study findings expected in a spring 2023 issue.
- Fact sheet summarizing key considerations and potential benefits of anaerobic co-digestion systems will be published in spring 2023 to the PRO-DAIRY website.
- A March 2023 on-farm “lunch and learn” program is planned by the CCE North Country Regional Ag Team; tentative site is Stauffer Farms, currently installing a new anaerobic digester system that will produce RNG.

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- Peter Wright, P.E., Agricultural Engineer, Cornell CALS PRO-DAIRY Program, PEW2@cornell.edu
- Economic Feasibility Case Study of Co-Digestion of Manure and Food Waste Webinar: https://cals.cornell.edu/co-digestion-webinar

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[1] New York State Pollution Prevention Institute. https://www.rit.edu/affiliate/nysp2i/organic-resource-locator.
[2] New York State Energy Research and Development Authority (NYSERDA). https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Natural-Gas/Monthly-Average-Price-of-Natural-Gas-Commercial.
[3] Vanguard Renewables. https://www.vanguardrenewables.com/portfolio-items/goodrich-farm-salisbury-vt/.

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

Scenario I Case Study

December 2022

Contents

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

Scenario II Case Study

December 2022

Contents

Scenario II Overview

Scenario II of the Co-Digestion of Manure and Food Waste on a Northern NY Dairy Case Study focuses on the anaerobic digestion (AD) of manure and food waste using a 50:50 percent by volume ratio. This case study provides an economic feasibility analysis of adding a new anaerobic digester system to a dairy farm processing the dairy's manure with an equal amount of food waste from local sources and producing renewable natural gas (RNG) from the biogas. The annual benefits are compared to the capital and operating costs of the project and the net present value (NPV) calculated for a 15-year term.

Farm System

Scenario II is modeled using a hypothetical farm with the same herd size and location in Northern New York as Scenario I, but with no existing anaerobic digester to analyze the economic impact of installing a new manure and food waste co-digestion 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. It is assumed that the farm beds with sawdust/wood shavings and stores the scraped manure from the barns in multiple long-term storage pits for field application in the spring and fall. The farm operates over 3,500 acres of land used for growing both corn and forages.

Anaerobic Digester System

The anaerobic digester is a complete mix, mesophilic system with a flexible membrane cover. The digester volume is approximately 1.7 million gallons to process the 31,280 gallons per day of manure with an equal amount by volume of total mixed food waste, using a design hydraulic retention time (HRT) of 25 days.

The biogas produced by the digester is converted to RNG by the onsite biogas purification equipment that removes hydrogen sulfide (H_2S), water vapor, carbon dioxide (CO_2), and other impurities, resulting in concentrated methane suitable for pipeline injection. The RNG is inserted into the gas pipeline at the digester site, which is possible due to an existing natural gas pipeline adjacent to the farm. The digester is heated using a biogas boiler system that heats a closed water loop and maintains the digester temperature at 100 degrees Fahrenheit.

Co-digesting food waste with manure has been known to improve digester organism performance, resulting in more complete digestion of the contents that leads to decreased solids recovery of the effluent. We assumed that there would not be enough solids post-digestion to separate for bedding with the co-digestion of large volumes of food waste that equal the manure volume. For this reason, we did not include solid-liquid separation as a part of the digester system and assumed the farm would continue to purchase bedding. Table 1 provides a summary of the key information about the farm and the anaerobic digester system.

Table 1. Farm and anaerobic digester system information.

Number of cows	1,860 lactating cow equivalents
Digester type	Complete mix
Digester volume	1.7 million gallons
Digester temperature	100 degrees F
Influent	Raw manure, milking parlor wash water, food waste
Stall bedding material	Sawdust / wood shavings
Solid-liquid separation	None
Biogas utilization	Upgraded to renewable natural gas (RNG)

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. The filter tool provided by the Organic Resource Locator was used to show only organic waste from food and beverage manufacturers located in the Northern NY region and within a reasonable radius of the case farm to minimize contaminants that are common in post-consumer food waste.

After applying the location and food waste type filters, we determined that cheese whey, bakery waste, and meat waste were three available waste types to model. In the food waste selection, packaged food waste was avoided so that de-packaging equipment would not be needed. De-packaging equipment is a significant capital and operating expense that needs careful assessment for the potentially higher tipping fee value that accepting packaged food waste can bring.

A previous assessment of a local cheese plant by Clarkson University[2] determined that the daily volume of cheese whey available is 8,700 gallons. The bakery waste and meat waste were then estimated in equal amounts to achieve a 50:50 manure to total food waste ratio. The daily amounts of each feedstock added to the digester are shown below in Table 2.

Table 2. Daily digester feedstock volumes and mass.

Digester feedstock[a]	Daily volume (gal)	Daily mass (kg)
Manure	31,280	118,400
Wash water	5,010	18,960
Cheese whey	8,700	32,930
Bakery waste	11,290	42,740
Meat waste	11,290	42,740
Daily total	**67,570**	**255,770**

The food waste is delivered every day by trucks to the farm. There are two 5,000 cu-ft (37,400 gal) inground reception tanks to hold the food waste until it is pumped into the digester at a prescribed rate. The bakery waste and meat waste are expected to have higher solids content requiring use of a macerator after reception and prior to entering the digester. Each of the reception tanks contains a 15-hp mixer to agitate the contents and a 10-hp pump to transfer the contents to the digester. Approximately 380 ft of piping from the reception pits to the digester is included in the cost analysis. Drive over truck scales and a new 500 ft access road are included to measure the weight of the food waste on each truck load and allow for unloading to the reception tanks.

Biogas Production and Energy Generation

The Cornell Manure-based Anaerobic Digester Simulation Tool (herein referred to as the *Cornell AD Tool*) was used to estimate biogas production from the selected digester feedstocks for scenario II. The Cornell AD Tool contains a library of organic wastes and the estimated biogas yield associated with each, based on the volatile solids (VS) content and either a typical laboratory analysis or use of the Buswell equation. Biogas production estimates were made by adding the individual feedstock biogas yield values, assuming the anaerobic digester is operating at steady state with an HRT of about 25 days (Table 3). Interactions between the various feedstocks may impact the actual biogas and methane yields from anaerobic digestion. Potential for increased biogas above the sum of each individual feedstock is likely in a co-digestion system[3].

[a] Manure volumes estimated using ASABE Standard. Milking center wash water volume estimated by owner of a similarly sized and operated farm.

Table 3. Individual digester feedstock characteristics and estimated biogas production.

Digester feedstock	Dry matter / Total solids (%)	Volatile solids (%)	Biogas yield	Biogas production (cfm)
Dairy manure (with wash water)	L.C. 13.1, H. 16.8[4]	12.1[b]	79 cf/LCE[5]	102
Cheese whey	5.7	5.1	8 cf/LCE, for 10% VS ratio w/ manure[5]	10
Meat waste	18.2[c]	17.5	972 L/kg VS	178
Bakery waste	44.1[c]	43.3	791 L/kg VS	358
Total	**N/A**	**N/A**	**N/A**	**648**

The biogas produced by the anaerobic digester is used in part to fuel a hot water boiler that provides the digester heating required for operation at 100 degrees F. The heat load was computed using the Cornell AD Tool that includes both the influent heating and maintenance heating loads of the system. Several design inputs are required for this calculation that are summarized in Table 4. The average hourly heating load per month was summarized, with the corresponding biogas input to the boiler and net biogas remaining for upgrading to renewable natural gas (RNG).

Table 4. Design inputs used for anaerobic digester heating requirements.

Parameter	Units	Value
Digester diameter	ft	100
Digester height (above ground)	ft	30
Digester wall and cover insulation R-value	h ft^2 deg F/BTU	18
Influent temp (T)		Ambient T, minimum > 32 deg F
Biogas boiler efficiency	%	80

It is assumed that the produced biogas has an average methane content of 60% (i.e., higher heating value was taken as 600 BTU/cf). A 2% biogas loss was included to account for potential leaks from the digester through the biogas cleaning and RNG upgrading system. The biogas cleaning and RNG upgrading system includes iron sponge H_2S removal, moisture removal using a glycol chiller, gas compression to 250 psig, and CO_2 removal using a multiple pass membrane technology with a 98% methane recovery efficiency[6]. The system also includes a flare used to burn off biogas during down times. Table 5 reports the monthly average heating load, biogas input to the heating boiler, net RNG production, and percentage of biogas used for digester heating. The total RNG that can be injected into the pipeline for sale is estimated to be 185,000 million BTU (MMBTU) per year, accounting for an assumed system downtime of 2% due to maintenance.

[b] Computed VS content of combined lactating cow and heifer manure using ASABE Standard.
[c] Dry matter content in reference was multiplied by 50% to account for expected dilution with the food manufacturer's wash water.

Table 5. Monthly digester heating and net RNG production estimated. MMBTU is million BTU.

Month	Avg digester heat load (MMBTU/hr)	Biogas input rate to boiler (MMBTU/hr)	Net RNG production (MMBTU)	Percent (%) of biogas used for digester heat
Jan	0.899	1.124	15,849	7
Feb	0.895	1.119	14,319	7
Mar	0.862	1.078	15,883	7
Apr	0.777	0.971	15,446	6
May	0.649	0.811	16,077	5
Jun	0.541	0.676	15,654	5
Jul	0.491	0.613	16,222	5
Aug	0.510	0.637	16,204	5
Sep	0.646	0.807	15,561	5
Oct	0.770	0.962	15,967	6
Nov	0.841	1.051	15,389	7
Dec	0.889	1.111	15,859	7
Total Annual			**188,430**	

The electricity usage of the added systems to the farm was also estimated to determine the cost of purchasing additional utility grid electricity. The largest use of electric power is the biogas cleaning and RNG upgrading system, estimated at 0.45 kW/cfm. This equates to approximately 2,550,000 kWh per year of electricity usage. Note that the farm's electricity usage prior to adding the AD to RNG system is estimated at 1,400,000 kWh/yr. In addition to the biogas cleaning and RNG upgrading parasitic electricity, there is also added electricity required for the food waste reception tank pumps, mixers, and macerator. These were estimated to use approximately 140,000 kWh/yr based on a 30% average runtime. Finally, there is also electricity usage of the digester itself for internal mixing (25,000 kWh/yr) and pumping the effluent (50,000 kWh/yr).

Nutrient Management and Storage Impacts

The farm operates over 3,500 acres of land and applies raw manure in their pre-digester management 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 50:50 manure and food waste digested effluent were calculated using values provided by previous Cornell PRO-DAIRY fact sheets for cheese whey[7] and dairy manure[8], and references for bakery waste[9] and meat processing waste[10]. Table 6 shows the total nutrient contents in pounds per 1000 gallons of effluent.

Table 6. Anaerobic digester effluent nutrient contents.

Nutrient	Lbs/1000 gallons of effluent
Total Nitrogen	38.42
Phosphorus as P_2O_5	8.19
Potassium as K_2O	16.08

Based on the values in Table 6, the volume of effluent needed to reach the nitrogen requirements of 122 pounds of nitrogen per acre was calculated to be 3,175 gallons per acre. Therefore, the additional volume provided by the food waste co-digested with the farm's manure would cover the 495 acres that received purchased fertilizer, as well as 3,100 additional acres.

The farm has roughly nine million gallons of on-farm manure storage, with five million gallons of additional remote storage. The existing storage does not have enough capacity to hold the additional volume that would be produced from the food waste, therefore a new on-farm storage was designed and included in the capital costs. The new storage was designed using the downloadable Animal Waste Management (AWM) created by the NRCS[11]. 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 we assumed would happen twice per year, once in May and again in October. The AWM tool estimated a storage measuring 136 ft by 893 ft with a depth of 14 ft. The volume of the new storage is roughly 1.2 million cu-ft, which is approximately 8.6 million gallons. A 2,080 ft fence is included around the new storage. We also assumed 1,300 ft of piping and a pump would be needed to transfer a portion of the digester effluent to the new storage, while the existing storage capacity would also be utilized.

Economics

Capital Costs

The capital costs of the installed infrastructure and equipment needed to take in the food waste and for the digester system are shown in Table 7. The capital costs for several of the system components were calculated using the USDA Environmental Quality Incentives Program cost list for New York State[12]. The list provides the average cost per unit for many services and materials used in various agriculture systems.

Table 7. Capital costs of new co-digestion system.

Capital costs	Cost ($)
reception tank system	$142,550
truck scales and access road	$135,120
solids macerator system	$200,000
anaerobic digester system	$4,535,000
biogas cleaning and upgrading	$2,500,000
pipeline injection point	$1,000,000
pipes and pumps for new storage	$47,875
new storage	$290,000
Total investment	**$8,850,545**

The reception tank system includes the two reception tanks as well as the associated agitators, pumps, and piping to the digester. The USDA cost list gave a price of $10/cu-ft for inground concrete reception pits, $9,930 for each of the reception pit agitators, $4,050 for each of the pumps, and $20/ft for 380 feet of piping running from the reception pits to the digester. We assumed an installation cost of $6,990 for the mixers and pumps associated with the reception tank system. The new 500 ft access road for the truck scales was priced at $30/ft for a constructed road with a heavy stone base and geotextile. The USDA cost list did not have a price for drive-over truck scales, so we estimated the cost to be $100,000 with $20,000 in installation costs. The USDA cost list did not have a price for a solids grinder or macerator pump, so we estimated the installed price to be $200,000 for this system.

The anaerobic digester system includes construction of the anaerobic digester vessel itself with the mixing and heating components, as well as the boiler used to heat the digester. The estimated cost for the anaerobic digester system is $4,535,000 based on discussions with developers and farmers and recent articles[13]. These resources also led us to an estimated cost of $2,500,000 for the biogas cleaning and upgrading to RNG equipment, and an assumed $1,000,000 for the gas pipeline injection point.

The additional pipes and pump for the new manure storage were priced at $20/ft for 1300 ft of piping, $12,300 for a 10-40 horsepower pump using the USDA cost list, with an additional $9,575 in estimated installation costs. The USDA cost list gave a cost of $0.25/cu-ft for the new storage, which includes construction costs. The fence to enclose the new storage was priced at $1.00/ft for a 2,080 ft fence.

Operating Costs

Additional operating costs and changes to existing farm operating costs are expected with the new digester system and are shown below in Table 8.

Table 8. Operating costs.

Annual operating costs	Cost ($)
additional spreading	$328,157
system O&M and management	$308,240
system electricity usage	$277,297
Total	**$913,694**

Additional spreading costs were calculated using $0.02/gallon for the stored effluent needed to cover the 495 acres of remaining land that the farm operates (approximately 3.6 million gallons per year), and $0.03/gallon for the additional land that would be needed to spread the remaining effluent from storage (approximately 8.5 million gal/year) that we assumed would be farther away than the farm's current operated acreage. The operating costs for spreading include fuel costs for equipment as well as additional labor. Digester system operations and management (O&M) costs include the maintenance and labor required for the new digester to RNG system and managing the food waste contracts. We included a cost of $250,000 per year for the system O&M including maintenance labor based on discussions with developers. Additional labor required to manage the food waste and system operations would cost $58,240 per year. The new digester to RNG system including the equipment needed to take in the food waste will increase the farm's electricity usage by an estimated 2,770,000 kWh annually and the farm's recent average utility cost of $0.10/kWh (inclusive of delivery and supply charges) was applied.

Annual Benefits

The benefits for scenario II include revenue from food waste tipping fees, revenue from RNG sales, and savings from reduced fertilizer purchases by the farm. The breakdown of the benefits for scenario II are shown in Table 9.

Table 9. Annual benefits.

Annual benefits	Benefit ($)
Tipping fees	$1,932,527
RNG sales	$1,850,000
Fertilizer savings	$21,137
Total	**$3,803,663**

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. A tipping fee of $50/US ton was used for the bakery and meat waste that are expected to have a higher solids content requiring the maceration pre-processing.

The fertilizer savings were determined by applying the average price of $700/ton for nitrogen fertilizer[14] to the 495 acres under the farm's current operation that would no longer require purchased fertilizer, saving the farm roughly 30 tons of fertilizer per year. No savings or value was included for the additional nutrients that would be spread from the digester effluent on 3,100 acres of land outside the farm's current operation.

We assumed that the RNG produced from the digester biogas could be sold at a rate of $10/MMBTU on the voluntary market. This value is equal to the Oct 2021 to Sep 2022 average natural gas price for industrial and commercial customers in New York State[15]. With the co-digestion operation, the farm should be able to sell 185,000 MMBTUs of RNG annually, leading to $1,850,000 in added revenue.

Economic Analysis

An economic analysis was performed to determine the gross profitability of the new co-digestion system over the course of fifteen years, considering the initial capital costs, annual operating costs, annual benefits, and the tax-related benefits[d] of accelerated depreciation and investment tax credit (Table 10). The US Inflation Reduction Act of 2022 introduced a 30% investment tax credit for anaerobic digester and biogas upgrading equipment[16]. This was applied to the anaerobic digester system and biogas cleaning and

[d] Consult a tax professional for advice on accelerated depreciation and investment tax credit opportunities.

upgrading costs of $7 million combined. Depreciation was included using a modified accelerated cost recovery system (MACRS) 10-year schedule (half-year convention).

Year 0 can be considered the installation and transition period, where the system is being paid for and installed. For a system of this size and complexity, this may take more than one calendar year. Year one and forward are the years that the digester system is fully operating. Operating costs and benefits are included for these years as the system is actively co-digesting food waste and the farm's manure and impacting the farm's operations and income. The net annual benefit row in Table 10 shows the net benefit for each of the years starting at the installation period.

The net present value (NPV) and discounted benefit to cost ratio for scenario II were calculated to be $19,922,594 and 2.1 respectively, assuming a discount rate of 8%. The NPV is a measure that evaluates the current value of future cash flows generated by a project or investment. A NPV of $19,922,594 indicates that the investment will have a positive return and the benefit to cost ratio greater than 1.0 is required for a good return on investment. No escalation of the operating costs or benefits are included for simplicity and because it is difficult to anticipate what these may be.

Table 10. Fifteen-year cash flow (undiscounted).

Year	0	1	2	3	4	5	6	7	8	9	10
Investment	($8,850,545)										
Investment tax credit	$2,110,500										
Operating cost		($913,694)	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)
Benefit		$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663
Depreciation tax benefit		$272,835	$491,104	$392,883	$314,306	$251,554	$201,080	$178,707	$178,707	$178,980	$178,707
Net annual benefit	($6,740,045)	$3,162,805	$3,381,073	$3,282,852	$3,204,276	$3,141,524	$3,091,049	$3,068,677	$3,068,677	$3,068,949	$3,068,677

Year	11	12	13	14	15
Investment					
Investment tax credit					
Operating cost	($913,694)	($913,694)	($913,694)	($913,694)	($913,694)
Benefit	$3,803,663	$3,803,663	$3,803,663	$3,803,663	$3,803,663
Depreciation tax benefit	$89,490	$0	$0	$0	$0
Net annual benefit	$2,979,459	$2,889,969	$2,889,969	$2,889,969	$2,889,969

Other Considerations

There are additional considerations that we took into account when planning scenario II 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, typically ranging from 1 to up to 7 years though shorter terms are most common. Thus, it is very likely that a co-digestion operation will need to secure several food waste contracts and expect to shift to new types and sources and withstand periods of unsteady volumes.

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 elevated levels of elements that may cause digester upset, such as excessive salts or vitamins.

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