**FCE** *Forcier Consulting Engineers, P.C.*

June 23, 2022

Mr. Thomas Murray
Vice President – Customers & Communities
Vermont Gas Systems, Inc.
85 Swift Street
South Burlington, Vermont 05403

RE: Middlebury Wastewater Treatment Plant
Renewable Energy Feasibility Study- Rev. 1

FCE Project 21030

Dear Tom:

Forcier Consulting Engineers, P.C. (FCE) is pleased to provide the enclosed Middlebury Wastewater Treatment Plant (MWTP) Renewable Energy Feasibility Study.

It has been a pleasure working with you on this project. If you have any questions or would like to go through the study in detail, I'd be happy to meet with you at your convenience.

Sincerely,
***Forcier Consulting Engineers, P.C.***

John D. Forcier, P.E.
President

# MIDDLEBURY WASTEWATER TREATEMENT PLANT
# RENEWABLE ENERGY FEASIBILITY STUDY

## June 23, 2022

**Prepared for:**


**Mr. Thomas Murray**
**Vice President Customers & Communities**
**Vermont Gas Systems**
**85 Swift Street**
**South Burlington, Vermont 05403**


**Prepared by:**


**Forcier Consulting Engineers, PC**

**174 Browns River Road**

**Essex Junction, Vermont 05452-2220**


The following is a renewable energy feasibility study prepared by an independent consultant Forcier Consulting Engineers for Vermont Gas Systems (VGS). This study has been prepared to evaluate the financial viability and suitability of a proposed anaerobic digester project at the Town of Middlebury's Wastewater Treatment Plant (MWTP). This report is private and confidential and is provided for use by VGS only.

# Table of Contents

# 1. Executive Summary:

## 1.1 Summary of Recommendations

Vermont Gas Systems, Inc. (VGS) is interested in renewable energy options for this facility. Forcier Consulting Engineers, P.C. (FCE) was contracted in September 2021 by VGS to conduct a Renewable Energy Feasibility Study using an anerobic digester at the MWTP facility.

All of the evaluated options have very promising paybacks. The standard of the industry for renewable energy projects is that a 'good project' pays back is less than seven years, and a 'great project' pays back is less than five years. Options 1, 3 and 4 all fall within the 'great project' window and option 2 is just outside of 'great' in the 'good' category. This makes any of the options very viable.

Based on the proposed project information, the technical feasibility, the market feasibility, the economic feasibility, the financial feasibility and the capabilities of the management team, FCE recommends moving forward with any one of the evaluated project options.

# 2. Technical Feasibility:

The Middlebury Wastewater Treatment Plant (MWTP) has the ability to generate renewable electricity or renewable natural gas. Existing background information for the MWTP was obtained from VGS and MWTP personnel. Background information included evaluating the existing MWTP operations as well as summarizing the MWTP's existing annual electricity costs, heating costs, sludge production, annual septage volumes and other relevant operational information.

## 2.1 Property Introduction and Background

The MWTP located at 243 Industrial Park Road in Middlebury, Vermont was built in 1999. The primary treatment processes at the MWTP include sequencing batch reactors (SBRs), ultra-violet disinfection, sludge thickening and high temperature lime stabilization/pasteurization for biosolids. The MWTP has an average annual hydraulic loading of approximately 1.0 million gallons per day (MGPD). The facility has a maximum daily average design flow of 2.2 MGPD.

The MWTP treats a combination of traditional municipal and commercial wastewater as well as residential and commercial septage which is trucked in from various locations. The municipal and commercial waste is processed through a screen and grit removal system and then pumped to the sequencing batch reactors (SBRs). Effluent from the SBR's is treated using UV disinfection before being discharged to the Otter Creek. The waste activated sludge from the SBR's is pumped to the aerated sludge holding tanks. Off-site septage trucked to the plant is not treated using the SBR's, it is pumped directly to the aerated sludge holding tanks.

Currently, the sludge is then dewatered using belt filter presses to an average solids content of approximately 15.5%. The liquids are recycled to the plant headworks. The dewatered sludge is processed through a 30-minute high-temperature lime stabilization/pasteurization process until the material meets the Class A Biosolids requirements. The material is then land applied at a local farm in Panton, Vermont as fertilizer.

The Town of Middlebury is currently undergoing a 20-year plant engineering evaluation which ultimately could result in future upgrades to one or more areas of the facility. Potential MWTP upgrades are beyond the scope of this study.

It was noted that there may be a reduction in wastewater flow in the future. This reduction is due to the anticipated loss of wastewater from the American Hard Cider Company which is anticipated to be redirected to a separate AD project. Flow from the American Hard Cider Company represents approximately 2% of the total daily average flow for the MWTP today. This loss of flow is negligible in the scope of this project and the timeline for this change Is unknown. Therefore, the loss of flow was not accounted for within these calculations.

The MWTP processes several types of industrial food processing wastes. There may be a potential for isolating some of this higher energy waste flow and adding it directly to the AD system. This could produce a higher amount of renewable energy. However, for conservative purposes, in this evaluation, the waste flow to the SBR systems was kept as is.

The MWTP property abuts property owned by Middlebury College. It was stated by MWTP staff that off-property land needed for an AD project would likely be donated to the municipality by the college. For this evaluation, costs related to land transactions have been estimated to be $0.

## 2.2 Overview of the Projects Evaluated

Vermont Gas Systems, Inc. (VGS) is interested in renewable energy options for this facility. Forcier Consulting Engineers, P.C. (FCE) was contracted in September 2021 by VGS to conduct a Renewable Energy Feasibility Study using an anerobic digester at the MWTP facility.

This Feasibility Study anticipates that the current wastewater treatment equipment and process would continue to be utilized on the front end of the process including, using the current screen, grit removal, SBR's and the aerated sludge holding tanks. Effluent leaving the SBR's would also still be disinfected by the existing UV system and released to the Otter Creek. The waste activated sludge leaving the SBR's would continue to go to the aerated sludge holding tank where the septage received at the facility will also continue to be added.

The sludge from the aerated sludge tank will then be pumped to a dewatering system. The liquids will continue to be pumped to the plant headworks, and the solids will be pumped to a new thermophilic anaerobic digester (AD). The temperatures in the thermophilic anaerobic digester will effectively replace the pasteurization process and the generated material will meet the Class A Biosolids requirements.

Biogas generated in the AD would then be cleaned and either be used to power a Combined Heat and Power unit (CHP) to generate heat and electricity, or to fuel a biogas boiler to heat the plant and processes or further refined into Renewable Natural Gas (RNG). The digestate material from the AD will be dewatered and the liquids will be routed to the headworks of the plant and the solids will be hauled off site and land applied as it is today. This study evaluates the economic and technical feasibility of four alternatives.

The four separate alternatives evaluated as part of this study include the following:

Alternative #1 – Electricity to the grid
Alternative #2 – RNG to VGS pipeline
Alternative #3 – Biogas for process heat and facility heat
Alternative #4 – A hybrid of Options 2 and 3- Biogas for process heat and facility heat with the excess biogas being upgraded to RNG and sent to the VGS pipeline.

Background information was collected for the MWTP including the 2021 average daily gallons per day (Avg. GPD), the 2021 costs and quantities for electricity and fuel. A dollar value of the annual operations, materials and disposal costs for the lime stabilization and pasteurization system. These values have been summarized below and were used for this evaluation.

Table 1 represents the existing plant operational information collected and 2021 relevant plant expenses.

**Table 1: Facility Information and Existing Expenses**

| 2021 MWTP Background Information | |
|---|---|
| Total Plant Receiving (Average Gallons Per Day (Avg. GPD)) | 860,667 |
| | |
| Cabot Receiving (Avg. GPD) | 376,075 |
| American Hard Cider Receiving (Avg. GPD) | 23,825 |
| Otter Creek Brewering Receiving (Avg. GPD) | 13,265 |
| Aqua Vitae Receiving (Avg. GPD) | 3,574 |
| Remaining Residential and misc. industrial flow (Avg. GPD) | 443,928 |
| | |
| Average Daily Septage Receiving (Avg. GPD) | 7,370 |
| Average (%) Solids Septage | 2.0 |
| | |
| Average Daily Waste Activated Sludge (Gal/Day) | 58,982 |
| Average (%) Solids Septage | 0.8% |
| Average Daily Sludge Cake -After Exisitng Belt Filter Press -used as AD influent (Avg. GPD) | 9,437 |
| Average (%) Solids Sludge Cake | 15.5% |

| 2021 MWTP Expenses | |
|---|---|
| Approximated Electricity Use (kWh/yr) | 1,674,251 |
| Electricity Cost ($/kWh) | $0.1515 |
| **Existing Electricity cost ($/yr)** | **$253,580.59** |
| | |
| MWTP Annual #2 Fuel Oil Usage (Gal) | 6,000 |
| BTU's Per Gallon #2 Fuel Oil | 139,600 |
| MWTP Total Annual BTU's Used (BTU's/yr) | 837,600,000 |
| MWTP Total Annual MMBTU's Used (MMBTU's/yr) | 837.6 |
| Average Fuel Oil Cost ($/Gal) | $5.00 |
| **Total Cost ($/yr)** | **$30,000.00** |
| | |
| **Total Estimated Annual Alum Costs ($/Yr)** | **Included below** |
| | |
| **Total Estimated Annual Polymer Costs ($/Yr)** | **Included Below** |
| | |
| **Total Annual Lime Stabilization/Disposal Costs ($/Yr)** | **$380,700** |
| | |
| **Total Existing expenses /yr** | **$664,281** |

For this evaluation the following conversion factors, general factors, and dollar values were used. The Electricity rate to the grid is based on the existing VEEP incentive available to facilities generating renewable energy of less than 150 kW, the thermal energy price er MMBtu was provided by VGS, The dollar amount for renewable energy credits (RECs) is based on the current value, however can vary.

Table 2 represents the base assumptions, factors and conversions used in this evaluation.

**Table 2: Assumptions/Factors/Conversions**

| General Assumptions | |
|---|---|
| Electricity Rate (to grid- power purchase) ($/kWh) | $0.199 |
| REC's ($/kWh) | $0.04 |
| Thermal Energy ($/MMBtu)Includes $ for REC's | $25.00 |
| Labor Rate (w/benefits) ($/hr) | $42.00 |
| CHP or Biogas Cleaning and Upgrading to RNG Maintenance ($/kWh) | $0.02 |
| Biogas Boiler Maintenance (10% of CHP costs) ($/kWh) | $0.0020 |
| Cost to Haul Solid Materials off site ($/ton) | $20.00 |
| Cost of land needed for project-assumed to be donated to municipality | $0.00 |

| General Factors/Assumptions/Conversions | |
|---|---|
| Conversion from kW to SCFM | 0.3 |
| Methane Raw Gas Available (%) | 60% |
| Methane Cleaned Gas Available (%) | 97% |
| Process Availability (%) | 92% |
| Electric Parasitic Load AD-CHP & Process & Facility Heat (%) | 10% |
| Electric Parasitic Load AD-RNG (%) | 20% |
| Thermal Parasitic Load ADs (%) | 10% |
| BTU/kW as defined by the EIA | 3,412 |
| BTU/cf of RNG as defined by the EIA | 1,037 |
| BTU/Gal #2 Fuel Oil as defined by the EIA | 139,600 |

| 2021 MWTP Specific Process Estimates | |
|---|---|
| Average Dry Material Generated (lbs/day) | 3,728 |
| Average Dry Material Generated (tons/year) | 679 |
| Dry Material Reduction After AD Processes (%) | 10% |

Based on the provided 2021 flows, processes and the noted factors, assumptions, and conversions, Table 3 represents the estimated potential energy and biproducts generated from the MWTP sludge and septage available.

**Table 3: Potential Biogas Energy and Bi-Products**

| Potential Energy and Bi-products | | | | |
|---|---|---|---|---|
| | **Input Materials** | **Gal/Day** | **Factor** | **kW** |
| **Electricity, Heat, or RNG from existing MWTP Sludge Cake and Septage** | MWTP Sludge Cake | **9,437** | 0.0200 | 188.7 |
| | | | | |
| | **Subtotal** | **9,437** | | **188.7** |
| | | | | |
| | **Total Potential Gross (kW)** | | **150** | **188.7** |
| | **Total Potential Gross @ 92% availibility (kWh/yr)** | | **1,208,880.0** | **1,521,112.8** |
| | | | | |
| | Potential Clean RNG available (SCFM) | | | 30.32 |
| | Potential Clean RNG available (SCF/Day) | | | 43,658.0 |
| | **Potential Available RNG Thermal (MMBtu/yr)** | | | **16,524.8** |
| | Existing Use (Heat at Plant) MMBtu/yr) | | | 837.60 |
| | Parasitic Load of AD (MMBtu/yr) | | | 1,652.5 |
| | Excess Available for Sale (MMBtu/yr) | | | 14,034.7 |

# 3. Market Feasibility:

Each project will provide the facility with some savings to their current costs and some revenue.

## 3.1 Project Description, Potential Revenue & Cost Savings

The potential revenue for each alternative was evaluated based on revenue and savings projections.

### 3.1.1 Option #1 - Electricity to the Grid

The first option considered was biogas production for use in generating electricity for the grid. This alternative would consist of a new sludge dewatering system, a thermophilic bio-digester system and associated equipment, a digestate dewatering system, a gas cleaning system, a flare, and a CHP unit and controls as well as electrical hookups.

Revenue for this alternative would be generated from the sale of electricity through a power purchase agreement (PPA). MWTP would have the opportunity to sell the electricity generated by the project to GMP. Additionally, revenue would be anticipated through the sale of renewable energy credits (REC's). Finally, MWTP operating cost savings are anticipated due to the elimination of the current high temperature lime stabilization/ pasteurization system.

### 3.1.2 Option #2 - RNG to the VGS Pipeline

The second option considered was biogas production to be upgraded to RNG quality for insertion into the VGS pipeline. This alternative would consist of a new sludge dewatering system, a thermophilic bio-digester system and associated equipment, a digestate dewatering system, a gas cleaning and upgrading system, a gas testing and monitoring system, a gas compressor and injection point as well as a small pipeline extension, a flare, controls, piping and appurtenances.

Revenue for this alternative would be generated from the sale of RNG to VGS through a gas purchase agreement. VGS noted that gas line connection fees would be waived for this project. Additionally, MWTP operating cost savings are anticipated due to the elimination of the current high temperature lime stabilization/pasteurization.

### 3.1.3 Option #3 – Biogas for Process and Facility Heat

The third option considered was biogas production for process and facility heat to be used at the MWTP. This alternative would consist of a new sludge dewatering system, a thermophilic bio-digester and associated equipment, a digestate dewatering system, a gas cleaning system, a flare, a biogas boiler and controls as well as piping and appurtenances.

The biogas would be used to offset the current thermal load at the wastewater plant as well as provide the heat required for the new thermophilic bio-digester. Excess biogas would be flared. Savings are anticipated due to the replacement of #2 fuel oil with biogas. Additionally, MWTP operating cost savings are anticipated due to the elimination of the current high temperature lime stabilization/pasteurization system.

### 3.1.4 Option #4 – Biogas for Process and Facility Heat plus RNG to the VGS Pipeline

The fourth option considered includes biogas production which would be used for process and facility heat and upgrading the excess biogas to RNG. The excess RNG would then be injected into the VGS pipeline. This alternative would consist of a new sludge dewatering system, a thermophilic bio-digester and associated equipment, a digestate dewatering system, a gas cleaning and upgrading system, a gas testing and monitoring

system, a gas compressor and injection point as well as a small pipeline extension, a flare, a biogas boiler and controls as well as piping and appurtenances.

Some of the generated biogas would be used to offset the current thermal load at the wastewater plant as well as heat for the new thermophilic bio-digester. Savings are anticipated due to the replacement of #2 fuel oil with biogas. Revenue for this alternative would be generated from the sale of the excess RNG to VGS through a gas purchase agreement. VGS noted that gas line connection fees would be waived for this project. Additionally, MWTP operating cost savings are anticipated due to the elimination of the current high temperature lime stabilization/pasteurization system.

## 3.2 Project Revenue Descriptions:

Below is a description of each of the above-mentioned revenue resources:

**3.2.1 Electricity Sales:** Through a power purchase agreement (PPA), the MWTP would have the opportunity to sell the electricity generated by the CHP project option to the GMP utility grid. For the purposes of this analysis a purchase rate of $0.199/kWh was used based on a Feed-In-Tariff (FIT) up to 150 kW through the Vermont Standard Offer Program.

**3.2.2 RECs:** The MWTP would also have the option to contract for the purchase the Renewable Energy Credits (REC's) created by the project option that generates electricity to the grid. A typical value of $0.04/kWh for CHP generated electricity was used for this assessment.

**3.2.3 RNG-Sales:** If an RNG Inject option is selected (#2 or4), the generated biogas refined to natural gas quality can be sold to the utility (VGS) with a pipe extension and injecting it into a local main distribution line. Based on VGS input, the possible revenue from the sale of the refined renewable gas is valued at $25/MMBtu and this value was used for this assessment.

**3.2.4 Solids Sales(potential):** Typically, on farm anaerobic digester facilities, the solids biproduct generated can be used for animal bedding and/or sold on the market to nearby farms creating another potential revenue stream for the facility. Based on FCE research, a value of $12/cy for the generated dry bedding materials is typical. However, as noted by the facility operator the existing material is hauled off-site by a local farm at a cost to the facility of $20 per ton. Since at this facility, the material is municipal wastewater derived this cost for disposal of the material was used in this assessment as a continued deficit rather than a revenue stream.

**3.2.5 Organic Fertilizer (potential):** Typically, on farm anaerobic digester facilities, the liquids biproduct generated can be used as an organic fertilizer with a typical value of $0.02/gal. However, since at this facility, the material is municipal wastewater derived, a value was not used as a revenue for this material in this evaluation, and this liquid biproduct will instead be piped to the facilities' headworks.

**3.2.6 Carbon Credits (potential):** For renewable energy facilities such as these, there is also the potential for the sale of Carbon Credits through a third-party coordinator. The amount fluctuates with the market and can be administratively intensive, however it can be used for all renewable fuel generated, even if it is simply flared. For the purposes of this evaluation, we did not consider the possible revenue from the sale of carbon credits.

Table 4 summarizes the potential revenue and savings as calculated for each project option.

## Table 4: Calculated Potential Gross Revenue & Savings

| Potential Revenue/Savings | | | | | |
|---|---|---|---|---|---|
| **Option 1 Electricity to the Grid** | **Electricity** | **Amount** | **Units** | **$ Rate/unit** | **Potential Revenue per Year** |
| | Electricity Sale to grid (maxed at 150kW) | 1,208,880 | kWh/yr | $0.199 | $240,567 |
| | REC's (@92% Available of all) | 1,521,113 | kWh/yr | $0.04 | $60,845 |
| | | | | | |
| | Removed processes (lime/pasturization/aeration) Materials/Maintenance, etc. Savings ($) | 380,700 | $/yr | | $380,700 |
| | **Total** | | | | **$682,112** |
| **Option 2 RNG to the VGS Pipe Line** | **RNG** | **Amount** | **Units** | **$ Rate/unit** | **Potential Revenue per Year** |
| | RNG Sales to VGS System | 16,525 | MMBtu/yr | $25.00 | $413,119 |
| | | | | | |
| | Removed processes (lime/pasturization/aeration) Materials/Maintenance, etc. Savings ($) | 380,700 | $/yr | | $380,700 |
| | **Total** | | | | **$793,819** |
| **Option 3 Biogas for Process & Facility Heat** | **Process & Facility Heat** | **Amount** | **Units** | **$ Rate/unit** | **Potential Revenue per Year** |
| | Savings only from existing heat costs using biogas | 6,000 | Gal/yr-#2 Fuel Oil | $5.00 | $30,000 |
| | | | | | |
| | Removed processes (lime/pasturization/aeration) Materials/Maintenance, etc. Savings ($) | 380,700 | $/yr | | $380,700 |
| | **Total** | | | | **$410,700** |
| **Option 4 Biogas for Process & Facility Heat Plus RNG to the VGS Pipeline** | **Process & Facility Heat + RNG** | **Amount** | **Units** | **$ Rate/unit** | **Potential Revenue per Year** |
| | Savings only from existing heat costs | 6,000 | Gal/yr-#2 Fuel Oil | $5.00 | $30,000 |
| | Excess RNG for Sale to VGS System | 14,035 | MMBtu/yr | $25.00 | $350,868 |
| | | | | | |
| | Removed processes (lime/pasturization/aeration) Materials/Maintenance, etc. Savings ($) | 380,700 | $/yr | | $380,700 |
| | **Total** | | | | **$761,568** |

# 4. Economic Feasibility:

In order to determine the economic feasibility of each project option, costs for operations and maintenance were evaluated as follows:

## 4.1 Projected Operation and Maintenance Costs

### 4.1.1 AD's Electrical and Heat Loads

The electrical parasitic loads for the CHP option and the process and facility heat option are estimated at 10% of the potential generated electricity. The electrical parasitic loads of the RNG injection options are estimated at 20% of the systems potential generated electricity to account for the gas upgrading system loads. The cost for these parasitic loads were based on the plant's current electrical rate per kW/hr.

The heat parasitic loads are estimated at 10% of the heat generated by the proposed system. For the CHP option, the heat exchanger portion of the CHP unit will provide the parasitic thermal energy for the digester, so there are no cost assumptions for the parasitic heat load on the CHP option. For the options that include a biogas boiler (#3&4), the heat for the process will be generated by the biogas boiler system so there are no cost assumptions for the parasitic heat load on these options.

### 4.1.2 AD Operations and Maintenance Costs

These systems require constant remote monitoring to run on a day-to day basis. These costs include the operations and maintenance of all equipment related to the AD system. These costs have been based on an estimated hourly rate and manhours to perform the work based on the systems projected size.

### 4.1.3 Overall System Administrative Costs

These systems also generate administrative costs relating to all aspects of parts replacement, testing and reporting for any revenue options and permits governing the system operations. These costs have been based on an estimated hourly rate and manhours to perform this work on the systems projected size.

### 4.1.4 CHP Option

CHP maintenance costs are based on the current costs for similar systems in operation. The estimated costs for these have been based on a system cost of $0.02 kW/hr generated.

### 4.1.5 RNG Options

Biogas cleaning, upgrading and compression to get to RNG quality equipment maintenance costs for option 2 are estimated to be similar to the maintenance costs for the CHP with the same amount of biogas. The RNG Cleaning, upgrading and compression equipment maintenance costs for option 4 are estimated to be half of this value due to the reduction in biogas to be cleaned, upgraded and compressed. It should be noted the equipment used in this evaluation can process up to 50 SCFM, and therefore there is capacity for additional gas production.

### 4.1.6 Process & Facility Heat Options

Maintenance costs for the biogas cleaning and biogas boiler equipment used in the Process and Facility Heat options (3&4) are fairly minimal. For this evaluation a value of 10% of the estimated maintenance costs for the CHP maintenance costs was used.

### 4.1.7 Other Assumptions

In order to minimize capital costs, existing components at the MWTP will be used as follows:

1. The existing lime stabilization/pasteurization building will be utilized for housing the sludge and digestate dewatering systems and the CHP or biogas boiler equipment.
2. The land needed for the digesters is owned by or will be donated to the Town.
3. Existing pumps in the SBRs and the sludge storage tanks will be used/repurposed
4. No changes are anticipated for the SBR equipment or the aerated sludge holding tanks.

Table 5 below provides a summary of the estimated operations and maintenance costs associated with the project options for this study:

**Table 5: Estimated Annual Operation Costs**

| Estimated Annual Operational Costs | | |
|---|---|---|
| **Option 1 Electricity To the Grid** | CHP (kW) | 188.7 |
| | Total Annual Electricity Generated (kWh) | 1,521,113 |
| | Electrical Parasitic Load ($/yr) | $23,039 |
| | Thermal Parasitic Load ($/yr) | N/A |
| | | |
| | Digester Operations and System Maintenance (1@14 hrs/wk) ($/yr) | $30,576 |
| | Overall System Dewatering Costs (1@ 10hr/wk) ($/yr) | $21,840 |
| | CHP Maintenance Costs ($/yr) | $30,422 |
| | Cost to Haul Dry Materials Off Site ($/yr) | $12,222 |
| | **TOTAL** | **$118,099** |
| **Option 2 RNG to the VGS Pipeline** | SCF/Day | 43,658.0 |
| | Electrical Parasitic Load ($/yr) | $46,077 |
| | Thermal Parasitic Load ($/yr) | $59,186 |
| | | |
| | AD Operations and System Maintenance (1@14 hrs/wk) ($/yr) | $30,576 |
| | Overall System Dewatering Costs (1@ 10hr/wk) ($/yr) | $21,840 |
| | RNG Cleaning and Compression Equipment Maintenance Costs | $30,422 |
| | Cost to Haul Dry Materials Off Site ($/yr) | $12,222 |
| | **TOTAL** | **$200,324** |
| **Option 3 Biogas for Process & Facility Heat** | SCF/Day | 43,658.0 |
| | Electrical Parasitic Load ($/yr) | $23,039 |
| | Thermal Parasitic Load ($/yr) | $0 |
| | | |
| | Digester Operations and System Maintenance (1@14 hrs/wk) ($/yr) | $30,576 |
| | Overall System Dewatering Costs (1@ 10hr/wk) ($/yr) | $21,840 |
| | Biogas Boiler Maintenance Costs ($/yr) | $3,042 |
| | Cost to Haul Dry Materials Off Site ($/yr) | $12,222 |
| | **TOTAL** | **$90,719** |
| **Option 4 Biogas for Process & Facility Heat Plus RNG to the VGS Pipeline** | SCF/Day | 43,658.0 |
| | Electrical Parasitic Load ($/yr) | $46,077 |
| | Thermal Parasitic Load ($/yr) | $0 |
| | | |
| | Digester Operations and System Maintenance (1@14 hrs/wk) ($/yr) | $30,576 |
| | Overall System Dewatering Costs (1@ 10hr/wk) ($/yr) | $21,840 |
| | Biogas Boiler Maintenance Costs ($/yr) | $3,042 |
| | RNG Cleaning and Compression Equipment Maintenance Costs | $15,211 |
| | Cost to Haul Dry Materials Off Site ($/yr) | $12,222 |
| | **TOTAL** | **$128,969** |

# 5. Financial Feasibility:

The financial feasibility of each Option comes down to the net difference between the potential revenue and system savings versus the system capital construction costs and annual operations and maintenance costs. Each option was evaluated for a preliminary system design and a cost was estimated for all aspects. Note that the estimated costs are based on historical project costs of similar facilities. Values assigned to each component are subject to change based on the current market. Below is a summary of the items necessary for each project.

## 5.1 Large System Items for Construction Cost Estimates:

### 5.1.1 Anaerobic Digesters

The AD system would include: a receiving tank; an anaerobic digester tank; a flare; two dewatering systems and associated appurtenances, pumps and piping.

### 5.1.2 CHP Option

The AD option with a combined CHP (#1) would include on-site biogas cleaning and an electrical interconnection to the electrical grid.

### 5.1.3 RNG Injection Options

The RNG options (#2&4) would require biogas cleaning and upgrading, installation of gas monitoring as well as a compression system to allow for the injection of RNG to the VGS pipeline. It should be noted the equ ipment used in this evaluation can process up to 50 SCFM, and therefore there is capacity for additional gas production.

### 5.1.4 Biogas for Process and Facility Heat at the MWTP

The AD option with the biogas for heat options (#3&4) would include onsite biogas cleaning, an onsite biogas boiler as well as associated appurtenances and piping.

### 5.1.5 All projects

Each project would also require permitting assistance estimated to be $40,000, engineering and project management estimated to be 3% of construction costs, and land acquisition currently estimated as $0 (likely to be donated by Middlebury College).

Table 6 represents the Engineers Opinion of Probable Construction Costs.

## Table 6: Engineers Opinion of Probable Costs

| Engineers Opinion of Probable Project Construction Costs | | |
|---|---|---|
| | **Item** | **Estimated Cost** |
| **Option 1 Electricity to the Grid** | 1- 67'Ø x10' tall Digester tank W/ Roof /Mixers/Controls-Start Up | $525,000.00 |
| | 1- 150 kW CHP+gas cleaning- controls & enclosure-including startup | $458,120.00 |
| | Dewatering Systems | $500,000.00 |
| | Flare & Other Equipment | $150,000.00 |
| | Installation/Site Work | $150,000.00 |
| | Cost of land for project - expected as donation | $0.00 |
| | **Subtotal Construction** | **$1,783,120.00** |
| | | |
| | Electrical Interconnection Fee | $75,000.00 |
| | Permitting assistance | $40,000.00 |
| | Engineering & Project Management(3%) | $53,493.60 |
| | Start-Up Cost | included above |
| | **Subtotal** | **$1,951,613.60** |
| | Contingency (10%) | $195,161.36 |
| | ***Total Estimated Cost*** | ***$2,146,774.96*** |

| | **Item** | **Estimated Cost** |
|---|---|---|
| **Option 2 RNG to the VGS Pipeline** | 1- 67'Ø x10' tall Digesters tank W/ Roof /Mixers/Controls-Start Up | $525,000.00 |
| | Dewatering Systems | $500,000.00 |
| | Biogas Cleaning, Upgrading, Compression & Interconnect Equipment | $850,000.00 |
| | Flare & Other Equipment | $150,000.00 |
| | Installation/Site Work | $150,000.00 |
| | Cost of land for project - expected as donation | $0.00 |
| | **Subtotal Construction** | **$2,175,000.00** |
| | | |
| | Pipe Extention and Connection (VGS) | $0.00 |
| | Permitting assistance | $40,000.00 |
| | Engineering & Project Management(3%) | $65,250.00 |
| | Start-Up Cost | included above |
| | **Subtotal** | **$2,280,250.00** |
| | Contingency (10%) | $228,025.00 |
| | ***Total Estimated Cost*** | ***$2,508,275.00*** |

| | **Item** | **Estimated Cost** |
|---|---|---|
| **Option 3 Biogas for Process & Facility Heat** | 1- 67'Ø x10' tall Digesters tank W/ Roof /Mixers/Controls-Start Up | $525,000.00 |
| | Dewatering Systems | $500,000.00 |
| | Biogas Boiler | $100,000.00 |
| | Flare & Other Equipment | $150,000.00 |
| | Installation/Site Work | $150,000.00 |
| | Cost of land for project - expected as donation | $0.00 |
| | **Subtotal Construction** | **$1,425,000.00** |
| | Pipe Extention and Connection (VGS) | $0.00 |
| | Permitting assistance | $40,000.00 |
| | Engineering & Project Management(3%) | $42,750.00 |
| | Start-Up Cost | included above |
| | **Subtotal** | **$1,507,750.00** |
| | Contingency (10%) | $150,775.00 |
| | ***Total Estimated Cost*** | ***$1,658,525.00*** |

| | Item | Estimated Cost |
|---|---|---|
| **Option 4 Biogas for Process & Facility Heat Plus RNG to the VGS Pipeline** | 1- 67'Ø x10' tall Digesters tank W/ Roof /Mixers/Controls-Start Up | $525,000.00 |
| | Dewatering Systems | $500,000.00 |
| | Biogas Boiler | $100,000.00 |
| | Biogas Cleaning, Upgrading, Compression & Interconnect Equipment | $600,000.00 |
| | Flare & Other Equipment | $150,000.00 |
| | Installation/Site Work | $150,000.00 |
| | Cost of land for project - expected as donation | $0.00 |
| | **Subtotal Construction** | **$2,025,000.00** |
| | | |
| | Pipe Extention and Connection (VGS) | $0.00 |
| | Permitting assistance | $40,000.00 |
| | Engineering & Project Management(3%) | $60,750.00 |
| | Start-Up Cost | included above |
| | **Subtotal** | **$2,125,750.00** |
| | Contingency (10%) | $212,575.00 |
| | ***Total Estimated Cost*** | ***$2,338,325.00*** |

## 5.2 Simple Payback:

Based on all of the above information, each project option was evaluated for simple payback. This was accomplished by dividing the estimated construction costs by the net revenue after accounting for the projects' operation and maintenance costs. Table 7 presents these values.

**Table 7: Simple Payback Summary**

| Simple Payback (without Grants) | | |
|---|---|---|
| **Option 1 Electricity to the Grid** | Total Operational Costs | $118,099 |
| | | |
| | Total Operational Revenue | $682,112 |
| | | |
| | **Net Annual Revenue** | **$564,013** |
| | | |
| | Total Project Construction Cost | $2,146,775 |
| | | |
| | **Simple Payback (Years)** | **3.8** |
| | | |
| **Option 2 RNG to the VGS Pipeline** | Total Operational Costs | $200,324 |
| | | |
| | Total Operational Revenue | $793,819 |
| | | |
| | **Net Annual Revenue** | **$593,496** |
| | | |
| | Total Project Construction Cost | $2,508,275 |
| | | |
| | **Simple Payback (Years)** | **4.2** |

| | | |
|---|---|---|
| **Option 3 Biogas for Process & Facility Heat** | Total Operational Costs | $90,719 |
| | | |
| | Total Operational Revenue | $410,700 |
| | | |
| | **Net Annual Revenue** | **$319,981** |
| | | |
| | Total Project Construction Cost | $1,658,525 |
| | | |
| | **Simple Payback (Years)** | **5.2** |

| | | |
|---|---|---|
| **Option 4 Biogas for Process & Facility Heat Plus RNG to the VGS Pipeline** | Total Operational Costs | $128,969 |
| | | |
| | Total Operational Revenue | $761,568 |
| | | |
| | **Net Annual Revenue** | **$632,599** |
| | | |
| | Total Project Construction Cost | $2,338,325 |
| | | |
| | **Simple Payback (Years)** | **3.7** |

A block flow diagram and a sketch with the components are included in the Appendix.

## 6. Management Feasibility:

FCE believes that the existing facility management team, is prepared to take on the maintenance and operation needs required by the evaluated projects.

## 7. Recommendations:

All of the evaluated options have very promising paybacks. The standard of the industry for renewable energy projects is that it is a 'good project' if the payback is less than seven years, and a 'great project' if the payback is less than five years. Options 1, 3 and 4 all fall within the 'great project' window and option 2 is just outside of 'great' in the 'good' category. This makes any of the options a very viable choice.

Based on the proposed project information, the economic feasibility, the market feasibility, the technical feasibility, the financial feasibility and the capabilities of the management team, FCE recommends moving forward with any one of the evaluated project options.

## 8. Qualifications:

Please refer to the attached resume for John D. Forcier, P.E., including related experience. We trust that this provides Vermont Gas Systems and the Middlebury Wastewater Treatment Plant with the Renewable Energy Feasibility Study that you had requested. We look forward to continuing to work with you in assisting you through to the successful completion of these exciting projects.

Sincerely,
***Forcier Consulting Engineers, PC***

John D. Forcier, P.E.
President

# *RESUME*

**John D. Forcier, P.E.** 174 Browns River Road, Essex Junction, VT 05452 (802) 657-3083

Mr. Forcier has more than 49 years of experience in the planning, design, permitting and construction of small through multi-million dollar municipal and private renewable energy, biogas, anaerobic digester, wastewater, projects throughout the eastern U.S.A. His unique experience includes design/competitive bid, design/build and construction management projects, both as the design project manager/project principal and as the construction project manager/estimator/scheduler/construction manager. He is also a Subject Matter Expert on Biogas/RNG and Anaerobic Digester Due Diligence and Claims throughout the U.S.A.

**PROFESSIONAL EXPERIENCE:**

2010 - Present FORCIER CONSULTING ENGINEERS, P.C., Essex Junction, Vermont
President/Founder - Overall responsibility for Civil/Environmental Consulting Engineering firm specializing in over 70 Renewable Energy, Biogas/RNG and Anaerobic Digester projects throughout the U.S.A., Mexico, Europe and the Caribbean.

1995 - 2010 FORCIER ALDRICH & ASSOCIATES, INC., Essex Junction, Vermont
1995 - 2010: President/Co-Founder/Senior Associate - Overall responsibility for 26 person Civil/Environmental Consulting Engineering firm specializing in Municipal Water, Wastewater, Solid Waste, Biogas and Civil/Site projects.

1991 - 1995 THERMO CONSULTING ENGINEERS, INC., Williston, Vermont
Project Manager/Department Manager - Civil & Environmental Engineering- Overall responsibility for 10 person Civil/Environmental Engineering Department specializing in Municipal Water, Wastewater, Solid Waste and Civil/Site projects throughout the northeastern U.S.A.

1986 - 1990 ENGELBERTH CONSTRUCTION, INC., Colchester, Vermont
Project Manager/Chief Estimator

1985 - 1986 M.A. BONGIOVANNI, INC., Syracuse, New York
Chief Estimator/Project Manager- Wastewater Treatment Plants in NY and Maryland.

1972 - 1985 PIZZAGALLI CONSTRUCTION COMPANY, INC., South Burlington, Vermont
Project Manager (1980-1985); Senior Project Engineer (1976-1979); Assistant Chief Estimator (1974-1976); Safety Engineer (1972-1974)

**EDUCATION:**

- University of Vermont, 1972; BSCE
- Honors: Chi Epsilon (Civil Engineering Honor Society)

**PROFESSIONAL ENGINEERING REGISTRATIONS:** Vermont License #3995, Maine License #4119

**PROFESSIONAL AFFILIATIONS:**

- American Council of Engineering Companies- ACEC/Vermont Section:(1998- present; National Director: 2005 - 2018, President: 2003 - 2005, Treasurer: 2002 - 2003, Secretary: 2000 - 2002); Board of Directors (2000 - present; Member), ACEC Small Firm Council (2007 - present; Member)
- Green Mountain Water Environment Association- GMWEA (2010 - present; Member)
- Lee Enterprises Consulting, Inc.- LEC- (2016 - present; Anaerobic Digestion/Biogas Expert)
- National Society of Professional Engineers/Vermont Society of Professional Engineers (1981 - present, President: 1991-1992 & 2005, Treasurer: 1997- 2010, MathCounts State Co-Coordinator: 1998 -2010)
- North East Biosolids & Residuals Association- NEBRA- (2012 - present; Member)
- UVM CEMS CEE Advisory Board- (1995 - present; Member, 2015 – present; Chair)
- Vermont Rural Water Association- VRWA- (2010 - present; Member)
- Vermont Society of Engineers- (1995 - present; Member)

**AWARDS:**

- **Lifetime Achievement Award** -American Council of Engineering Companies/Vermont (2021)
- **Vermont "Engineer of the Year" 2000**
- **Tau Beta Pi** (Engineering Honor Society)- **Inducted as an Eminent Engineer** in 1999.

Updated: March 29, 2022

# RELATED EXPERIENCE (BIOGAS/DIGESTERS/COMPOSTING):

**AGreen Energy, LLC (Boston, MA)- CO, FS, RFP, PA:**

- **Barway Farm Biogas (South Deerfield, MA) & Barstow's Longview Farm Biogas (Hadley, MA):** Performed an RFP and feasibility study including interviews and rating & ranking of four Design-Build teams and design/construction review for 2@ 500 kW complete mix anaerobic digester systems at the 250 milking cow farms and including food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock; Project Manager.
- **Jordan Dairy Farm Biogas (Rutland, MA):** Provided technical assistance for permitting and upgrades from a 300kW to a 500 kW complete mix anaerobic digester system with manure from a 300 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock; Project Manager.
- **Barstow's Longview Farm Biogas (Hadley, MA):** Provided technical assistance for permitting for a new 300kW complete mix anaerobic digester with manure from a 250 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock; Project Manager.

**Agricultural Digesters, LLC (Williston, VT)- CO, FS:**

- **Bullis-Savage View Farm AD (Grand Isles, VT)-** Performed USDA-Rural Development REAP Feasibility Study & cost opinions in support of loan/grant applications. Proposed project includes containerized complete mix anaerobic digester facility to handle cow manure from a 750 head dairy farm to produce electricity via a 150 kW CHP/generator set, Carbon Credits, to provide 500,000 BTU/hr. of process heat and excess heat for surrounding buildings and to provide animal bedding to replace purchased bedding and with excess bedding to be sold off-site; FCE Project Manager.
- **Magnan Brothers Dairy AD (Fairfield, VT)-** Performed USDA-Rural Development REAP Feasibility Study & cost opinions in support of loan/grant applications. Proposed project includes containerized complete mix anaerobic digester facility to handle cow manure from a 1,200 head dairy farm to produce electricity via a 150 kW CHP/generator set, Carbon Credits, to provide 500,000 BTU/hr. of process heat and excess heat for surrounding buildings and to provide animal bedding to replace purchased bedding and with excess bedding to be sold off-site; FCE Project Manager.

**Barway Farm Biogas (South Deerfield, MA)- (As a sub-consultant to CH-Four Biogas)- PA, LG, PR:**

- Provided technical assistance and design review for permitting and loan/grant applications for a new 1.2MW complete mix anaerobic digester system with manure from a 250 milking cow farm and with Fats-Oils-Grease (FOG) and food waste and liquid, semi-solid and solid source-separated organics feedstock. Also includes a solids separator system that produces animal bedding to replace purchased bedding; Project Manager

**Benjamin Family- Riverview Farm (Franklin, VT)- CA, CR, OR, PR, RE, RFP:**

- Performed RFP, Construction Administration and part-time Construction Observation services, USDA-NRCS certification report and 1603 Treasury Grant commissioning report for a complete mix anaerobic digester facility to handle cow manure from a 450 head dairy farm and food waste and source-separated organics feedstock with biogas that fuels 2@95 kW CHP generator sets and provides process heat and excess heat for surrounding buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding; FCE Project Manager.

**BerQ RNG (Toronto, ON)- Anaerobic Digester Upgrades to RNG - CA, CO, OR, OT, PR, RE, RM:**

- **Adirondack Farms (Peru, NY) Anaerobic Digester Upgrade to RNG-** Providing Peer Review, RFP, Construction Administration, and part-time Construction Observation services of proposed upgrade of complete mix anaerobic digester system to convert from 633 kW of electrical energy to the grid to renewable natural gas (RNG). The biogas will be conditioned and upgraded to Biomethane (RNG) for compression, virtual pipeline transportation, decompression and injection into the natural gas pipeline to sell for RIN's & CA LCFS; FCE Project Manager.
- **Woodcrest Farms (Ogdensburg, NY) Anaerobic Digester Upgrade to RNG-** Providing Peer Review, RFP, Construction Administration, and part-time Construction Observation services of a 4-farm hub & spoke system including proposed upgrade of complete mix anaerobic digester system to convert from electrical energy to the grid to renewable natural gas (RNG). The biogas will be conditioned and upgraded to Biomethane (RNG) for compression and injection into the natural gas pipeline to sell for RIN's & CA LCFS. Also includes pumping manure from 3 nearby dairy farms to the

host farm with an additional AD system to produce additional RNG; FCE Project Manager.

**BioWatts (Florida)- CO, FS, OR:**

- Prepared feasibility studies for three Design/Build/Own/Operate collaborative facilities in Central Florida. These included both Anaerobic Digester and Pyrolysis technologies, which allow for multiple organic waste streams including pre-consumer and post-consumer food waste, animal waste, Fats-Oils-Grease (FOG), wastewater biosolids and yard waste. Outputs and by-products of each project include ~200,000 MMBtu/yr. of BioCNG or BioMethane (RNG), agricultural fertilizer and 1,300 tons/year of Biochar soil amendment; FCE Project Manager.

**Boucher Farm Biogas (Highgate Center, VT)- CO, FS:**

- Participated in an RFP and feasibility study for a 633 kW complete mix anaerobic digester project for this 250 head Vermont dairy farm. This MWK system would utilize cow manure and crop substrates to power a biogas/methane generator to produce electricity as well as heat for the farm residences and nearby utility buildings. Food waste substrates were also considered. Ultimately, with major changes in the crop markets, it was determined that this system was not economically feasible for this application; Project Manager.

**City of Burlington, VT- CA, CO, FD, OR, OT, PR, RE:**

- Construction phase engineering, start-up and operator assistance services for the Main Wastewater Treatment Facility; 5.3 mgd average flow, 13 mgd peak daily flow, 75 mgd CSO vortex separator and up to 200 mgd peak CSO flow; conventional activated sludge wastewater treatment plant (Project Manager) including:
  - Design of numerous unit process components including sludge dewatering (2 @ 2 meter belt filter presses) and associated chemical feed systems.
  - Design and operator training for PLC system and SCADA system.
  - As part of first year services, suggested and helped implement biological phosphorus removal, which provides significant savings in reduced chemical and biosolids disposal costs; Project Manager.

**Casella Organics (Rutland, VT/Portland, ME)**

- **Grasslands Facility (Chateaugay, NY)- CA, CO, OR, RE:** Provided RFP, Construction Administration and part-time Construction Observation services for a Schwing "Bioset" Advanced Alkaline Stabilization Technology system. This system can process 250 wet tons/day (~91,000 wet tons/year) of municipal biosolids, utilizing a controlled exothermic reaction to pasteurize and compost the biosolids. This process produces Class A (PFRP) compost in 45 minutes, compared to 6 or 8 weeks for traditional composting. The work included 128,000 s.f. of new paved composted storage areas and a 16,800 s.f. covered compost storage building; Project Manager.
- **BGreen Energy, LLC (Barstow's Longview Farm Biogas, Hadley, MA)-CO, FS, PR:** Prepared a feasibility study for a 300kW complete mix anaerobic digester system with manure from a 250 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock; Project Manager.

**Town of Castleton, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.54 mgd Sequential Batch Reactor WWTF expansion/upgrade including biological phosphorous removal, septage receiving facility and a 400,000 gallon aerobic digester; Project Manager.

**Chittenden Solid Waste District (CSWD, Williston, VT)**

- **Food Waste Digester Feasibility Study- CO, FS:**
  - Selected as only firm to do a Desktop Feasibility Study for an Anaerobic Digester System for handling ~2,500 tons/year of food waste (pre-consumer and post-consumer, including cafeteria food waste) and Fats-Oils-Grease (FOG) for all of Chittenden County.
  - Prepared Desktop Feasibility Study which studied three technologies and recommended one complete mix anaerobic digester technology; Project Manager.

- **Biosolids Composting RFP/Feasibility Study- CO, FS, OR, RFP:**
  - Prepared an RFP and a Feasibility Study with rating/ranking of biosolids disposal/reuse options.
  - Assisted with implementation of a regional solution of beneficial reuse via windrow composting of 15,000 tons/year of biosolids; Project Manager.
- **Biosolids Screw Conveyor- CA, CO, OR, OT, RE, RFP:**
  - Provided design and construction phase services for a design-build horizontal screw conveyor to handle 15,000 tons/year of biosolids to be distributed in 40 c.y. trailer dump trucks at the central dewatering facility at the main Wastewater Treatment Facility in Burlington, VT; Project Manager.
- **Biosolids Processing Facility, South Burlington, VT- CA, OR, PR, RE:**
  - Peer review and part-time construction inspection of paddle-type sludge drying/pelletizing system for processing 12,000 wet tons/year of biosolids; Project Manager.
  - Expert Witness for construction claim mitigation.

**Confidential Client, California (As a subconsultant to Leidos Engineering)- IES, PR:**

- **12 Dairy Farm Anaerobic Digester Facilities Producing Biomethane to Natural Gas Pipeline-** Anaerobic Digester Subject Expert on Independent Engineering Study and Peer Review of 12 farm covered lagoon anaerobic digesters to handle cow manure from ~100,000 dairy cows and to produce biogas, which is conditioned and upgraded to BioMethane (RNG) and connected to the Natural Gas pipeline (totaling ~10 MWe equivalent) to sell for CA RIN's & LCFS; FCE Project Manager.

**Confidential Client, California (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Dairy Farm Partial Mix Plug Flow Anaerobic Digester System-** Worked as the Anaerobic Digester Subject Expert on potential litigation including preliminary findings; FCE Project Manager

**Confidential Client, Michigan (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Commercial/Municipal Anaerobic Digester With FOG/Food Waste, WWTF Sludge and Cow Manure Feedstocks-** Working as the Anaerobic Digester Subject Expert on potential litigation including preliminary findings; FCE Project Manager.

**Confidential Client, New Jersey (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Municipal Wastewater Treatment Facility Anaerobic Digester FOG/Food Waste Feedstock System-** Working as the Anaerobic Digester Subject Expert on potential litigation including site visit, preliminary findings and deposition; FCE Project Manager.

**Confidential Client, New Jersey (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Municipal Wastewater Treatment Facility Anaerobic Digester Gas Holder Cover-** Working as the Anaerobic Digester Subject Expert on mediation and pending litigation including site visit, mediation and preliminary findings; FCE Project Manager.

**Confidential Client, New York City, NY (As a Consultant to Lee Enterprises Consulting)- FS:**

- **Food Waste from 50+ Restaurants in NYC to Anaerobic Digesters vs. Landfills-** Work with LEC Team as the Anaerobic Digester Subject Expert on a Feasibility Study to divert organic food waste from 50+ NYC restaurants to Anaerobic Digester systems; FCE Project Manager.

**Confidential Client, Texas (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Industrial Wastewater Treatment Facility Anaerobic Digester System-** Working as the Anaerobic Digester Subject Expert on a Commercial Insurance Claim including preliminary findings; FCE Project Manager.

**Confidential Client, Virginia (as a Consultant to Lee Enterprises Consulting)- EW:**

- **Dairy Farm Partial Mix Plug Flow Anaerobic Digester System-** Working as the Anaerobic Digester Subject Expert on potential litigation including site visit and preliminary findings; FCE Project Manager.

**Confidential Client, Wisconsin (As a Consultant to Lee Enterprises Consulting)- IES, PR:**

- **2 Dairy Farm Anaerobic Digester Facilities Producing Biomethane to Natural Gas Pipeline-** Anaerobic Digester Subject Expert on Independent Engineering Study and Peer Review of 2 farm anaerobic digesters to handle cow manure from ~18,000 dairy cows and to produce biogas (from the hub & spoke system), which will be conditioned and upgraded to Biomethane (RNG) for compression, virtual pipeline transportation, decompression and injection into the natural gas pipeline (totaling ~200,000 MMBtu/yr. of RNG) to sell for RIN's & CA LCFS; FCE Project Manager.

**Ductor Americas (Raleigh, NC/Helsinki, Finland)- CA, CO, FD, OR, OT, PR, RFP, VE:**

- **Juanita Anaerobic Digester (Aquascalientes, Mexico)-** Performed Peer Review, Cost Opinions, RFP, Value Engineering, Preliminary & Final Design and Construction Administration services for a complete mix anaerobic digester facility to handle 100% chicken litter producing biogas that fuels a biogas boiler that provides ~500,000 BTU/hr. of process heat and excess heat for surrounding buildings. Also includes a proprietary ammonia stripping technology which produces valuable Ammonia Nitrogen organic fertilizer; FCE Project Manager.
- **Catawba Biogas (Lilesville, NC)-** Performed Peer Review, Cost Opinions, RFP, Preliminary & Final Design (as the Lead Designer) and Value Engineering services for a complete mix anaerobic digester facility to handle 142 tons/day (52,000 tons/yr.) of 100% chicken litter, producing biogas, which is conditioned and upgraded to biomethane (RNG) and connected to the Natural Gas pipeline (totaling ~300,000 MCF/yr. of RNG) to sell for RIN's & CA LCFS. Also produces high NPK organic fertilizer and also includes a proprietary ammonia stripping technology which produces valuable Ammonia Nitrogen organic fertilizer; FCE Project Manager.

**Entropy Investment Management (Charlotte, NC):**

- **Orbit Energy Charlotte (Charlotte, NC)- CA, CO, FD, OR, OT, PR, RE, RM:**
  **5.2 MW AD Facility-** Providing Peer Review, initial AD operations recommendations, recipe management assistance and process improvements including Final Design for facility upgrades to improve the material handling, pumping and processing to optimize the process and work towards reaching nameplate capacity and construction observation for a complete mix anaerobic digester facility that can handle 356 T/day (130,000 T/year) of food waste, Fats-Oils-Grease (FOG) and source-separated organics (SSO) with biogas that fuels 5.2 MW of CHP generator sets and provides up to 17 MMBtu/hour of process heat and excess heat for nearby buildings. Also includes a Scott Thor Organics De-Packaging system and a sludge drying system that produces Class A dried solids used as organic fertilizer for nearby land application; FCE Project Manager.

- **Orbit Energy Rhode Island (Johnston, RI)- CA, CO, FD, OR, OT, PR, RE, RM:**
  **3.2 MW AD Facility-** Provided Peer Review, initial AD operations recommendations, recipe management assistance and process improvements including Final Design for facility upgrades to improve the material handling, pumping and processing to optimize the process and work towards reaching nameplate capacity and construction observation for a complete mix anaerobic digester facility that can handle 263 T/day (96,000 T/year) of food waste, Fats-Oils-Grease (FOG) and source-separated organics (SSO) with biogas that fuels 3.2 MW of CHP generator sets and provides up to 11 MMBtu/hour of process heat and excess heat for nearby buildings. Also includes a Scott Turbo Organics De-Packaging system and a sludge drying system that produces Class A dried solids used as organic fertilizer for nearby land application; FCE Project Manager.

**Exeter Agri-Energy @ Stonyvale Farm (Exeter, ME)- CA, CO, CR, FD, OR, OT, PA, PR, RE, RFP, RM:**

- **1MW to 3MW Upgrade of AD Facility (2017-2018)-** Performed overall design (as Lead Designer), RFP, construction administration and part-time observation services, Feasibility Study and USDA-RD Reap Grant/Loan Applications for a complete mix anaerobic digester facility to handle cow manure from a 1,000 head dairy farm with 123 tons/day (45,000 tons/year) of dairy manure plus 123 tons/day (45,000 tons/yr.) of food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock with biogas that fuels 3 @1 MW CHP generator sets and provides ~10,000,000 btu/hr. of process heat and excess heat for surrounding buildings. Also includes a solids separator system that produces animal bedding

to replace purchased bedding. Also coordinating with Scott Turbo Organics De-Packaging system; FCE Project Manager.

- **1MW AD Facility (2010-2011)-** Performed design, RFP, construction administration and part-time observation services, USDA Rural Development certification and 1603 Treasury Grant commissioning report for a complete mix anaerobic digester facility to handle cow manure from a 1,000 head dairy farm with 83 tons/day (30,000 tons/yr.) of dairy manure plus 35 tons/day (12,900 tons/year) of Fats-Oils-Grease (FOG) and source-separated organics feedstock with biogas that fuels a 1.0 MW CHP generator set and provides 3,700,000 btu/hr of process heat and excess heat for surrounding buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding; FCE Project Manager.

**Green Mountain Power, Rutland, VT- CO, FS, PR:**

- **St. Albans, VT Regional Anaerobic Digester System- Peer Review:**
  - Performed a Peer Review of a Preliminary Engineering Study to consider a regional anaerobic digester system in St. Albans, VT to handle cow manure, Fats-Oils-Grease (FOG) and food waste to fuel a CHP generator set and provide process heat and excess heat for nearby buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding. Options range from:
    - Two adjacent dairy farms with 1,400 milking cows and 145 dry cows and liquid food waste to produce 580 kW of electrical energy to the grid, 2,200,000 Btu/hour of thermal energy and 4,800 tons/year of animal bedding.
    - Six nearby dairy farms totaling 2,800 milking cows and 315 dry cows and food waste and source separated organics (SSO) to produce 1.25 MW of electrical energy to the grid, 4,800,000 Btu/hour of thermal energy and 9,200 tons/year of animal bedding.
- **Rutland, VT- 8 MGD WWTF Anaerobic Digester Feasibility Study:**
  - Performed a Feasibility Study at the 8 mgd ADF WWTF to take their wastewater sludge and nearby food waste, Fats-Oils-Grease (FOG) and other organics and produce 600 kW of electrical energy and 2,200,000 BTU/hr of thermal energy to completely meet the WWTF energy needs and to convert the remaining biogas to BioCNG (240 dge/day) for their entire municipal fleet.
- **Dual-Train Organics to Energy Solution Study:**
  - Prepared a Conceptual Study of a Combined Anaerobic Digester & Pyrolysis System to handle animal waste, yard waste, wastewater sludge/septage, pre-consumer and post-consumer food waste, Fats-Oils-Grease (FOG) and other organic waste products. Includes nutrient capture system to capture high solids phosphorus to be sold off-site while producing much lower phosphorus organic fertilizer to improve lake quality. Other by-products include biochar (a valuable soil amendment), wood vinegar (a valuable AD substrate) and animal bedding. The pyrolysis system provides complete removal of contaminants, including emerging contaminants (prions, pharmaceuticals, etc.)

**Green State Biochar (Barton, VT)- LG-FD-PS-**

- Provided Technical Assistance for Vermont Phosphorus Innovation Challenge (VPIC) Grant Application:
  - Assisted with getting VPIC Phase 2 Grant:
    - Performed Final Design and coordination of innovative pilot biochar filtration systems to capture 90%+ of phosphorus from manure runoff from farm corn fields, milk waste, barn yard runoff and yogurt whey effluent at:
      - Butterworks Farm, Westfield, VT
      - Churchill Farm, Cabot, VT
  - Assisted with getting VPIC Phase 3 Grant:
    - Provided technical assistance and support for additional pilot biochar filtration systems.

**Town of Greenfield, MA/Massachusetts Clean Energy Center (Mass CEC) (As a subconsultant to BEAM Engineering, Brattleboro, VT)- CO, FS:**

- Process design team member in preparing a Transfer Station Anaerobic Digester feasibility study to compare several anaerobic digester technologies utilizing nearby municipal wastewater sludge, food

waste, fats-oils-grease (FOG) and source-separated organics feedstock to fuel a 300 kW CHP generator set and to provide process heat and excess heat for surrounding buildings. Another option was considered to provide 100 SCFM of BioCNG (RNG) for the entire municipal fleet. Includes processing of dewatered digestate to be composted at a nearby compost facility to produce Class A (PFRP) compost. Also considered a Pyrolysis option (including by-products of syngas, synthetic oil and biochar) in lieu of Anaerobic Digestion; FCE Project Manager.

**GSR Solutions (Burlington, VT)- CO, FS:**

- **Guillemette Farm AD (Shelburne, VT)-** Performed USDA-Rural Development REAP Feasibility Study & cost opinions in support of loan/grant applications. Proposed project includes containerized complete mix anaerobic digester facility to handle cow manure from a 300 head dairy farm to produce electricity via 2@ 22 kW CHP/generator sets, to provide 150,000 BTU/hr. of process heat and excess heat for surrounding buildings, to provide animal bedding to replace purchased bedding, with excess bedding to be sold off-site; FCE Project Manager.

**Hi-Vu Acres (Batavia, NY) (As subconsultant to Larsen Engineers, Rochester, NY)- FS, FD:**

- Provided feasibility study and initial process design assistance for partial mix covered lagoon anaerobic digester system to handle cow manure from 1,500 heifers and source-separated organics feedstock with biogas that fuels a 400 kW CHP generator set and provides 1,500,000 Btu/hour of thermal energy for process heat and excess heat for nearby buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding; FCE Project Manager.

**Inlandsis Fund (Montreal, Que.) (As subconsultant to Lee Enterprises)- CO, IES, PR:**

- **Adirondack Farms (Peru, NY) Anaerobic Digester Upgrade- Independent Engineering Study:** Anaerobic Digester Subject Expert on Independent Engineering Study and Peer Review of proposed upgrade of complete mix anaerobic digester system to convert from 633 kW of electrical energy to the grid to renewable natural gas. The biogas will be conditioned and upgraded to Biomethane (RNG) for injection into the natural gas pipeline to sell for RIN's & CA LCFS; FCE Project Manager.

**Jasper Hill Farm (Greensboro, VT)- CO, FD, OR, OT, PR, RM:**

- Assisted with the design of an anaerobic digester system to handle cow manure/separated liquid from 45 dairy cows and on-site cheese whey to produce biogas fueling a biogas boiler to provide ~100,000 btu/hr of process heat for the cheese making. Coordinated with the other project components including solid separator, heat-recovery aerated static pile composting and "Living Machine" biological wastewater treatment system; Project Manager.

**Village of Johnson, VT- CA, CR, FD, OR, OT, PA, RE, RFP, RM:**

- Construction phase, first year, start-up and operator training services for 0.27 mgd Sequential Batch Reactor WWTF expansion/upgrade including sludge dewatering and aerobic digester; Project Manager.
- Construction phase, first year, start-up and operator training services for windrow biosolids composting facility; Project Associate/Project Manager.

**Magic Hat Brewery (South Burlington, VT)/Purpose Energy- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Design Team Manager for the design of a combination horizontal plug flow/partial mix and fixed film anaerobic digester for the beer processing facility in South Burlington, VT. This system utilizes the beer process by-products to produce biogas (RNG) to fuel boilers for the beer process heat and for their facility building heat. Excess biogas fuels a 350 kW generator; FCE Project Manager.
- Prepared an RFP, rating and ranking and assisted in the selection of the design/build team; FCE Project Manager.

**Town of Milton, VT- CA, CO, CR, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 1.0 mgd Sequential Batch Reactor WWTF expansion/upgrade including biological nutrient removal, centrifuge sludge dewatering,

sludge distribution conveyor and aerobic digester; Project Associate/Project Manager.

**NativeEnergy, Inc. (Burlington, VT)- CA, CO, FD, FS, LG, RE, RFP:**

- **Laroche Dairy AD (Highgate Center, VT)-** Performed USDA-Rural Development REAP Feasibility Study & cost opinions in support of loan/grant applications. Performed Final Design and RFP assistance for containerized complete mix anaerobic digester facility to handle cow manure from a 200 head dairy farm to produce electricity via 2@ 22 kW CHP/generator sets, Carbon Credits and to provide 150,000 BTU/hr. of process heat and excess heat for surrounding buildings; FCE Project Manager.

**City of Newport, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 1.0 mgd Conventional Activated Sludge WWTF expansion/upgrade including septage receiving, sludge dewatering and anaerobic digester additions and upgrades; Project Associate/Project Manager.

**Nordic Holstiens (Charlotte, VT)- FS, CO, LG, FD, RFP, CA, RE, RM, OT, CR:**

- Performed Feasibility Study for converting an abandoned vertical plug flow digester to a complete mix anaerobic digester facility to handle cow manure from a 275 head dairy farm, Fats-Oils-Grease (FOG) and source-separated organics feedstock with biogas that fuels a 100 kW CHP generator set and provides 370,000 btu/hr of process heat and excess heat for surrounding buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding; Project Manager.
- Coordinating with proprietary supplementary process that will utilize the separated liquid (from the AD digestate) to grow specialized algae in adjacent greenhouses and will produce bio-diesel and bio-jet fuel; Project Manager.

**Town of Plainfield, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.125 mgd Sequential Batch Reactor WWTF expansion/upgrade including aerobic digesters; Project Associate/Project Manager.

**Town of Plymouth, MA/Massachusetts Clean Energy Center (Mass CEC) (As subconsultant to BEAM Engineering, Brattleboro, VT)- CO, FS:**

- Process design team member in preparing a Wastewater Treatment Facility Anaerobic Digester feasibility study to compare several anaerobic digester technologies utilizing on-site municipal wastewater sludge, off-site food waste, fats-oils-grease (FOG) and source-separated organics feedstock to fuel a 400 kW CHP generator set, to provide 50 SCFM of BioCNG (RNG) to fuel the municipal fleet and to provide process heat and excess heat for surrounding buildings. Also includes an on-site compost facility to produce Class A (PFRP) compost from the digestate. Also considered a Pyrolysis option (including by-products of Syngas, Synthetic Oil and Biochar) in lieu of Anaerobic Digestion; FCE Project Manager.

**City of Portland, ME- CM, OR, OT:**

- Construction project management and chief of engineering for construction of a 15.2 mgd ADF (60 mgd peak) conventional activated sludge wastewater treatment plant and of a $2,200,000 wastewater pump station; Sludge processing including: sludge thickener tanks, gravity table thickeners, air flotation thickeners, aerobic digesters, belt filter presses and “Zimpro” sludge heat treatment system; Senior Project Engineer/Chief Engineer.

**Village of Poultney, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.5 mgd Sequential Batch Reactor WWTF expansion/upgrade including biological phosphorus removal and aerobic digester expansion/upgrade; Project Associate/Project Manager.

**Village of Sheldon, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.1 mgd WWTF expansion/upgrade including aerobic digester; Project Associate/Project Manager.

**Town of Springfield, VT- CA, CO, FD, OR, OT, PA, RE, RFP, RM:**

- Construction phase, first year, start-up and operator training services for 1.4 mgd Conventional Activated Sludge WWTF expansion/upgrade including anaerobic selectors for biological nutrient removal, sludge dewatering and anaerobic digester additions and upgrades; Project Associate/Project Manager.
- Construction phase, first year, start-up and operator training services for upgrades to the aerated static pile composting facility including solid waste full certification; Project Associate/Project Manager.

**Spruce Haven Farm (Fleming, NY)- (As sub to Larsen Engineers, Rochester, NY)- CO, PR, RM:**

- Provided process enhancements and start-up assistance for partial mix covered lagoon anaerobic digester system to handle cow manure from 1,660 milking cows, 1,500 heifers and 200 dry cows with biogas that fuels a 500 kW CHP generator set and provides 1,700,000 Btu/hour of thermal energy for process heat and excess heat for nearby buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding and a sand separation system to remove the sand from the manure for the digester feed and to reuse the sand bedding; FCE Project Manager.

**Town of Stowe, VT: CO, PR, VE:**

- Process design team member at Value Engineering Workshop for new 1.0 mgd SBR wastewater treatment facility with tertiary filtration, UV disinfection, auto-thermal thermophilic aerobic digestion (ATAD) and centrifuge sludge dewatering; Project Manager.

**City of Taunton, MA/Mass DEP- CO, FS:**

- Source-Separated Organics/Food Waste Anaerobic Digester and Composting Feasibility Study
- Prepared a feasibility study for a complete mix anaerobic digester facility to handle 360 tons/day (130,000 tons/year) of Fats-Oils-Grease (FOG) and source-separated organics/food waste and to produce 3.5 MW of electrical energy and 11 MMBtu/hr. for process heat and for heat for nearby buildings; Project Manager.
- Prepared a feasibility study for an aerated static pile compost facility to handle 360 tons/day of dewatered source-separated organics/food waste digestate and 170 tons/day of yard waste to produce valuable compost products; Project Manager.

**United Dairy Group (Frankton, IN)- FS, CO:**

- Provided a Feasibility Study and Cost Opinions for a 4-farm hub & spoke system, each with a complete mix anaerobic digester system, to handle cow manure from a total of 8,000 milking cows and food waste to produce renewable natural gas (RNG) to the grid. The biogas will be conditioned and upgraded to Biomethane (RNG) for compression, virtual pipeline transportation, decompression and injection into the natural gas pipeline (totaling about 140,000 MMBtu's/yr.) to sell for RIN's & CA LCFS; FCE Project Manager.

**University of Vermont (UVM), Burlington, VT- CO, FS:**

- UVM Miller Farm Anaerobic Digester Feasibility Study- Looked at cow and horse manure plus food waste (from the UVM cafeterias) and other on-campus organics to feed an anaerobic digester to provide heat for adjacent buildings and to power a 100 kW generator.
  - Phase I- Selected as one of two firms hired for feasibility studies to each study three technologies and prepared report with rating and ranking of three technologies; Project Manager.
  - Phase II- Selected as only firm to prepare Phase II feasibility study on overall selected technology and prepared report describing the layout, costs and feasibility of the selected technology; Project Manager.

**Vanguard Renewables (Wellesley, MA):**

- **Deerfield AD1 LLC @ Barway Farm (S. Deerfield, MA)- PR, PA:** Provided a Peer Review of the design and permitting assistance for a new 1.2 MW biogas system with manure from a 250 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and liquid, semi-solid and solid source-separated organics feedstock. Also includes a solids separator system that produces animal bedding

to replace purchased bedding; Project Manager

- **Hadley AD1, LLC @ Barstow's Longview Farm Biogas (Hadley, MA)- CA, CO, FD, OR, OT, PA, RE, RFP:** Provided final design, permitting assistance, construction phase, start-up and operator training services for upgrades from a 300kW to a 800 kW biogas system with manure from a 250 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and liquid, semi-solid and solid source-separated organics feedstock; Project Manager.
- **Rutland AD1, LLC @ Jordan Dairy Farm Biogas (Rutland, MA)- CA, CO, FD, OR, OT, PA, RE, RFP:** Provided final design, permitting assistance, construction phase, start-up and operator training services for upgrades from a 500kW to a 800 kW biogas system with manure from a 300 milking cow farm and with food waste, Fats-Oils-Grease (FOG) and liquid, semi-solid and solid source-separated organics feedstock; Project Manager.

**City of Vergennes, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.660 WWTF expansion/upgrade including tertiary filtration and aerobic digester; Project Associate/Project Manager.

**Village Green Ventures (Brunswick, Maine)- FD, OT, RM:**

- Provided initial AD operations recommendations, recipe management assistance and process improvements assistance for a complete mix anaerobic digester facility that handles wastewater sludge cake, septage, Fats-Oils-Grease (FOG) and source-separated organics with biogas that fuels a 1 MW CHP generator set and provides process heat and excess heat for nearby buildings. Also includes a PFRP system that produces Class A biosolids used as organic fertilizer for nearby land application; FCE Project Manager.

**Wagner Farms AD (Poestenkill, NY)- RM:**

- Provided recipe management assistance and process improvements assistance to help recover a "sick" complete mix anaerobic digester facility that handles manure from 400 milking cows and food waste with biogas that fuels a 100kW CHP generator set and provides process heat and excess heat for nearby buildings; FCE Project Manager.

**Town of West Rutland, VT- CA, CO, FD, OR, OT, PA, RE, RFP:**

- Construction phase, first year, start-up and operator training services for 0.45 mgd Sequential Batch Reactor WWTF expansion/upgrade including biological phosphorous removal and aerobic digester; Project Associate/Project Manager.

**Westminster Farms (Westminster, VT)- CO, FS:**

- Prepared a feasibility study for the USDA Rural Development Grant/Loan application for upgrades from a 225 kW to a 450 kW modified plug flow anaerobic digester facility to handle cow manure from 100 additional (700 vs. 600) dairy cows and material handling and feeding of additional food waste, Fats-Oils-Grease (FOG) and source-separated organics feedstock; FCE Project Manager.

**Whitcomb's North Williston Cattle Company (Williston, VT)- CO, FS, LG, RFP:**

- Performed a Feasibility Study, Cost Opinions, AD Technology Company Selection Assistance and Loan/Grant Application Technical Assistance for a complete mix anaerobic digester facility to handle cow manure from a 275 head dairy farm and Fats-Oils-Grease (FOG) and source-separated organics feedstock with biogas that fuels a 150 kW CHP generator set and provides 550,000 btu/hr of process heat and excess heat for surrounding buildings. Also includes a solids separator system that produces animal bedding to replace purchased bedding; Project Manager.

**INDEX:**

CA: Construction Administration
CM: Construction Management
CO: Cost Opinions
CR: Commissioning Reports (USDA-NRCS, USDA-RD, etc.)
EW- Expert Witness

FD: Final Design
FS: Feasibility Study
IES- Independent Engineering Study
LG: Loan/Grant Application Assistance
OR: Owner's Representative
OT: Operator Training & Startup Assistance
PA: Permitting Assistance
PD: Preliminary Design
PR: Peer Review of Design
RE: Resident Engineering/Construction Observation
RFP: Request For Proposals/Rating & Ranking
RM: Recipe Management Assistance (Anaerobic Digesters and Compost Facilities)
VE: Value Engineering