ecoengineers
people-driven solutions

Anaerobic Digester Feasibility Study

City of Madison

November 2020

[clean energy economy]

Anaerobic Digester Feasibility Study

Prepared for:

City of Madison, Wisconsin

215 Martin Luther King Jr. Blvd.

Madison, WI 53703

[biogas | noun

A mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel]

Executive Summary

The City of Madison (City) is the second largest city in the state of Wisconsin, with an estimated population of 260,000.[i] The City of Madison has significant sustainability goals and believes that an anaerobic digester project would provide more sustainable means to handle food waste generated throughout the City. The food waste is currently being landfilled, and an anaerobic digester may create a new revenue stream for the City through the production of renewable natural gas (RNG). This new stream of revenue for the City may come from different sources, depending on the ownership and contract structure of the project. Potential revenue sources may include tipping fees, the sale of natural gas, the sale of Renewable Identification Number (RIN) credits, and the sale of California Low Carbon Fuel Standard (LCFS) credits. Tipping fees would be paid by waste haulers delivering food waste to the digester facility. RIN and LCFS credits would come from participation in the United States Renewable Fuel Standard (RFS) and the LCFS programs. A project producing biogas from landfill waste may have different structures based on the agreements between parties involved. The project structure will ultimately dictate the potential revenues each party will receive. The overall facility ownership structure may include the City owning and operating the facility, the City could enter into a partnership and share ownership with another party, or the City could engage with an outside developer to own and operate the facility.

The City's main goal is to divert food waste from landfills, helping reduce the greenhouse emissions (GHE) that are inevitable with landfill use. Subsequently, by reducing the amount of waste sent to the City's landfills, the City may also be able to extend the life of these landfills, reducing future investment.

Overall, this project provides for an efficient and advantageous avenue to produce renewable energy in Wisconsin, while promoting a more sustainable way to mitigate waste in the state. Currently, there are various digester facilities in the state of Wisconsin already producing renewable natural gas from different types of feedstocks, including landfill waste and dairy manure. These facilities have successfully registered with the United States Environmental Protection Agency (USEPA) for participation under the RFS program. Similar to the project outlined in this report, the Dane County – Department of Waste & Renewables has successfully developed a landfill waste-to-RNG project in Madison, Wisconsin. Developing a second digester project producing RNG would provide for another avenue to mitigate waste in the area, further advancing renewable energy production in the state.

EcoEngineers reviewed the potential for the City to construct a new anaerobic digestion facility. The project would process food waste to generate biogas, which would then be upgraded to RNG for injection into the natural gas pipeline for end use as transportation fuel. The City could realize the following benefits:

- Potential revenue stream to the City
- Better utilization of waste streams
- Production of a renewable transportation fuel which will displace traditional fossil fuels
- Water quality improvements through reduced nutrient runoff
- Nutrient recovery and recycling
- Reduce greenhouse emissions to help meet the City's sustainability goals

[Overall, this project provides for an efficient and advantageous avenue to produce renewable energy in Wisconsin, while promoting a more sustainable way to mitigate waste in the state.]

The City engaged EcoEngineers to complete a feedstock analysis to estimate the available feedstock in Dane County from various sources throughout the City, including, but not limited to, waste haulers, food production facilities, and grocers. The City also tasked EcoEngineers with providing recommendations on the appropriate technology relevant to an anaerobic digester process, including biogas production and cleaning operations. In addition, EcoEngineers was engaged to provide a financial analysis of the project to help determine the overall project feasibility. EcoEngineers completed the following tasks:

1. Detailed potential feedstock quantities from a variety of food waste sources throughout the City of Madison.
2. Outlined the benefits of developing the digester project at the Yahara Hills Golf Course, as well as site selection considerations to evaluate should the City search for a different site.
3. Analyzed the biogas production from food waste generated in the City.
4. Estimated the cost of anaerobic digestion and biogas upgrading systems, including capital and O&M costs.
5. Estimated the value of carbon credits available through the RFS and LCFS for the displacement of fossil from the transportation sector by RNG from a waste digester.
6. Explored overall feasibility of an anaerobic digester project, including a financial sensitivity analysis.

After a preliminary review of the City of Madison area and through conversations with the City and Dane County, EcoEngineers considered a potential location to analyze the possible feedstock for the project: the Yahara Hills Golf Course, across from the Dane County Sanitary Landfill. **Figure 1 illustrates the location of the Dane County Sanitary Landfill. Figure 2 illustrates the location of the Yahara Hills Golf Course, across from the landfill, which EcoEngingeers recommends for the project as a potential location to build the digester facility.**

FIGURE 1: DANE COUNTY SANITARY LANDFILL LOCATION IN MADISON, WISCONSIN[ii]

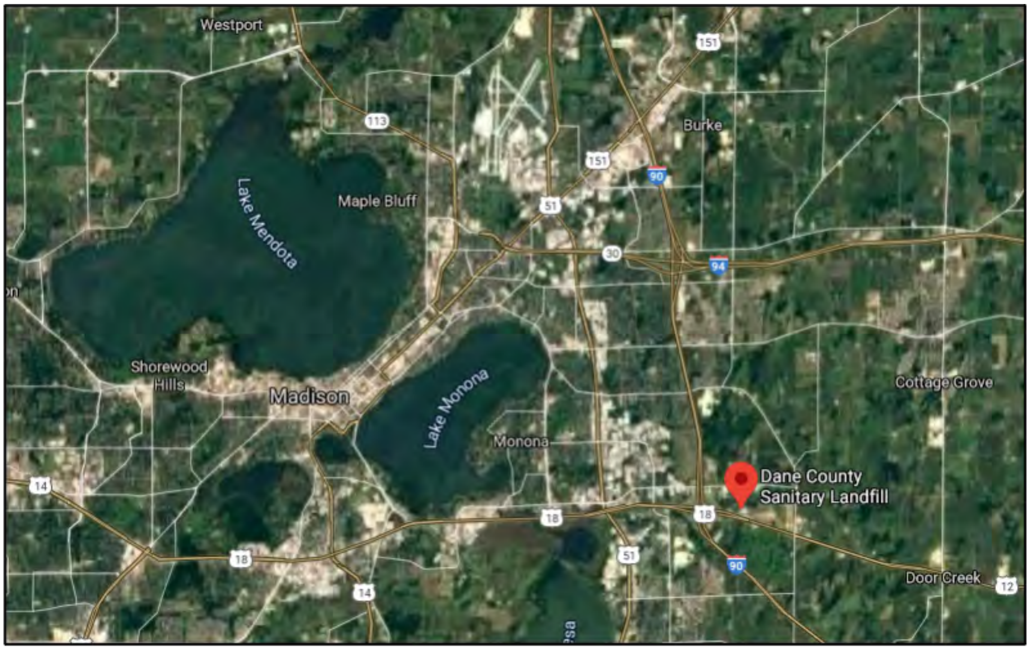


FIGURE 2: YAHARA HILLS GOLF COURSE LOCATION IN MADISON, WISCONSIN[iii]

EcoEngineers analyzed different feedstock sources in Dane County generating food waste. We considered the proximity of all these sources to the Dane County Sanitary Landfill to determine the reasonableness to transport the feedstock. EcoEngineers then estimated the amount of food waste generated by the different feedstock sources, including educational institutions, food manufacturing and processors, food wholesale and retail, landfill, residential, and restaurants and food services.

To narrow down this list of feedstock sources, data from the USEPA's Excess Food Opportunities Map (EPA Map Tool) was compiled and reviewed to determine the estimated amount of food waste in Dane County. The EPA Map Tool provided data on the estimated amount of food waste generated by each type of source. In addition, EcoEngineers reviewed previous studies conducted in the state of Wisconsin to understand the previous extent of participation in similar programs. We interviewed local members of the City of Madison community to help understand the current handling of food waste, the potential interest of a future food waste program, and important factors that will help shape the community's level of participation.

Since it is unlikely there will be 100% from the food waste sources identified from the EPA Map Tool, EcoEngineers applied an 80% conservative factor to the restaurant and food services, food wholesale and retail, educational, and food manufacturing and processors categories. Similarly, the residential sector will likely not meet 100% participation and EcoEngineers applied a 20% conservative factor to account for partial participation. Lastly, EcoEngineers assumed food waste would be diverted from the Dane County Sanitary landfill once food waste is collected from the other food waste sources identified. To account for this, EcoEngineers assumed 75% of food waste currently going to the landfill would be diverted, applying a 25% conservative factor to the estimated amount of landfill food waste.

Based on the review of data collected, the conservative factors applied, and interviews conducted, EcoEngineers created a list of feedstock sources for the City to focus on during the initial phases of the project.

Table 1 illustrates the feedstock and biogas production estimates for the aforementioned categories based on a low, moderate, and high scenarios to account for variances in the amount of feedstock procured.

TABLE 1: SUMMARY OF THE FEEDSTOCK SCENARIOS ESTIMATED BY ECOENGINEERS

		LOW	MODERATE	HIGH
Food Waste Source	Madison/Dane County	Tons/year	Tons/year	Tons/year
Restaurant and Food Services	Dane	7,015	13,081	19,148
Food Wholesale and Retail	Dane	1,025	17,766	34,507
Educational	Dane	1,231	3,965	6,699
Food Mfg. and Processors	Dane	2,125	4,471	6,816
Residential	Dane	1,476	6,721	11,967
Landfills	Madison	1,063	6,375	8,500
	Total Food Waste (Tons/Year)	**13,934**	**52,379**	**87,637**

EcoEngineers reviewed the preliminary feedstock estimates on Table 1 with the City and identified a "probable" scenario at 30,000 tons per year of total food waste. This scenario was identified as the most realistic amount of total feedstock the City believes may be possible to procure in the initial phases of the project. **Ultimately, all scenarios identified (low, probable, moderate, and high) were assessed to estimate biogas production yields, as shown in Table 2.** More information on the biogas production estimates can be found in Section 4 of this report.

TABLE 2: SUMMARY OF BIOGAS PRODUCTION ESTIMATES BASED ON A LOW, PROBABLE, MODERATE AND HIGH FEEDSTOCK SCENARIOS

	LOW	PROBABLE	MODERATE	HIGH
Raw Biogas (scfm)	91	196	342	571
Biogas Estimate (MMBtu/Day)	73	157	275	460

Based on the four feedstock volume scenarios (low, probable, moderate, and high), EcoEngineers created a detailed capital cost estimate. The capital cost estimate includes feedstock management and storage, the anaerobic digester system, solids dewatering and storage, the biogas upgrading system, the finished gas pipeline to the interconnection site, and associated utilities and civil or site work costs.

The estimate is based on continuously stirred tank reactors ("CSTR") anaerobic digester vessels and a membrane biogas upgrading system. EcoEngineers used estimates previously done for similar projects to help produce the capital cost estimate. The values were scaled and adjusted based on the size, location, and project differences. The total capital cost estimate for the low, probable, moderate, and high feedstock scenario were $13 million, $17 million, $20 million, and $30 million, respectively. These values are illustrated in Table 3.

The operation and maintenance (O&M) costs include utilities, materials, operational staffing requirements, third-party costs, and long-term maintenance costs. The third-party costs include the following:

- Professional consulting services;
- Gas transport, offtake and marketing;
- Pipeline operation and maintenance;
- Lab testing; and
- Administrative, legal, and reporting.

EcoEngineers estimated the operating costs for the facility for the low, probable, moderate and high feedstock volume scenarios. The project costs were scaled based on the incoming feedstock volumes and the biogas production volumes. The estimated operating cost for the low, probable, moderate, and high feedstock scenarios were $850,000, $1.5 million, $1.98 million, and $2.8 million, respectively.

Financial projections were prepared for each feedstock scenario (low, probable, moderate, and high) to estimate annual expenses, revenue, and net annual profit. These projections were done using RFS and LCFS values at current market conditions. **An overview of the results of these analyses are shown in Table 3.**

TABLE 3: COMPARISON OF ALL FEEDSTOCK SCENARIOS AT CURRENT MARKET CONDITIONS

	LOW	PROBABLE	MODERATE	HIGH
Feedstock Reception (Tons)	13,934	30,000	52,379	87,637
Biogas Production (MMBtu/day)	73	157	275	460
Capital Cost	$ 13,000,000	$ 17,000,000	$ 20,000,000	$ 30,000,000
Natural Gas Price	$ 2.00	$ 2.00	$ 2.00	$ 2.00
D5 RIN Credit Price	$ 0.77	$ 0.77	$ 0.77	$ 0.77
LCFS Credit Price	$ 200.00	$ 200.00	$ 200.00	$ 200.00
Gross Tipping Fee Revenue ($45/ton)	$ 630,000	$ 1,350,000	$ 2,340,000	$ 3,915,000
Gross Commodity Revenue	$ 51,000	$ 110,000	$ 193,000	$ 322,000
Gross D5 Revenue	$ 232,000	$ 499,000	$ 870,000	$ 1,453,000
Gross LCFS Revenue	$ 629,000	$ 1,356,000	$ 2,365,000	$ 3,949,000
Gross Revenue	$ 1,542,000	$ 3,315,000	$ 5,768,000	$ 9,639,000
Expenses	$ (1,181,000)	$ (2,127,000)	$ (3,037,987)	$ (4,482,000)
EBITDA	$ 361,000	$ 1,188,000	$ 2,730,000	$ 5,157,000
Payback Period	**36.0**	**14.3**	**8.0**	**5.8**

EcoEngineers took the probable and moderate feedstock scenarios in Table 3 and further assessed these projections by completing a financial sensitivity analysis for low, moderate, and high credit market conditions. **Tables 4 and 5 (next page) show a summary comparison of the financial sensitivity analysis for the probable and moderate feedstock scenarios, respectively.** More information on the financial projections and sensitivity analyses performed are included in Section 10 of this report. All pro formas completed are included in **Appendix A**.

TABLE 4: FINANCIAL SENSITIVITY ANALYSIS AT VARIOUS MARKET CONDITIONS FOR THE PROBABLE FEEDSTOCK SCENARIO (30,000 TONS PER YEAR)

	CURRENT CONDITIONS	LOW	MODERATE	AGGRESSIVE
Capital Investment: $17,000,000				
Gross Revenue	$3,315,000	$2,332,000	$2,801,000	$3,565,000
Expenses	$(2,127,000)	$(1,911,592)	$(2,015,748)	$(2,174,472)
Net Revenue*	$1,188,000	$420,408	$785,252	$1,390,528
Net Revenue/MMBtu	$21.50	$7.61	$14.21	$25.17
5-Year Total Net Revenue	$5,451,000	$2,187,818	$4,086,483	$7,236,366

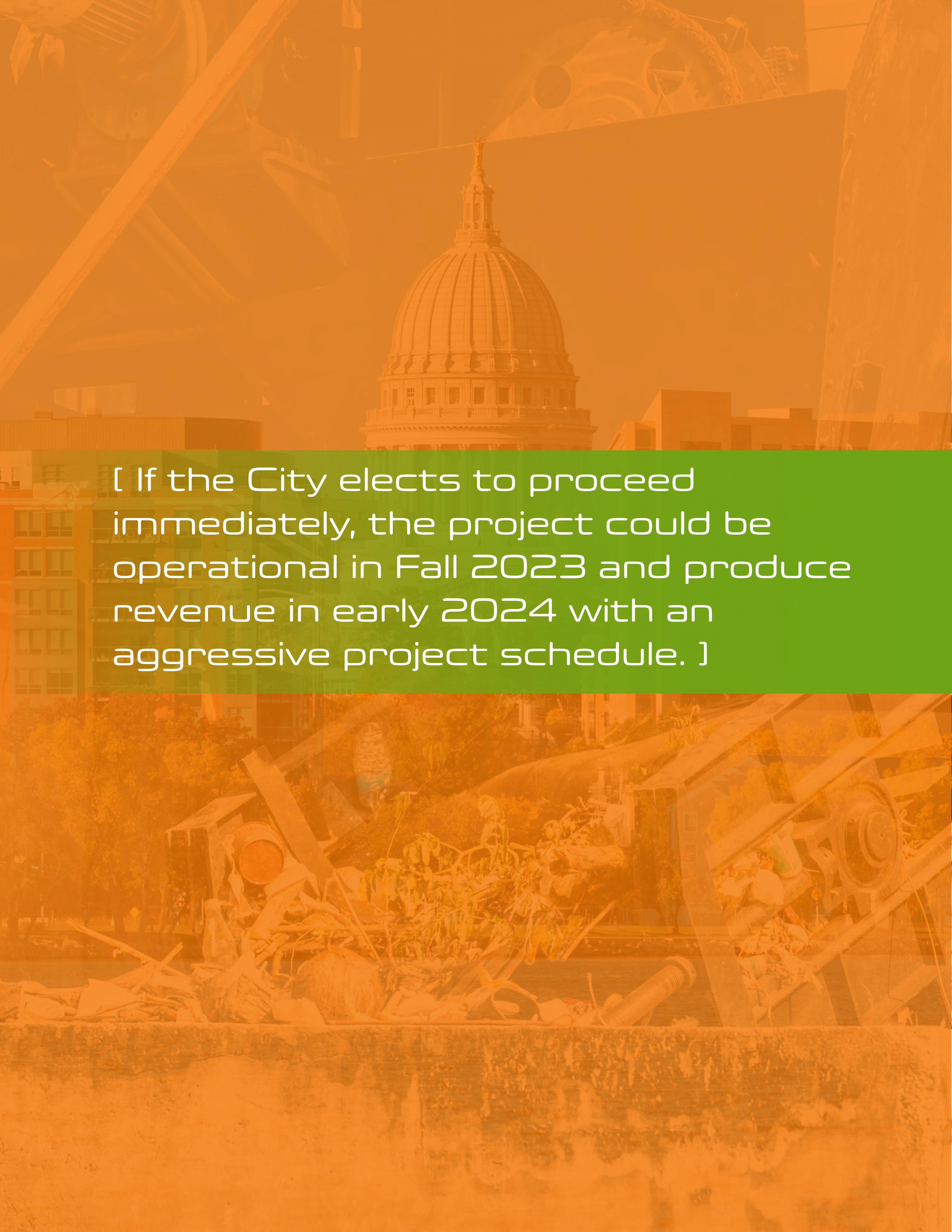
TABLE 5: FINANCIAL SENSITIVITY ANALYSIS AT VARIOUS MARKET CONDITIONS FOR THE MODERATE FEEDSTOCK SCENARIO (52,000 TONS PER YEAR)

	CURRENT CONDITIONS	LOW	MODERATE	HIGH
Capital Investment: $20,000,000				
Gross Revenue	$5,768,000	$4,055,000	$4,872,000	$6,206,000
Expenses	$(3,037,987)	$(2,662,511)	$(2,844,251)	$(3,121,208)
Net Revenue*	$2,730,000	$1,392,489	$2,027,749	$3,084,792
Net Revenue/ MMBtu	$27.19	$13.87	$20.20	$30.73
5-Year Total Net Revenue	$12,409,000	$6,726,166	$10,032,083	$15,532,978

If the City elects to proceed immediately, the project could be operational in Fall 2023 and produce revenue in early 2024 with an aggressive project schedule. **A potential project timeline is outlined in Table 6 and shows the tasks to be completed with target completion dates.**

TABLE 6: NEXT STEPS AND POTENTIAL PROJECT SCHEDULE

TASK	COMPLETION TARGET
Decision to Proceed	November 2021
Feedstocks Procured	Winter 2021
Financing Procured	Winter 2021
Preliminary Design and Technology Selection	Spring 2022
Design Engineer Selection	Spring 2022
Natural Gas Utility Pipeline Agreement Finalized	Summer 2022
Construction Begins	Summer 2022
Offtake and Gas Marketing Negotiations	December 2022
Construction and Technology Installation	Fall 2022
Startup	Fall 2023
RFS Registration Complete	Winter 2023
Revenue Generation Begins	Spring 2024
LCFS Registration Complete	Spring 2024

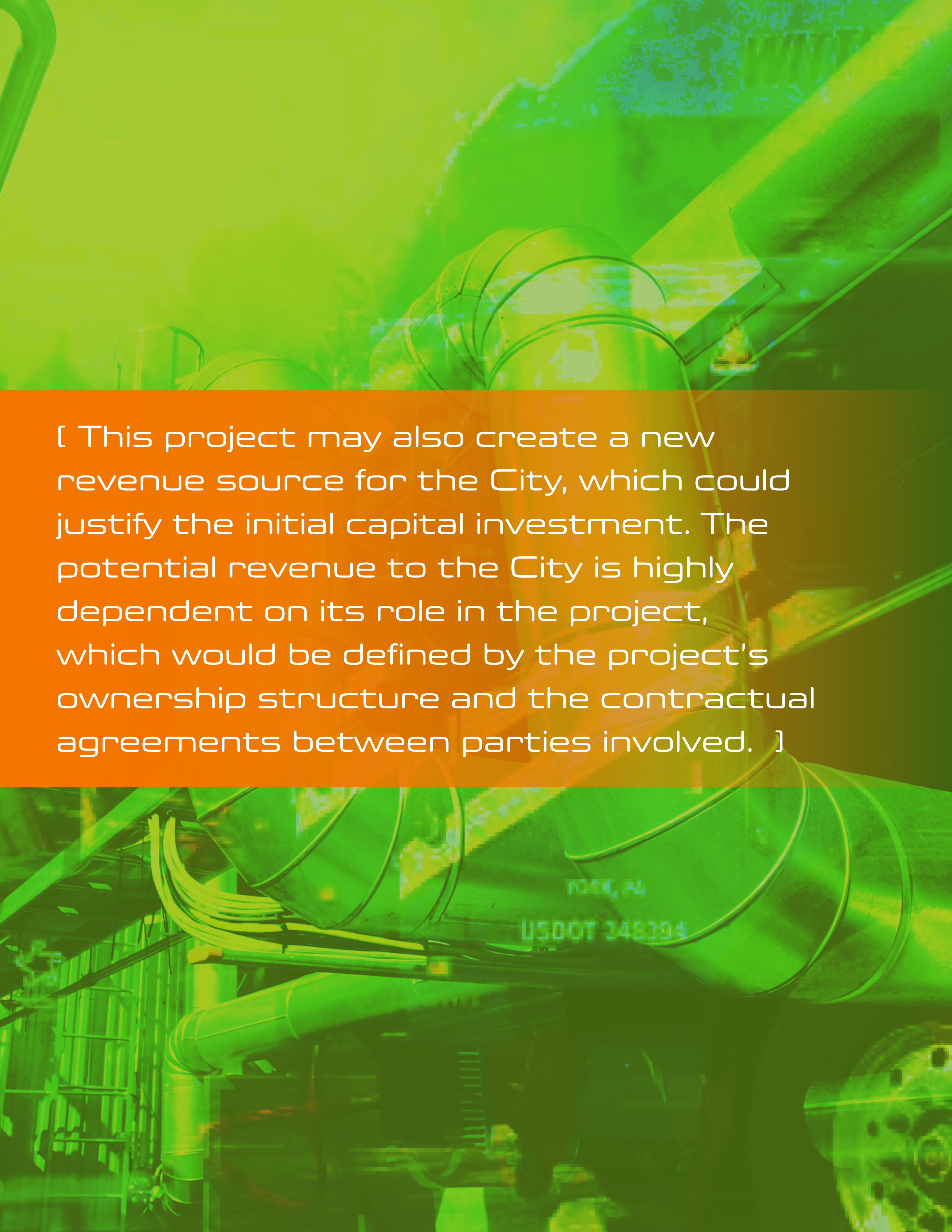


[If the City elects to proceed immediately, the project could be operational in Fall 2023 and produce revenue in early 2024 with an aggressive project schedule.]

Table of Contents

Tables

Figures



[This project may also create a new revenue source for the City, which could justify the initial capital investment. The potential revenue to the City is highly dependent on its role in the project, which would be defined by the project's ownership structure and the contractual agreements between parties involved.]

1.0 The City of Madison Opportunity

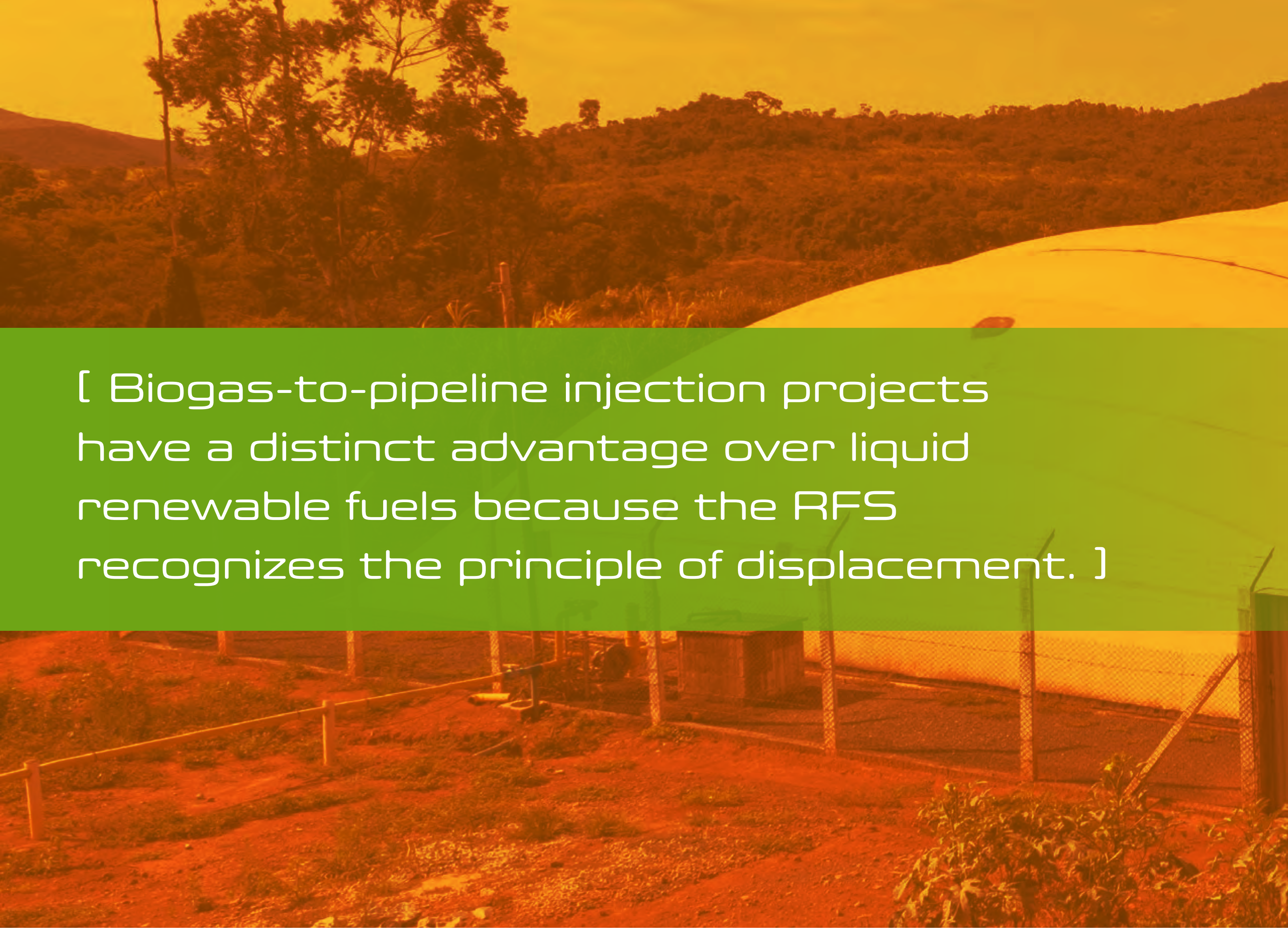
The City of Madison (City) is considering the opportunity to develop a waste digester project that will divert waste from the landfills to produce renewable natural gas (RNG), extend the life of the Dane County landfill, and reduce greenhouse gas emissions. The City has a specific interest in finding ways to divert food waste generated throughout the City from entering a landfill.

Developing a digester facility would provide a means to reuse food waste as a feedstock source to produce renewable energy, provide another outlet for food waste in the Madison area, reduce greenhouse gas emissions (GHEs), and capitalize on other environmental benefits. Diverting food waste from landfills would not only reduce GHEs, but it would also help extend the life of the existing landfills, which could help reduce future investment into these facilities. Most importantly, the project would help promote the production of renewable energy in the state, while providing for a more sustainable method to mitigate food waste generated throughout the city.

According the United States Environmental Protection Agency (USEPA), municipal solid waste (MSW) landfills are the third-largest source of human-related methane emissions in the United States. Landfills account for approximately 15% of methane emissions in the U.S. MSW deposited in landfills undergoes anaerobic digestion, producing methane. The methane is then collected by landfill gas (LFG) collection systems. The USEPA has established that the LFG collection systems only capture approximately 75% of the methane produced, and the other 25% is emitted directly into the atmosphere. Anaerobic digesters, for comparison, can capture approximately 98% of the methane produced. By diverting waste to an anaerobic digester, the City of Madison would be reducing GHEs from the waste produced throughout the city.

This project may also create a new revenue source for the City, which could justify the initial capital investment. The potential revenue to the City is highly dependent on its role in the project, which would be defined by the project's ownership structure and the contractual agreements between parties involved. Overall, potential revenue sources for the project include tipping fees, the sale of natural gas, the sale of Renewable Identification Number (RIN) credits, and the sale of Low Carbon Fuel Standard (LCFS) credits. First, a new digester facility would help divert food waste from landfills. This will inherently provide an opportunity for the project to generate revenue from tipping fees paid by waste haulers. Through community outreach, including education on the importance of diverting food waste from landfills and awareness of the City's new digester project, food waste sent to the digester facility could be maximized. It is important for the project owner to provide a competitive tipping fee to motivate and incentivize waste haulers to participate in this program.

In addition to revenue from tipping fees, the project has the opportunity to generate revenue from the production of RNG and by participating in various energy and carbon credit programs. If the project owner decides to use the RNG produced as transportation fuel, the project owner may be eligible to participate in the United States Renewable Fuel Standard (RFS) and other low carbon fuel standards, such as those in California (LCFS), Oregon (CFP), and British Columbia (RLCFR). The RNG produced would need to be used as transportation fuel anywhere in the United States for the RFS or the other respective locations to be able to participate in the low carbon fuel standard programs. It is important to note that RNG can also generate revenue under various voluntary sustainability programs and emissions cap-and-trade programs.



[Biogas-to-pipeline injection projects have a distinct advantage over liquid renewable fuels because the RFS recognizes the principle of displacement.]

The project may have different ownership structures that will dictate potential revenues. The overall facility ownership structure may include the City owning and operating the facility, the City could enter into a partnership and share ownership with another party, or the City could engage with an outside developer to own and operate the facility. These ownership structures will determine the potential revenue going to the City. For example, tipping fees are typically paid to the party owning and operating the digester facility. Revenue from the RFS and other low carbon fuel standards will be dependent on the ownership structure of the project and the contractual agreements between parties. Overall, under the RFS and LCFS programs, there is typically a percent revenue share back, from the party generating credits and monetizing from their sale, to the other parties involved. Section **10.0 Revenue Estimates & Financial Analysis** will outline the potential project revenues from tipping fees and the sale of natural gas, RIN credits, and LCFS credits based on different feedstock supply scenarios.

Biogas-to-pipeline-injection projects have a distinct advantage over liquid renewable fuels since the RFS recognizes the principle of displacement. RNG molecules are completely fungible with the fossil natural gas molecules in the pipeline. Under the RFS, RNG can be injected into the natural gas distribution grid anywhere in the 48 contiguous states and qualify as an eligible renewable fuel, as long as an equivalent volume of compressed natural gas (CNG) is used as transportation fuel at any point along the interconnected distribution grid. The renewable (environmental) attributes of RNG will displace an equal volume of non-renewable attributes of fossil fuel. The California LCFS program also recognizes this principle. The project

ecoengineers
people-driven solutions

owner could inject the RNG into a commercial distribution natural gas pipeline in Wisconsin and secure virtual offtake contracts anywhere in the United States to demonstrate use as transportation fuel. If the offtake vendor is located in California or Oregon, it gives the project owner the ability to stack state credit programs with the RFS.

The value of RNG used as CNG for transportation in California has reached as high as $50 per one million British Thermal Units (MMBtu) for RNG with a similar CI score, with approximately $2-3 attributed to the energy value of the physical commodity and the rest to its "green" environmental attributes. This has resulted in an increase in CNG dispensing over the past several years per CARB data, making up a large segment of fuel used for heavy-duty engines. It is unlikely this level of CNG dispensing in California will be significantly reduced over the next several years. Due to the current high value of LCFS credits, along with the ability to qualify for RFS RIN credits and LCFS credits through displacement, investment in biogas upgrade projects is increasing throughout the country. The City is one of many entities considering ways to reap both financial and environmental benefits by processing an existing waste stream to produce a renewable fuel. The RFS and LCFS are further explained in section **2.0 Regulatory Background**.

Another source of revenue to the project may come from the distribution to existing CNG stations near the project site for local fuel sales. However, it is important to consider whether the size of the local consumer base can support the volume of RNG produced. There are grant programs available for entities interested in fleet conversion through companies like Clean Energy Renewable Fuels (CERF). Local fueling may be attractive to fuel users that currently use more expensive fuel alternatives, such as diesel. The amount of diesel displaced by RNG is determined by comparing the energy content of both fuel types. Diesel has a heating value of 139,000 Btu/gal. One MMBtu of RNG is equivalent to approximately 7.2 gallons of diesel fuel. For example, if the project generates 500 MMBtu per day of RNG, it is equivalent to producing 1,900 gallons of diesel every day (or 693,500 gallons annually). That means a single, local CNG station may not produce enough sales to consume the total volume of RNG produced by the project.

Using the fuel locally also will not allow the project to participate in California's LCFS, as the end use of the fuel is not within California's border. Revenue from LCFS credits constitutes a minimum of 40% of the gross total revenue for the project, making participation in the program significant to the economic feasibility of the project. It is recommended to send fuel to California in the short-term to capitalize on the high value of LCFS credits and the significant demand for renewable fuels with a low carbon intensity. Once the project's capital costs are paid off, the City of Madison, or project owner, could re-examine RNG market placement.

To perform a financial evaluation of the project, it is important to assess the available feedstock for the project. EcoEngineers' methodology for feedstock selection was based on the City's interest to use food waste as the primary type of feedstock for the project, as well as EcoEngineers' recommendation for developing the site at the Yahara Hills Golf Course.

EcoEngineers performed the following services to complete the financial evaluation:

1. Analyzed different feedstock sources in Dane County generating the most amount of waste.

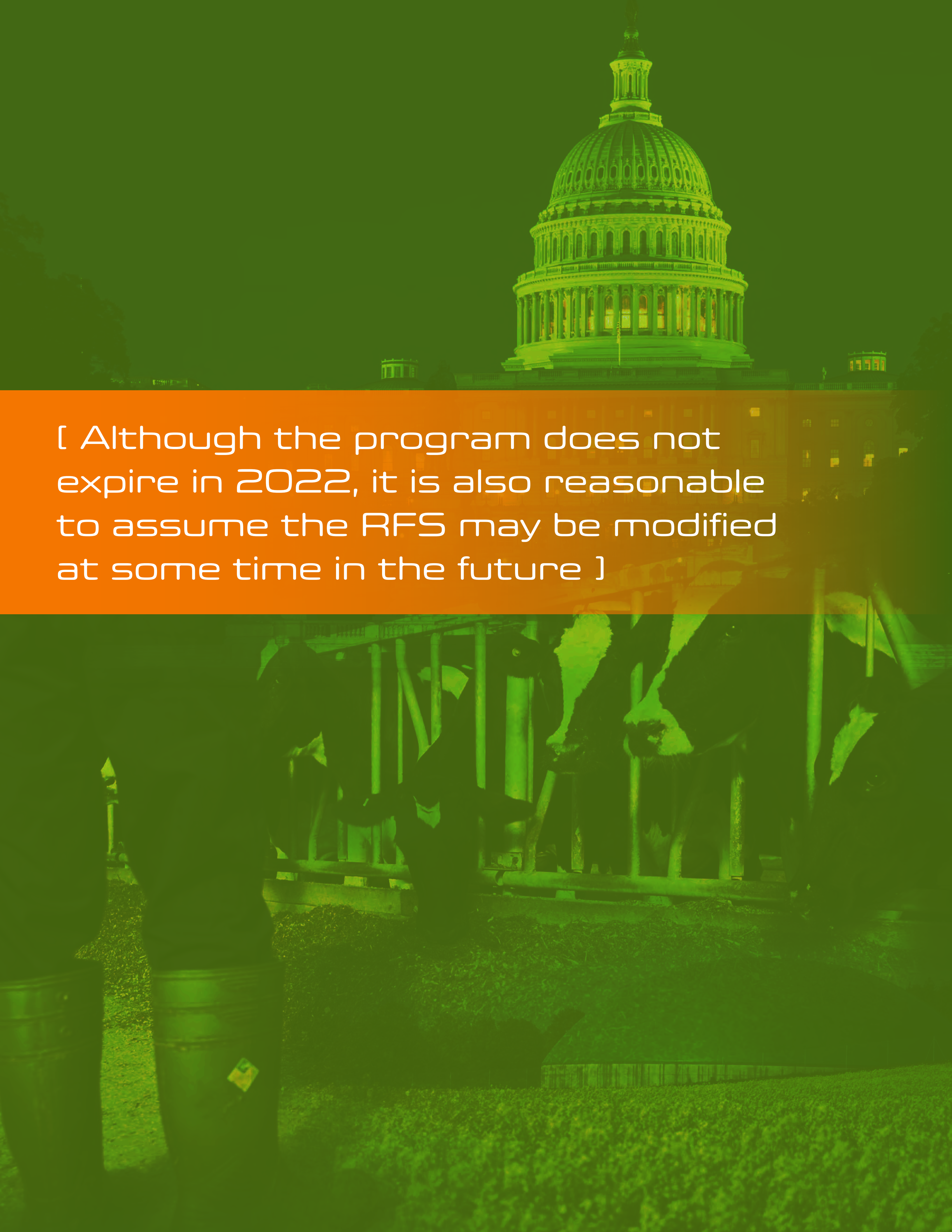
2. Considered the proximity of all these sources to the potential location of the site to determine the reasonableness to transport the feedstock.

3. Evaluated the estimated amount of food waste generated by different feedstock sources to narrow down the potential feedstock suppliers for the project. Due to the estimated amounts (tons) of food waste generated per year, EcoEngineers ultimately narrowed down the feedstock source categories to: educational institutions, food manufacturing and processors, food wholesale and retail, landfill, residential, and restaurants and food services. A more detailed description of the methodology used to arrive at these categories and the biogas production estimates for these can be found in section **4.0 Feedstock Analysis**.

The site selection must be analyzed to assess the feasibility to transport food waste from different sources, as well as determine the proximity to a pipeline interconnection. Since the project will be located in Wisconsin, participating in low carbon standard programs outside of the state will be dependent on the project's ability to inject RNG into a pipeline. Considering the Dane County Sanitary Landfill already has an injection point interconnecting with the ANR Pipeline, developing the project across from the landfill at Yahara Hills Golf Course would be beneficial in reducing the potential capital costs associated with building an interconnection. Typically, building a pipeline to interconnect with a commercial pipeline costs approximately $1 million per mile of pipeline. Depending on the location of the injection point within the Yahara Hills Golf Course, running a pipeline from the golf course straight to the interconnection point at the landfill is not expected to be more than one mile long. Building the digester facility at a different location would likely result in a longer pipeline to reach a commercial pipeline and in return more capital costs for the project.

Ultimately, the goal of this study is to provide the City with the necessary information to understand the opportunity, understand the financials and revenues of a potential anaerobic digestion project, and help decide whether to move into the next phase of project development. Through this study, the above scenarios are analyzed in terms of potential project capital costs, annual operation and maintenance (O&M) costs, and revenues. Additionally, this study outlines the next steps the City would need to take in order to start this process toward construction and operation of the project. A brief description of each section of the report is listed below.

- **1.0 The City of Madison Opportunity:** This section introduces the specific regulations, project scenarios considered, and goal of the report in terms of the project.
- **2.0 Regulatory Background:** This section further analyzes and explains the regulations pertaining to the credits that incentivize construction of the project as much of the potential revenues of the project comes from the sale of RNG.
- **3.0 Site Selection:** This section discusses the methods, procedures, and final recommendations regarding site selection.
- **4.0 Feedstock Analysis:** This section analyzes the feedstock options EcoEngineers considered by type of feedstock, source location, and potential biogas production.
- **5.0 Anaerobic Digestion System:** This section explains the anaerobic digestion process in terms of the project being considered and outlines digestate characteristics.
- **6.0 Biogas Usage Options & Comparative Values:** This section is an overview of other uses for biogas, as well as the corresponding potential value when used.
- **7.0 Biogas Upgrading Process:** This section explains the process for upgrading biogas to RNG, so it can be of a high enough quality to inject into the pipeline.
- **8.0 Capital Costs and Estimates:** This section analyzes the capital costs of the scenarios, highlighting the above scenario with the smaller facility.
- **9.0 Operation & Maintenance Costs:** This section analyzes the operation and maintenance costs of the above scenarios, highlighting the scenario with the smaller facility.
- **10.0 Revenue Estimates and Financial Analysis:** This section analyzes the estimates revenues from RIN and LCFS credit generation, based on conservative, moderate, and aggressive market conditions.
- **11.0 Project Schedule:** This section outlines the recommended project schedule timeline based on a Spring 2022 online goal.
- **12.0 Next Steps:** This section outlines next steps to maintaining the recommended project schedule.



[Although the program does not expire in 2022, it is also reasonable to assume the RFS may be modified at some time in the future]

2.0 Regulatory Background

2.1. Renewable Fuel Standard

The United States Renewable Fuel Standard (RFS) was passed by Congress in 2005 as part of the Energy Policy Act (EPAct). The RFS required that all transportation fuel commercially sold in the United States must contain minimum volumes of renewable fuels. The EPAct was expanded and extended by the Energy Independence and Security Act (EISA) of 2007, which proposed a schedule for an increasing amount of renewable fuels to be blended with transportation fuels each year until 2022. At that point, 20% of all transportation fuels must come from renewable sources. **Table 7 outlines a list of common terms and definitions used in the RFS.**

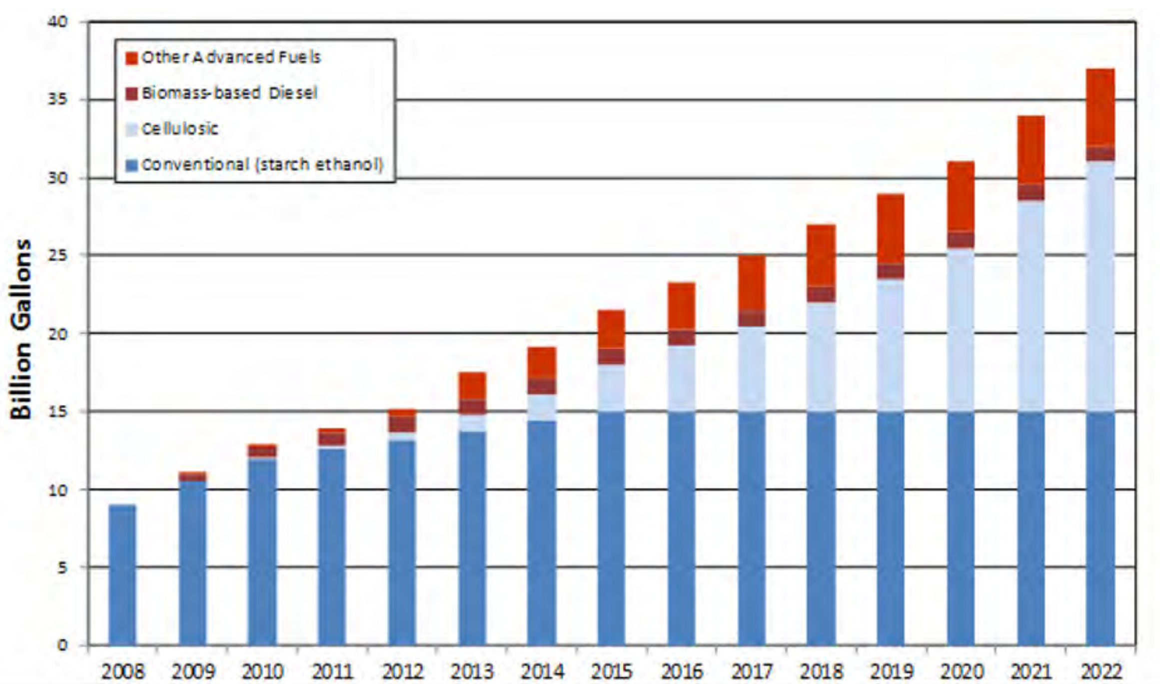
TABLE 7: KEY TERMS AND DEFINITIONS FOR THE RFS

TERMS	DEFINITIONS
USEPA	United States Environmental Protection Agency: Federal agency that sets and enforces the RFS
RFS	Renewable Fuel Standard: Federal program under 40 CFR 80 Subpart M, sets goal of 36 billion gallons of renewable transportation fuel by 2022
RVO	Renewable Volume Obligation: Each obligated party is obligated to meet its RVO by demonstrating that it has retired a sufficient number of RINs to satisfy its obligation
RIN	Renewable Identification Number: A unique number generated to represent a volume of renewable fuel; the “currency” of the RFS
EMTS	USEPA-Moderated Transaction System: Online system for completing all RIN transactions under the RFS
GHG	Greenhouse Gases: These gases have potential to warm the atmosphere
D-Code	Code assigned to RINs generated from renewable fuel: The D-code used must be specified in Table 1 (§80.1426), which corresponds to the pathway that describes the producers’ operations

QAP	Quality Assurance Plan: The list of elements checked to verify that RINs generated are valid; designates RINs as Q-RINs if in compliance under a QAP
CDX	Central Data Exchange: The USEPA's electronic reporting and registration site
Part 79	Registration under the Fuel and Fuel Additive Registration (FFARS): Required for liquid fuels
Part 80	Registration under 40 CFR 1450: Includes the specific pathway and fuel type; requires an independent third-party engineering review and CDX Registration
Obligated Party	Any refiner that produces or imports gasoline or diesel fuel: An obligated party is required to demonstrate that it has satisfied all RVO requirements

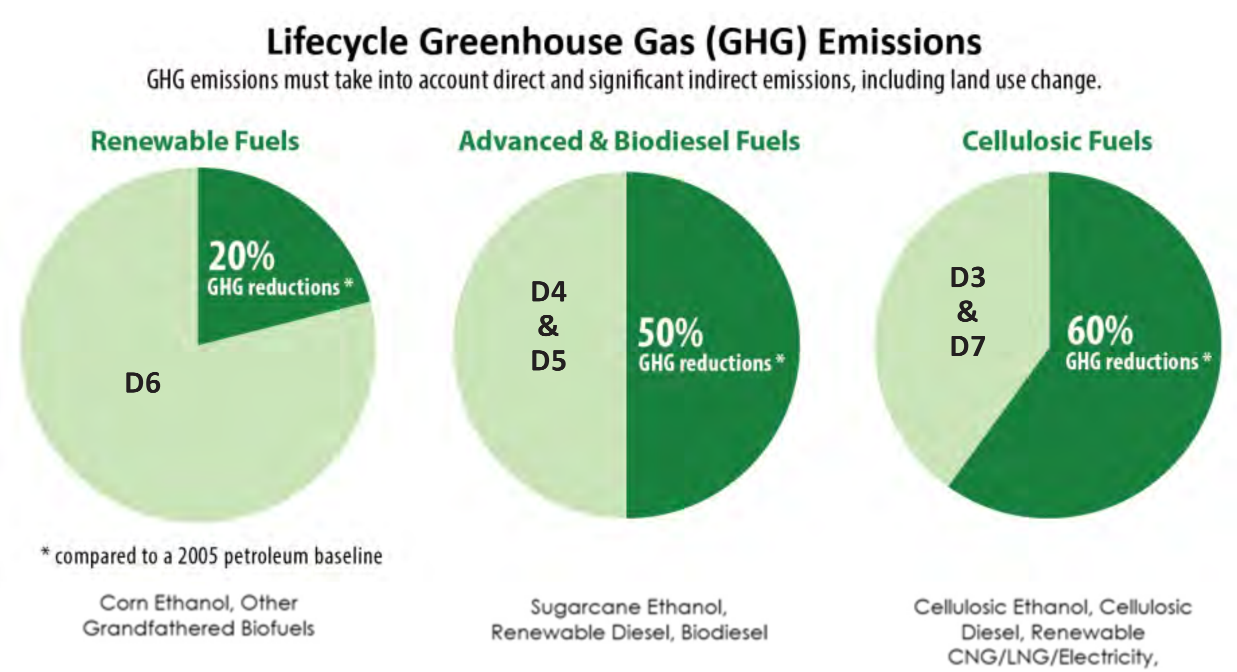
Figure 3 shows the original volume requirements for each renewable fuel category by year. Although this schedule was established by Congress, the USEPA determines a specific renewable volume obligation (RVO) annually. The RVO is the actual, total volume of renewable fuels that must be blended into the transportation sector during a given year.

FIGURE 3: RFS FUEL VOLUME REQUIREMENTS BY YEAR



Each gallon of renewable fuel under the RFS is eligible to generate credits or "Renewable Identification Numbers" (RINs). RINs are the currency of the RFS and are used by obligated parties as a compliance mechanism to meet the annual RVO mandate. "Obligated parties" are petroleum refiners and importers of refined fuel into the United States. Obligated parties can obtain RINs by producing renewable fuels that qualify for RINs, purchasing renewable fuels with RINs attached, or purchasing RINs that have been separated from renewable fuels from projects. RINs are classified by fuel types such as biodiesel, ethanol, natural gas, and other approved renewable fuels. RIN classifications are further broken down according to the type of feedstock and processes used to create those fuels, along with the calculated reduction of greenhouse gas (GHG). These classifications are called D-Codes. **Figure 4 shows the various categories of renewable fuels, minimum GHG reduction expected, and associated D-Codes.**

FIGURE 4: GREENHOUSE GAS EMISSIONS BY FUEL TYPE



RNG generated from waste digesters, like that proposed for the City of Madison, is classified by the USEPA as an advanced biofuel. Advanced biofuels are eligible to generate D5 or D3 RINs depending on the type of feedstock processed to produce the RNG. RNG produced from "non-cellulosic" feedstock at an anaerobic digester qualifies for D5 RINs, while manures, cover crops, and crop residues from agricultural waste process qualify for D3 RINs. These are considered "cellulosic" feedstock. Feedstocks that can generate D5 RINs are food waste; glycerin; most industrial high-strength waste; and other feedstocks high in fat, sugar, or starch content. If the City of Madison plans to produce RNG from food waste, the RINs generated would fall under the D5 RIN designation. Co-digestion of non-cellulosic feedstock, such as food waste, and cellulosic feedstock, such as dairy manure, would still result in a D5 RIN designation. Section **4.0 Feedstock Analysis** discusses feedstock selection in more detail.

The RVO schedule shown in Figure 3 is effective through 2022. Even though the program will not expire in 2022, it is also reasonable to assume that the RFS may be modified. Predicting the type and amount of modifications that could occur is difficult, but some of the potential changes to the program may include:

- A new methodology to establish annual RVOs post-2022. If the end result creates a greater difference between the RVO and actual production of renewable fuels, the mean price for RIN credits will increase. If RVO levels are similar to actual production levels, mean credit prices will decrease.

- A differentiation of incentives offered for first-generation biofuels versus second-generation biofuels, resulting in higher RIN values for second generation biofuels. Increased coordination with state and local programs could occur. As the California LCFS and Oregon Clean Fuels Program (CFP) grow and other states adopt similar programs, components of their programs might be considered for adoption to or alignment with the federal RFS.

The price of RINs is based on market conditions, and RINs are traded, bought, and sold daily. EcoEngineers tracks RIN prices on a daily basis. **Figure 5 demonstrates the volatility of RIN prices on a daily or monthly basis, but the long-term trend shows D5 RIN prices have remained in the $0.40 - 0.70 RIN range over the past year.** While D5 prices have remained somewhat consistent in the past year, Figure 5 demonstrates the pricing volatility in the market through the years.

FIGURE 5: HISTORICAL RIN PRICE DATA

2.2 Low Carbon Fuel Programs

In addition to the federal RFS, two state programs also promote the production and use of renewable fuels. The State of California issued the LCFS in 2007 and the State of Oregon issued the CFP in 2015. The LCFS and CFP resemble the RFS by requiring obligated parties to purchase and use renewable fuels or to purchase credits generated from renewable fuel production.

2.2.1 California Low Carbon Fuel Standard (LCFS)

California's LCFS was originally adopted in 2007, amended in 2011, and re-adopted in 2018 as a legislative tool to incentivize and regulate carbon intensity (CI) reduction of transportation fuels within the state. The CI for a transportation fuel is determined by measuring the carbon dioxide emissions during the fuel's life cycle. The goal of the LCFS is to reduce the CI of transportation fuels by a minimum of 20% by 2030. The program was designed to benefit California by diversifying the pool of available renewable fuels, reducing petroleum dependency, and minimizing vehicle emissions for improved air quality. The transportation sector in California contributes 40% of total GHG emissions, 80% of nitrogen oxide (NOx) emissions, and 95% of particulate matter emissions. The RFS designates petroleum refiners and importers as obligated parties, but the LCFS obligates any party that sells transportation fuel within California to comply with the regulation. The LCFS aims to meet a 20% reduction in the CI of transportation fuels by 2030. To meet this goal, the LCFS has a compliance curve that sets annual CI targets, which are lowered each year. The lower the CI of the fuel compared to the annual schedule, the more credits it can produce. LCFS credits have no expiration date, so they can be banked and used for compliance at any later date. LCFS credits have a $200 price ceiling (adjusted annually for inflation) but have no price floor. **Table 8 outlines a list of common terms and definitions used in the LCFS.**

TABLE 8: KEY TERMS AND DEFINITIONS FOR THE LCFS

TERMS	DEFINITIONS
CARB	California Air Resources Board – Established LCFS, implements program and has rule-making authority over LCFS
LCFS	Low Carbon Fuel Standard – Aims to achieve 20% reduction of carbon intensity by 2030
CI	Carbon Intensity – Amount of life cycle greenhouse gas emissions per unit of fuel energy
CA-GREET 3.0	Model used for life-cycle analysis in the LCFS program
LCFS Credit	Credits generated by fuels with a CI below the annual goal of the LCFS program
Regulated Parties	Companies that produce or import transportation fuel into California.
AFP	Alternative Fuels Pathway – Online registration system for facilities and fuel pathway applications
FPC	Fuel Pathway Code – Identification code that applies to a specific fuel pathway
LRT	LCFS Reporting Tool – Platform for quarterly and annual reporting and credit generation and transactions

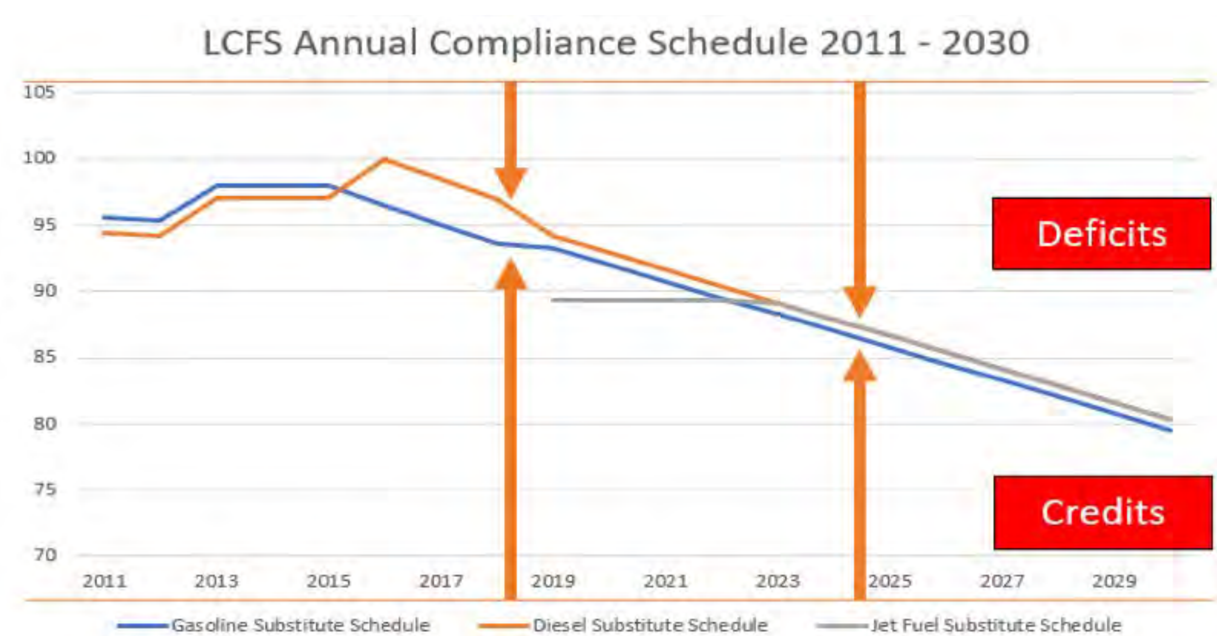
One LCFS credit is equal to one metric ton of CO_2. The LCFS awards credits based on a produced fuel's CI score versus the CI score of the fuel it is displacing. Currently, the market value is $200 dollars per LCFS credit, giving project developers a strong incentive to produce lower-CI fuels. For example, if landfill gas-derived RNG consumed in California has a CI of 45 gCO_2e/MJ and RNG produced from a municipal wastewater treatment plant has a CI of 0 gCO_2e/MJ, the RNG sourced from wastewater will generate approximately 45 more credits per megajoule of fuel when compared with landfill RNG. RNG produced from manure-based digesters has received the lowest CI scores of any facility and fuel type with some as low as-270 gCO_2e/MJ. The CI scores assigned to a facility are specific only to that facility, as they are calculated based of the input and output data from that facility.

The amount of credits a fuel receives depends on its CI score relative to the carbon intensity goal for the California fuel pool or compliance curve, which is seen in Figure 6. Compliance curves have been established for gasoline, diesel, and natural gas.

When a fuel has a CI score lower than the established compliance curve, it generates credits. Fuels with CI scores above the compliance curve generate deficits, and those deficits need to be satisfied by LCFS credits. It is advantageous to produce fuel with a low CI score, as the fuel can generate more credits under the LCFS system.

RNG can also displace conventional fossil natural gas in natural gas vehicles. Displacing diesel is more profitable because diesel's CI is higher than fossil natural gas (greater compliance curve) and therefore, will generate more LCFS credits. However, the cost to convert vehicle engines to RNG is significant and often depends upon availability of government incentives. Most RNG placement into California displaces fossil CNG, and most offtake agreements share the incremental LCFS value between the CI score of the RNG production facility and the CI of dispensing fossil CNG as transportation fuel.

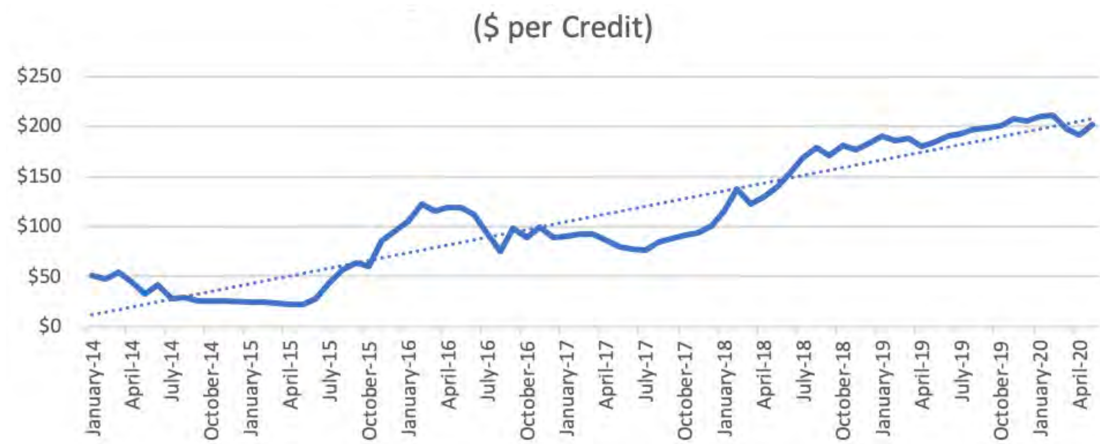
FIGURE 6: LCFS ANNUAL COMPLIANCE CURVE



CARB has established a credit for the for the diversion of waste from landfills because landfills are large sources of methane emissions. By diverting waste from a landfill to a digester, the methane can be captured and used, thus reducing greenhouse gas emissions. The City of Madison digester plans to divert the majority of the waste from the landfill, which allows the City to take advantage of the landfill diversion credit and lower the CI of the RNG produced from the City's digester. The CI score of a food waste digester that does not take in landfill-diverted waste is approximately 35-40 gCO_2e/MJ. The CI score of a food waste digester that does accept landfill-diverted waste is approximately-0 to-75 gCO_2e/MJ.

Figure 7 shows the historical price of LCFS credits. Prices fluctuate daily but have remained above $170 since January 2019. The most recent increase in credit prices is mainly due to the lowered annual compliance target and net deficits of the program. It is anticipated that the trend will continue, and there will be continued high demand for low-CI fuels in California.

FIGURE 7: AVERAGE MONTHLY LCFS CREDIT PRICE

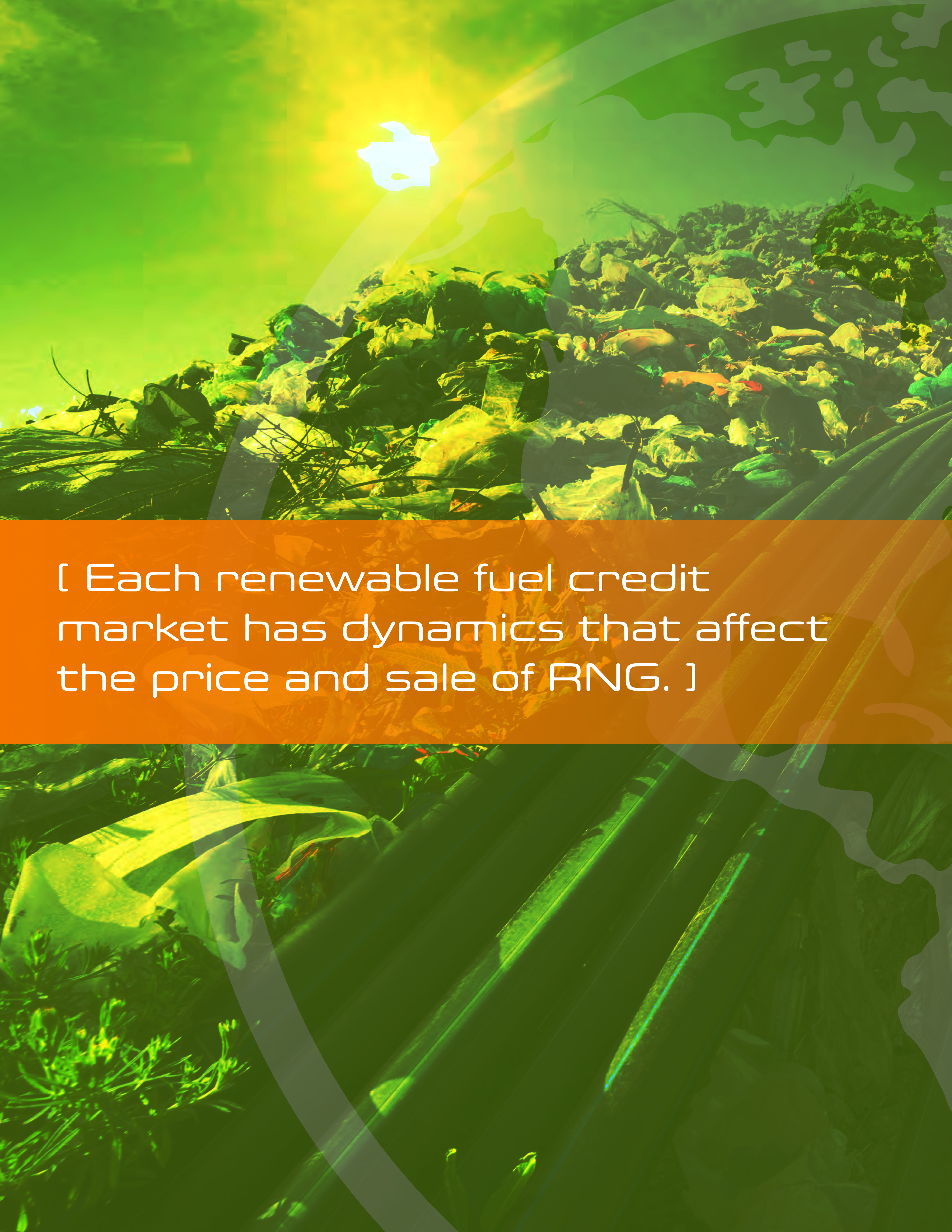


With the ability to stack RINs and LCFS credits and the increasing value of credits in California, placement of RNG into California is very competitive. Currently, nearly all fuel dispensed as compressed natural gas (CNG) in California is from renewable sources. New projects producing RNG must have a low CI score to participate and generate LCFS credits; while the exact CI score required for RNG placement into California will vary between offtake parties, many have indicated that CI scores below 30 gCO_2e/MJ can currently be placed into California. Ultralow CI scores of-100 and better are currently highly desired in California.

Table 9 shows the credits generated based off the CI score for RNG and the price per MMBtu. The CI score determines the amount of LCFS credits generated. Depending on the fuel the RNG is substituting, the compliance curve for the original transportation fuel will change and impact the number of credits generated.

TABLE 9: CI SCORE IMPACT ON CREDIT GENERATION

DIESEL COMPLIANCE YEAR	RNG CI UNDER LCFS	RNG VOLUME* (THERMS)	MARKET VALUE OF CI CREDITS	NUMBER OF LCFS CREDITS GENERATED	TOTAL VALUE OF CREDITS	$/MMBTU
2020	-325	10,000	$200.00	440	$88,200	$88.18
2020	-100	10,000	$200.00	204	$40,700	$40.71
2020	0	10,000	$200.00	98	$19,600	$19.61
2020	40	10,000	$200.00	56	$11,200	$11.17



[Each renewable fuel credit market has dynamics that affect the price and sale of RNG.]

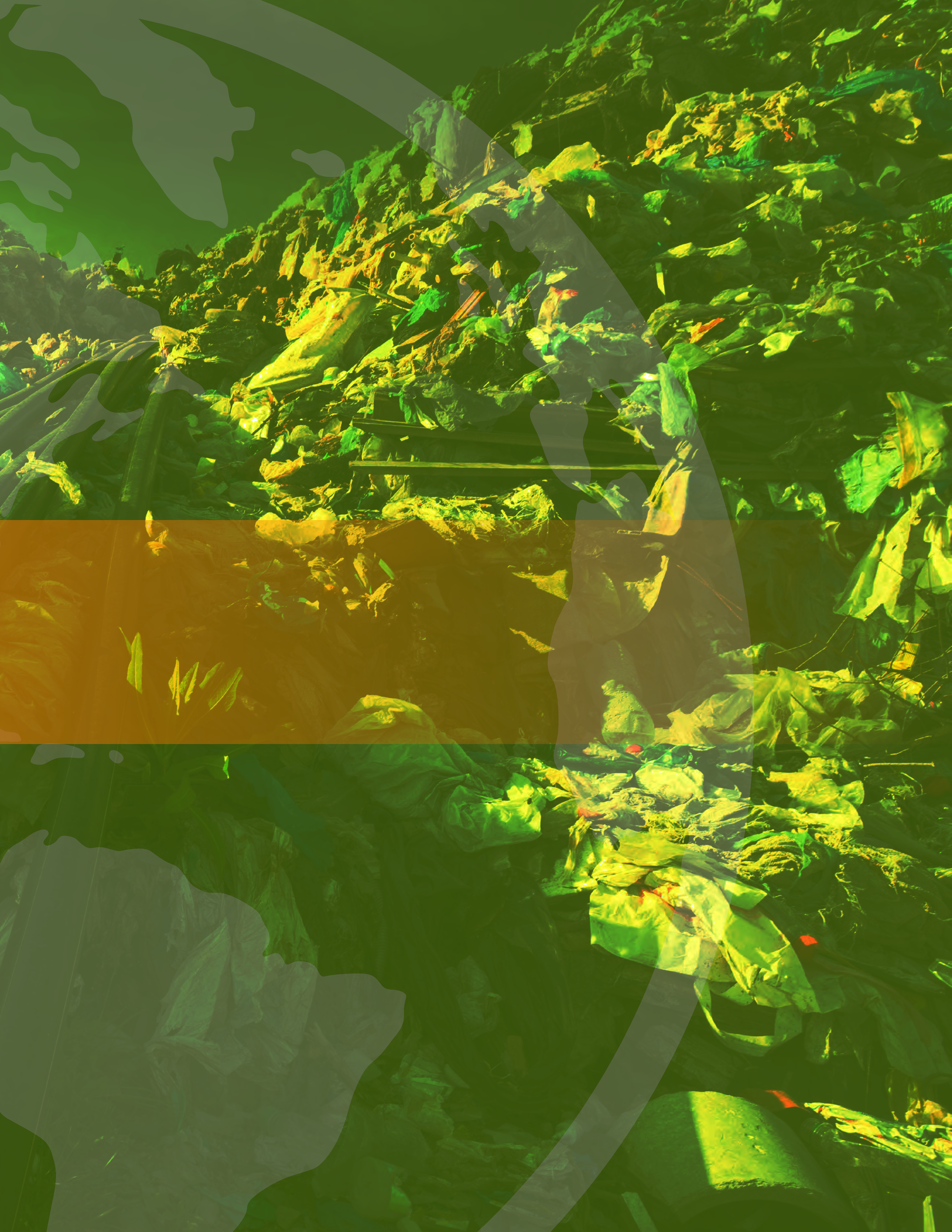


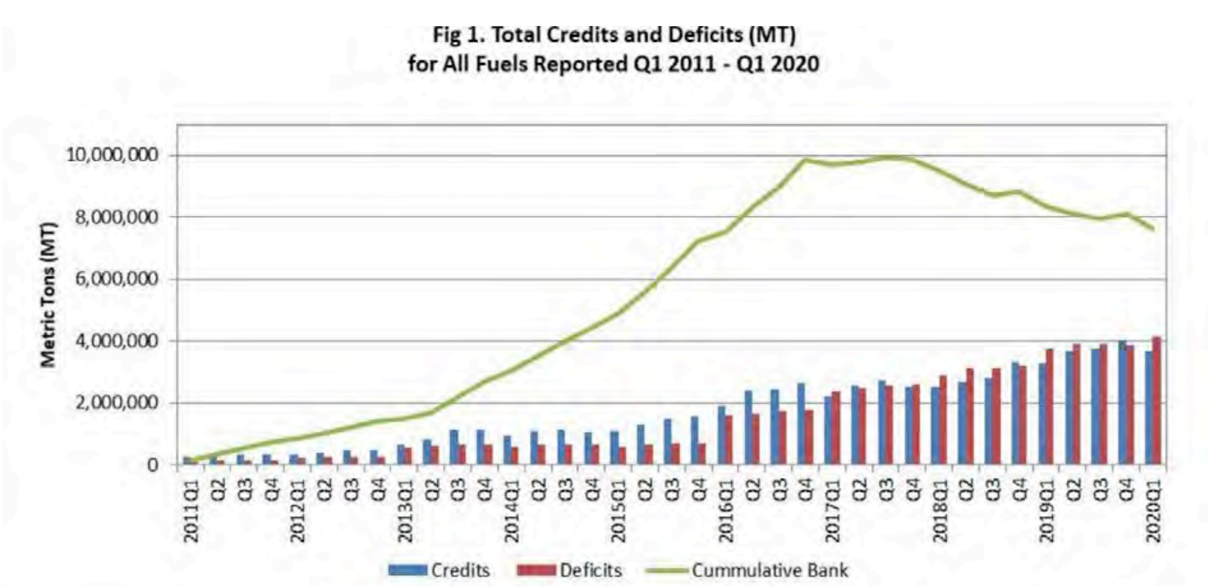
Figure 8 shows the total debits and credits generated as well as the cumulative bank of credits since 2011. Until 2017, credit generation outpaced the debits and a large bank of credits could be built up. The decrease in banked credits in late 2016 led to significant credit pricing increases, as credit deficits began to outpace credit generation. This has continued into 2020, which is why LCFS credit prices have traded near the $200 price cap. It is important to also note that the California LCFS market is nearing its saturation point, which can lower the value of the LCFS credits; the RNG currently dispensed in California is nearly equal to the amount of CNG dispensed. However, there is still a strong demand in California for RNG with low CI scores. While LCFS credit prices have been at all-time high for the past two years, there are significant volumes of low-CI RNG entering the California markets along with other emerging renewable fuels in California, like renewable electricity and renewable diesel. Due to this, EcoEngineers envisions a scenario where credit generation may outpace the deficit generation within the next three to five years. This would decrease the value of LCFS credits in the market, which may potentially reduce the revenues of the project.

Although EcoEngineers cannot predict what the LCFS market will look like after the next three to five years, we anticipates this project may continue to have an opportunity to be placed in the California market due to its anticipated CI score.

Landfill-diverted projects are likely to have a CI score below zero, which would allow the project to easily displace other projects, such as landfill and wastewater projects that tend to have a CI score between 35-50. To take advantage of the current strong market that can be expected for at least the next three years, EcoEngineers recommends the City implement this project as soon as is possible, if a decision to proceed has been made. It is important to note that there are other potential state LCFS programs that may be established in the next few years, which could provide another revenue avenue for this project.

See more information discussed in section **10.0 Revenue Estimates and Financial Analysis**.

FIGURE 8: TOTAL LCFS CREDITS AND DEFICITS[iv]



ecoengineers people-driven solutions

2.2.2 Oregon Clean Fuels Program (CFP)

Oregon passed a bill authorizing the Oregon Environmental Quality Commission with the aim to reduce emissions from transportation sector and promote low-emission alternative fuels. The Oregon Environmental Quality Commission proposed rules to reduce the carbon intensity of transportation fuels by 10% by 2025. The Oregon Legislature passed those rules in 2015 and fully implemented the Clean Fuels Program in 2016. The program was adopted to incentivize the use of low carbon fuels and minimize emissions from the transportation sector. **Table 10 provides key terms and definitions associated with the CFP.**

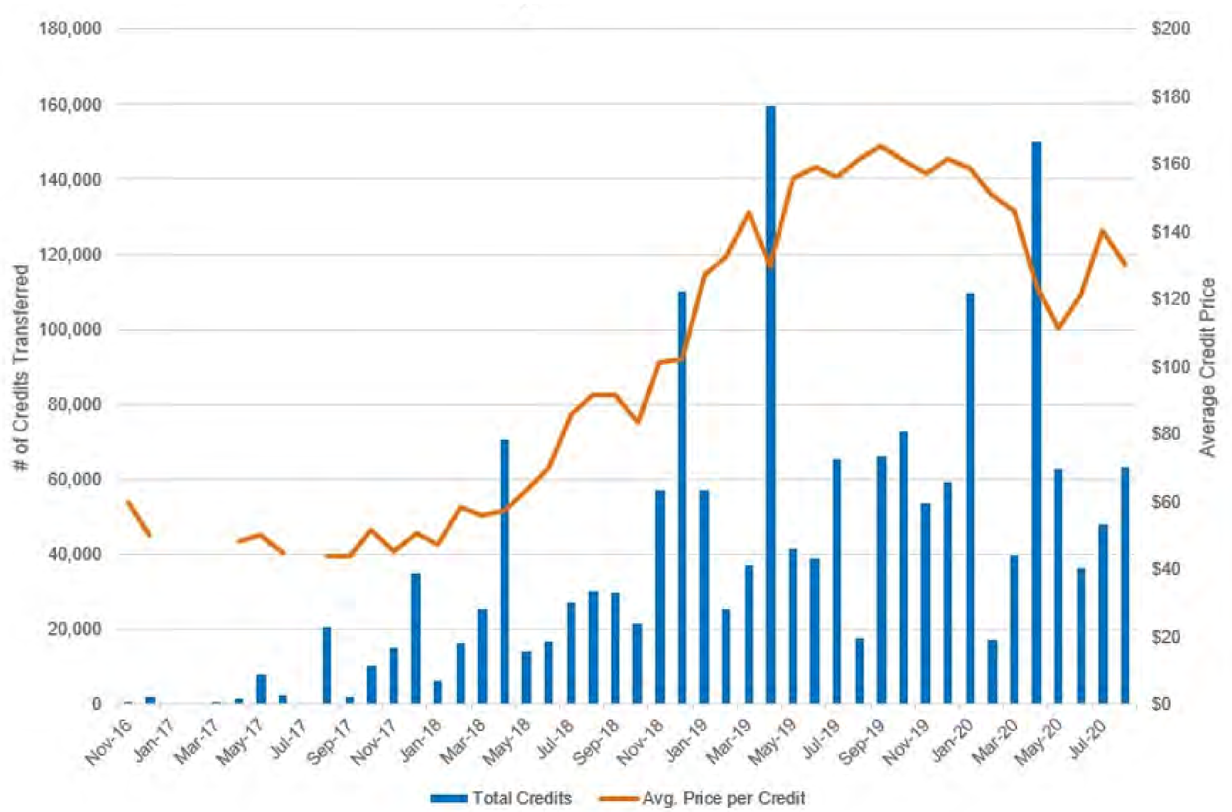
TABLE 10: KEY TERMS AND DEFINITIONS FOR THE CFP

TERMS	DEFINITIONS
OR DEQ	Oregon Department of Environmental Quality – Oversees air quality, water quality, hazardous waste, etc. in Oregon
CFP	Clean Fuels Program – Low carbon fuel standard program in Oregon with a goal of 10% reduction in GHG by 2025
OR-GREET 3.0	Life-cycle analysis model used for determining CI score of transportation fuel
Regulated Parties	Companies that produce or import transportation fuel into Oregon
CFP Credit	Credits generated by fuels with a CI below the annual goal of the CFP
AFRS	Alternative Fuels Registration System – registration system for the Oregon CFP

Producers of renewable fuel can submit facility-specific pathway applications to the OR DEQ to be approved to sell fuel into Oregon. Producers with certified California LCFS pathways can also register the certified pathway under the CFP. When submitting the application to the OR DEQ, the application must include the documentation used to establish the CARB pathway. The CI score is determined through OR-GREET modeling, which is similar to CA-GREET but needs to be updated for the change in transportation distance to Oregon. Fuel pathways that have been approved under the CA-GREET model can be approved in Oregon by updating the transportation distance to Oregon.

The price of CFP credits has been steadily rising over the past 18 months and is around $127 per credit now, as seen in Figure 9 (Page 20). Producers of renewable transportation fuels can take advantage of both the RIN credits and CFP credits. By selling renewable transportation fuels into Oregon, that excludes the seller from LCFS credits, as only one state-level credit can be applied.

FIGURE 9: CFP CREDIT PRICE AND CREDIT VOLUME TRADED



By transporting RNG into Oregon, it is possible to earn both RINs and CFP credits. However, RNG can only get credit from one state and cannot stack CFP and LCFS credits. The CFP offers an additional market for parties shipping fuel in case there are issues with participating in the LCFS. Renewable fuel producers are able to send a certain portion of the fuel to California and the rest of the fuel to Oregon. Because of the credit pricing difference between California and Oregon and the fact that the California market is approximately 10 times larger than the Oregon market, most renewable fuel projects target California first.

2.2.3 British Columbia Renewable and Low Carbon Fuel Requirements (RLCFR)

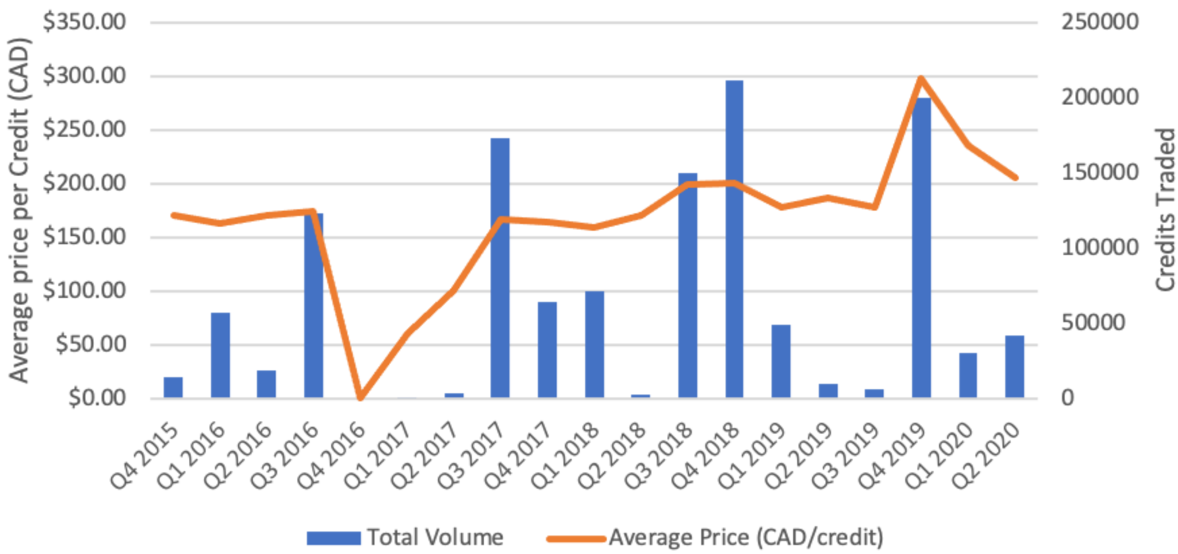
The Renewable and Low Carbon Fuel Requirements Act was passed in April 2008 by the Legislative Assembly of British Columbia in Canada.

Under this act, a Renewable and Low Carbon Fuel Requirement (RLCFR) clause was included to promote carbon reduction in transportation fuels. The RLCFR targets a 10% reduction in greenhouse gas intensity by 2020.

Like the LCFS and CFP, the RLCFR sets a CI limit and generates credits or deficits for fuels with higher or lower CI scores than the compliance curve. Figure 10 shows the total volume traded and average credit price for

British Columbia's RLCFR Program. **During Q4 2016, Figure 10 shows a dip in credit prices close to zero dollars.** It is important to note this dip does not necessarily mean the credit prices dropped that low, but rather, it's possible there were not enough reported credit transactions, which dropped the average credit price down for this period.

FIGURE 10: RLCFR CREDIT PRICE AND CREDIT VOLUME TRADED



Producers of renewable fuels, like RNG, can sell into British Columbia using a preset CI score or choose to apply for a facility-specific CI score, which are generally much lower than the preset value. British Columbia uses the GHGenius model to determine the carbon intensity of a fuel. GHGenius does not include indirect land use change unlike the CA-GREET and OR-GREET models.

Regulated parties under the RLCFR are any seller or importer of diesel, gasoline, any transportation fuel that can be blended with petroleum-based fuels, CNG, hydrogen, and electricity. The RLCFR allows regulated parties to be flexible when choosing their compliance method. Regulated parties can choose the lowest-cost option between reducing the carbon content of the fuel, switching technologies to lower carbon alternatives, purchasing available credits, or using previously banked credits. When selling RNG into British Columbia from the United States, the environmental attribute value can only come from the RLCFR credits, as RINs cannot be generated for fuels sold outside of the United States. The RLCFR is less attractive for producers because of the lost revenue from not generating RINs and the lower credit price as compared to an LCFS credit. **Table 11 provides a summary of the average annual price for each fuel program over the past three years.**

TABLE 11: AVERAGE ANNUAL PRICES FOR VARIOUS FUEL PROGRAMS

TYPE	2017	2018	2019
RFS (D5 RIN)	$2.80	$2.26	$1.30
LCFS	$88	$155	$187
CFP	$47	$75	$138
RLCFR	$123	$182	$183

[… Building the digester facility across from the Dane County Sanitary Landfill would be beneficial since this landfill facility already has an existing interconnection with ANR's pipeline.]

2.2.4 Other State Low Carbon Fuel Standard Programs

The California LCFS program is an example for other programs to follow worldwide and CARB works in partnership with other states that are working towards establishing their own program. There are also multiple coalitions that have been formed throughout the United States to advance lower GHEs initiatives, including state low carbon fuel standard programs that promote renewable fuel production for use as transportation fuel.

There are already multiple states currently seeking a low carbon fuel standard program. Oregon being the first state to follow California, the CFP program is already established and closely mirrors the California LCFS program regulations. Other states following, to name a few, include Colorado, New York, and Washington. New York introduced a low carbon fuel standard bill in 2019 with a goal to reduce GHEs from the transportation sector by 20% by year 2030. The bill is currently under review in the senate under the Environmental Conservation Committee. New York continuous to actively seek progress in its initiative in the year 2021. Washington is also working towards adopting a low carbon fuel standard to help reduce its GHEs from the transportation sector by 50% below the 1990 levels by 2030. A draft of the proposed rule was released at the end of 2019 and it's currently under review.

2.3 The Fuel Pathway and How RINs are Generated

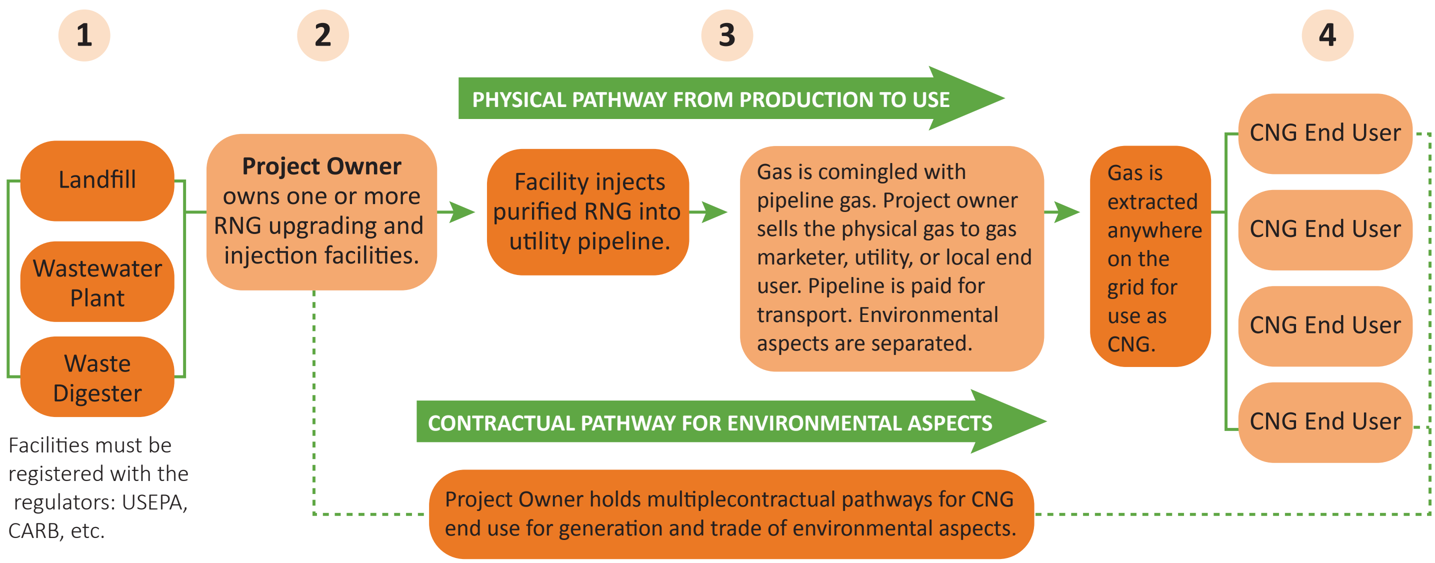
A facility must be registered with the USEPA to sell into the RFS market. To register the RNG pathway under the RFS, an independent third-party engineering review must be submitted to the USEPA, which is based upon a site visit and review of relevant documents. To qualify the project's RINs under the RFS registration, the project owner must demonstrate the physical and contractual pathway of the RNG from production to end use as transportation fuel. An interconnect agreement with a utility company would support this physical pathway, illustrating the transport of the RNG to the end user: a CNG station in California.

For the City's project, building the digester facility across from the Dane County Sanitary Landfill would be beneficial since this landfill facility already has an existing interconnection with ANR's pipeline. Accessing this injection point would allow the City to save about $2-3 million in capital expenses associated with building a new interconnection.

The contractual pathway can be supported by the contracts that will be established between all parties involved. As such, the City of Madison, the project owner, would likely choose to partner with a California offtake marketer to match up the RNG with natural gas volumes dispensed as vehicle fuel by a CNG station in California. In this case, the contract between the City of Madison and the offtake marketer, as well as the contract between the offtake marketer and the CNG station in California, would help support the contractual pathway for the project.

Figure 11 shows the four phases of a typical biogas-to-CNG transportation fuel pathway for RIN generation. The assumption used for this report is that the City of Madison will serve as "project owner," which includes management of the entire pathway along with generation and sale of RINs.

FIGURE 11: BIOGAS-TO-CNG FUEL PATHWAY



1. Food waste generates biogas from the anaerobic digestion process.

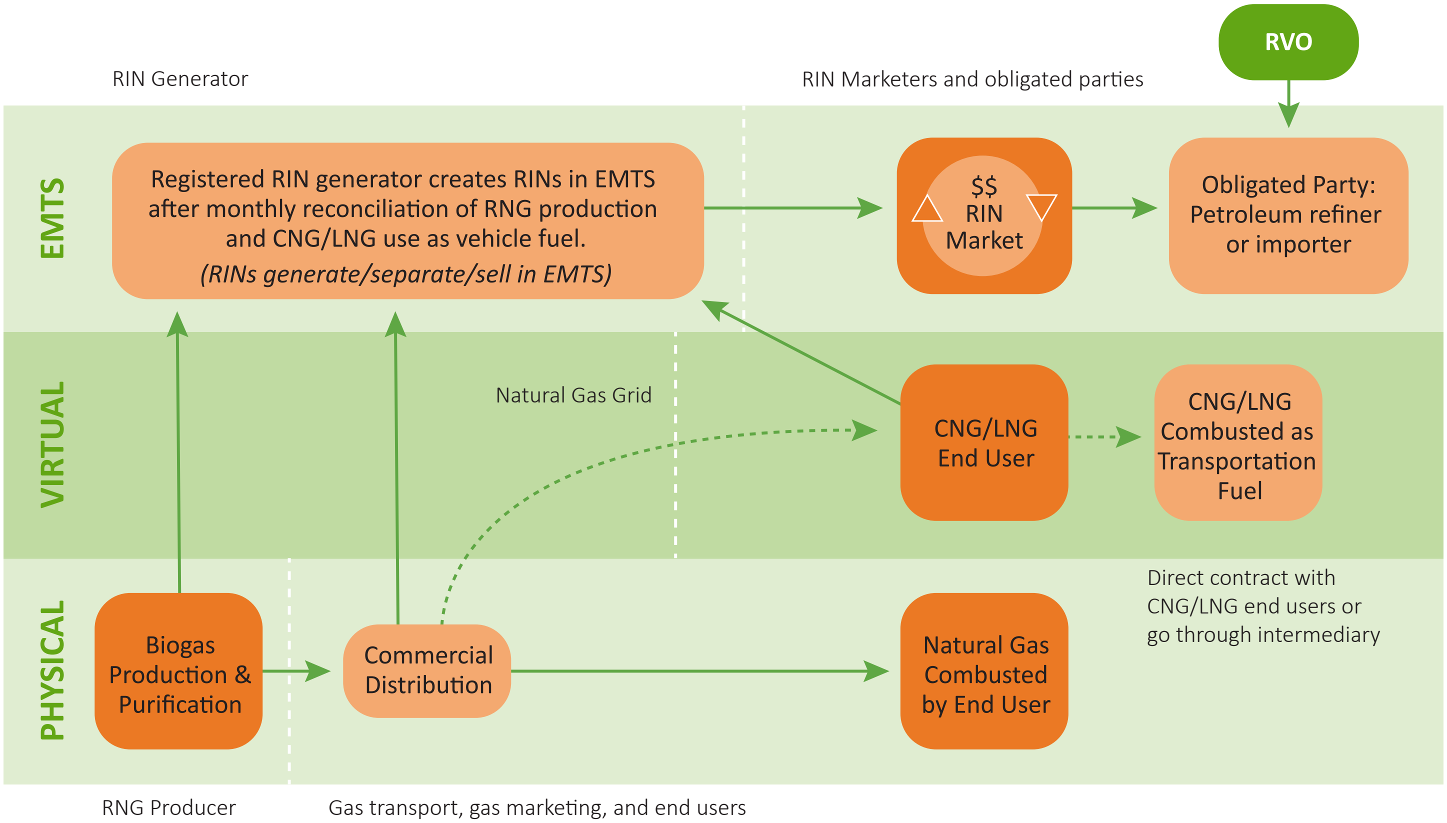
2. The biogas is purified to meet pipeline-quality specifications for renewable natural gas with the intent to use the RNG as transportation fuel and is injected into a commercial natural gas pipeline.

3. The pathway to demonstrate CNG end use is established. Commercial pipeline injection provides the necessary flexibility to connect to CNG end use. City of Madison will establish contractual agreements with CNG end users anywhere within the continental United States along the natural gas grid, preferably in California to capitalize on RINs and LCFS credits.

4. CNG is dispensed for transportation use at a fueling station. When either a CNG fueling station or vehicle fleet owner enters into a contractual agreement with the City of Madison or an offtake marketer, they are required to provide documented proof of CNG dispensing. The dispensed CNG is matched up with the RNG volumes produced and injected into the natural gas pipeline by the City of Madison. This pairing closes the loop from production to transportation fuel usage. To help in securing end-user cooperation, contract negotiations usually provide for a portion of revenues from RIN sales to be shared with the end user.

The following example, Figure 12, provides a realistic application of the biogas-to-CNG transportation fuel pathway. This example assumes the RNG is used in California and that the City of Madison generates the RNG and LCFS credits.

FIGURE 12: ROLES IN THE RIN SPACE



1. Virtual contract is secured between the City of Madison and a CNG station or fleet owner(s), or with a third-party offtake broker in California.
2. The City of Madison produces an "X" amount (MMBtu) of purified RNG in a given month.
3. The physical volume of RNG is injected into a natural gas pipeline.
4. A CNG station owner(s) in California allocates an "X" amount (MMBtu) of their CNG usage to the City of Madison.
5. The City of Madison generates RINs for the "X" amount (MMBtu) of RNG production.
6. The City of Madison generates LCFS credits for the "X" amount (MMBtu) of RNG production.
7. RINs and LCFS credits are sold to obligated parties at market value.
8. Revenues are split based on the contractual agreements between all parties.

The City of Madison will have an account in the USEPA Moderated Transaction System (EMTS) and with the LCFS Reporting Tool (LRT) to process generation and sale of RINs and LCFS credits. The obligated party will report the RIN purchases to USEPA and CARB to verify compliance. Note that the credits generated from the production of this renewable fuel are not tax credits, and they are purchased by obligated parties to comply with the RFS and LCFS.

2.4 Transportation Fuel Options

RNG can be used as transportation fuel for large vehicles such as trucks and buses and will normally displace diesel in the transportation fuel market. In order for RNG to qualify for RINs or LCFS credits, it is necessary to demonstrate that RNG has been used for transportation purposes. Transportation use can be documented through a virtual contract swap or by actual sales from a fueling station.

2.4.1 Virtual Contract Swap

The RFS and LCFS allow injection of RNG into a "commercial distribution pipeline," as opposed to liquid renewable fuels that are produced, sold, and tracked in physical batches. Once the RNG volume joins the national natural gas pipeline grid, virtual contract swaps can be arranged between the producer and end users from any location on the grid within the continental United States. This unique feature creates the option for the City of Madison to upgrade the agricultural waste biogas in Wisconsin, compress and inject the RNG into a nearby pipeline utility, establish virtual contracts with end users in California, and generate and/or sell credits in the RFS and LCFS.

2.4.2 Local Fueling and Use

The Dane County Sanitary Landfill has an existing interconnect that accepts RNG. This means main challenge is delivering the RNG to that interconnect station. Building the digester facility nearby will likely provide access to the existing injection point at the Dane County Sanitary Landfill. If the City were to build the digester facility at a different site, access to a pipeline might be unavailable or cost prohibitive. In this case, construction of an on-site fueling station is an option. Virtual pipelines are possible as well, but typically a direct pipeline interconnection is more cost-effective.

Another possibility is distribution to existing CNG stations near the project site for local fuel sales. It is important, however, to consider whether the size of the local consumer base can support the volume of RNG produced. There are grant programs available for entities that are interested in fleet conversion through companies like Clean Energy Renewable Fuels (CERF). Local fueling may be attractive to fuel users that currently utilize more expensive fuel alternatives.

The amount of diesel displaced by RNG is determined by comparing the energy contents of both fuel types. Diesel has a heating value of 139,000 Btu/gal. One MMBtu of RNG is equivalent to approximately 7.2 gallons of diesel fuel. For example, if the City of Madison generates 500 MMBtu per day of RNG, it is equivalent to producing 1,900 gallons of diesel every day or 693,500 gallons annually. A single, local CNG station may not produce enough sales to consume the total volume of RNG produced.

Using the fuel locally also will not allow the City of Madison to participate in California's LCFS, as the end use of the fuel is not within California's border. Revenue from LCFS credits comprises a minimum of 40% of the gross total revenue for the project, making participation in the program significant to the economic feasibility of the project. It is recommended to send fuel to California in the short-term to capitalize on the high value of LCFS credits and the significant demand for renewable fuels with a low carbon intensity. EcoEngineers anticipates this project will have the opportunity to be placed into the California market based on the anticipated negative CI score. As credit generation begins to outpace deficits in three to five years, this landfill-diverted waste project may still have an opportunity to be placed in the California LCFS market by displacing other projects, such as landfill and wastewater projects which may have CI scores between 35-50. Once the project's capital costs are paid off, the City of Madison could re-examine RNG market placement. There are other state LCFS programs that may be established in the next few years, which may provide an alternative way to monetize from this project

[EcoEngineers identified the Yahara Hills Golf Course, across from the Dane County Sanitary Landfill, as a potential site location for the anaerobic digester facility.]

3.0 Site Selection

There are several factors that should be taken into consideration for a preliminary site selection. Several of the key factors are described in more detail below.

- **Feedstock Transportation:** Transportation costs greatly depend on local conditions. It is important to consider proximity to the sources of feedstock and the frequency and volumes at which those sources produce the feedstock. It is ideal to be located near the sources of the desired feedstock to keep transportation costs down, especially if the feedstock has a high water content. Dewatering the feedstock prior to transport is a way to reduce hauling volumes and cost.

- **Utility Considerations:** Determining the electrical, natural gas, and water demand for the facility and the wastewater discharge and effluent characteristics is imperative. The City should identify if the targeted area has the required electric power, natural gas, water, and wastewater infrastructure to support the project. It might be necessary to build the infrastructure necessary to support the project.

- **Material Handling:** There needs to be enough space for feedstock and effluent storage, depending on the amount and the frequency of material coming into and out of the facility. The size of the feedstock pretreatment equipment and anaerobic digester (AD) needs to be determined in order to handle the incoming feedstock. If the AD facility receives significant organics or high-strength waste from the area, the facility must ensure that it is has properly designed roadways and the surrounding area has adequate infrastructure to accommodate the heavy-duty truck traffic (i.e. requiring trucks to pass through or near residential areas to get to the AD site is not recommended). Odors from the hauling process might also occur. It is critical to require haulers to have sufficient covers, containment, etc.

- **Digestate Storage:** If digestate is ultimately land-applied, there are typically land application windows (twice per year). Digestate may have to be stored for up to six months, so adequate space for storage is critical. This can require significant land area.

- **Future Expansions:** Purchasing additional land initially to accommodate any future expansion plans is recommended. This will save on time, cost, and the potential to be “held hostage” by adjacent landowners at future expansion dates.

- **Odor:** Ideally an AD site is located away from residential or commercial buildings. Accounting for and treating odors on-site can mitigate odor concerns. Proper containment, along with biological or chemical treatment, is highly recommended. EcoEngineers has heard of at least two facilities with significant odor issues that partially contributed to the closure of the facilities.

- **Desired Biogas End Use:** The desired end use of the biogas is a very important consideration during site selection. If upgrading the biogas to RNG, siting near a natural gas utility pipeline is critical to keeping costs down. If electricity production is desired, then a site that can connect to the electrical grid is more critical.

EcoEngineers identified the Yahara Hills Golf Course, across from the Dane County Sanitary Landfill, as a potential site location for the anaerobic digester facility. Based on the report issued by the City’s Task Force on Municipal Golf in Madison Parks (Task Force), EcoEngineers identified the possibility of land becoming available at the Yahara Hills Golf Course. The Task Force report recommended the elimination of eighteen holes at the Yahara Hills Golf Course.[v] Per the Task Force report, “the courses represent a

451.08 acre assemblage of parcels." With the resolution issued by the City to adopt this report[vi], the elimination of eighteen holes may result in shutting down a large portion of the course, possibly up to half of the course. This would provide more than enough acreage to build a digester facility including all its necessary equipment, including truck unloading, feedstock pretreatment, anaerobic digester, conditioning, upgrading, and compression equipment.

A full facility that includes a feedstock reception area and digestate processing and storage will require approximately five acres and approximately 15 acres for composting of the digestate. If the City is interested in this location, EcoEngineers recommends the City confirms the amount of land that will become available at the Yahara Hills Golf Course to ensure there is enough space for a facility of this size.

Figures 13 and 14 map the location of the Dane County Sanitary Landfill and Yahara Hills Golf Course, respectively. **Figure 13 illustrates the landfill's location relative to the City of Madison, while Figure 14 shows its proximity to the golf course (right across Highway 18).**

For purposes of this study, EcoEngineers focused on food waste, as this is the primary type of feedstock targeted by the City of Madison for its digester facility. Based on EcoEngineers' recommended site location, the Yahara Hills Golf Course, and the targeted type of feedstock, EcoEngineers focused its analysis on the types of feedstock sources generating the most food waste per year in Dane County. These generators were all within approximately 35 miles from the Yahara Hills Golf Course, which EcoEngineers believes is a feasible distance to collect and transport the feedstock to the digester site.

To narrow down the list of feedstock generators, data from the USEPA's Excess Food Opportunities Map (EPA Map Tool) was compiled and reviewed to determine the estimated amount of food waste in Dane County. Specifically, the EPA Map Tool provided data on the estimated amount of food waste generated by different types of establishments, or feedstock sources, including the following:

- Correctional facilities
- Educational institutions
- Food banks
- Healthcare facilities
- Hospitality industry
- Food manufacturing and processors
- Food wholesale and retail
- Restaurants and food services

The EPA Map Tool pinpointed the location of the different types of food waste generators. EcoEngineers reviewed the data and ultimately narrowed it down to four that produced the most amount of waste per year. **Figures 15, 16, 17, and 18 (pages 30-31) illustrate the locations of the food wholesale and retail, restaurant and food services, food manufacturing and processors, and educational establishments generating food waste in Dane County, respectively.**

FIGURE 13: DANE COUNTY SANITARY LANDFILL LOCATION IN MADISON, WISCONSIN[vii]

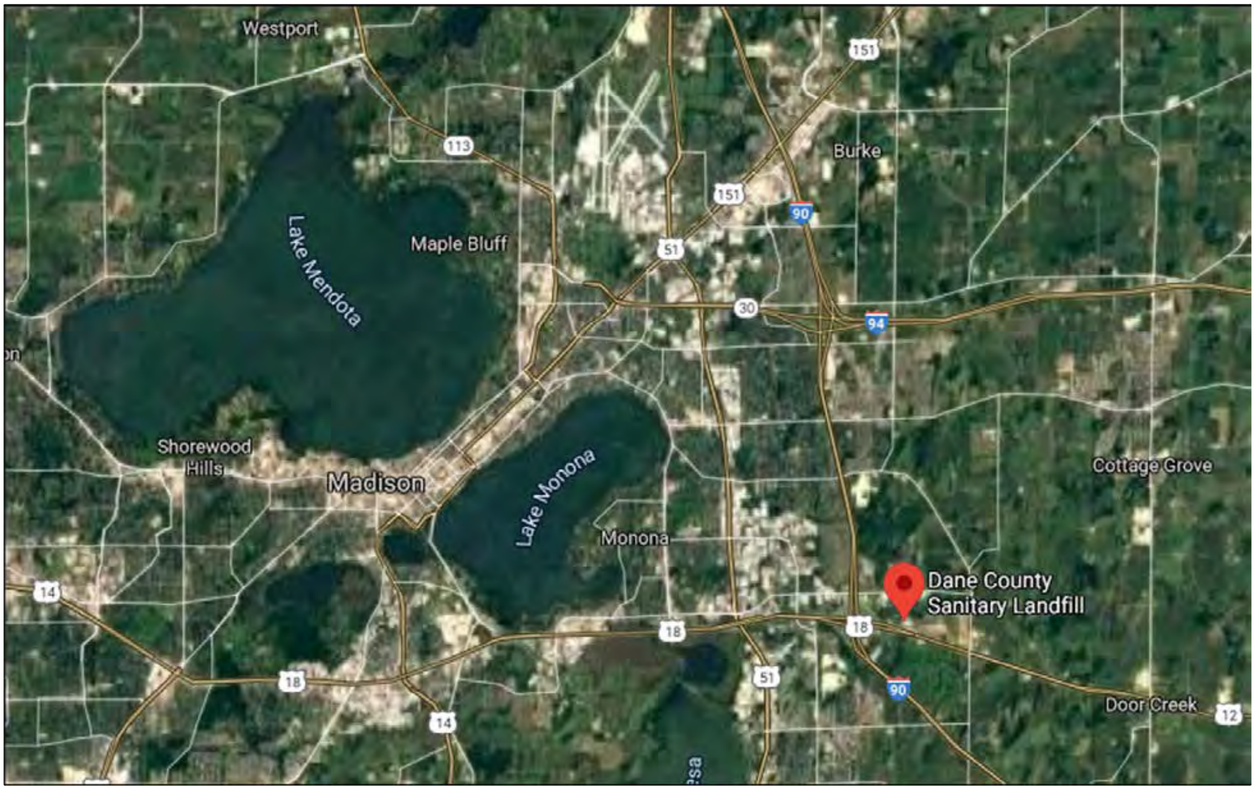


FIGURE 14: YAHARA HILLS GOLF COURSE (ACROSS FROM DANE SANITARY LANDFILL)[viii]

FIGURE 15: FOOD WHOLESALE AND RETAIL IN DANE COUNTY (321 ESTABLISHMENTS IDENTIFIED IN DANE COUNTY)[ix]

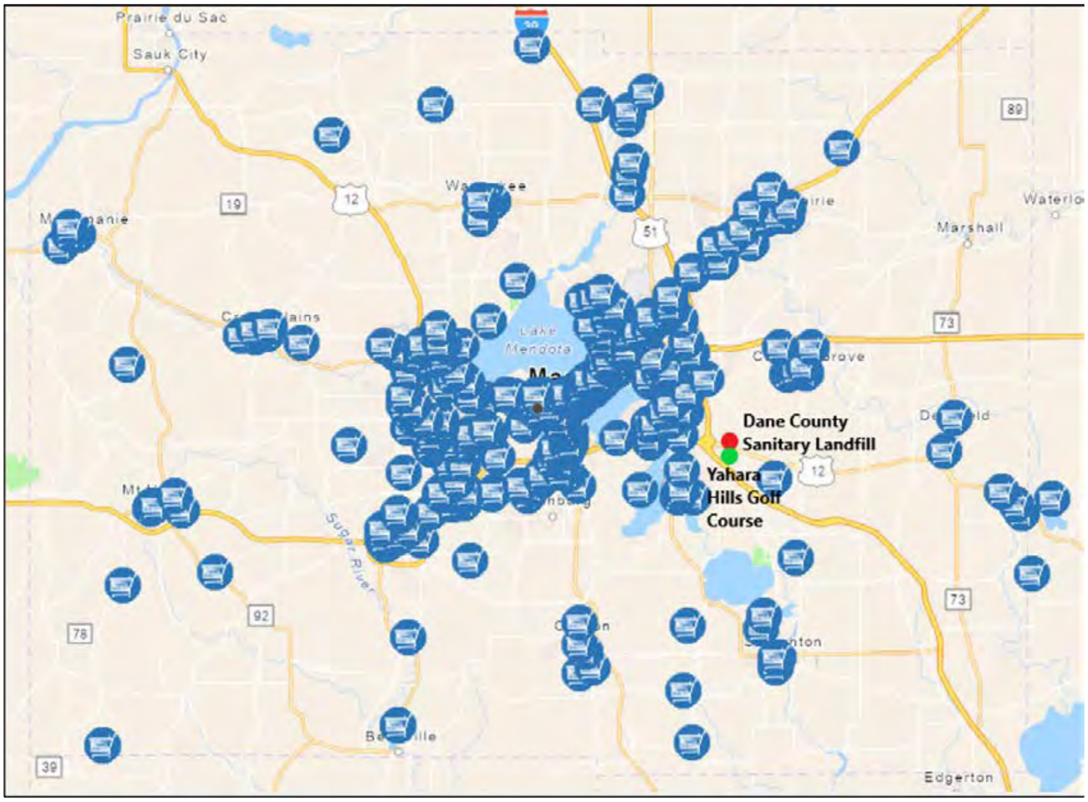


FIGURE 16: RESTAURANT AND FOOD SERVICES IN DANE COUNTY (1,000 ESTABLISHMENTS IDENTIFIED IN DANE COUNTY)[x]

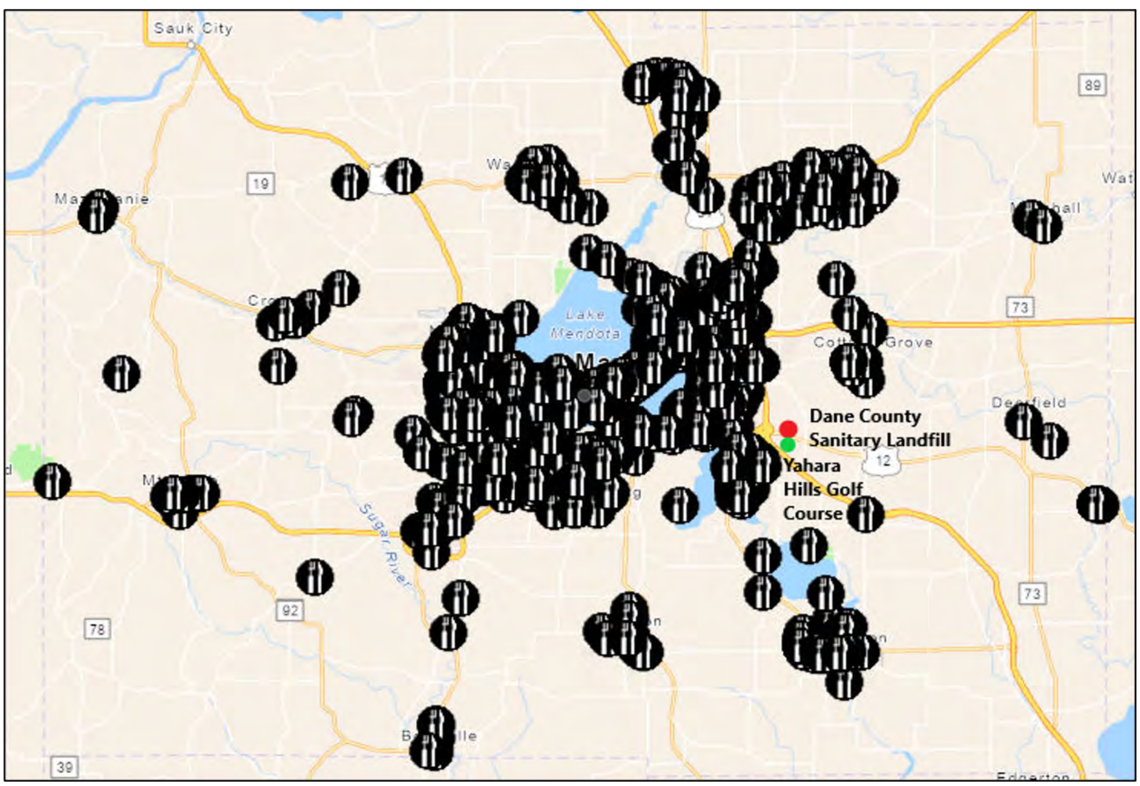


FIGURE 17: FOOD MANUFACTURING AND PROCESSORS IN DANE COUNTY (109 ESTABLISHMENTS IDENTIFIED IN DANE COUNTY)[xii]

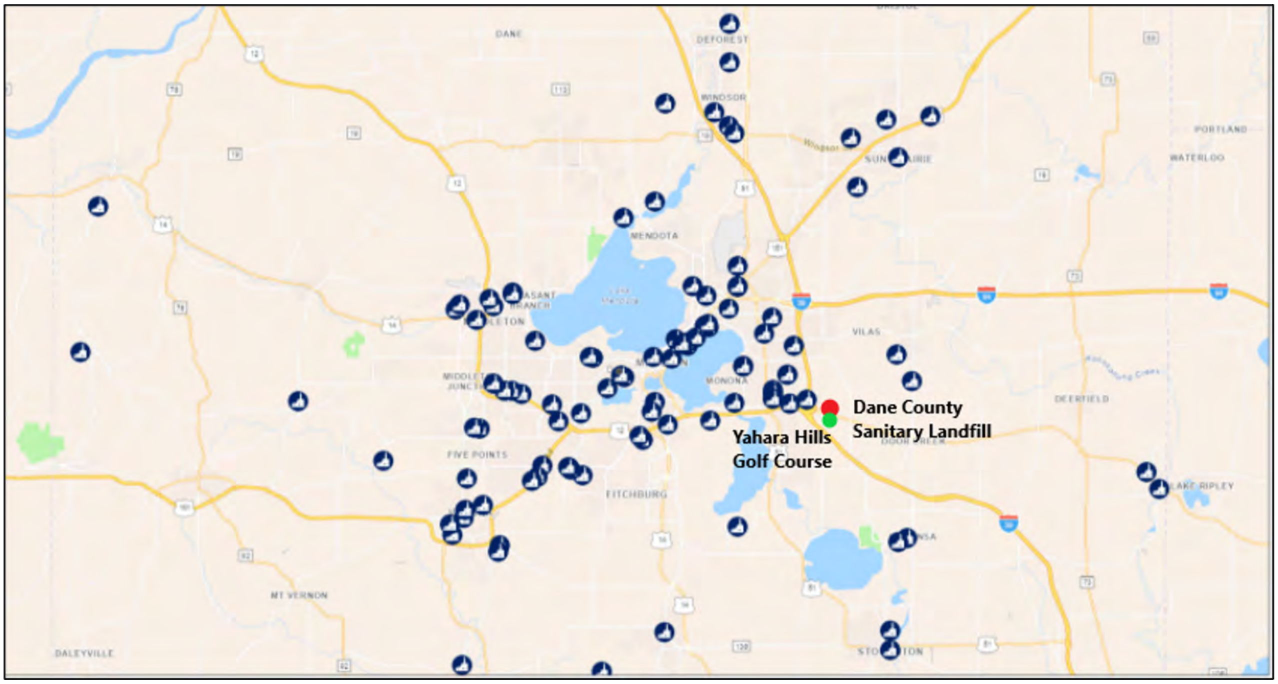
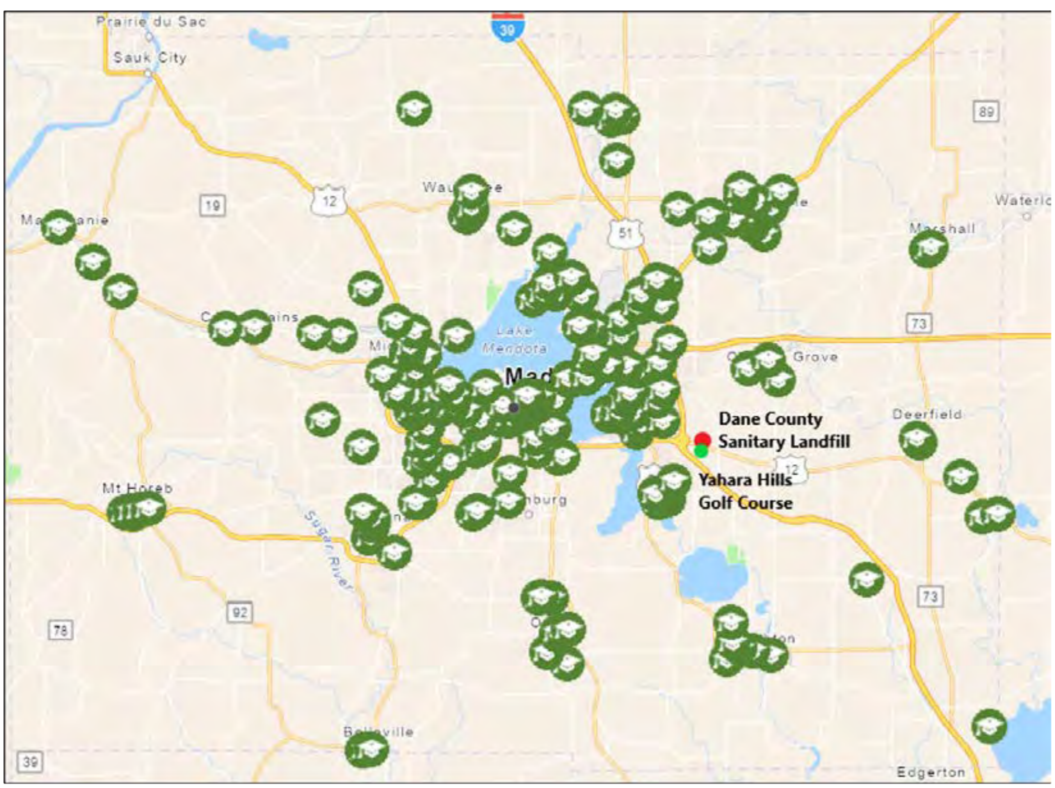


FIGURE 18: EDUCATIONAL ESTABLISHMENTS IN DANE COUNTY (204 ESTABLISHMENTS IDENTIFIED IN DANE COUNTY)[xii]



EcoEngineers also considered food waste generated from the residential sector. This data was not found in the EPA Map tool. Instead, EcoEngineers relied on data from the United States Census Bureau (Census), including the estimated number of households within Dane County from 2014-2018.[xiii] We also used the total population within Dane County estimated by the Census in 2019.[xiv]

EcoEngineers believes building the anaerobic digester site next to the Dane County Sanitary Landfill is reasonable and comes with benefits. The site would be located within 35 miles of all the potential feedstock sources identified, including the residential sector and the top four categories narrowed down with the EPA Map Tool.

Major waste haulers already collecting waste within this area could transport the waste to the project's digester facility, especially if this is located next to the landfill, where the waste would be transported to anyway. Initially, it may make sense for the City to focus on collecting waste from the top generators identified through the EPA Map tool, as well as the residential waste. Some of the other food waste not specifically targeted would still be sent directly to the landfill next door. As such, developing the site next to the landfill gives an opportunity for the landfill to send additional food waste to the digester facility directly; this adds another benefit to this site selection.

The digester site also could be developed in a different area within the City of Madison and be convenient for major waste haulers. However, available land next to a different landfill in the area is scarce. Not developing the site next to a landfill in the City of Madison area may limit — if not eliminate — the amount of food waste sent to the digester facility directly from a landfill. In addition, if the RNG is to be injected into a pipeline for participation in the RFS and LCFS programs, larger distances from a different site location to a commercial pipeline will result in higher capital costs associated with building an interconnect. Typically, building a pipeline to interconnect with a commercial pipeline costs approximately $1 million per mile of pipeline. Running a pipeline from the golf course straight to the interconnection point at the landfill may not be more than one mile long. Building the digester facility at a different location would very likely result in a longer distance to reach a commercial pipeline and in return more capital costs for the project.

Another option is to truck the RNG from the project's facility to the point of interconnection. This would likely amount to approximately $750,000 in capital costs to purchase two trucks and $100,000 per-driver yearly operating costs. In addition, higher electricity costs would be expected as much higher gas compression would be needed. With a potential point of interconnection with such proximity to the site recommended at the Yahara Hills Golf Course, it is very likely that building a pipeline may the least expensive option. If a different site is considered, trucking the RNG may be a more reasonable option to consider.

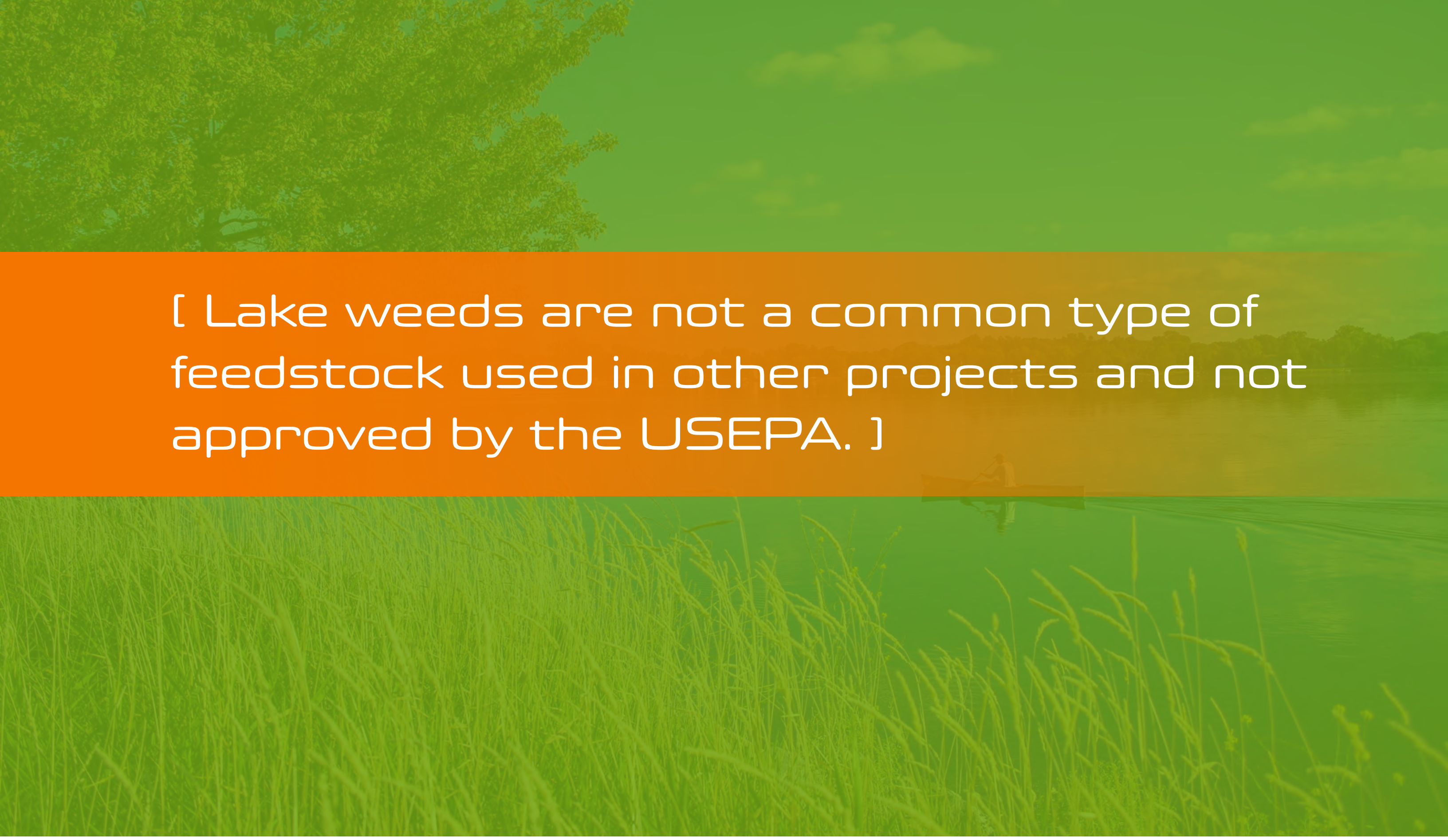
4.0 Feedstock Analysis

For this study, EcoEngineers considered a variety of potential feedstocks for the proposed digester project. The main feedstocks considered were:

- Food waste
- Manure
- Lake weeds

As part of the analysis, EcoEngineers had to determine the preliminary D-Code eligibility of each feedstock, as that affects revenue generation. If a feedstock is considered "cellulosic," then it qualifies for D3 RINs, and if a feedstock is considered "non-cellulosic," then it qualifies for D5 RINs. The USEPA does not currently have a methodology to attribute the biogas produced to its respective feedstock. If cellulosic and non-cellulosic feedstocks are mixed and co-digested, then all biogas produced by the digester would only be eligible for D5 RINs. Of the waste feedstocks analyzed by EcoEngineers, food waste is considered "non-cellulosic", manure is considered "cellulosic", and lake weeds are uncategorized.

Food waste is great to use in an anaerobic digester because it has high biogas yields, and often there are incentives to use it. The LCFS offers a credit to projects that produce RNG from food waste that has been diverted from landfills because digesters capture approximately 98% of the methane produced compared to only 75% for landfills. These landfill-diverted projects can have negative CI scores, typically around -50 gCO_2e/MJ, which is attractive in the California market. Projects that use food waste that has not been diverted from a landfill typically have a CI score of around 35-45 gCO_2e/MJ which is much less attractive.



[Lake weeds are not a common type of feedstock used in other projects and not approved by the USEPA.]

Animal manure also is an attractive feedstock because it qualifies for a similar avoided methane emissions credit. Manure is often stored in lagoons or deep pits where anaerobic conditions are present and methane production occurs. The methane produced in these lagoons or deep pits is typically released directly to the atmosphere. By installing a digester and capturing that methane, projects can take advantage of the avoided methane emissions credits resulting in ultralow CI scores. The ultralow CI scores are very attractive, so the market for acquiring manure as a feedstock is very competitive. Project developers pay for manure instead of receiving tipping fees to accept it.

The City also talked about an initiative to remove lake weeds and asked what could be done with that biomass. Lake weeds are not a common type of feedstock used in other projects and not approved by the USEPA. A sample of the lake weeds would need to be tested for adjusted cellulosic content to assess whether it meets the minimum 75% threshold of cellulose, hemicellulose, or lignin components. If it meets this threshold, there is an opportunity to petition to the USEPA for the inclusion of lake weeds in the pathway for D3 RINs. If it does not meet the 75% threshold, it would be possible to petition to the USEPA for inclusion under the D5 designation instead. Whether the City is interested in petitioning for a D5 or D3 RIN, EcoEngineers still recommends the City engages further with the USEPA if lake weeds will be added to the digester system for other reasons, such as boosting biogas production or additional tipping fees. Any time a feedstock not already clearly defined by the USEPA under approved pathways is added to the digester, the USEPA must be engaged to ensure this won't cause any issues with feedstock disqualification.

It is important to note that co-digesting D5 eligible feedstock, such as food waste, and D3 eligible feedstock, such as manure and, potentially, lake weeds, would still result in D5 RINs. The USEPA currently have not approved a methodology for allocation of D3 and D5 RINs when co-digested.

As a result, the facility would only generate lower value D5 RINs, even if some of the feedstock is D3-eligible. EcoEngineers recommends the City focus on securing food waste or other landfill-diverted organics from the different types of sources in Dane County. However, if "cellulosic" feedstock is still of interest to the City, and if there is enough cellulosic material (municipal biosolids, manure, and other cellulosic feedstocks), then it is worth investigating whether a separate digester tank would need to be constructed to allow for D3 RIN generation. With proper biogas measurement, the City could generate D3 RINs from that RNG and D5 RINs from the food waste digesters.

EcoEngineers worked with the City of Madison to establish parameters for the feedstock sources and target the feedstock sources generating the highest potential of food waste per year (tons/year). To narrow down the list of feedstock sources, EcoEngineers reviewed available data and information obtained from the EPA Map Tool (as described in Section 3.0 Site Selection), previous studies conducted in Wisconsin, conversations with the City of Madison and Dane County, and conversations with individuals in the City of Madison community. The City helped connect EcoEngineers with different contacts within the community. During these conversations, EcoEngineers obtained feedback on the level of interest in a food waste collection program, experience with previous similar programs or studies, and advise for a successful program. EcoEngineers had discussions with the following community members:

- **John Welch**, Dane County Department of Waste & Renewables
- **Susan Quam**, Wisconsin Restaurant Association
- **Steve Youngbauer**, Madison Metropolitan School District
- **Missy Nergard**, Director of Sustainability, University of Wisconsin – Madison
- **Travis Blomberg**, Campus Resource Coordinator, University of Wisconsin – Madison
- **Ian Aley**, Green Fund Program Manager, University of Wisconsin – Madison
- **Alex Frank**, University of Wisconsin – Madison
- **Bonnie Koenig**, Environmental Health Services
- **Mike Karman**, Director of U.S. Procurement, Sanimax

John Welch is the Director at the Dane County Department of Waste & Renewables. The Department of Waste & Renewables currently operates the Dane County Sanitary Landfill. Mr. Welch provided EcoEngineers with data to estimate the amount of food waste that is received by the landfill annually. EcoEngineers used this data and other information provided by Mr. Welch to form the basis of the feedstock analysis.

Susan Quam is the Executive Vice President of the Wisconsin Restaurant Association. Ms. Quam provided valuable information regarding the types of restaurants in the City of Madison to better understand the varying levels of pre-consumer and post-consumer type of food waste found in different types of establishments. Ms. Quam categorized each restaurant establishment as either simple, moderate, or complex. These classifications range from bars and fast food restaurants to sit-down environments with a considerable amount of food prep. Ms. Quam believes it is likely to have mostly post-consumer waste at a "simple" type of restaurant and mostly pre-consumer waste at a "complex" type of restaurant. The City may consider this information when evaluating different types of food waste and procuring feedstock from the different types of restaurants. Ms. Quam recommended considering pest control and odor when developing the waste collection methods for the project, as this may impact the restaurants' interest in participating in a food-waste collection program. She also mentioned there would likely be more restaurant participation if financial incentives where implemented. These incentives could include lowering waste disposal fees. Restaurants and food services generate a significant amount of food waste per year, and EcoEngineers recommends the City to consider an incentive program to encourage these establishments to handle food waste properly. This could maximize the amount of food waste collected, while minimizing pretreatment operations.

Steve Youngbauer is the Food & Nutrition Services Director at the Madison Metropolitan School District. Mr. Youngbauer provided valuable information regarding the types of kitchens found at each type of school — elementary, middle, or high school. Different types of food waste can be expected from the different types of kitchens. For example, typical elementary school kitchens have limited food prep, and most of the food served is pre-packaged and shipped from another location. Shipping the pre-packaged food can lead to higher amounts of waste if the number of meals needed were not properly estimated for the day. High schools typically have a full kitchen setup, and food is prepared on-site. This leads to less food waste, as the schools can adjust the number of meals based on the attendance level. If the City were to pursue the collection of food waste from the education sector, the level of packaging found with the food waste would be important to consider when selecting the appropriate feedstock pre-treatment process. Mr. Youngbauer also mentioned the importance of the collection method. The school district does not have an established method to separate food waste from other types of waste. It would be beneficial for the City to develop a separation method that could be carried out at the schools to maximize the amount of food waste collected and sent to the digester site. Mr. Youngbauer said it's also important to consider the frequency at which collection will occur, as the amount of food waste generated depends on the type of school kitchen.

Overall, all the interviewed community members expressed interest in a food waste collection program and willingness to continue to be involved in the development of such program.

EcoEngineers estimated the biogas production based on the potential amount of food waste per year in each of the feedstock sources mentioned. In these biogas estimates, EcoEngineers did not differentiate between different types of food waste, such as fats, oils, and grease (FOGs), starches and other. These differentiations should be made once the City begins to narrow its focus during the feedstock procurement process. EcoEngineers recommends the City completes testing of the different types of food waste during this process to help determine the properties of each and better estimate the amount of biogas yield that can be expected. For purposes of this study, EcoEngineers focused on the following types of food waste sources:

1. Educational institutions
2. Food manufacturing and processors
3. Food wholesale and retail
4. Landfill
5. Residential
6. Restaurants and food services

As described in section **3.0 Site Selection**, the EPA Map Tool was used to obtain data on the estimated amount of food waste from the following food waste generators in Dane County: restaurant and food services, food wholesale and retail, educational, and food manufacturing and processors. The EPA Map Tool provided an estimate of the amount of food waste (tons/year) under a low and a high scenario. The EPA Map Tool relied on commercial and government databases to obtain statistics under each category, along with previous food waste studies to ultimately calculate the estimated amount of food waste generated. EcoEngineers utilized the low and high case food waste estimates provided by the EPA Map Tool to estimate a "moderate" scenario for food waste generation. To estimate the amount of food waste from the residential factor, EcoEngineers relied on Census information for Dane County, as described in Section 3.0 of the report. The City and Dane County estimated 200,000 tons of waste is landfilled from the area each year. Then, based on the "DC Samples" spreadsheet provided by the City, EcoEngineers estimated the percent of food waste found in the municipal solid waste per sample listed. EcoEngineers calculated the average of this food waste percentage at 17%; resulting in approximately 34,000 tons per year of food waste found in landfills in the City of Madison. EcoEngineers assumed that 75% of the food waste originally going to the landfill would be diverted by establishing a food waste collection program as this. As a result, EcoEngineers applied a 25% for the 34,000 tons per year to estimate the amount of food waste under the high feedstock scenario for landfills. EcoEngineers estimated the low and moderate feedstock scenarios for the landfill category by calculating 50% and 75% of the high feedstock scenario, respectively.

It is unlikely there will be 100% participation from the different feedstock sources. To be conservative in the method used to estimate food waste amounts, EcoEngineers applied safety factors in the calculations of each source category. For the restaurant and food services, food wholesale and retail, educational, and food manufacturing and processors categories, EcoEngineers applied a 0.8 factor to the estimated food wastes from the EPA Map Tool to account for only 80% participation. For the residential category, EcoEngineers applied a 0.2 factor to account for only 20% participation from households in Dane County; this was a very conservative approach given the results of a previous study conducted for the City of Fitchburg in 2013. According to the study, there was an 85% participation rate in the 2012 program.

Based on the review of data collected, the interviews conducted, and the conservative factors applied, EcoEngineers created a list of feedstock sources to focus feedstock procurement during the initial phases of the project. **Table 12 illustrates the feedstock estimates for the aforementioned categories based on a low, moderate, and high scenarios to account for variances in the amount of feedstock procured.**

TABLE 12: LOW-, MODERATE-, AND HIGH-SCENARIO FOOD WASTE ESTIMATES

		LOW	MODERATE	HIGH
Food Waste Source	Madison / Dane County	Tons/year	Tons/year	Tons/year
Restaurant & Food Services	Dane	7,015	13,081	19,148
Food Wholesale & Retail	Dane	1,025	17,766	34,507
Educational	Dane	1,231	3,965	6,699
Food Mfg & Processors	Dane	2,125	4,471	6,816
Residential	Dane	1,476	6,721	11,967
Landfills	Madison	1,063	6,375	8,500
	Total Food Waste (Tons/Year)	**13,934**	**52,379**	**87,637**

Once the low, moderate, and high scenarios in Table 12 were established, EcoEngineers reviewed these preliminary feedstock estimates with the City and identified a "probable" scenario at 30,000 tons per year of total food waste. This scenario was identified as the most realistic amount of total feedstock the City may be able to procure in the initial phases of the project from the food waste sources listed in Table 12.

EcoEngineers calculated the biogas production estimates based on low, probable, moderate, and high scenarios of feedstock quantities. We used historical data to estimate the amount of biogas generated from anaerobic digestion. The base assumptions used to estimate the biogas quantities include:

- 70% volatile solid (VS) destruction through the anaerobic digester process
- 17 ft^3 per pound of VS destroyed
- 60% methane concentration in the biogas
- 95% methane recovery rate through the biogas upgrading process
- 18% total solids (TS)

Tables 13, 14, 15, and 16 outline the estimated biogas production per year for low, probable, moderate, and high feedstock scenarios.

TABLE 13: LOW-SCENARIO BIOGAS PRODUCTION ESTIMATE

FEEDSTOCK		ASSUMED CHARACTERISTICS				BIOGAS PRODUCTION	
Description	USEPA RFS D-Code	TS %	Wet Tons/Day	Dry Tons/Day	VS %	VS lbs./ Day	Biogas [scfm]
Low Scenario (13,934 tons per year)	D5	18	38	6.9	80%	10,994	91
			RNG to Pipeline in MMBtu/Day				**73**

TABLE 14: PROBABLE-SCENARIO BIOGAS PRODUCTION ESTIMATE

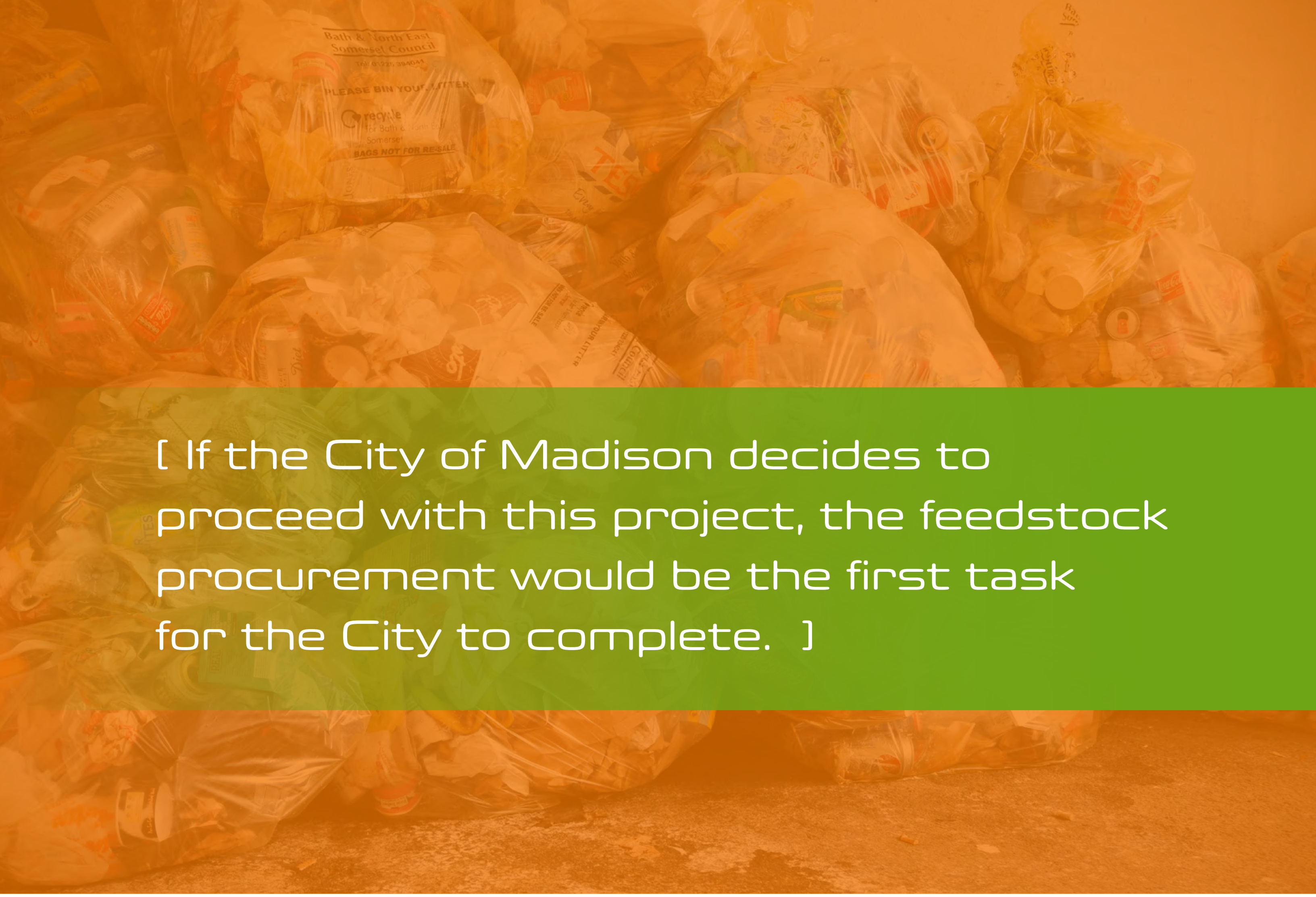
FEEDSTOCK		ASSUMED CHARACTERISTICS				BIOGAS PRODUCTION	
Description	USEPA RFS D-Code	TS %	Wet Tons/Day	Dry Tons/ Day	VS %	VS lbs./ Day	Biogas [scfm]
Realistic Scenario (30,000 tons per year)	D5	18	82	14.8	80%	23,671	196
			RNG to Pipeline in MMBtu/Day				**157**

TABLE 15: MODERATE-SCENARIO BIOGAS PRODUCTION ESTIMATE

FEEDSTOCK		ASSUMED CHARACTERISTICS				BIOGAS PRODUCTION	
Description	USEPA RFS D-Code	TS %	Wet Tons/Day	Dry Tons/ Day	VS %	VS lbs./ Day	Biogas [scfm]
Moderate Scenario (57,379 tons per year)	D5	18	144	25.8	80%	41,329	342
			RNG to Pipeline in MMBtu/Day				**275**

TABLE 16: HIGH-SCENARIO BIOGAS PRODUCTION ESTIMATE

FEEDSTOCK		ASSUMED CHARACTERISTICS				BIOGAS PRODUCTION	
Description	USEPA RFS D-Code	TS %	Wet Tons/Day	Dry Tons/ Day	VS %	VS lbs./ Day	Biogas [scfm]
High Scenario (87,637 tons per year)	D5	18	240	43.2	80%	69,149	571
			RNG to Pipeline in MMBtu/Day				**460**



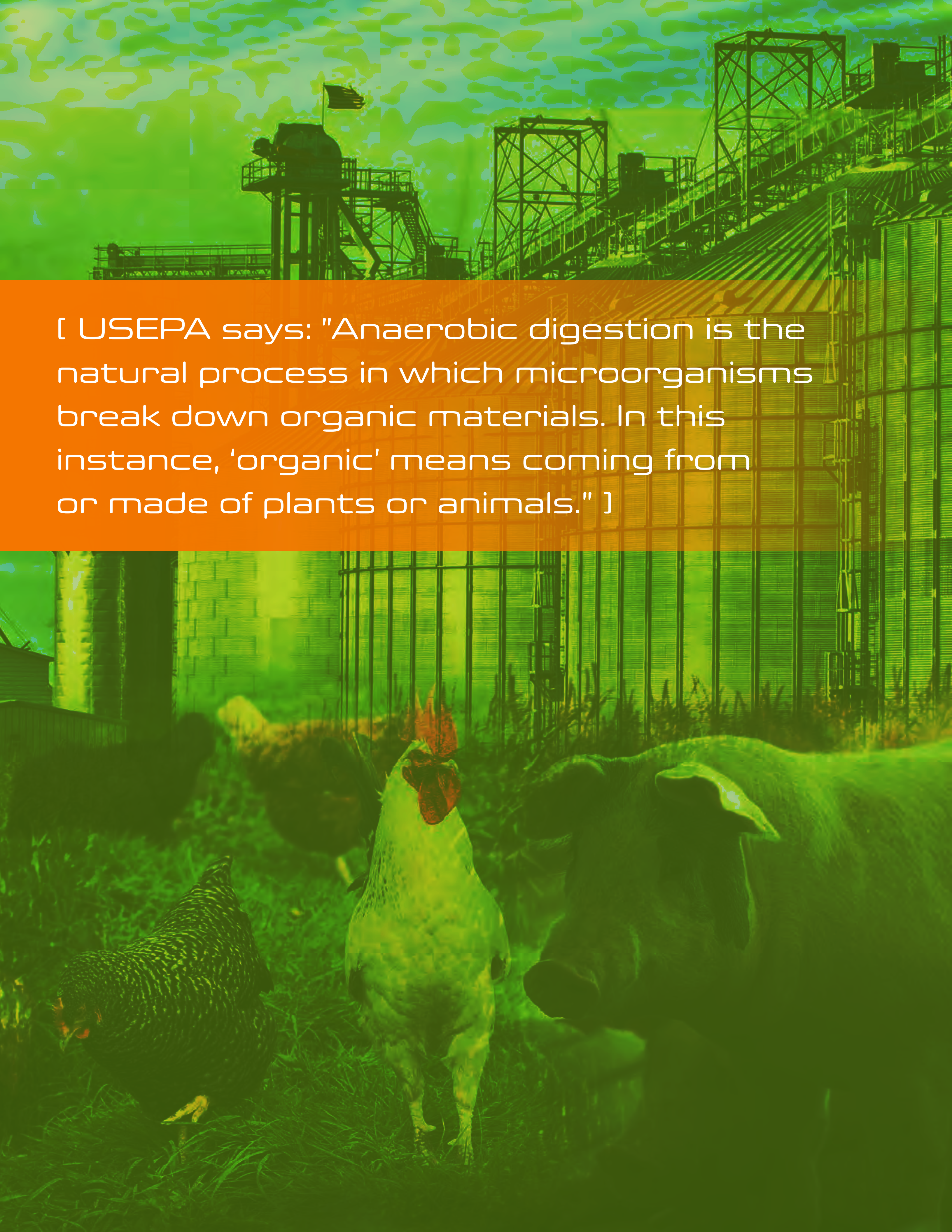
> [If the City of Madison decides to proceed with this project, the feedstock procurement would be the first task for the City to complete.]

Securing a variety of feedstock sources mitigates risk and ensures uninterrupted biogas production. Although there are other food waste sources, EcoEngineers believes the six categories listed in Table 12 used in the biogas estimates above have the highest potential for food waste generation, based on data reviewed. Once the facility is operating, the City could seek to increase the feedstock capacity of the digester facility with different feedstocks.

If the City of Madison decides to proceed with this project, the feedstock procurement would be the first task for the City to complete. More conversations — and possible training — with the different waste haulers in the City would be necessary to capture their interest, further assess potential feedstock availability, and review hauling frequencies.

The digester site would require a great deal of cooperation from the different waste haulers to secure feedstock supply. EcoEngineers recommends reducing the current landfill fee ($50 per ton) to incentivize haulers to transport food waste to the digester facility instead. To assess the potential project's revenue from tipping fees, EcoEngineers utilized a $45 per ton tipping fee, as outlined in section **10.0 Revenue Estimates and Financial Analysis**. Developing appropriate collection and separation methods will also be critical in maximizing the amount of food waste collected. Pest and odor control methods should be considered to help facilitate and encourage food waste separation by the different waste generators.

All the feedstock scenarios identified, including the "probable" scenario, were further assessed to develop a financial analysis of the project. This can be found in section **10.0 Revenue Estimates & Financial Analysis.**



[USEPA says: "Anaerobic digestion is the natural process in which microorganisms break down organic materials. In this instance, 'organic' means coming from or made of plants or animals."]

5.0 Anaerobic Digestion System

Anaerobic digestion (AD) is a biological process used to reduce and stabilize volumes of sludge, organic material, and manure. In the absence of oxygen, microorganisms break down the organic material in a four-step process:

1. **Hydrolysis:** Large protein molecules, fats, and carbohydrates — such as cellulose and starch — are broken down into amino acids, fatty acids, and sugars.
2. **Acidogenesis:** The compounds are fermented into a variety of volatile fatty acids.
3. **Acetogenesis:** Bacteria consume the fermented compounds and generate acetic acid, carbon dioxide, and hydrogen.
4. **Methanogenesis:** Methanogenic organisms consume these products to produce methane gas.

5.1 Anaerobic Digestion Technologies

AD technologies are typically classified into one of two categories: wet and dry. Wet, or low-solids, digesters are typically described as processing less than 15% total solids. Dry, or high-solids, digesters process material with a total solids content above 15%. Digesters may operate with a continuous flow or batch flow depending on the technology and can consist of single-stage or two-stage digestion. To summarize, most digestion technologies and equipment can be categorized into one of the following categories and offer the following advantages and disadvantages:

1. WET OR LOW-SOLIDS SYSTEMS

a. Single-stage continuous flow

i. Advantages: Simple to design and operate compared to multi-stage AD, lower capital and O&M cost compared to multi-stage

ii. Disadvantages: Lower organic loading rate required, higher residence times required, pretreatment to remove inert compounds is typical

b. Two-stage continuous flow

i. Advantages: Higher organic loading rate, lower residence times, increased methane production

ii. Disadvantages: Higher capital and O&M costs, complex operations compared to single-stage

2. DRY OR HIGH-SOLIDS SYSTEMS

a. Single-stage continuous flow

i. Advantages: Similar biogas generation rates compared to wet systems, dilution often not required, increased organic loading rates, minimal pretreatment required, system more tolerant of contaminants

ii. Disadvantages: Handling and mixing challenges, specialized pumps, conveyors, and augers are necessary to move high solids materials, higher capital costs

3. BATCH SYSTEMS

a. Single-stage, low solids

i. Advantages: Simple to design and operate compared to multi-stage AD, lower capital and O&M cost compared to multi-stage

ii. Disadvantages: Reduced or uneven biogas production, lack of stability, larger footprint, intermittent storage in between batches required

Most digesters in the U.S. are wet, single-stage continuous systems.[xv] Single-stage systems are generally less expensive and are simpler to design, build, and operate. However, the single-stage have a limitation. Because all of the stages of anaerobic digestion take place in a single tank, the acid produced during the hydrolysis stage can be difficult for the methanogenic organisms to tolerate. Thus, the organic loading rate to the digester is limited.[xvi] Two-stage digesters avoid this problem by separating the methanogenic organisms from the low-pH stages of digestion. This process pre-treats the material and allows for higher organic loading rates in the second stage of the process. However, the complexity of two-stage systems and the assumed expense of the installation of multi-stage systems frequently outweighs the benefits of improved digestion and higher loading capabilities.[xvii] Nevertheless, multi-stage digestion systems hold a lot of potential value for facilities that are limited on digestion capacity, adding a pretreatment or "first stage" to their anaerobic digestion system could help solve their capacity challenge.

The digestion system that would likely be selected for the City of Madison is a dry type, single-stage, continuous, high-rate system; this will ultimately depend on the properties, including TS%, of the food waste collected for the project. In this study, it was assumed that the food waste would be 18% TS; however, until testing is done by the City of the actual food waste procured for the project, the TS% is only an estimate. Once tested, if the TS% is higher than 15%, it still does not mean a dry type digester would be needed. Any pretreatment to the incoming feedstock should also be considered, as this may introduce extra water, where a wet type digester may be necessary. EcoEngineers recommends the City to test food waste samples once feedstock supply is established. Based on the food waste characteristics, the design of the digester system would be determined.

High-rate systems are completely mixed and heated; standard-rate systems aren't and require much longer retention times to achieve similar levels of treatment.[xviii] The digester would likely be operated under mesophilic conditions, meaning it is kept within a temperature range of 85 - 100°F.[xix] Mixing is typically accomplished by gas recirculation, mechanical mixers, pumping, or draft tube mixers.[xx] The feed to the digester should be pumped continuously or on a consistent cycle to maintain consistent conditions.[xxi] As fresh feedstock is added, a corresponding volume is drawn off to maintain a constant level within the digester. This digested sludge is typically about half as concentrated as the incoming feed, given that the digester is well-mixed, and the volatile solids are reduced by 75-80% and released as biogas.[xxii]

The digester tanks themselves can be cylindrical, rectangular or egg-shaped. Rectangular tanks do not allow for complete mixing, and the most common design in the U.S. is a short, vertical cylinder.[xxiii] Cylindrical tanks can range from 20- 125 feet in diameter and are designed for a water depth between 25 feet and 45 feet.[xxiv] **An example of a vertical cylinder agricultural digester is shown in Figure 19.**

FIGURE 19: CYLINDRICAL DIGESTERS AT AGRIRENEW IN IOWA[xxv]

Egg-shaped digesters are designed to prevent accumulation of grit on the bottom of the tank and are very common in Europe.[xxv]

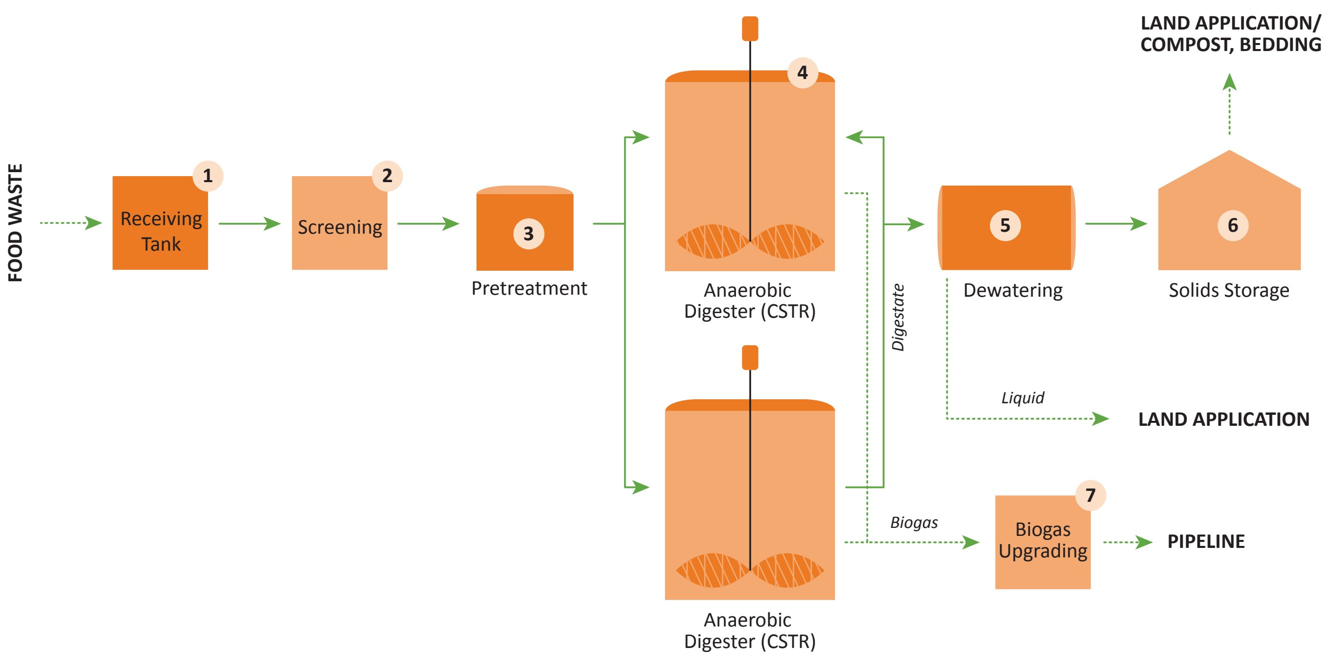
Another important aspect of digester design is the cover. There are two main types of digester covers: fixed and floating. The head space above the liquid level is filled with biogas and not air so accommodating changes in liquid level is critical. As liquid levels fall, the head space pressure decreases, and air cannot be drawn into the vessel. When liquid levels increase, the head space pressure increases, and biogas cannot be pushed out of the digester. Floating covers are designed to eliminate the potential problems associated with liquid-level changes because the cover moves with the liquid level (it floats on top of the digester contents) and has a fixed head space volume for biogas to accumulate. Fixed digester covers are vulnerable to liquid-level changes creating pressure problems and require external biogas storage. This allows biogas to be drawn into the digester as needed and creates a destination for biogas that is forced out of the digester as liquid level increases.

The digester will need a heat source to maintain mesophilic temperatures. Typically, this comes from a boiler producing steam with accompanying sludge-steam heat exchangers. The amount of heat needed and the style and size of the boiler and heat exchanger system will be evaluated as part of the design phase.

5.2 Preliminary Process Flow

A preliminary process flow diagram of the conceptual digester system is shown in Figure 20.

FIGURE 20: PROCESS FLOW FOR ANAEROBIC DIGESTER



Food waste is processed in the pretreatment system until its ready to be sent as feedstock to the digester. After digestion, the effluent from the digester is dewatered and the resulting liquid can be recycled back for farmland application. The digestate liquid will be high in nutrients — such as phosphorous, nitrogen, and potassium — and can be stored at the site to sell to later be sold to farmers to use as fertilizer for crops. These nutrients may also be removed from the liquid at the project's site. The resulting water could then be discharged to a local water source. Another option is for liquids to be send to wastewater facility for treatment.

The dewatered solids are stored before being disposed of through land application as compost or as bedding material. The biogas produced during digestion is collected with a small blower, which "pulls" the biogas out of the digester and routes it to the biogas upgrading plant. First, the biogas will have the hydrogen sulfide removed; then the carbon dioxide will be separated; and finally the contaminants are taken out. Once the biogas has been upgraded to pipeline-quality RNG, it will be compressed and tested at the pipeline interconnect station before injection into the natural gas pipeline. This system in Figure 20 is described in more detail below.

1. RECEIVING TANK

The food waste will be offloaded onto a large tank or bin. The material will likely be stored in piles and moved to screening process.

a. **Inputs:** Packaged and non-packaged food waste and contaminants (if not properly separated prior to digester facility)

a. **Outputs:** Packaged and non-packaged food waste and contaminants (if not properly separated prior to digester facility)

2. SCREENING

The screening process includes a visual inspection of waste to remove any unwanted contaminants, such as paper, metals, etc. This may be an optional step in the process with a mechanical pre-treatment process in place, as listed in step 3.

a. **Inputs:** Packaged and non-packaged food waste and contaminants (if not properly separated prior to digester facility)

a. **Outputs:** Non-packaged food waste

3. PRE-TREATMENT

A mechanical pre-treatment system may help remove packaging material and pre-process the food waste before feeding it into the digester system. Pre-processing may include grinding of the material into smaller pieces. The recovered food waste is then conveyed to the digester system.

a. **Inputs:** Packaged or non-packaged food waste

a. **Outputs:** Recovered food waste (organics)

4. ANAEROBIC DIGESTERS

The digesters will likely be continuously stirred tank reactors (CSTRs) that are heated to maintain mesophilic conditions. Mixing and heating help optimize digester performance by keeping the microorganisms constantly exposed to food and in conditions conducive to their life cycle. Two digesters in parallel allows for uninterrupted operation should there be a mechanical problem or maintenance work done on the other digester. It also allows for a smaller footprint per digester. However, final design conditions including the volume of feedstock to be processed and other site and operational factors will determine the number and size of the digester(s). The pressure inside the head space of the digester can vary depending on how fast the biogas is drawn out, so some storage of biogas is possible inside the digester. The biogas is pulled out of the digester by a blower and sent to the biogas upgrading plant.

a. **Inputs:** AD feedstock stream, electricity, heat

a. **Outputs:** Digestate, biogas

5. DEWATERING

The digestate flowing out of the digesters has a lower solids concentration than the incoming feed, as a portion of the solids has been converted to biogas. To save on storage and potential hauling costs, the digestate is dewatered. The digester effluent is typically dewatered using a centrifuge, screw press, or belt filter press to produce a high-solids byproduct rich in nutrients and suitable for land application or animal bedding. The liquid digestate stream from the dewatering system contains high concentrations of nitrogen and phosphorus.

a. **Inputs:** Digestate, chemicals to aid in dewaterability

a. **Outputs:** Solids, liquid

[Mixing and heating help optimize digester performance by keeping the microorganisms constantly exposed to food and in conditions conducive to their life cycle.]

6. SOLIDS STORAGE

The solid stream exiting the dewatering process will be conveyed to a storage unit. This unit will likely be a covered concrete slab equipped with a load-out system, so the solids can be loaded onto trucks. This solid material also contains valuable nutrients, and can be land applied in accordance with Wisconsin Department of Natural Resources Environmental Management laws, used as compost, or as animal bedding.

a. **Inputs:** Dewatered digestate solids, electricity, fuel for front-end loaders

a. **Outputs:** Dewatered digestate solids

7. BIOGAS UPGRADING

The biogas upgrading plant will remove all contaminants in the biogas to produce a pipeline-quality renewable natural gas for injection into the pipeline. This process is outlined in detail in **7.0 Biogas Upgrading Process**.

a. **Inputs:** Raw biogas, electricity, adsorbent medias

a. **Outputs:** Condensate, exhaust gas, waste adsorbent media

5.3 Operational Requirements and Digestate Overview

Depending on the ultimate size of the facility, EcoEngineers estimates that three to five full-time equivalents (FTEs) will be needed to operate and maintain the anaerobic digestion and biogas upgrading systems based on discussions and experience with operational facilities. Connections to electrical and natural gas utilities, telecommunications, water, and sanitary sewer/septic systems will be needed. A detailed operation and maintenance (O&M) estimate is shown in Section 9.0.

The digestate influent consists of total solids (TS), the total amount of solids in the influent, volatile solids (VS), the solids able to be converted to biogas, and liquids. It is assumed that 70% of the volatile solids entering the digester are converted to biogas. **Table 17 shows expected digestate characteristics for the low-, moderate-, and high-feedstock scenarios.**

TABLE 17: DIGESTATE QUANTITIES SUMMARY

	INFLUENT			EFFLUENT		
	TS [lbs./day]	VS [lbs./day]	Liquids [gal/day]	TS [lbs./day]	VS [lbs./day]	Liquids [gal/day]
Low	13,800	10,994	7,475	6,072	7,696	7,475
Probable	29,600	23,671	16,201	13,024	16,570	16,201
Moderate	51,600	41,329	28,316	22,704	28,930	28,316
High	86,400	69,149	47,194	38,016	48,404	47,194

EcoEngineers recommends that digestate streams be dewatered to concentrate solids, as lower values allow liquids to flow freely off the pad. If the streams are dewatered through press or centrifuge, the resulting nutrient-rich liquid stream would be available to be land applied, composted, or used for animal bedding.

If the dewatered, solid digestate stream were to be dried to approximately +90% solids, it could add another $2-3 million in capital costs, plus the additional natural gas costs to operate the drying system. Dewatering to 30% is sufficient for land application, and drying was not assumed for this analysis. There is also an option to sell the digestate solids as a product rather than pay to dispose of it as a waste. There are a few major cities around the country (Seattle, Washington D.C., Houston, Philadelphia, etc.[xxvi]) and at least one private company, Magic Dirt, that market and sell biosolids commercially. However, it takes time to develop a market for the material. The financial analysis in this report assumes a five-year window to establish the market with the goal to make solids disposal a net-zero expense.

Final nutrient concentrations will depend on the final feedstock mix and the anaerobic digestion system and operation. In general, the majority of the nutrients introduced to the digester end up in the liquid portion of the digestate. A digester manufacturer reported that typically 99% of the incoming nitrogen and 100% of the incoming phosphorus end up in the digestate. The phosphorus in the liquid portion of the digestate may limit land application.[xxvii] Removing the phosphorus through struvite recovery can increase the ability to land apply the digestate.[xxviii] Additionally, struvite can be marketed as a slow-release fertilizer product, and its removal increases dewaterability and reduces polymer use in dewatering.[xxix] Laboratory analyses of all feedstocks and input on digester performance from manufacturers is needed to develop a detailed mass and energy balance.

ecoengineers people-driven solutions

6.0 Biogas Usage Options & Comparative Values

Biogas is primarily a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic materials in the absence of oxygen (anaerobic). Biogas production from the anaerobic digestion (AD) of residual organic feedstock is an established process and can be implemented as an effective energy recovery and reuse strategy wherever there are wastewater treatment plants, landfills, and/or animal feedlots.

The methane from biogas is chemically identical to natural gas from fossil sources and can displace it after proper conditioning and injection into a natural gas pipeline.

The injected RNG will then be used to produce renewable electricity or compressed natural gas (CNG).

As shown in Figure 21, specific and commercially proven uses for biogas include:

- **Thermal applications:** Biogas is used directly on site to heat digesters, buildings, or maintenance shops; to fuel boilers or kilns; and to generate heat or steam.
- **Power generation:** Electricity is produced through an internal combustion engine, gas turbine, or micro-turbine technologies for on-site use or sale to the electric grid.
- **Combined heat and power:** CHP systems increase overall energy efficiency of electricity systems by producing heat and electricity at the same time.
- **Vehicle fuels:** Upgraded biogas can be converted to fuels including compressed natural gas, liquefied natural gas, hydrogen, and liquid transportation fuels.

FIGURE 21: BIOGAS PURIFICATION LEVELS AND ASSOCIATED USES

Desired end-use for the biogas will dictate the amount of purification (upgrading) required. Minimal upgrading is needed for biogas to be used in a boiler for heat production and is typically limited to drying and hydrogen sulfide removal.

To use biogas in a generator for electricity or heat production, minor upgrading is required, such as removal of hydrogen sulfide and siloxanes. Due to vehicle engine specifications, significant upgrading is necessary to use biogas as vehicle fuel. Nearly all non-methane components must be removed, including hydrogen sulfide, siloxanes, oxygen, water, carbon dioxide and nitrogen. Purification of biogas for pipeline injection is similar to vehicle fuel but may vary according to requirements of the pipeline owner.

The estimated values of biogas based on how it is used and the values of the commodities to be replaced is shown in Table 18. Uses that require significant upgrading (pipeline injection) will incur higher capital investment. The data in Table 18 demonstrates that pipeline injection for transportation fuel offers the potential for a greater revenue stream. Participation in governmental incentive programs is essential to realize the full revenue potential of this option.

TABLE 18: BIOGAS VALUES BASED ON USE AND COMMODITY REPLACEMENT VALUES

		Low		High	
		Commodity Price*	Biogas Value per MMBtu	Commodity Price	Biogas Value per MMBtu
Commodity	Natural Gas (MMBtu)	$2.00		$4.00	
Biogas Use	Boiler Steam Production		$2.00		$4.00
Commodity	Electricity (kW)	$0.04		$0.08	
Biogas Use	Generator Electricity Production[xxx]		$3.86		$7.76
Commodity	LCFS Credit	$100.00		$215.00	
Commodity	D3 RIN Credit	$0.30		$1.00	
	CI Score	0		-75	
Biogas Use	Pipeline Injection-Vehicle Fuel (D3 RINs & LCFS)		$13.88		$50.71

*Commodity prices are approximated and will vary based on multiple local, regional, and national factors

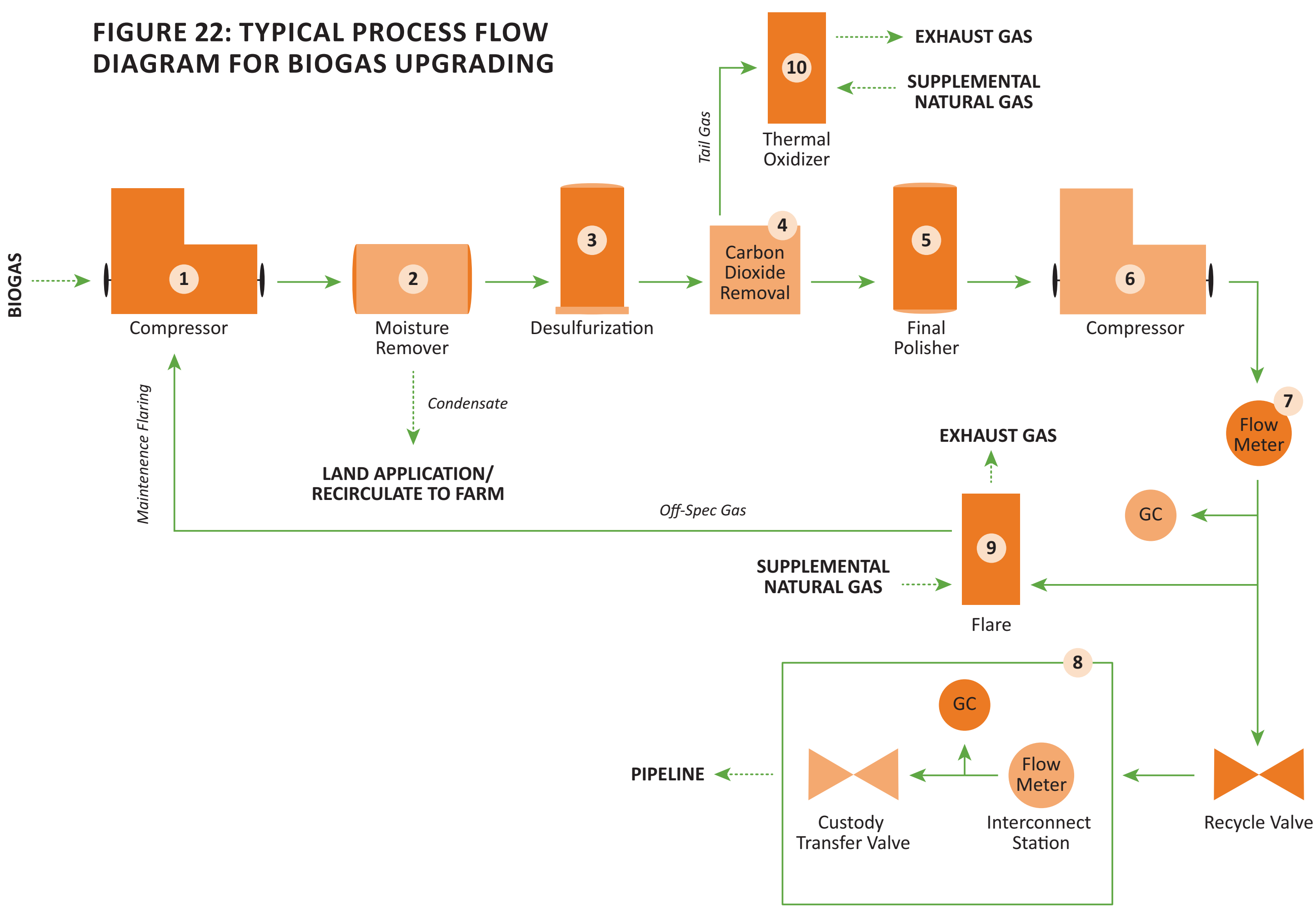
7.0 Biogas Upgrading Process

Raw biogas produced from an agricultural waste digester typically contains 55-65% methane, 52-62% carbon dioxide (CO_2), and 1-3% nitrogen, oxygen, hydrogen sulfide (H_2S), siloxanes, and volatile organic compounds (VOCs). To generate a renewable fuel capable of being utilized as transportation fuel and injected into a pipeline, the agricultural waste gas needs to be upgraded to "pipeline quality." This means the upgraded agricultural waste gas, or RNG, must meet a pipeline company's gas specifications and minimum standards. To achieve pipeline quality, most, if not all, of the non-methane components have to be removed. With the lack of a national pipeline standard, each pipeline company has different requirements. The primary components typically monitored and measured by pipeline companies include:

- Heating value/Btu content/methane content
- Oxygen, O_2
- Hydrogen sulfide, H_2S
- Total sulfur
- Carbon dioxide, CO_2
- Water/water vapor
- Temperature

7.1 Process Overview

FIGURE 22: TYPICAL PROCESS FLOW DIAGRAM FOR BIOGAS UPGRADING



1. COMPRESSOR

The first compression unit is typically packaged with the core carbon dioxide removal system.

2. MOISTURE REMOVAL

The moisture removal block represents a chiller that will dry the biogas.

3. DESULFURIZATION

The desulfurization unit will be either an adsorptive media-based system or a biological or chemical scrubber system. The choice between the two will depend on the quantity of hydrogen sulfide present in the raw biogas. A detailed description of this unit and other potential "pre-treatment" steps is shown in Section 7.1.6.

4. CARBON DIOXIDE REMOVAL

This step is sometimes referred to as the "biogas upgrading system" because it is the core technology supplied by the biogas upgrading technology vendors. The pretreatment, compression, and moisture removal are buy-outs for these vendors. The carbon dioxide removal system will be a skid-mounted, turnkey package that will remove the carbon dioxide from the biogas. A membrane system was used for this analysis, but there are other technology options for this step. Some membrane systems can also remove the bulk of the hydrogen sulfide from the biogas, depending on the level present in the raw biogas. Not all membrane systems can do this, so depending on the upgrading system vendor was selected, upstream hydrogen sulfide removal may be required.

5. FINAL POLISHER

The final polisher is usually a sacrificial-media based scrubber to ensure that all the VOCs/siloxanes/ hydrogen sulfide has been removed to pipeline-quality levels. The media in this vessel will have to be changed periodically, depending on how much gas flows through it and the level of contaminants present in the gas, as well as the size of the polisher. It can be sized larger or smaller to change the frequency of the change outs.

6. COMPRESSOR (FINAL)

The final compression will depend on the destination of the gas but can be provided by the biogas upgrading system vendor or procured independently.

7. FLOWMETER/GC (QUALITY MONITORING)

The flowmeter and in-line gas chromatograph (GC) represent all the quality monitoring equipment that is needed to monitor the finished gas quality upstream of the pipeline interconnect station – methane, oxygen and nitrogen, moisture, temperature, and hydrogen sulfide (VOCs and siloxanes have to be measured with a grab sample and laboratory analysis). This item is crucial; it allows the biogas producer to divert gas that does not meet pipeline requirements before it reaches the interconnect station, and thus the "official" quality monitoring that the natural gas company will be analyzing. This protects the producer from being shut-in by the pipeline and filling any high-pressure, finished-gas pipeline with off-spec gas that has no practical method of disposal

8. INTERCONNECT STATION

The interconnect station will vary depending on the pipeline, but usually includes quality monitoring, pressure regulation and safety valves, a flowmeter, and a custody transfer valve.

9. FLARE

The flare is the final destination for the gas when it cannot go into the pipeline or when the upgrading system is down for maintenance. Neither the biogas nor upgrading RNG can be released to atmosphere because of clean air regulations, although firm restrictions will be established by the local government entity with jurisdiction over air quality.

10. THERMAL OXIDIZER

The thermal oxidizer will destroy any potential air pollutants present in the tail gas stream. Restrictions on pollutants released to the atmosphere will be established by the local government entity with jurisdiction over air quality.

The four most common technologies used for the carbon dioxide removal, or "biogas upgrading system," are pressure swing adsorption, water scrubbing, chemical scrubbing, and membrane filtration. It is important to have a baseline understanding of each technology, so the owner and operator can weigh the pros and cons and make an informed decision on which technology to use.

7.1.1 Pressure Swing Adsorption (PSA)

Pressure swing adsorption utilizes a selective media to separate carbon dioxide and other compounds from the biogas. First, the biogas is compressed and fed into a pressure vessel containing the media. The carbon dioxide is adsorbed by the media while the methane passes through. The media has a limited capacity to adsorb CO_2, so at fixed intervals the pressure vessel will go into a "purge" cycle. During this cycle, the flow of raw biogas is shut off, and a vacuum pump system is used to decrease pressure to allow the CO_2 to desorb and flow into a "tail gas" stream. This stream will contain residual methane that requires further treatment, usually by a flare or thermal oxidizer (TOX). Normally, the tail gas stream does not have sufficient heating value for combustion, so it is supplemented with natural gas. The "pressure swing" cycle is continuous in pressure swing systems, so multiple pressure vessels are necessary to ensure the system is always producing RNG.

Depending on the manufacturer and the type of media used, PSA can remove limited amounts of nitrogen and oxygen, but most do not remove hydrogen sulfide. One manufacturer's system is capable of removing hydrogen sulfide through the PSA process using a proprietary media. Remaining manufacturers' technologies will require pretreatment of the biogas to prevent hydrogen sulfide from corrupting the media used in traditional PSA systems. **Figure 23 outlines a typical PSA process.**

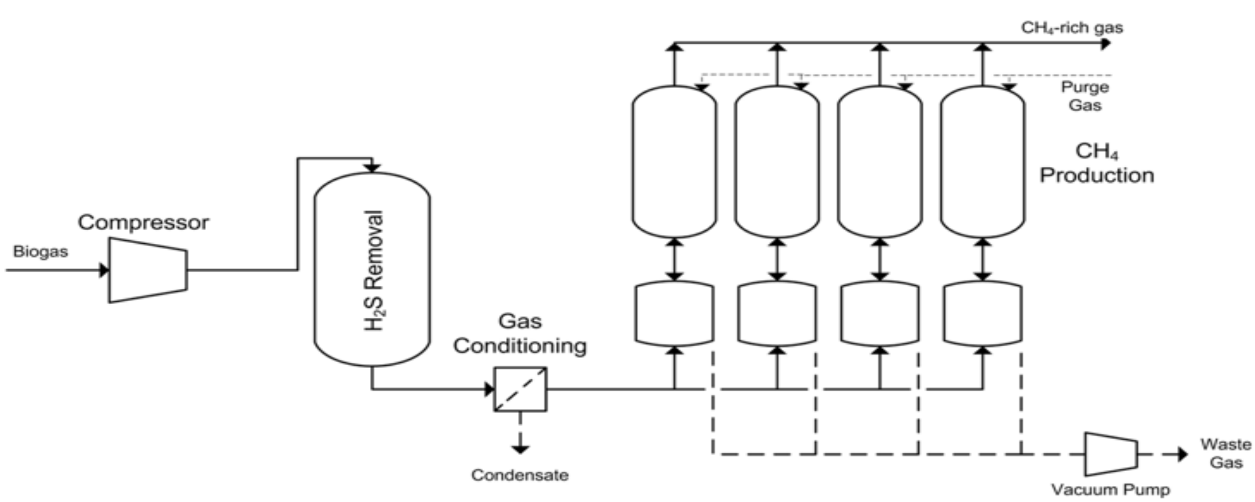
The benefits of a PSA system are:

- Proven technology with 50-plus installations in the U.S.
- Typical uptime is > 98%
- No water required
- No heating required
- May not require H_2S pretreatment

The disadvantages of the PSA process are:

- Higher electrical usage
- Lower efficiency/methane recovery (85-92% typically)
- Requires media replacement
- Many mechanical components (valves, blowers, etc.)

FIGURE 23: TYPICAL PROCESS SCHEMATIC OF A PSA SYSTEM[xxxi]

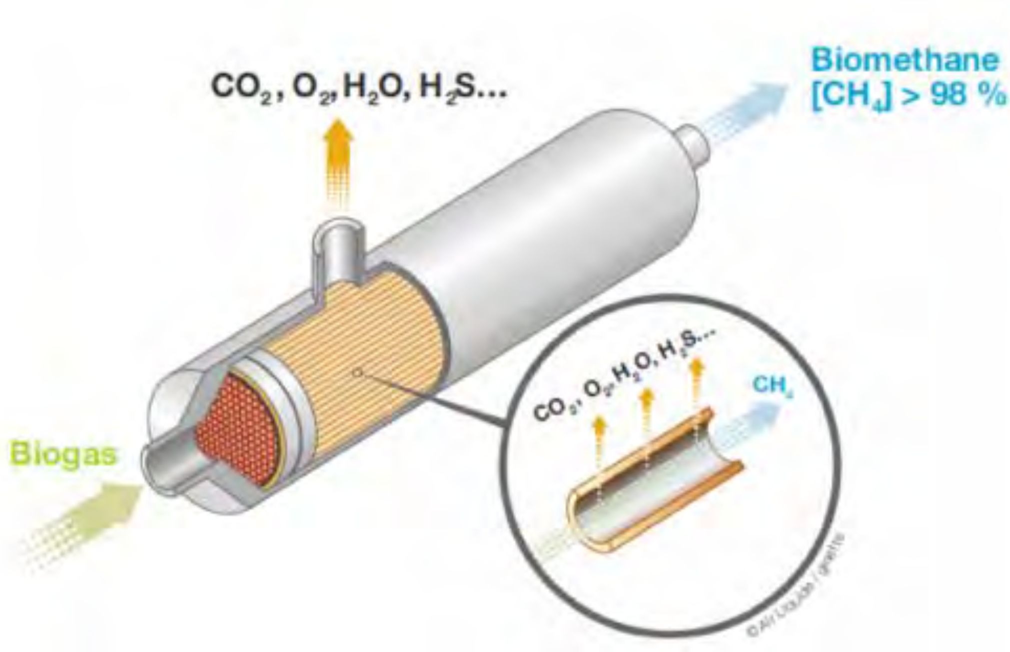


7.1.2 Membrane Filtration

A biogas upgrading system that includes membrane filtration consists of a pretreatment step to remove water and hydrogen sulfide, followed by compression of the biogas before injection into a membrane filtration system. **The membranes are permeable, and each of the components of the biogas permeate at different rates (see Figure 24).** In this example, carbon dioxide permeates the fastest, followed by oxygen, water, hydrogen sulfide, etc. Methane permeates slowly, which is why there are only small amounts of methane in the permeate stream. However, the performance of these systems is affected by the back pressure on the permeate side of the membranes and the flow rate through the membranes.

The pretreatment step is necessary to prevent condensation during the compression stage and to lower the concentration of hydrogen sulfide sent to the membrane filter. The membrane will separate hydrogen sulfide but is not capable on its own of removing enough of the H_2S to meet quality requirements. There is one vendor in the market that provides a membrane system that can handle much larger concentrations of H_2S, but as of this writing, it has only been applied to conventional natural gas installations.

FIGURE 24: GRAPHICAL REPRESENTATION OF MEMBRANE FILTRATION[xxxii]



Membrane filtration will remove carbon dioxide and some hydrogen sulfide and oxygen. Recycle streams and multiple stages of membranes are used in different configurations by membrane manufacturers to achieve the quality of gas and methane recovery required. **Figure 25 shows a typical process flow diagram of a membrane filtration system.**

The benefits of membrane filtration systems are:

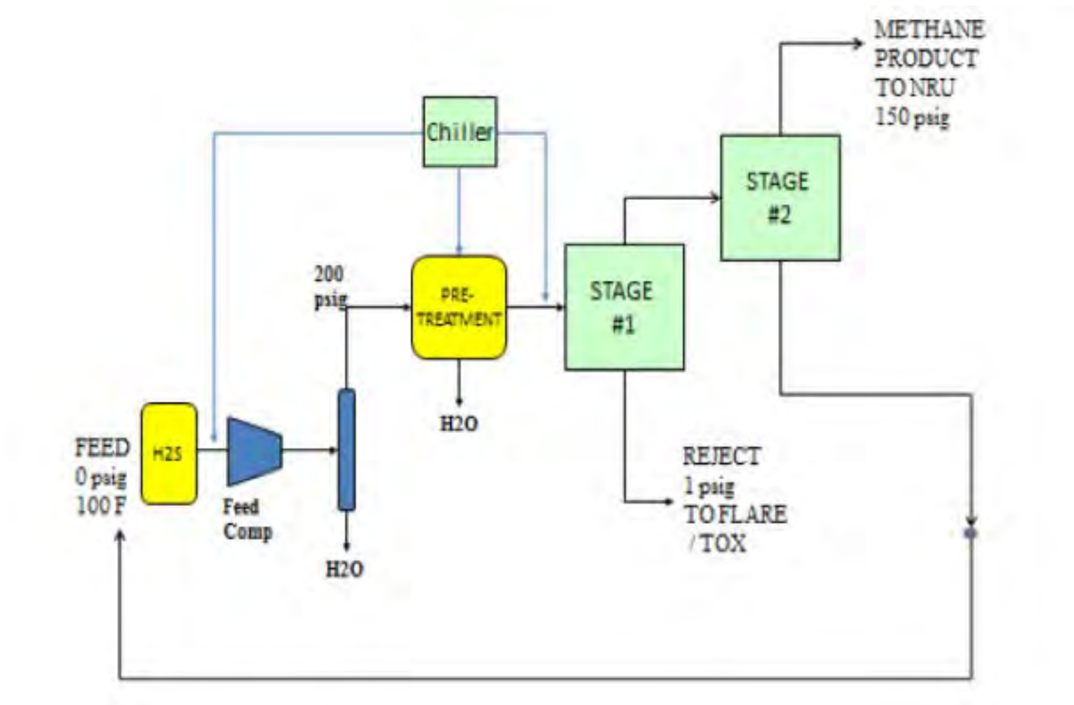
- No water, chemicals, or heating required
- Few moving parts
- High methane recovery (up to 99%)
- > 95% uptime, some can be > 98% (depending on configuration)

The disadvantages of membrane systems are:

- Membranes will have to be replaced every 5-10 years
- Requires pretreatment of H_2S
- Requires media-based equipment for siloxane removal

ecoengineers people-driven solutions

FIGURE 25: TYPICAL PROCESS SCHEMATIC OF A MEMBRANE FILTRATION SYSTEM[xxxiii]



7.1.3 Water Scrubbing

Water scrubbing utilizes a counter-current water shower that scrubs the undesirable gases, such as carbon dioxide and limited amounts of hydrogen sulfide, out of the biogas stream. The biogas is compressed and sent into the bottom of the scrubber, where it flows upward through packing material. Meanwhile, water flows downward, collecting the carbon dioxide and hydrogen sulfide from biogas. The scrubbed biogas exits the top of the scrubber and goes through a gas dryer. The "dirty" water exits the bottom of the scrubber and is recycled using a stripping column. The air stream exiting the stripping column contains impurities such as H_2S that were removed from the biogas, and therefore, must be treated before being released to the atmosphere. A key characteristic of a water scrubber system is that it does not remove nitrogen or oxygen from the biogas. The water scrubbing process can typically only remove up to 2,500 ppm of hydrogen sulfide. **Figure 26 (page 54) shows a typical process flow diagram of a water scrubbing system.**

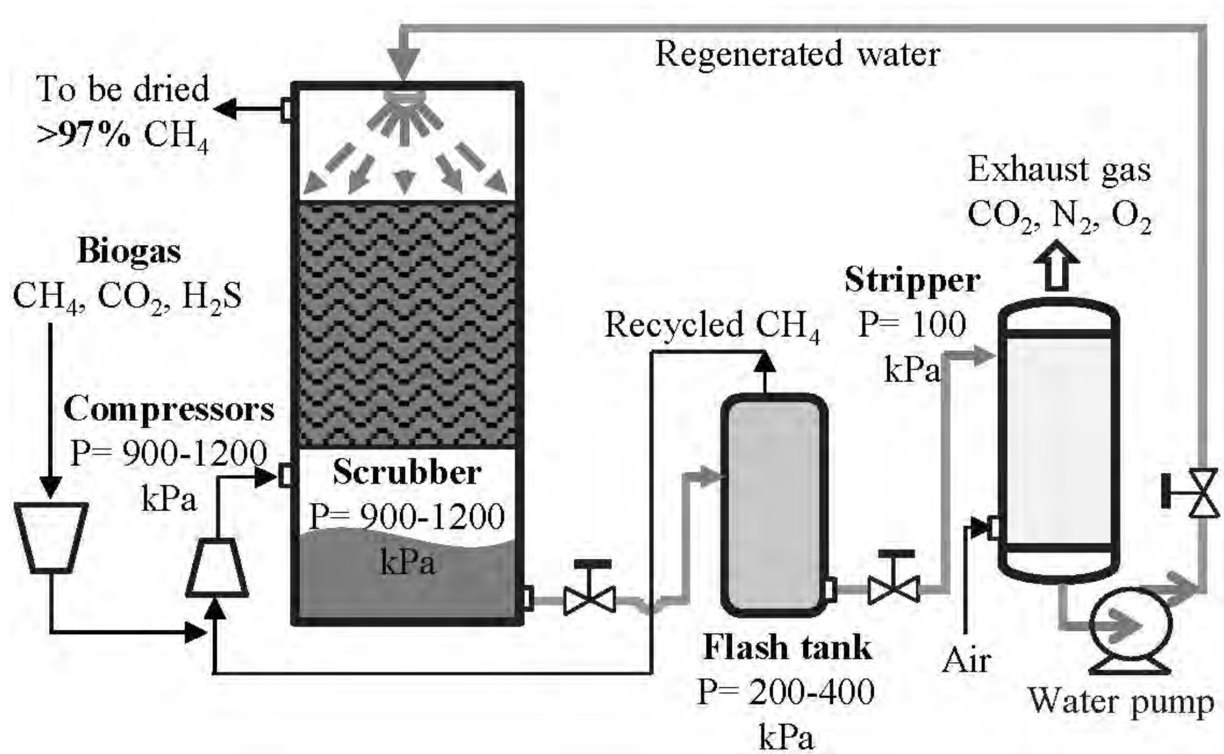
The benefits of a water scrubbing system are:

- No heating required
- No chemicals required
- Can remove H_2S up to 2,500 ppm
- Proven technology with 20-plus years of experience
- Typical uptime is 95-96%

The disadvantages of a water scrubbing system are:

- Often times additional processes (like PSA) are paired with water scrubbing systems when pipeline specifications are strict
- Water required (potable water is preferred, although clean process water can work)
- Wastewater generated
- Requires pretreatment for H_2S concentrations > 2,500 ppm

FIGURE 26: TYPICAL PROCESS SCHEMATIC OF A WATER SCRUBBING SYSTEM[xxxiv]



7.1.4 Chemical Scrubbing

A chemical scrubbing biogas upgrading system is similar to a water scrubbing system. The biogas passes through an absorber column, where it is counter-currently washed with a solution of amines. The amines chemically bind the CO_2 and H_2S, and methane leaves from the top of the column. The amine solution is recycled to a stripper column similar to the water scrubbing process, however chemical scrubbing requires heat to be added. The stripper column has a boiler, both to boil the amine solution and produce steam. This improves the speed and efficiency of the release of CO_2 and H_2S from the amine solution. The steam/CO_2/H_2S mixture leaves from the top of the column, the steam is condensed and returned to the stripper, and the CO_2 and H_2S leave the system for further treatment in the tail gas stream.

Amine scrubbing is a mature technology but is still under some development. There are many installations of this technology in Europe but none in the U.S. This technology removes carbon dioxide and a limited amount of hydrogen sulfide but will not address nitrogen or oxygen. The purified biogas requires drying upon leaving the system. **Figure 27 shows the typical process of an amine scrubbing system.**

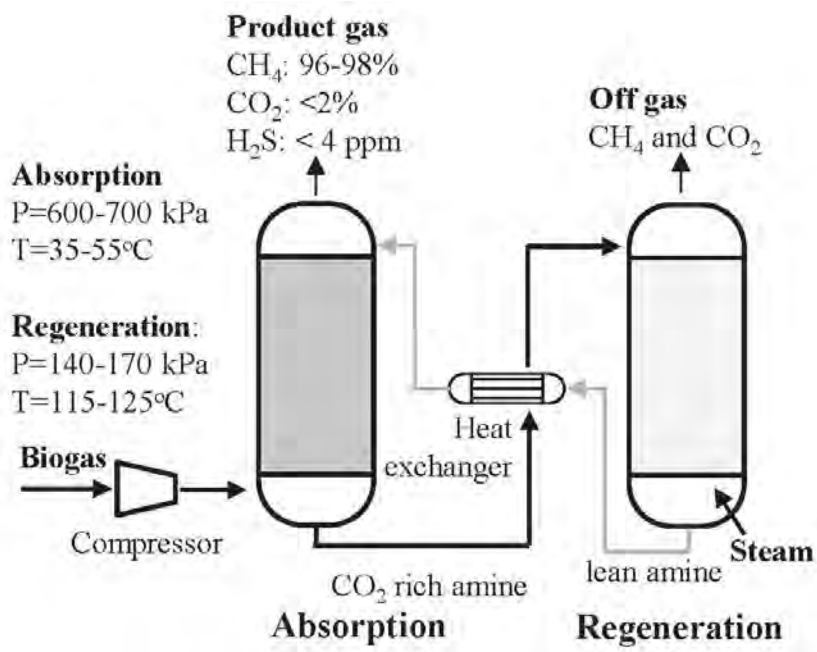
The benefits of a chemical scrubbing system are:

- No water required
- High methane recovery (up to 98%)
- 96% uptime of the equipment

Disadvantages of a chemical scrubbing system are:

- Heating and water cooling are necessary
- Chemical amine solution required
- Requires pretreatment for H_2S in most cases
- Common operational issues include failure to meet specifications, foaming, amine loss and corrosion

FIGURE 27: TYPICAL PROCESS SCHEMATIC FOR A CHEMICAL SCRUBBING SYSTEM[xxxv]



7.1.5 Biogas Upgrading Technology Comparison

It is important to clearly define the available space and utilities and operator experience prior to deciding on the best technology for a biogas upgrading project. Additionally, the quality of the raw biogas and the requirements of the receiving pipeline are important factors, as each technology has slightly different recovery rates and removal capacities. For example, a membrane system may offer a high methane recovery but may remove little to no nitrogen and oxygen and will likely require separate treatment for hydrogen sulfide, siloxanes, nitrogen and oxygen. Consequently, a complete system may require membranes, a small PSA system, a sacrificial-media system (like an iron sponge), a nitrogen rejection unit (NRU), and a catalytic oxygen removal system.

Based on EcoEngineers' experience, the difference between the technologies is insignificant when compared using a 20-year life-cycle cost analysis. EcoEngineers recommends consideration of the following criteria for comparison and selection of the most appropriate technology (and vendor) for the City:

- Capital cost
- O&M cost
- Number of installations and experience
- Methane recovery rate
- Historical uptime information
- Performance guarantees by vendors

Site visits to existing installations will allow the City to interact directly with operators and vendor representatives and to gain a clearer understanding of system operations. Determination of needs along with evaluation and comparison of costs and technologies is performed during the preliminary design phase.

7.1.6 Other Required Equipment

In addition to the core upgrading system, several components will be necessary to achieve pipeline-quality requirements and to optimize performance of the biogas upgrading equipment.

7.1.6.1 Pretreatment

Pretreatment is often required to remove hydrogen sulfide, siloxanes and VOCs because the core upgrading system cannot remove these constituents to the extent needed for pipeline quality. Since hydrogen sulfide and siloxanes can be hard on equipment, up-front removal will reduce maintenance costs. Pretreatment processes include:

- **Wet Scrubbing:** As previously discussed in Sections 7.1.3 and 7.1.4, biogas contaminants are washed or dissolved into water or a chemical fluid.

- **Dry Scrubbing**: Biogas passes over packing material/media which absorbs the contaminants. Media used in dry scrubbers can be sacrificial, like a hydrogen sulfide "iron sponge". Once the sponge is saturated with the contaminant, it must be removed and discarded. Other media, such as PSA media, is regenerable. The dry scrubber may be a small PSA system or a temperature swing adsorption system (TSA).

Applicable air-permitting regulations should be considered when selecting a pretreatment technology. If either a wet scrubber or dry scrubber with regenerable media is used, the stripped contaminants will be released in a waste air stream and enter the atmosphere without further treatment.

Dry-scrubbing, sacrificial medias capture the contaminants but must be discarded as solid waste. It will be important to work closely with the design team, including the engineer and the vendors, to explore and evaluate ramifications of pretreatment processes and equipment prior to selection.

7.1.6.2 Waste Gas Treatment

Waste gas results from failure to meet quality specifications, production downtime due to maintenance or other problems, or issues preventing injection into the pipeline. The simplest and most effective option is to combust the waste gas. It is possible to store waste gas, but a back-up disposal method must exist in case of storage limitations. Raw biogas that is produced during system maintenance must be destroyed.

The reject gas stream from the upgrading system is usually referred to as "tail gas." This gas requires treatment prior to atmospheric release. Tail gas is a carbon dioxide-rich stream, and depending on the methane recovery rate, contains several percent (by volume) of methane. Contingent upon the level of pretreatment, small amounts of hydrogen sulfide, VOCs or siloxanes may also be found in tail gas. Treatment and/or disposal of waste gas is another key factor in the selection of the pretreatment equipment. The fewer contaminants in the gas before it enters the core upgrading system, the less treatment the tail gas will need.

Several waste gas treatment technologies are available, including:

1. **Thermal oxidizer or flare:** A thermal oxidizer is a burner designed to destroy waste gas streams with low Btu value. Supplemental natural gas is often required to aid in startup, and depending on the design, to aid main combustion. Design options include regenerative thermal oxidizers that use less supplemental natural gas. Some manufacturers are able to combine the thermal oxidizer burner with the flare in one unit. The required temperature to adequately destroy contaminants and volume of gas to be destroyed are key considerations in choosing waste gas technology.

2. **Dry scrubber:** A non-combustion treatment option for waste gas, using either sacrificial or regenerable media.

3. **Biofilter:** Another non-combustion option that is essentially a wet biological scrubber.

If the percentage of methane is significant (according to air permitting), options No. 2 and No. 3 will not suffice. The waste gas must be combusted.

7.2 Pipeline Connection Possibilities

The Dane County Sanitary Landfill already has an existing interconnect with a utility company. Developing the City's digester facility across from the landfill at Yahara Hills Golf Course would potentially provide access to this interconnect. EcoEngineers recommends engaging in conversations with the landfill to establish whether access to this interconnect would be allowed. If it is, a contract arrangement should be signed. An added benefit to developing the site at the Yahara Hills Golf Course is the potential cost savings associated with building a pipeline to interconnection point that would be such a short distance. The proximity between the golf course and the landfill will result in lower capital costs associated with building a pipeline. Typically, it costs approximately $1 million per one mile of pipeline built.

If the project is not developed at the Yahara Hills Golf Course, EcoEngineers recommends the City reaches out to utility companies directly for details regarding potential pipeline interconnections. Specifically, the City should check whether the utility companies have the required existing infrastructure in the area near other potential sites for pipeline injection and whether they would accept RNG into its pipelines. The utility companies will identify potential connection configurations for the City's digester facility. Based on the distance between the interconnection point and the City's facility, the pipeline companies can provide a better estimated cost for constructing the required facilities needed for injection into the pipeline. EcoEngineers recommends the City obtains these quotes as part of the capital assessment of this project.

Note each utility company has specific quality requirements to allow RNG injection into their pipeline. EcoEngineers recommends the City identifies these requirements, as these will need to be considered when designing the facility, including the upgrading system and monitoring systems. Final quality requirements and any annual operations and/or maintenance fees owed to the utility will be determined during negotiation of an interconnect agreement. Final agreement terms may vary from initial quotes provided by the utility companies. Additional discussions with both pipelines to determine the optional interconnection entity, route, and cost will be required during the preliminary design phase.

8.0 Capital Cost Estimates

EcoEngineers created a detailed capital cost estimate around the moderate-feedstock volume scenario. The capital cost estimate includes feedstock management and storage, the anaerobic digester system, solids dewatering and storage, the biogas upgrading system, the finished gas pipeline to the interconnection site, and associated utilities and civil/site work costs. The estimate is based on CSTR anaerobic digester vessels and a membrane biogas upgrading system. EcoEngineers used estimates done for similar projects to produce this capital cost estimate.

The Preliminary Capital Cost Estimate shown in Table 19 is based on the cost estimates completed for similar projects. The total capital cost estimate for the moderate feedstock scenario is $20,038,000. The values were scaled and adjusted based on the size, location, and project differences. Also included is a "Contingency on Equipment Costs," which is equal to 20% of the construction cost estimate.

EcoEngineers estimated capital costs for the low-, probable- and high-feedstock volume scenarios. The capital costs for the low-, probable-, and high-feedstock scenarios were scaled based on the volumes of feedstock and the amount of biogas being produced. The total capital cost estimate for the low, probable, moderate, and high feedstock scenario were $13 million, $17 million, $20 million, and $30 million, respectively.

TABLE 19: PRELIMINARY CAPITAL COST ESTIMATE FOR THE MODERATE FEEDSTOCK SCENARIO (52,000 TONS PER YEAR)

CITY OF MADISON PRELIMINARY CAPITAL COST ESTIMATE DIGESTER RNG PROJECT - 275 MMBTU/DAY, 140 TONS/DAY		
CIVIL/SITE WORK		
Demolition and Site Preparation	$	100,000
Civil/Site Work	$	1,500,000
Civil/Site Work Subtotal	**$**	**1,600,000**
FEEDSTOCK PRETREATMENT		
Feedstock Reception and Storage	$	100,000
Feedstock Loading Equipment	$	250,000
Feedstock Pulping and Separation	$	600,000
Building	$	250,000
Pretreatment Subtotal	**$**	**1,200,000**
ANAEROBIC DIGESTERS		
Feedstock Storage Tank	$	300,000
Digester Pretreatment and Feeding	$	250,000
Anaerobic Digester	$	3,000,000
Digestate Extraction	$	500,000
Biogas Collection, Piping, Safety	$	500,000
Solids/Liquids Separation	$	750,000
Digestate Storage	$	500,000
Digestion Subtotal	**$**	**5,300,000**

UTILITIES		
Natural Gas Service	$	100,000
Potable Water Service	$	100,000
Communications Service	$	100,000
Utilities Subtotal	**$**	**300,000**

GAS PURIFICATION SYSTEM		
Connection to Gas Purification System	$	30,000
Inlet Compression, Pretreatment	$	250,000
Biogas Upgrading System (CO_2 Removal)	$	1,200,000
Thermal Oxidizer	$	300,000
Condensate Return System	$	50,000
Startup and Commissioning	$	50,000
Gas Purification Subtotal	**$**	**1,880,000**

FINISHED GAS TRANSPORTATION		
Finished Gas Pipeline	$	1,000,000
Pipeline Appurtenances (Valves, fittings, etc.)	$	100,000
Finished Gas Pipeline Subtotal	**$**	**1,100,000**

ELECTRICAL AND CONTROLS		
3-Phase Electrical Service	$	250,000
Motor Control Center (Building & Equipment)	$	500,000
Instrument Air	$	50,000
Gas Flow & Quality Monitoring Equipment	$	250,000
Controls Equipment	$	150,000
Electrical And Controls Subtotal	**$**	**1,200,000**

INSTALLATION COSTS (30%)	**$**	**4,000,000**

SUBTOTAL W/O PIPELINE	$	16,030,000
CONSTRUCTION CONTINGENCY (20%)	$	3,206,000
TOTAL CONSTRUCTION COSTS	$	19,236,000

ENGINEERING, SURVEYING, LEGAL, ETC. (10%)	$	1,924,000

Total Project Cost	**$**	**20,038,000**

9.0 Operation & Maintenance Costs

The operation and maintenance (O&M) costs include utilities, materials, operational staffing requirements, third-party costs, and long-term maintenance costs.

The third-party costs include:

- **Professional Consulting:** Consulting fees associated with RFS and LCFS-related special reporting or projects related to the anaerobic digester or biogas upgrading systems.
- **Gas Transport, Offtake, and Marketing:** Costs for marketing, sales negotiations, and transportation of RNG through the pipeline grid.
- **Pipeline Operations & Maintenance:** Costs paid to a third party to operate and maintain the finished gas pipeline. This also includes estimated operations and maintenance are fees charged by the pipeline for the interconnect station. This cost is estimated based on the volume of RNG produced by this project and estimates EcoEngineers has received from other pipelines.
- **Lab Testing:** Costs of periodic grab sampling and laboratory analyses of digester feedstock, digestate, and RNG to monitor digester performance and prove conformance with pipeline specifications and RFS Quality Assurance Program (QAP) requirements.
- **Administrative, Legal, and Reporting:** Cost of time required to address reporting and administration for RIN generating activities and QAP requirements, as well as responding to potential legal questions or issues that may occur.

Table 20 lists the costs for each category of operations & maintenance activity and projects a total estimated annual O&M cost of $2.1 million for the moderate feedstock scenario.

EcoEngineers also estimated the operating costs for the facility for the low-, probable- and high-feedstock volume scenarios. The project costs were scaled based on the incoming feedstock volumes and the biogas production volumes. The estimated operating cost for the low, probable, moderate, and high feedstock scenarios were $850,000, $1.5 million, $1.98 million, and $2.8 million, respectively.

TABLE 20: OPERATING COST ESTIMATE FOR THE MODERATE FEEDSTOCK SCENARIO (52,000 TONS/YEAR)

CITY OF MADISON BIOGAS UPGRADING PRELIMINARY ANNUAL OPERATION AND MAINTENANCE COST ESTIMATE SEPTEMBER 2020				
UTILITIES	**PRICE**	**QTY**	**UNIT**	**ANNUAL TOTAL**
Electricity	$ 0.08	385	kWh	$ 270,000
Natural Gas	$ 1.85	125	DTH/D	$ 80,000
Waste Disposal (Solids Separated)	$ 50.00	5,200	$/ton	$ 260,000
RNG Delivery	$ 2.50	250	MMBtu	$ 228,000
Communications	$ 1,000	12	Mo.	$ 12,000
Water Supply	$ 1,000	12	Mo.	$ 12,000
Sanitary Sewer/Septic System	$ 1,500	12	Mo.	$ 18,000
			UTILITIES SUB-TOTAL	**$ 880,000**
MATERIALS				**ANNUAL TOTAL**
System Materials (1% of CAPEX)				$ 210,000
			Materials Subtotal	**$ 210,000**

OPERATIONS	**QTY**	**UNIT**	**ANNUAL TOTAL**
Staff at $75,000 Salary & Benefits	4	FTE	$ 300,000
		Operations Subtotal	**$ 300,000**

THIRD PARTY COSTS	**ANNUAL TOTAL**
Professional Consulting	$ 75,000
Lab Testing	$ 50,000
Administrative, Legal, Reporting	$ 25,000
Third Party Costs Subtotal	**$ 250,000**

LONG-TERM MAINTENANCE ITEMS	**FREQUENCY**	**ANNUAL COST**
Pumps, Pumping Systems, Motor Starters	5 Years	$ 25,000
Media Replacement	5 Years	$ 25,000
Vehicles/Equipment	5 Years	$ 25,000
Biogas Upgrading Membrane Replacement	10 Years	$ 10,000
Feedstock Processing Parts	1 year	$ 15,000
Other items, including: Compressor Rebuilds, Computer Equipment Replacement, Safety Valve Rebuilds, Annual Calibrations, etc	5 Years	$ 25,000
	Long Term Maintenance Items Subtotal	**$ 125,000**

SUB-TOTAL	$ 1,655,000
CONTINGENCY 20%	$ 331,000

Total Operations And Maintenance Costs	**$ 1,986,000**

[EcoEngineers works with project developers as a trusted advisor to walk alongside a project team as a consulting resource, compliance manager, and auditor.]

10.0 Revenue Estimates & Financial Analysis

Pro forma financial projections were prepared using current market pricing to calculate potential revenue for the low-, probable-, moderate-, and high-feedstock scenarios. In addition, a financial sensitivity analysis was performed based on low-, moderate-, and high-market conditions for the project. Each of the analyses includes 10-year revenue streams from the sale of the physical natural gas, RINs, LCFS credits, and tipping fees.

10.1 General Assumptions

The following assumptions have been applied to the pro forma calculations for conservative, moderate, and aggressive market conditions:

1. Average biogas quantities as outlined in Section 3.0 Feedstock Analysis.
2. 96% uptime of the anaerobic digestion and biogas upgrading system.
3. 95% recovery rate of methane.
4. 100% of the estimated annual RNG production is injected into the pipeline and used as a qualifying transportation fuel.
5. All monetary figures are based on 2021 dollars.
6. Normal rate of inflation and current market and regulatory conditions will be applied to the 10-year projection period.
7. Natural gas sales pricing is $2.00 per MMBtu, based on Henry Hub pricing, and no third-party commissions will be deducted from physical gas sales.
8. Natural gas prices will increase at the rate of 2% annually.
9. D3 RIN prices will increase at the rate of 2% annually.
10. Tipping fees of $45/ton.
11. The facility receives a CI score of-50 gCO_2e/MJ, based on conservative preliminary carbon intensity modeling. These estimates are dependent on assumptions, and therefore should be re-modeled when actual data becomes available.
12. Virtual contracts are secured with LCFS obligated parties in California to allow the City of Madison to generate and sell LCFS credits.
13. Third-party offtakers receive a fee of 15% for RINs and 25% for LCFS credits.
14. Dane County Sanitary Landfill receives $2.50 per MMBtu to receive RNG
15. LCFS credit prices will increase at the rate of 2% annually.
16. Project financing and debt service is assumed to be a 20-year term at a 2.5% interest rate.

10.2 Comparison of Scenarios

EcoEngineers projected the potential revenue for the project for the four feedstock scenarios (low, probable, moderate, and high). Table 21 shows a summary of the four scenarios and estimated potential revenues for the project. Individual financial pro formas for each scenario are attached to this report in **Appendix A**.

Under current market conditions, D5 RINs and LCFS credits are priced at approximately $0.77 and $200, respectively. **Table 21 shows assumed values and calculations for an estimate of the Year 1 pro forma for the project.** EcoEngineers added an additional expense line for compliance and RIN management, which is explained below.

TABLE 21: YEAR 1 FINANCIAL COMPARISON OF ALL FEEDSTOCK SCENARIOS AT CURRENT MARKET CONDITIONS

	LOW	PROBABLE	MODERATE	HIGH
Year 1 (2021)				
Days of Operation per Year	350	350	350	350
Average NG Price	$2.00	$2.00	$2.00	$2.00
D5 RIN Price	$0.77	$0.77	$0.77	$0.77
LCFS Credit Price	$200.00	$200.00	$200.00	$200.00
Average LCFS $/MMBTU	$27.26	$27.26	$27.26	$27.26
Assumed Carbon Intensity (CI)	-50	-50	-50	-50
Revenues				
Tipping Fees	$630,000	$1,350,000	$2,340,000	$3,915,000
Gross NG Revenue	$51,000	$110,000	$193,000	$322,000
Gross D5 RIN Revenue	$232,000	$499,000	$870,000	$1,453,000
Gross LCFS Credit Revenue	$629,000	$1,356,000	$2,365,000	$3,949,000
Gross Total Revenue	$1,542,000	$3,315,000	$5,768,000	$9,639,000
Expenses				
Third-Party Offtake and RIN Sales	$(192,000)	$(414,000)	$(722,000)	$(1,205,000)
Compliance and RIN Management	$(75,000)	$(75,000)	$(75,000)	$ (75,000)
Total RIN Expenses	$(267,000)	$(489,000)	$(797,000)	$(1,280,000)
Facility O&M Costs	$ (850,000)	$(1,500,000)	$(2,000,000)	$(2,800,000)
Interconnection Costs	$(64,000)	$(138,000)	$(241,000)	$(402,000)
EBITDA	$361,000	$1,188,000	$2,730,000	$5,157,000
Annual Debt Service	$(834,000)	$(1,091,000)	$(1,347,000)	$(1,924,000)
Net Profit After Financing	**$(473,000)**	**$97,000**	**$1,383,000**	**$3,233,000**

[In order for the project to break even, EcoEngineers estimates that the project will have to take in approximately 18,500 tons of food waste per year.]

- **Gross Total Revenue** includes revenue from tipping fees, RNG, D5 RIN, and LCFS credit sales.

- **Third-Party Offtake and RIN Sales Costs** represent the fee paid to a third party who is responsible for securing offtake/end-use contracts to demonstrate transportation use of the RNG. RINs are generated for actual amount of RNG that is consumed as transportation fuel, not the amount of RNG injected into the pipeline. When more RNG is injected into the pipeline than what is consumed by the transportation sector, RINs cannot be generated on the excess RNG; although an option exists for storing RNG for later use. The cost of RIN sales represents the fee paid to a third party who contracts with obligated parties to sell the RINs at either fixed or spot pricing.

- **Compliance and RIN management** represents the fees to contract with an USEPA-approved, third-party verifier who validates RIN generations against quality assurance program (QAP) requirements. Third-party verification is necessary to receive full value of D3 RINs. Beginning in 2020, renewable fuel producers participating in the LCFS program will also be required to utilize a third-party QAP provider to verify LCFS credits. The cost estimate for “Compliance and RIN Management” within the includes the cost of both programs.

- **Facility O&M Costs** as described in section **9.0. Operations & Maintenance Costs.**

Under current market conditions, the low feedstock case does not break even. This means that the low feedstock scenario of approximately 14,000 tons per year is not enough to support the project in tipping fees or gas production. In order for the project to break even, EcoEngineers estimates that the project will have to take in approximately 18,500 tons of food waste per year.

10.3 Financial Sensitivity Analysis

To understand how different market conditions will affect the financials of the project, EcoEngineers evaluated the probable (30,000 tons per year) and moderate (52,000 tons per year) feedstock scenarios further. As such, EcoEngineers performed a market sensitivity analysis around the probable and moderate food waste reception scenarios. EcoEngineers completed this financial sensitivity analysis to determine how this two feedstock scenarios may perform in veracious market conditions, including low, moderate, and high market conditions.

Tables 22 and 23 summarize the results of the financial sensitivity analysis for the probable and moderate feedstock scenarios. The full pro formas are shown in **Appendix A**.

TABLE 22: FINANCIAL SENSITIVITY ANALYSIS AT VARIOUS MARKET CONDITIONS FOR THE PROBABLE FEEDSTOCK SCENARIO (30,000 TONS PER YEAR)

	CURRENT CONDITIONS	LOW	MODERATE	AGGRESSIVE
Capital Investment: $17,000,000				
Gross Revenue	$3,315,000	$2,332,000	$2,801,000	$3,565,000
Expenses	$(2,127,000)	$(1,911,592)	$(2,015,748)	$(2,174,472)
Net Revenue*	$1,188,000	$420,408	$785,252	$1,390,528
Net Revenue/MMBtu	$21.50	$7.61	$14.21	$25.17
5-Year Total Net Revenue	**$5,451,000**	**$2,187,818**	**$4,086,483**	**$7,236,366**

TABLE 23: FINANCIAL SENSITIVITY ANALYSIS AT VARIOUS MARKET CONDITIONS FOR THE MODERATE FEEDSTOCK SCENARIO (52,000 TONS PER YEAR)

	CURRENT CONDITIONS	LOW	MODERATE	HIGH
Capital Investment: $20,000,000				
Gross Revenue	$5,768,000	$4,055,000	$4,872,000	$6,206,000
Expenses	$(3,037,987)	$(2,662,511)	$(2,844,251)	$(3,121,208)
Net Revenue*	$2,730,000	$1,392,489	$2,027,749	$3,084,792
Net Revenue/ MMBtu	$27.19	$13.87	$20.20	$30.73
5-Year Total Net Revenue	**$12,409,000**	**$6,726,166**	**$10,032,083**	**$15,532,978**

10.3.1 Low Market Conditions

Financial projections for a 10-year period based on low market conditions apply similar assumptions used for current market conditions, with the following exceptions:

- D5 RIN prices fall to $0.30 per RIN.
- LCFS credits outpace deficits and credit prices fall to $100 per credit.

The EBITDA for this projection is $1,392,000 in the first year of operation for the moderate feedstock scenario and $420,000 for the probable feedstock scenario. The full pro formas is shown in **Appendix A.**

ecoengineers people-driven solutions

10.3.2 Moderate Market Conditions

Financial projections for a 10-year period based on moderate market conditions apply similar assumptions used for current market conditions, with the following exceptions:

- D5 RIN prices fall to $0.50 per RIN.
- LCFS credits outpace deficits and credit prices fall to $150 per credit.

The EBITDA for this projection is $2,028,000 in the first year of operation for the moderate feedstock scenario and $785,000 for the probable feedstock scenario. The full pro forma is shown in **Appendix A**.

10.3.3 High Market Conditions

Financial projections for a 10-year period based on high market conditions apply similar assumptions used for current market conditions, with the following exceptions:

- D5 RIN prices increase to $1.00 per RIN.
- LCFS prices increase to $215 per credit.

The EBITDA for the Project is $3,085,000 in the first year of operation for the moderate feedstock scenario and $1,391,000 for the probable feedstock scenario. The full pro forma is shown in **Appendix A.**

10.4 Risk Mitigation

The transportation fuel RIN market has inherent risk due to uncertainty of the regulatory environment. An effective method to mitigate this risk is by diversifying the project income stream to include other revenue sources. Pipeline injection provides access to California transportation end users, outside of local use, in order to be eligible for the California LCFS credits. By purifying biogas to pipeline-quality injection, The City will have greater flexibility to shift to more lucrative incentive programs as new markets evolve. Common risk-mitigation approaches include:

1. Diversifying into other low-carbon fuel markets, as outlined in Section 2.2 Other Low Carbon Fuels Programs.
2. Exploring alternate RNG markets such as voluntary carbon markets or cap-and-trade emissions markets.
3. Securing long-term, fixed-price purchase agreements for the “green” attributes of RNG.
4. Transferring risk to a third-party project developer.

Typically, agricultural digester projects rely on multiple revenue streams including tipping fees, nutrient recovery, natural gas sales, and sale of environmental attributes. The City of Madison project focuses on natural gas sales, sale of environmental attributes, and tipping fees with the potential for future revenues from digestate sales. Because of the assumed low carbon intensity score of the facility (-50), this project is well-positioned to participate in California’s LCFS when compared to other biogas-to-RNG projects, such as landfill and wastewater projects.

Consideration of the balance between risk and reward is essential to successful project planning. EcoEngineers can assist the City of Madison in developing a strategy that meets the project goals in regard to revenue streams, risk management, and contribution to environmental improvement. Additional risk mitigation analysis is recommended for the next phase of the project.

[EcoEngineers can assist the City in developing a strategy that meets the project goals in regard to revenue streams, risk management, and contribution to environmental improvement.]

11.0 Project Schedule

A potential project timeline is outlined below. Construction for new anaerobic digestion facilities is typically 18 to 24 months. Biogas upgrading system construction and regulatory and offtake work are performed simultaneously.

TASK	COMPLETION TARGET
Decision to Proceed	November 2021
Feedstocks Procured	Winter 2021
Financing Procured	Winter 2021
Preliminary Design and Technology Selection	Spring 2022
Design Engineer Selection	Spring 2022
Natural Gas Utility Pipeline Agreement Finalized	Summer 2022
Construction Begins	Summer 2022
Offtake and Gas Marketing Negotiations	December 2022
Construction and Technology Installation	Fall 2022
Startup	Fall 2023
RFS Registration Complete	Winter 2023
Revenue Generation Begins	Spring 2024
LCFS Registration Complete	Spring 2024

12.0 Next Steps

In order to sustain momentum, EcoEngineers recommends the following next steps for your consideration:

- Collect and analyze feedstock samples from different sources for lab analysis to confirm biogas generation estimates and co-digestion compatibility.
- Go/no-go process: The City decides how to proceed.
- Obtain Letters of Intent (LOI) or feedstock agreements from the key feedstock sources in the area.
- Meet with Dane County Sanitary Landfill to determine if use of the existing injection point is possible. Otherwise, meet with pipeline utilities to determine optimal interconnection location and to obtain a draft interconnection agreement.
- Review financing options and grant opportunities.
- Discuss with anaerobic digester manufacturers the capacities of their systems and associated capital costs to find the ratio of biogas production (feedstock capacity) and capital cost.
- Solicit proposals from engineering firms for design services.
- Request firm proposals from upgrade system vendors.
- Meet with potential offtake partners with demand in California to discuss the project and their associated fees (share of RINs and LCFS credits).
- Attend a site tour(s) of an existing biogas upgrading installation.
- Determine potential risk mitigation strategies including financing structures.
- Review local air quality management district permitting requirements to determine pretreatment and tail gas treatment needs.
- Finalize project size, capital cost, O&M cost, and financial pro forma after discussions with feedstock providers.
- Determine whether to send fuel to California in the short-term to capitalize on the high value of LCFS credits and the significant demand for low-CI renewable fuels.

The City can begin the next phase of the project without committing to spending the entire capital cost of the project. EcoEngineers expects the next phase of the project to cost approximately $100,000-150,000 for additional consulting, laboratory analysis, biogas visits, and preliminary design services to accomplish the above tasks.

[Appendix A:
Pro Formas]

Appendix A: Pro Formas

City of Madison, Food Waste Digester
August 2020
52,000 Tons per Year
Current Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$2.04	$2.08	$2.12	$2.16	$2.21	$2.25	$2.30	$2.34	$2.39
D5 RIN Price	$0.77	$0.79	$0.80	$0.82	$0.83	$0.85	$0.87	$0.88	$0.90	$0.92
LCFS Credit Price	$200.00	$204.00	$208.08	$150.00	$125.00	$127.50	$130.05	$132.65	$135.30	$138.01
Avg LCFS $/MMBTU	$27.26	$27.81	$28.36	$20.45	$17.04	$17.38	$17.73	$18.08	$18.44	$18.81
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 1,350,000	$ 1,377,000	$ 1,404,540	$ 1,432,631	$ 1,461,283	$ 1,490,509	$ 1,520,319	$ 1,550,726	$ 1,581,740	$ 1,613,375
Gross NG Revenue	$ 110,000	$ 112,200	$ 114,444	$ 116,733	$ 119,068	$ 121,449	$ 123,878	$ 126,355	$ 128,883	$ 131,460
Gross D5 RIN Revenue	$ 499,000	$ 508,980	$ 519,160	$ 529,543	$ 540,134	$ 550,936	$ 561,955	$ 573,194	$ 584,658	$ 596,351
Gross LCFS Credit Revenue	$ 1,356,000	$ 1,383,000	$ 1,410,000	$ 1,017,000	$ 847,000	$ 864,000	$ 881,000	$ 899,000	$ 917,000	$ 935,000
Gross Total Revenue	$ 3,315,000	$ 3,381,180	$ 3,448,144	$ 3,095,906	$ 2,967,485	$ 3,026,894	$ 3,087,152	$ 3,149,275	$ 3,212,281	$ 3,276,186
Expenses										
3rd Party Offtake & RIN Sales	$ (414,000)	$ (422,097)	$ (430,374)	$ (333,681)	$ (292,770)	$ (298,640)	$ (304,543)	$ (310,729)	$ (316,949)	$ (323,203)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (489,000)	$ (501,000)	$ (513,000)	$ (420,000)	$ (384,000)	$ (394,000)	$ (405,000)	$ (416,000)	$ (428,000)	$ (440,000)
Facility O&M Costs	$ (1,500,000)	$ (1,523,000)	$ (1,546,000)	$ (1,569,000)	$ (1,593,000)	$ (1,617,000)	$ (1,641,000)	$ (1,666,000)	$ (1,691,000)	$ (1,716,000)
Interconnection Costs	$ (138,000)	$ (140,760)	$ (143,575)	$ (146,447)	$ (149,376)	$ (152,363)	$ (155,410)	$ (158,519)	$ (161,689)	$ (164,923)
EBITDA	$ 1,188,000	$ 1,216,000	$ 1,246,000	$ 960,000	$ 841,000	$ 864,000	$ 886,000	$ 909,000	$ 932,000	$ 955,000
Annual Debt Service	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)
Net Profit After Financing	**$ 97,000**	**$ 125,000**	**$ 155,000**	**$ (131,000)**	**$ (250,000)**	**$ (227,000)**	**$ (205,000)**	**$ (182,000)**	**$ (159,000)**	**$ (136,000)**

City of Madison, Food Waste Digester
August 2020
52,000 Tons per Year
Low Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$2.04	$2.08	$2.12	$2.16	$2.21	$2.25	$2.30	$2.34	$2.39
D5 RIN Price	$0.30	$0.31	$0.31	$0.32	$0.32	$0.33	$0.34	$0.34	$0.35	$0.36
LCFS Credit Price	$100.00	$102.00	$104.04	$106.12	$108.24	$110.41	$112.62	$114.87	$117.17	$119.51
Avg LCFS $/MMBTU	$13.63	$13.90	$14.18	$14.47	$14.76	$15.05	$15.35	$15.66	$15.97	$16.29
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 1,350,000	$ 1,377,000	$ 1,404,540	$ 1,432,631	$ 1,461,283	$ 1,490,509	$ 1,520,319	$ 1,550,726	$ 1,581,740	$ 1,613,375
Gross NG Revenue	$ 110,000	$ 112,200	$ 114,444	$ 116,733	$ 119,068	$ 121,449	$ 123,878	$ 126,355	$ 128,883	$ 131,460
Gross D5 RIN Revenue	$ 194,000	$ 197,880	$ 201,838	$ 205,874	$ 209,992	$ 214,192	$ 218,476	$ 222,845	$ 227,302	$ 231,848
Gross LCFS Credit Revenue	$ 678,000	$ 691,560	$ 705,391	$ 719,499	$ 733,889	$ 748,567	$ 763,538	$ 778,809	$ 794,385	$ 810,273
Gross Total Revenue	$ 2,332,000	$ 2,378,640	$ 2,426,213	$ 2,474,737	$ 2,524,232	$ 2,574,716	$ 2,626,211	$ 2,678,735	$ 2,732,310	$ 2,786,956
Expenses										
3rd Party Offtake & RIN Sales	$ (199,000)	$ (202,572)	$ (206,623)	$ (210,756)	$ (214,971)	$ (219,270)	$ (223,656)	$ (228,129)	$ (232,692)	$ (237,345)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (274,000)	$ (281,000)	$ (289,000)	$ (298,000)	$ (306,000)	$ (315,000)	$ (324,000)	$ (334,000)	$ (343,000)	$ (354,000)
Facility O&M Costs	$ (1,500,000)	$ (1,523,000)	$ (1,546,000)	$ (1,569,000)	$ (1,593,000)	$ (1,617,000)	$ (1,641,000)	$ (1,666,000)	$ (1,691,000)	$ (1,716,000)
Interconnection Costs	$ (138,000)	$ (140,760)	$ (143,575)	$ (146,447)	$ (149,376)	$ (152,363)	$ (155,410)	$ (158,519)	$ (161,689)	$ (164,923)
EBITDA	$ 420,000	$ 434,000	$ 448,000	$ 461,000	$ 476,000	$ 490,000	$ 506,000	$ 520,000	$ 537,000	$ 552,000
Annual Debt Service	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)
Net Profit After Financing	**$ (671,000)**	**$ (657,000)**	**$ (643,000)**	**$ (630,000)**	**$ (615,000)**	**$ (601,000)**	**$ (585,000)**	**$ (571,000)**	**$ (554,000)**	**$ (539,000)**

City of Madison, Food Waste Digester
August 2020
52,000 Tons per Year
Moderate Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$2.04	$2.08	$2.12	$2.16	$2.21	$2.25	$2.30	$2.34	$2.39
D5 RIN Price	$0.50	$0.51	$0.52	$0.53	$0.54	$0.55	$0.56	$0.57	$0.59	$0.60
LCFS Credit Price	$150.00	$153.00	$156.06	$159.18	$162.36	$165.61	$168.92	$172.30	$175.75	$179.26
Avg LCFS $/MMBTU	$20.45	$20.86	$21.27	$21.70	$22.13	$22.58	$23.03	$23.49	$23.96	$24.44
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 1,350,000	$ 1,377,000	$ 1,404,540	$ 1,432,631	$ 1,461,283	$ 1,490,509	$ 1,520,319	$ 1,550,726	$ 1,581,740	$ 1,613,375
Gross NG Revenue	$ 110,000	$ 112,200	$ 114,444	$ 116,733	$ 119,068	$ 121,449	$ 123,878	$ 126,355	$ 128,883	$ 131,460
Gross D5 RIN Revenue	$ 324,000	$ 330,480	$ 337,090	$ 343,831	$ 350,708	$ 357,722	$ 364,877	$ 372,174	$ 379,618	$ 387,210
Gross LCFS Credit Revenue	$ 1,017,000	$ 1,037,340	$ 1,058,087	$ 1,079,249	$ 1,100,834	$ 1,122,850	$ 1,145,307	$ 1,168,213	$ 1,191,578	$ 1,215,409
Gross Total Revenue	$ 2,801,000	$ 2,857,020	$ 2,914,160	$ 2,972,444	$ 3,031,892	$ 3,092,530	$ 3,154,381	$ 3,217,469	$ 3,281,818	$ 3,347,454
Expenses										
3rd Party Offtake & RIN Sales	$ (303,000)	$ (308,907)	$ (315,085)	$ (321,387)	$ (327,815)	$ (334,371)	$ (341,058)	$ (347,879)	$ (354,837)	$ (361,934)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (378,000)	$ (388,000)	$ (398,000)	$ (408,000)	$ (419,000)	$ (430,000)	$ (442,000)	$ (453,000)	$ (466,000)	$ (478,000)
Facility O&M Costs	$ (1,500,000)	$ (1,523,000)	$ (1,546,000)	$ (1,569,000)	$ (1,593,000)	$ (1,617,000)	$ (1,641,000)	$ (1,666,000)	$ (1,691,000)	$ (1,716,000)
Interconnection Costs	$ (138,000)	$ (140,760)	$ (143,575)	$ (146,447)	$ (149,376)	$ (152,363)	$ (155,410)	$ (158,519)	$ (161,689)	$ (164,923)
EBITDA	$ 785,000	$ 805,000	$ 827,000	$ 849,000	$ 871,000	$ 893,000	$ 916,000	$ 940,000	$ 963,000	$ 989,000
Annual Debt Service	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)
Net Profit After Financing	**$ (306,000)**	**$ (286,000)**	**$ (264,000)**	**$ (242,000)**	**$ (220,000)**	**$ (198,000)**	**$ (175,000)**	**$ (151,000)**	**$ (128,000)**	**$ (102,000)**

City of Madison, Food Waste Digester
August 2020
52,000 Tons per Year
High Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$ 2.04	$ 2.08	$ 2.12	$ 2.16	$ 2.21	$ 2.25	$ 2.30	$ 2.34	$ 2.39
D5 RIN Price	$ 1.00	$ 1.02	$ 1.04	$ 1.06	$ 1.08	$ 1.10	$ 1.13	$ 1.15	$ 1.17	$ 1.20
LCFS Credit Price	$ 215.00	$ 219.30	$ 223.69	$ 228.16	$ 232.72	$ 237.38	$ 242.12	$ 246.97	$ 251.91	$ 256.94
Avg LCFS $/MMBTU	$29.31	$ 29.89	$ 30.49	$ 31.10	$ 31.72	$ 32.36	$ 33.01	$ 33.67	$ 34.34	$ 35.03
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 1,350,000	$ 1,377,000	$ 1,404,540	$ 1,432,631	$ 1,461,283	$ 1,490,509	$ 1,520,319	$ 1,550,726	$ 1,581,740	$ 1,613,375
Gross NG Revenue	$ 110,000	$ 112,200	$ 114,444	$ 116,733	$ 119,068	$ 121,449	$ 123,878	$ 126,355	$ 128,883	$ 131,460
Gross D5 RIN Revenue	$ 648,000	$ 660,960	$ 674,179	$ 687,663	$ 701,416	$ 715,444	$ 729,753	$ 744,348	$ 759,235	$ 774,420
Gross LCFS Credit Revenue	$ 1,457,000	$ 1,486,140	$ 1,515,863	$ 1,546,180	$ 1,577,104	$ 1,608,646	$ 1,640,819	$ 1,673,635	$ 1,707,108	$ 1,741,250
Gross Total Revenue	$ 3,565,000	$ 3,636,300	$ 3,709,026	$ 3,783,207	$ 3,858,871	$ 3,936,048	$ 4,014,769	$ 4,095,064	$ 4,176,966	$ 4,260,505
Expenses										
3rd Party Offtake & RIN Sales	$ (461,000)	$ (470,679)	$ (480,093)	$ (489,694)	$ (499,488)	$ (509,478)	$ (519,668)	$ (530,061)	$ (540,662)	$ (551,475)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (536,000)	$ (549,000)	$ (563,000)	$ (576,000)	$ (591,000)	$ (605,000)	$ (620,000)	$ (636,000)	$ (651,000)	$ (668,000)
Facility O&M Costs	$ (1,500,000)	$ (1,523,000)	$ (1,546,000)	$ (1,569,000)	$ (1,593,000)	$ (1,617,000)	$ (1,641,000)	$ (1,666,000)	$ (1,691,000)	$ (1,716,000)
Interconnection Costs	$ (138,000)	$ (140,760)	$ (143,575)	$ (146,447)	$ (149,376)	$ (152,363)	$ (155,410)	$ (158,519)	$ (161,689)	$ (164,923)
EBITDA	$ 1,391,000	$ 1,424,000	$ 1,456,000	$ 1,492,000	$ 1,525,000	$ 1,562,000	$ 1,598,000	$ 1,635,000	$ 1,673,000	$ 1,712,000
Annual Debt Service	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)	$ (1,091,000)
Net Profit After Financing	**$ 300,000**	**$ 333,000**	**$ 365,000**	**$ 401,000**	**$ 434,000**	**$ 471,000**	**$ 507,000**	**$ 544,000**	**$ 582,000**	**$ 621,000**

City of Madison, Food Waste Digester August 2020 87,000 Tons per Year Current Market Conditions										
Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$ 2.04	$ 2.08	$ 2.12	$ 2.16	$ 2.21	$ 2.25	$ 2.30	$ 2.34	$ 2.39
D5 RIN Price	$0.77	$ 0.79	$ 0.80	$ 0.82	$ 0.83	$ 0.85	$ 0.87	$ 0.88	$ 0.90	$ 0.92
LCFS Credit Price	$200.00	$ 204.00	$ 208.08	$ 150.00	$ 125.00	$ 127.50	$ 130.05	$ 132.65	$ 135.30	$ 138.01
Avg LCFS $/MMBTU	$27.26	$ 27.81	$ 28.36	$ 20.45	$ 17.04	$ 17.38	$ 17.73	$ 18.08	$ 18.44	$ 18.81
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 3,915,000	$ 3,993,300	$ 4,073,166	$ 4,154,629	$ 4,237,722	$ 4,322,476	$ 4,408,926	$ 4,497,104	$ 4,587,046	$ 4,678,787
Gross NG Revenue	$ 322,000	$ 328,440	$ 335,009	$ 341,709	$ 348,543	$ 355,514	$ 362,624	$ 369,877	$ 377,274	$ 384,820
Gross D5 RIN Revenue	$ 1,453,000	$ 1,482,060	$ 1,511,701	$ 1,541,935	$ 1,572,774	$ 1,604,229	$ 1,636,314	$ 1,669,040	$ 1,702,421	$ 1,736,470
Gross LCFS Credit Revenue	$ 3,949,000	$ 4,028,000	$ 4,109,000	$ 2,962,000	$ 2,468,000	$ 2,517,000	$ 2,568,000	$ 2,619,000	$ 2,672,000	$ 2,725,000
Gross Total Revenue	$ 9,639,000	$ 9,831,800	$ 10,028,876	$ 9,000,274	$ 8,627,039	$ 8,799,220	$ 8,975,864	$ 9,155,021	$ 9,338,742	$ 9,525,077
Expenses										
3rd Party Offtake & RIN Sales	$ (1,205,000)	$ (1,229,309)	$ (1,254,005)	$ (971,790)	$ (852,916)	$ (869,884)	$ (887,447)	$ (905,106)	$ (923,363)	$ (941,720)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (1,280,000)	$ (1,308,000)	$ (1,337,000)	$ (1,059,000)	$ (944,000)	$ (966,000)	$ (988,000)	$ (1,011,000)	$ (1,034,000)	$ (1,058,000)
Facility O&M Costs	$ (2,800,000)	$ (2,842,000)	$ (2,885,000)	$ (2,928,000)	$ (2,972,000)	$ (3,017,000)	$ (3,062,000)	$ (3,108,000)	$ (3,155,000)	$ (3,202,000)
Interconnection Costs	$ (402,000)	$ (410,040)	$ (418,241)	$ (426,606)	$ (435,138)	$ (443,840)	$ (452,717)	$ (461,772)	$ (471,007)	$ (480,427)
EBITDA	$ 5,157,000	$ 5,272,000	$ 5,389,000	$ 4,587,000	$ 4,276,000	$ 4,372,000	$ 4,473,000	$ 4,574,000	$ 4,679,000	$ 4,785,000
Annual Debt Service	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)	$ (1,924,000)
Net Profit After Financing	**$ 3,233,000**	**$ 3,348,000**	**$ 3,465,000**	**$ 2,663,000**	**$ 2,352,000**	**$ 2,448,000**	**$ 2,549,000**	**$ 2,650,000**	**$ 2,755,000**	**$ 2,861,000**

City of Madison, Food Waste Digester
August 2020
14,000 Tons per Year
Current Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$ 2.04	$ 2.08	$ 2.12	$ 2.16	$ 2.21	$ 2.25	$ 2.30	$ 2.34	$ 2.39
D5 RIN Price	$0.77	$ 0.79	$ 0.80	$ 0.82	$ 0.83	$ 0.85	$ 0.87	$ 0.88	$ 0.90	$ 0.92
LCFS Credit Price	$200.00	$ 204.00	$ 208.08	$ 150.00	$ 125.00	$ 127.50	$ 130.05	$ 132.65	$ 135.30	$ 138.01
Avg LCFS $/MMBTU	$27.26	$ 27.81	$ 28.36	$ 20.45	$ 17.04	$ 17.38	$ 17.73	$ 18.08	$ 18.44	$ 18.81
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 630,000	$ 642,600	$ 655,452	$ 668,561	$ 681,932	$ 695,571	$ 709,482	$ 723,672	$ 738,145	$ 752,908
Gross NG Revenue	$ 51,000	$ 52,020	$ 53,060	$ 54,122	$ 55,204	$ 56,308	$ 57,434	$ 58,583	$ 59,755	$ 60,950
Gross D5 RIN Revenue	$ 232,000	$ 236,640	$ 241,373	$ 246,200	$ 251,124	$ 256,147	$ 261,270	$ 266,495	$ 271,825	$ 277,261
Gross LCFS Credit Revenue	$ 629,000	$ 642,000	$ 655,000	$ 472,000	$ 393,000	$ 401,000	$ 409,000	$ 417,000	$ 426,000	$ 434,000
Gross Total Revenue	$ 1,542,000	$ 1,573,260	$ 1,604,885	$ 1,440,883	$ 1,381,261	$ 1,409,026	$ 1,437,186	$ 1,465,750	$ 1,495,725	$ 1,525,120
Expenses										
3rd Party Offtake & RIN Sales	$ (192,000)	$ (195,996)	$ (199,956)	$ (154,930)	$ (135,919)	$ (138,672)	$ (141,440)	$ (144,224)	$ (147,274)	$ (150,089)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (267,000)	$ (275,000)	$ (283,000)	$ (242,000)	$ (227,000)	$ (234,000)	$ (242,000)	$ (250,000)	$ (258,000)	$ (266,000)
Facility O&M Costs	$ (850,000)	$ (863,000)	$ (876,000)	$ (889,000)	$ (902,000)	$ (916,000)	$ (930,000)	$ (944,000)	$ (958,000)	$ (972,000)
Interconnection Costs	$ (64,000)	$ (65,280)	$ (66,586)	$ (67,917)	$ (69,276)	$ (70,661)	$ (72,074)	$ (73,516)	$ (74,986)	$ (76,486)
EBITDA	$ 361,000	$ 370,000	$ 379,000	$ 242,000	$ 183,000	$ 188,000	$ 193,000	$ 198,000	$ 205,000	$ 211,000
Annual Debt Service	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)	$ (834,000)
Net Profit After Financing	**$ (473,000)**	**$ (464,000)**	**$ (455,000)**	**$ (592,000)**	**$ (651,000)**	**$ (646,000)**	**$ (641,000)**	**$ (636,000)**	**$ (629,000)**	**$ (623,000)**

City of Madison, Food Waste Digester
August 2020
14,000 Tons per Year
Current Market Conditions

Year	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Days of Operation per Year	350									
Avg NG Price	$2.00	$ 2.04	$ 2.08	$ 2.12	$ 2.16	$ 2.21	$ 2.25	$ 2.30	$ 2.34	$ 2.39
D5 RIN Price	$0.77	$ 0.79	$ 0.80	$ 0.82	$ 0.83	$ 0.85	$ 0.87	$ 0.88	$ 0.90	$ 0.92
LCFS Credit Price	$200.00	$ 204.00	$ 208.08	$ 150.00	$ 125.00	$ 127.50	$ 130.05	$ 132.65	$ 135.30	$ 138.01
Avg LCFS $/MMBTU	$27.26	$ 27.81	$ 28.36	$ 20.45	$ 17.04	$ 17.38	$ 17.73	$ 18.08	$ 18.44	$ 18.81
Assumed Carbon Intensity (CI)	-50									
Revenues										
Tipping Fees	$ 2,340,000	$ 2,386,800	$ 2,434,536	$ 2,483,227	$ 2,532,891	$ 2,583,549	$ 2,635,220	$ 2,687,924	$ 2,741,683	$ 2,796,517
Gross NG Revenue	$ 193,000	$ 196,860	$ 200,797	$ 204,813	$ 208,909	$ 213,088	$ 217,349	$ 221,696	$ 226,130	$ 230,653
Gross D5 RIN Revenue	$ 870,000	$ 887,400	$ 905,148	$ 923,251	$ 941,716	$ 960,550	$ 979,761	$ 999,357	$ 1,019,344	$ 1,039,731
Gross LCFS Credit Revenue	$ 2,365,000	$ 2,413,000	$ 2,461,000	$ 1,774,000	$ 1,478,000	$ 1,508,000	$ 1,538,000	$ 1,569,000	$ 1,600,000	$ 1,632,000
Gross Total Revenue	$ 5,768,000	$ 5,884,060	$ 6,001,481	$ 5,385,291	$ 5,161,517	$ 5,265,187	$ 5,370,331	$ 5,477,977	$ 5,587,157	$ 5,698,900
Expenses										
3rd Party Offtake & RIN Sales	$ (722,000)	$ (736,360)	$ (751,022)	$ (581,988)	$ (510,757)	$ (521,083)	$ (531,464)	$ (542,153)	$ (552,902)	$ (563,960)
Compliance & RIN Management	$ (75,000)	$ (78,800)	$ (82,700)	$ (86,800)	$ (91,100)	$ (95,700)	$ (100,500)	$ (105,500)	$ (110,800)	$ (116,300)
Total RIN Expenses	$ (797,000)	$ (815,000)	$ (834,000)	$ (669,000)	$ (602,000)	$ (617,000)	$ (632,000)	$ (648,000)	$ (664,000)	$ (680,000)
Facility O&M Costs	$ (2,000,000)	$ (2,030,000)	$ (2,060,000)	$ (2,091,000)	$ (2,122,000)	$ (2,154,000)	$ (2,186,000)	$ (2,219,000)	$ (2,252,000)	$ (2,286,000)
Interconnection Costs	$ (240,987)	$ (245,807)	$ (250,723)	$ (255,737)	$ (260,852)	$ (266,069)	$ (271,391)	$ (276,818)	$ (282,355)	$ (288,002)
EBITDA	$ 2,730,000	$ 2,793,000	$ 2,857,000	$ 2,370,000	$ 2,177,000	$ 2,228,000	$ 2,281,000	$ 2,334,000	$ 2,389,000	$ 2,445,000
Annual Debt Service	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)	$ (1,283,000)
Net Profit After Financing	**$ 1,447,000**	**$ 1,510,000**	**$ 1,574,000**	**$ 1,087,000**	**$ 894,000**	**$ 945,000**	**$ 998,000**	**$ 1,051,000**	**$ 1,106,000**	**$ 1,162,000**

References

i. https://www.census.gov/quickfacts/fact/table/madisoncitywisconsin/LND110210
ii. https://www.google.com/maps/place/Dane+County+Sanitary+Landfill/@43.0467306,-89.2659852,660m/data=!3m2!1e3!4b1!4m5!3m4!1s0x8806507681ba9cf3:0x7650066c82c13d83!8m2!3d43.0467267!4d-89.2637965
iii. https://www.google.com/maps/place/Yahara+Hills+Golf+Course/@43.0411721,-89.2615069,2644m/data=!3m1!1e3!4m5!3m4!1s0x0:0xd45950877f93efba!8m2!3d43.0420454!4d-89.260118
iv. https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/dashboard/quarterlysummary/20200731_q1datasummary.pdf
v. https://madison.legistar.com/View.ashx?M=F&ID=8755253&GUID=05AA93A4-5B11-4F66-9C72-9CA3A70C2C71
vi. https://madison.legistar.com/ViewReport.ashx?M=R&N=Master&GID=205&ID=4625412&GUID=0A5103EC-4A26-4102-BAFC-E2B74FCDE4B9&Extra=WithText&Title=Legislation+Details+(With+-Text)
vii. https://www.google.com/maps/place/Dane+County+Sanitary+Landfill/@43.0467306,-89.2659852,660m/data=!3m2!1e3!4b1!4m5!3m4!1s0x8806507681ba9cf3:0x7650066c82c13d83!8m2!3d43.0467267!4d-89.2637965
viii. https://www.google.com/maps/place/Yahara+Hills+Golf+Course/@43.0411721,-89.2615069,2644m/data=!3m1!1e3!4m5!3m4!1s0x0:0xd45950877f93efba!8m2!3d43.0420454!4d-89.260118
ix. https://geopub.epa.gov/ExcessFoodMap/
x. https://geopub.epa.gov/ExcessFoodMap/
xi. https://geopub.epa.gov/ExcessFoodMap/
xii. https://geopub.epa.gov/ExcessFoodMap/
xiii. https://www.census.gov/quickfacts/danecountywisconsin
xiv. https://www.census.gov/quickfacts/danecountywisconsin
xv. https://wef.org/globalassets/assets-wef/direct-download-library/public/03---resources/wsec-2017-fs-002-mrrdc-anaerobic-digestion-fundamentals-fact-sheet.pdf
xvi. http://www.calrecycle.ca.gov/publications/Documents/1275/2008011.pdf
xvii. http://www.calrecycle.ca.gov/publications/Documents/1275/2008011.pdf
xviii. (Metcalf & Eddy, 1991)
xix. (Metcalf & Eddy, 1991)
xx. (Metcalf & Eddy, 1991)
xxi. (Metcalf & Eddy, 1991)
xxii. (Metcalf & Eddy, 1991)
xxiii. (Metcalf & Eddy, 1991)
xxiv. (Metcalf & Eddy, 1991)
xxv. (Metcalf & Eddy, 1991)
xxvi. http://www.sludgenews.org/about/sludgenews.aspx?id=5
xxvii. https://www.biofermenergy.com/
xxviii. https://www.biofermenergy.com/
xxix. Centrisys-CNG Combined Proposal for Alton, IL_3.08.2016
xxx. http://www.eia.gov/electricity/annual/html/epa_08_02.html
xxxi. http://biogasprocessing.blogspot.com/2012/02/h2s-removal.html
xxxii. https://www.airliquideadvancedseparations.com/our-membranes/biogas
xxxiii. https://www.airliquideadvancedseparations.com/
xxxiv. https://ohioline.osu.edu/factsheet/AEX-653.1-14
xxxv. https://ohioline.osu.edu/factsheet/AEX-653.1-14

The information contained in this report provides general guidance on matters discussed. The interpretation and application of environmental regulations are subject to specific facts involved. Given the changing nature of these regulations and the unique set of facts related to each project, there may be inconsistencies between the information contained in this report and a specific interpretation or application of a rule at a specific site by a federal or state agency. While we have made every attempt to ensure that the information contained in this report is accurate and reliable, EcoEngineers is not responsible for any errors or omissions, or for the results obtained from the use of this information. The information on this report is provided with the understanding that the authors are not herein engaged in rendering legal, accounting, tax, or other professional advice and services. As such, it should not be used as a substitute for consultation with professional accounting, tax, legal or other competent advisers.

ecoengineers

people-driven solutions