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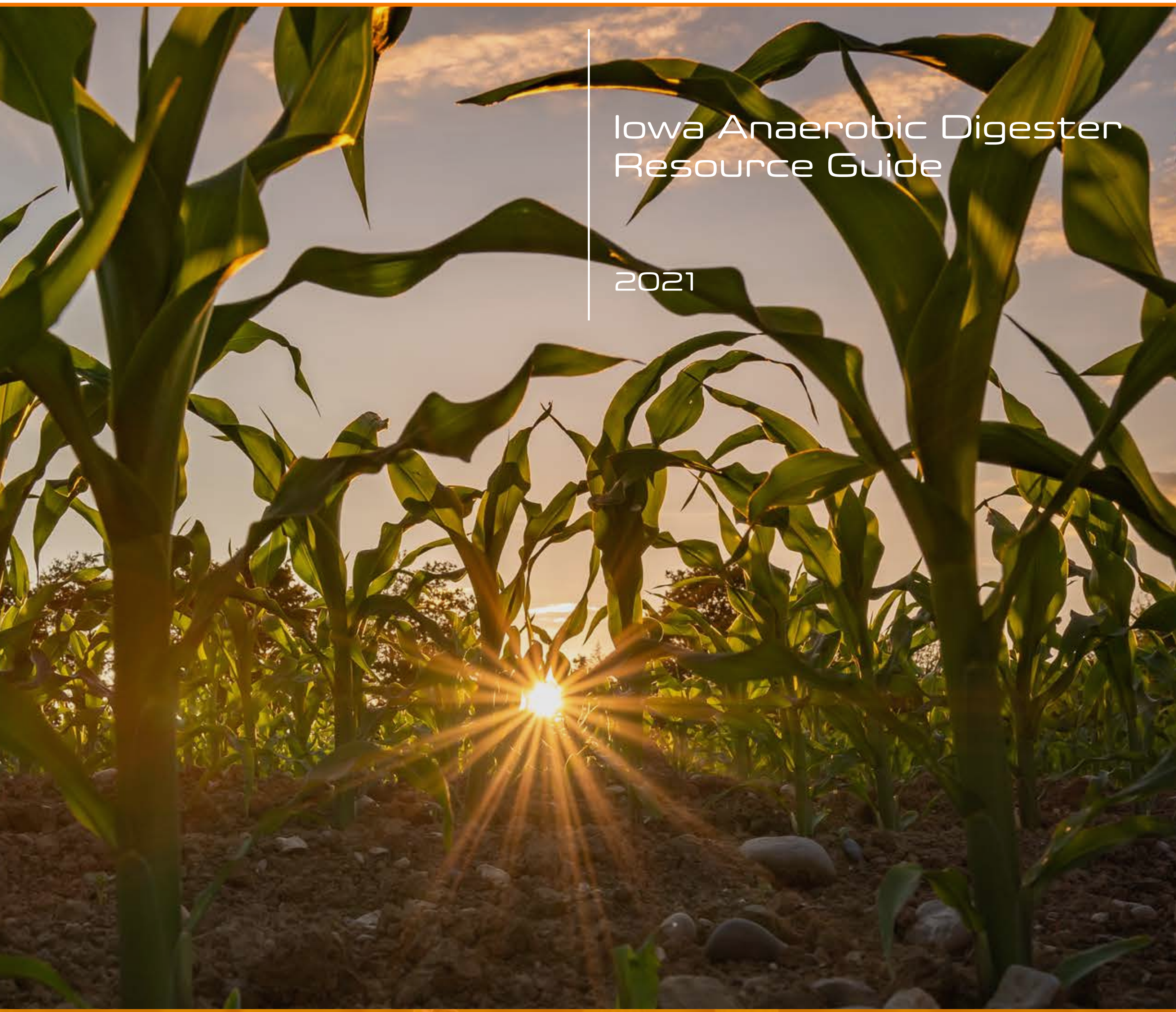
Iowa Anaerobic Digester Resource Guide

2021



[clean energy economy]

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Iowa Anaerobic Digester Resource Guide

Prepared for:

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[biogas | noun

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

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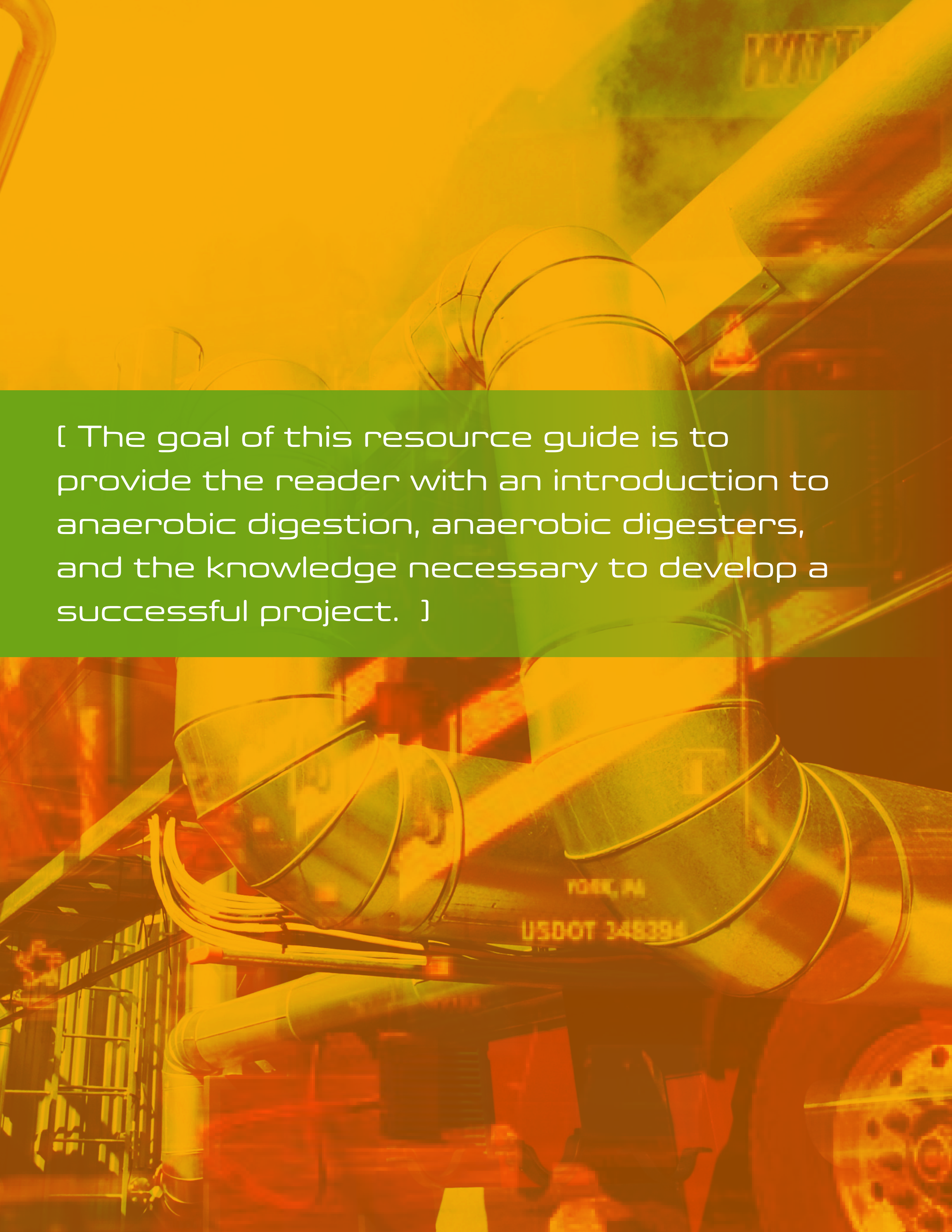

[The goal of this resource guide is to provide the reader with an introduction to anaerobic digestion, anaerobic digesters, and the knowledge necessary to develop a successful project.]

Introduction

Managing all the various components and complexities of a pipeline-quality renewable natural gas (RNG) project can be a challenge. Each component of the project must be carefully planned and coordinated to deliver a successful project. The Iowa Anaerobic Digester Resource Guide provides an overview of anaerobic digester (AD) project development and presents the technological, economic, and regulatory considerations that affect the feasibility and success of AD projects.

The goal of this resource guide is to provide the reader with an introduction to anaerobic digestion, anaerobic digesters, and the knowledge necessary to develop a successful project. Farm owners, energy service providers, state agencies and local government, community members, and other interested stakeholders will benefit from information provided in this handbook, as they work together to develop successful AD projects.

The guide is organized into 14 Sections.

- **Section 1.0** – Abbreviations for Anaerobic Digester Projects
- **Section 2.0** – Anaerobic Digestion Basics
- **Section 3.0** – Anaerobic Digestion System
- **Section 4.0** – Biogas Usage Options and Comparative Values
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Using the Project Development Resource Guide

The resource guide provides basic information that relates to all AD projects as well as presents a detailed overview of project specific considerations. Additionally, this guide covers the status of AD projects in the Unites States and the basic steps of developing an AD project.

Disclaimer

The resource guide is not an official guidance document. Instead, this document provides general information regarding AD projects. It does not address all information, factors, applicable regulations, local, state, or federal permitting, and considerations that may be relevant or required. Any reference to private entities, products, or services are strictly for informational purposes and do not constitute an endorsement of that entity, product, or service. Regulations are subject to change and could impact the successfulness of a project.

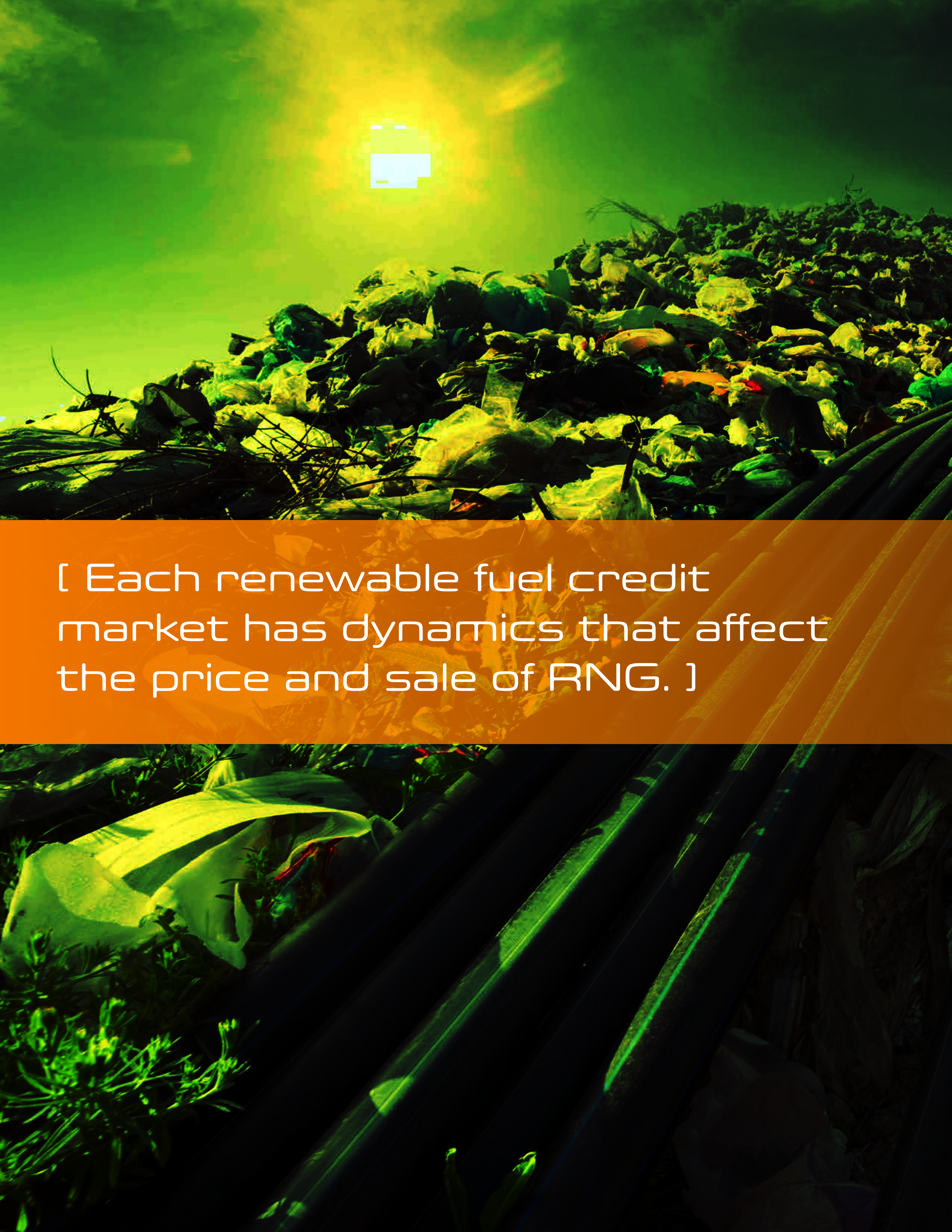
1.0 Abbreviations for Anaerobic Digester Projects

TERM	DEFINITION
ABC	American Biogas Council
AD	Anaerobic digester
AFDC	Alternative Fuels Data Center
AFO	Animal feeding operation
ASBR	Anaerobic sequencing batch reactors
BMP	Biomethane potential assay
BOD	Biochemical oxygen demand
Btu	British thermal unit
°C	Degrees Celsius
CAA	Clean Air Act
CARB	California Air Resources Board
CAFO	Concentrated animal feeding operation
CFR	Code of Federal Regulations
CH_4	Methane
CHP	Combined heat and power
CI	Carbon intensity
CNG	Compressed natural gas
CNMP	Comprehensive Nutrient Management Plan
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand

TERM	DEFINITION
CREST	Cost of Renewable Energy Spreadsheet Tool
CSANR	Center for Sustaining Agriculture and Natural Resources
CSTR	Continuous-stirred tank reactors
DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiency
EQIP	Environmental Quality Incentives Program
EV	Electric vehicles
°F	Degrees Fahrenheit
FDA	Food and Drug Administration
FERC	Federal Energy Regulatory Commission
FOG	Fats, oils, and greases
gCO_2e/MJ	Grams of carbon dioxide equivalent per megajoule (unit for measuring CI)
GHG	Greenhouse gas
H_2	Hydrogen
H_2S	Hydrogen sulfide
HAP	Hazardous air pollutants
HRT	Hydraulic retention time
HSAD	High solids anaerobic digestion

TERM	DEFINITION
kW	Kilowatt
kWh	Kilowatt-hour
LCFS	California Low Carbon Fuel Standard
LFG	Landfill gas
LNG	Liquified natural gas
MMBtu	Million British Thermal Units
$MMTCO_2e$	Million metric tons of carbon dioxide equivalent
MSW	Municipal solid waste
MW	Megawatt
MWh	Megawatt-hour
NAAQS	National Ambient Air Quality Standards
NH_3	Anhydrous Ammonia
NH_4	Ammonium
NOx	Nitrogen oxides
O_2	Atmospheric diatomic oxygen
O&M	Operations and Maintenance
OLR	Organic loading rate
OPEX	Operating Expenses
POTW	Publicly owned treatment works
PPA	Power purchase agreement
ppm	Parts per million
psi	Pounds per square inch
PTC	Production Tax Credit

TERM	DEFINITION
R-CNG	Renewable compressed natural gas
REAP	Rural Energy for America Program
REC	Renewable Energy Certificate
RFS	Renewable Fuel Standard
R-LNG	Renewable liquid natural gas
RNG	Renewable natural gas
RPS	Renewable Portfolio Standards
SOx	Sulfur oxides
SPP	Simple Payback Period
SRT	Solid retention time
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
tpy	Tons per year
TS	Total solids
TVS	Total volatile solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
VS	Volatile solids
VSS	Volatile suspended solids
WARM	Waste Reduction Model
WRRF	Water Resource Recovery Facility
WWTP	Wastewater Treatment Plant



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

2.0 Anaerobic Digestion Basics

2.1 What is Anaerobic Digestion?

Anaerobic digestion is the biological process by which microorganisms break down organic matter in the absence of oxygen. This is a four-step process:

1. **Hydrolysis:** Large protein molecules, fats, and carbohydrates — such as cellulose and starch — are broken down by fermentative bacteria into amino acids, fatty acids, and sugars.

2. **Acidogenesis**: The compounds are fermented into a variety of volatile fatty acids.

3. **Acetogenesis:** Acetogenic bacteria consume the fermented compounds and generate acetic acid, carbon dioxide, and hydrogen.

4. **Methanogenesis:** Methanogenic bacteria consume these products to produce methane gas.[i]

Anaerobic digestion is used to reduce and stabilize volumes of sludge, organic material, and manure. It generates two end products: biogas and digestate. The required low-oxygen environment can be manually generated, such as an enclosed vessel, or naturally occurring, like in flush lagoons at dairy and swine farms or in landfills.

Methanogenic bacteria are important for the final conversion to biogas, which is rich with methane; however, these bacteria are slow-growing and take time to produce significant volumes of biogas from the feedstock. Anaerobic digestion is a sensitive process because the acidogenic bacteria can produce acids that can kill the methanogenic bacteria in the digester and reduce biogas production. If the feedstock is fed too quickly, the acidogenic bacteria will grow out of proportion.

Therefore, proper feedstock loading is important to a well-run digester. If processing large feedstocks, grinding or shredding is necessary to reduce the particle size of the feedstock to be more easily digested by the microbes.

If processing multiple feedstocks, mixing will be needed to produce a homogenous mixture to be fed into the anaerobic digester.

2.2 Stages of Anaerobic Digestion

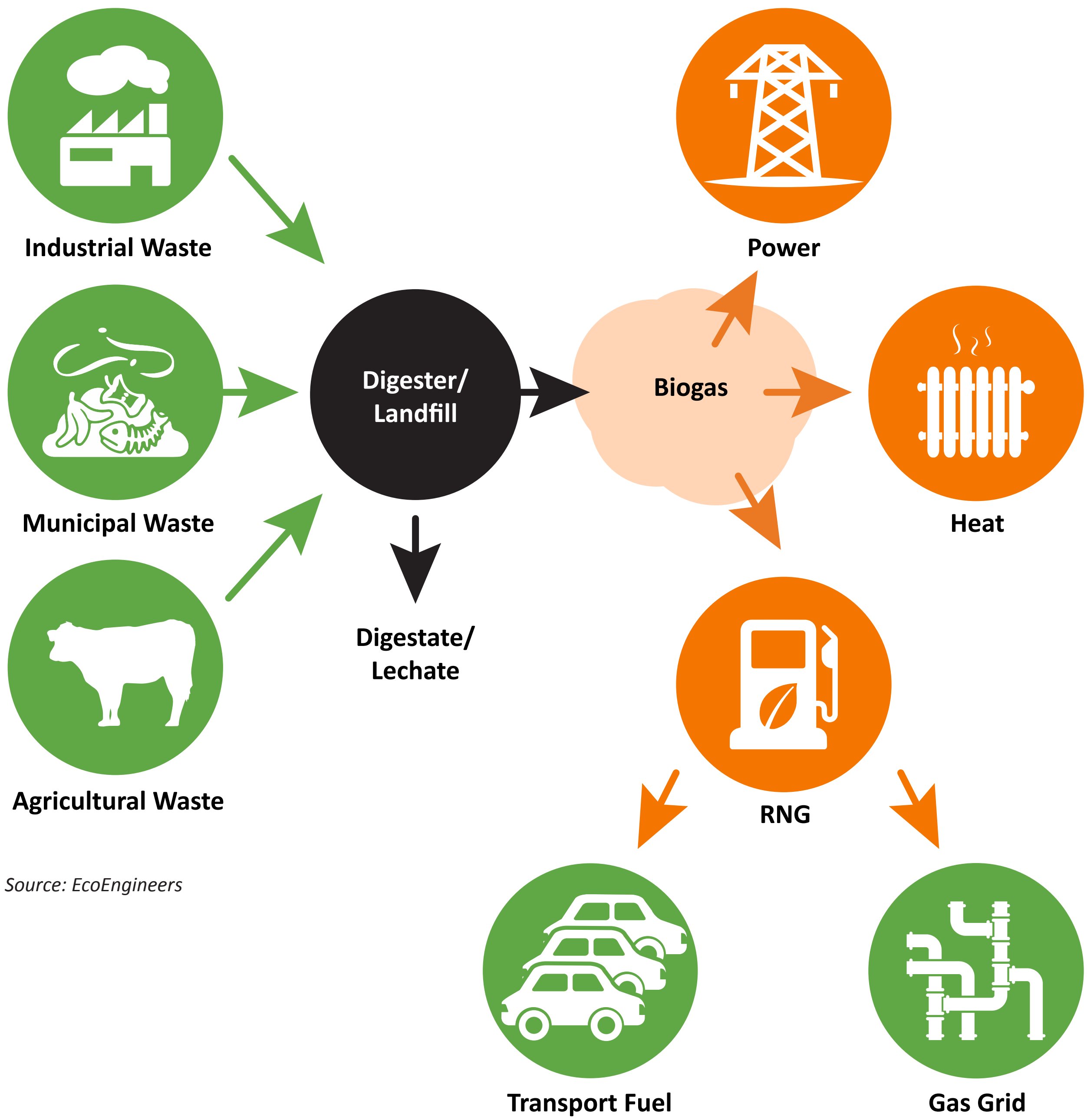
While anaerobic digesters can come in many different shapes and sizes, the process is commonly the same. There are typically four main stages of digester operation:

- Feedstock receiving and AD loading
- Digestion
- Biogas removal
- Digestate removal

Once the feedstock has been received by the facility, the project can start the feedstock loading phase.

It is important that the digester can process the feedstock. The feedstock may have to go through a pre-processing phase like contaminant removal and grinding. After processing, the feedstock can be fed into the digester where the digestion stage will take place. When the feedstock is loaded into the digester, the microbes begin to breakdown the material into two main components: biogas and digestate. The biogas collects at the top of anaerobic digester where it can be easily removed by a biogas removal system and can be utilized for several different end uses. As more material is added to the digester, digestate is removed. The digestate can be used for fertilizer, compost, or bedding. Figure 1 outlines the project flow from the feedstock to the end products.

FIGURE 1: OVERALL PROCESS FLOW OF AN ANAEROBIC DIGESTER



Source: EcoEngineers

The covered lagoon, tank-based digester, or other enclosed vessel is typically what is referred to as an anaerobic digester (AD) and comes in many different shapes, sizes, and configurations. ADs can be designed to accommodate many site-specific conditions and different feedstock options.

2.3 Applications of Anaerobic Digesters

Anaerobic digesters can process a wide range of materials but are used in these main application systems: municipal, landfill, industrial, and agricultural. The following sections provide further detail on each application.

2.3.1 Municipal AD Systems

Anaerobic digesters are commonly found at water resource recovery facilities (WRRF) or wastewater treatment plants (WWTP). Anaerobic digesters have been in use at WRRFs since the early 1900s to treat the solids present in the wastewater.[ii] The purpose of ADs at WRRFs is to process the solids, or sludge, and greatly reduce the amount of organic matter before that sludge is land-applied, sent to landfills, or burned in incinerators. The sludge may contain concentrated levels of contaminants. Depending on the operating temperature of the AD, the digestion process can result in significant destruction of pathogens present in the sludge and reduce overall sludge volumes. The result of AD processing is a digestate that is chemically stable, has reduced levels of pathogens, and is nearly odorless. According to the USEPA, there are approximately 1,250 WRRFs in the U.S. that use anaerobic digesters.[iii]

WRRF ADs can be used for co-digesting other organic waste streams beyond the sludge present in wastewater. If the ADs at WRRFs have excess capacity, organic waste from nearby industrial facilities can be added in to increase biogas production. This can create new revenue streams through tipping fees or generate more biogas for the production of energy.

2.3.2 Landfill AD Systems

Anaerobic digesters can also be found in landfill facilities to treat municipal solid waste (MSW). The purpose of landfill AD systems is to process organic material found in MSW, such as wood, paper, yard trimmings, and food, to help mitigate greenhouse emissions at landfills. Landfill AD systems produce landfill gas (LFG) for different end uses, such as vehicle fuel and electricity.

Per the USEPA's Landfill Methane Outreach Program (LMOP), which tracks LFG-to-energy projects, there were 67 landfill RNG operational projects mid-2020.[iv] With more landfill projects currently in development, LFG-to-RNG projects continue to become a more common practice to mitigating human-related greenhouse emissions.

2.3.3 Industrial / Commercial AD Systems

Anaerobic digesters can be used to process organic waste from industrial and commercial facilities. These types of anaerobic digesters are often used to process industrial waste, food waste, or organic waste from industrial processing, food processing plants, groceries, restaurants, and other food waste sources. ADs can be used to process high-strength organic waste from other industrial operations. These facilities can operate on a merchant basis through accepting organic waste from the surrounding community and charging tipping fees or gate fees to accept and process the waste.

In the past, these types of ADs have been much more limited in number than those at WRRFs, but they have been growing in recent years. Organic or food waste bans from landfills in certain parts of the country have driven many facilities to find other ways to process the waste, and ADs are an attractive option to divert waste from landfills due to their ability to produce biogas.

2.3.4 Agricultural AD Systems

Agricultural digesters are used to process and manage agricultural residues or animal manure produced from farming operations. ADs can be commonly found on dairy or swine farms but can be used to process any animal manure. ADs on farms are typically used to reduce GHG emissions by capturing the methane generated by the manure in deep, open lagoon systems instead of direct venting to the atmosphere. They also reduce odor and destroy pathogens in the manure due to the heat of the system. The nutrients in the manure are retained in the solid and liquid digestate and can be used as a fertilizer after the digestion process.

Agricultural digesters can also be used to process other agricultural products like corn stover, animal mortalities, cover crops, and more.

Careful management and preprocessing are necessary for these other agricultural products, as they could increase the solids content of the feedstock beyond what the digester can handle, shock the bacteria, and depress biogas production, or invalidate the biogas from qualifying for credits from certain programs.

Agricultural digesters have rapidly been growing in number due to policies in the states of California and Oregon. These state programs provide large incentives to capture methane and use it as a transportation fuel, which has spurred the development of many AD systems. Both states allow RNG to be produced at any location connected to the natural gas pipeline grid. This RNG is injected into the grid to displace an equivalent amount of natural gas dispensed as transportation fuel within California or Oregon. This process is generally referred to as “book-and-claim accounting.” By reducing GHG emissions through capture of methane in biogas, the biogas produced from agricultural digesters can be very valuable. According to the AgSTAR’s Livestock Anaerobic Digester Database, there are 288 ADs currently in operation or under construction in the U.S.[v]

2.4 Benefits of Anaerobic Digestion

2.4.1 Financial Benefits

Anaerobic digesters offer a way to diversify revenue, which can be key to long-term stability for project stakeholders (e.g., farmers, developers, municipalities, etc.). Digesters provide an opportunity to process many different types of waste, such as manure, crop residue, wastewater solids, and food waste. Nearby companies or organizations may be looking for alternatives for their waste processing that can be used as a feedstock in the digester to produce more biogas for energy production.

After the feedstocks have been processed by the digester, the resulting digestate is rich with nutrients. The organic nutrients in the liquid and solid fractions can be used as a farm fertilizer. These nutrients can be sold to farmers or other local and regional agriculture sources. Additionally, the solid fraction of the digestate can be used and sold as animal bedding. This adds two potential new revenue streams for AD projects. Further discussion of digestate end uses is presented in **Section 5.0.**

As anaerobic digesters break down the feedstocks, biogas is produced. This biogas is rich with methane that can be used as a source of renewable energy. This methane can be used to produce heat, electricity, or as a transportation fuel. Each of the products have great value and can be a source of additional income for farmers.

2.4.2 Economic Benefits

Anaerobic digester projects are great for spurring investment in rural communities and rural economic growth. AD projects can also benefit urban communities with dense populations that have trouble disposing of organic wastes or have interest in reusing organic waste to promote green initiatives. This also supports economic growth.

Digester construction requires expertise in site work, plumbing, electrical, permitting, and concrete, which can all be met with local contractors. This means that the construction of digesters can provide work for many different industries within a local scale.

Digesters require personnel for operation and maintenance to keep the digester in good working order. Locations with a digester can spur job growth in communities. Proper training is be needed to produce the skilled labor necessary for those roles because digesters and their upkeep can be complicated.

2.4.3 Environmental Benefits

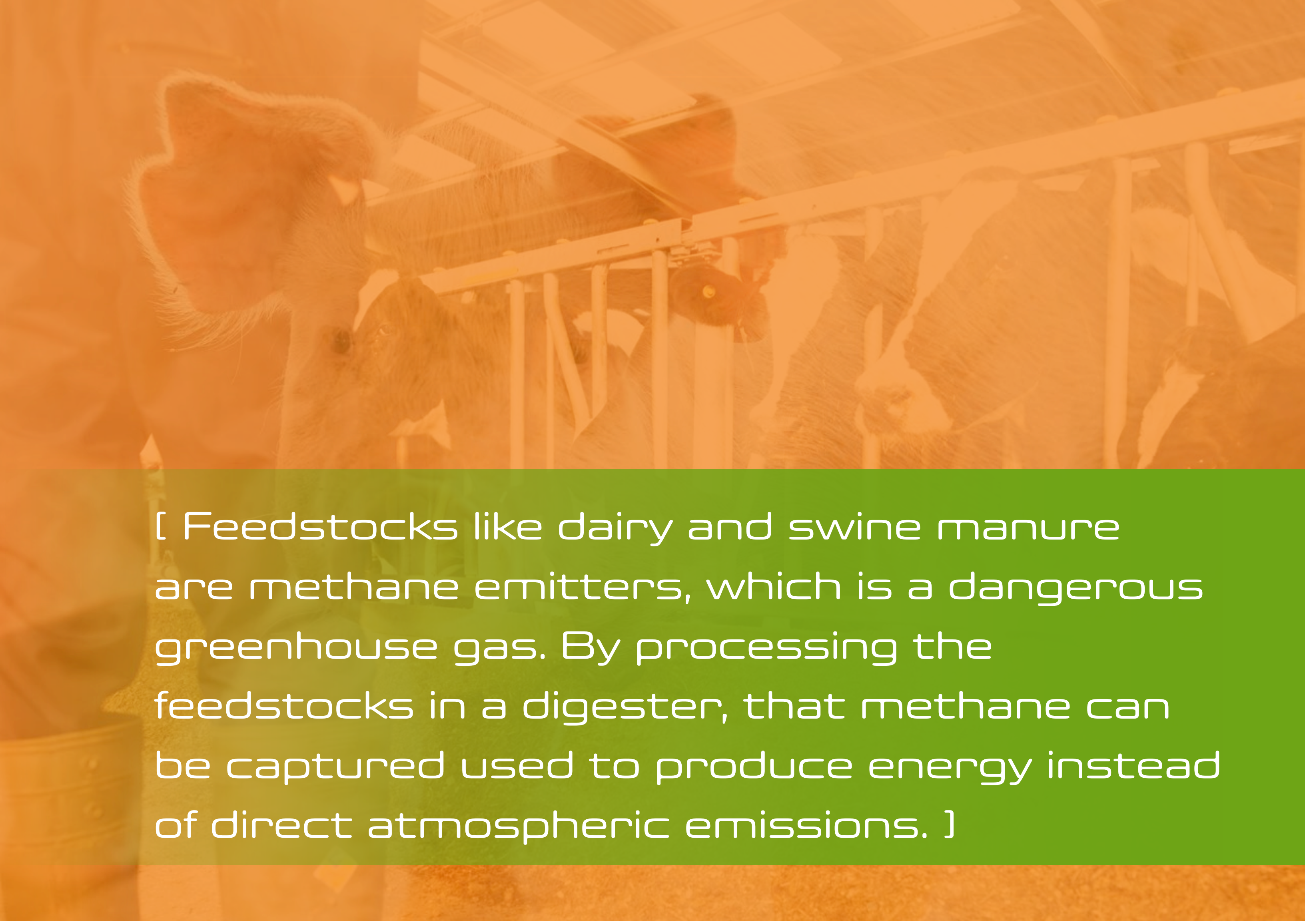
Anaerobic digesters offer a large number of environmental benefits including greenhouse gas reduction, improved soil health, and improved water quality. Feedstocks like dairy and swine manure are methane emitters, which is a dangerous greenhouse gas. By processing the feedstocks in a digester, that methane can be captured used to produce energy instead of direct atmospheric emissions.

Digesters can improve soil health by concentrating the nutrients and converting them into forms that are easier for plants to use. As the feedstocks are processed in the digester, the bacteria work to break down the material, including the nutrients like nitrogen, phosphorous, and potassium.

Digesters can improve water quality by reducing nutrient runoff and destroying pathogens. The nutrients in the feedstock are available in more plant-friendly form that are less prone to runoff, keeping the nutrients out of the watershed and in the fields. The digester operates at a prolonged high temperature that kills off any pathogens and allows them to process animal carcasses that may have died due to a disease or illness.

2.4.4 Energy Generation Benefits

Anaerobic digesters are a great opportunity to produce renewable energy. The main product of anaerobic digestion is biogas, which typically contains 50-65% methane. The methane can be used to meet many different energy needs. It can be used to produce heat, electricity, or a transportation fuel. Depending on the markets and the end use of the biogas, it can provide an additional revenue stream for the project



[Feedstocks like dairy and swine manure are methane emitters, which is a dangerous greenhouse gas. By processing the feedstocks in a digester, that methane can be captured used to produce energy instead of direct atmospheric emissions.]

owner. Methane is a more potent GHG than carbon dioxide. By capturing the methane and using it to produce energy, the project is avoiding methane emissions to the atmosphere.

2.5 Potential for New AD Systems

There is a large potential for new AD systems throughout the United States. According to a study completed by the American Biogas Council, there is potential for 8,300 new agricultural digesters, 4,000 new WRRF digesters, and 1,000 new food waste/industrial digesters. In the U.S. alone, 66.5 million tons of food waste are produced each year, and 31 billion gallons of wastewater is produced every day. There are 8 billion cows, hogs, chickens, and turkeys producing manure, which can all be processed in ADs.[vi] The potential for biogas production across the U.S. is immense.

Federal and state regulations and policies also exist to support the development of AD system. The renewable or environmental attributes of the energy produced from AD can be monetized for a significant premium above the value of the energy itself.

Iowa has an abundance of biomass resources that can be processed in AD systems. According to the Billion Ton Report published by the USEPA, most of Iowa falls within highest potential or second-highest potential biomass supply categories with 500-5,000 dry tons per square mile. Biomass includes municipal solid waste, manure, and agricultural supplies like crop residues and energy crops.[vii]

3.0 Anaerobic Digestion System

3.1 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.[viii] Single-stage systems are generally less expensive and are simpler to design, build, and operate. However, the single-stage ADs have a common limitation; because all 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 limiting the organic loading rate to the digester.[ix] Two-stage digesters avoid this problem by separating the methanogenic organisms from the low-pH stages of digestion. This process pretreats the material and allows for higher organic loading rates in the second stage of the process. However, the complexity and installation expense of multi-stage systems frequently outweighs the benefits of improved digestion and higher loading capabilities.[x] Nevertheless, multi-stage digestion systems hold a lot of potential value for facilities that are limited on digestion capacity, as adding a pretreatment or “first stage” to their anaerobic digestion system could help solve their capacity challenge.

While anaerobic digestion can occur at a wide range of temperatures, higher temperatures are conducive to faster and more efficient decomposition. There are two main types of anaerobic digestion: mesophilic and thermophilic. Mesophilic digestion typically occurs between 85-100 °F, and thermophilic digestion occurs above 122 °F.[xi] Thermophilic digestion is preferred for high-rate systems, as temperature increases bacteria activity. Digesters located in colder climates that are unheated or uninsulated may be prone to lower biogas production in the winter due to the lower temperatures.

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.[xii] The digester would likely be operated under mesophilic conditions. Mixing is typically accomplished by gas recirculation, mechanical mixers, pumping, or draft tube mixers.[xiii] The feed to the digester should be pumped continuously or on a consistent cycle to maintain consistent conditions.[xiv] 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.[xv]

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.[xvi] Cylindrical tanks can range from 20-125 feet in diameter and are designed for a water depth between 25 feet and 45 feet.[xvii] An example of a vertical cylinder agricultural digester is shown in Figure 2.

FIGURE 2: CYLINDRICAL ANAEROBIC DIGESTERS

Source: Shutterstock

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

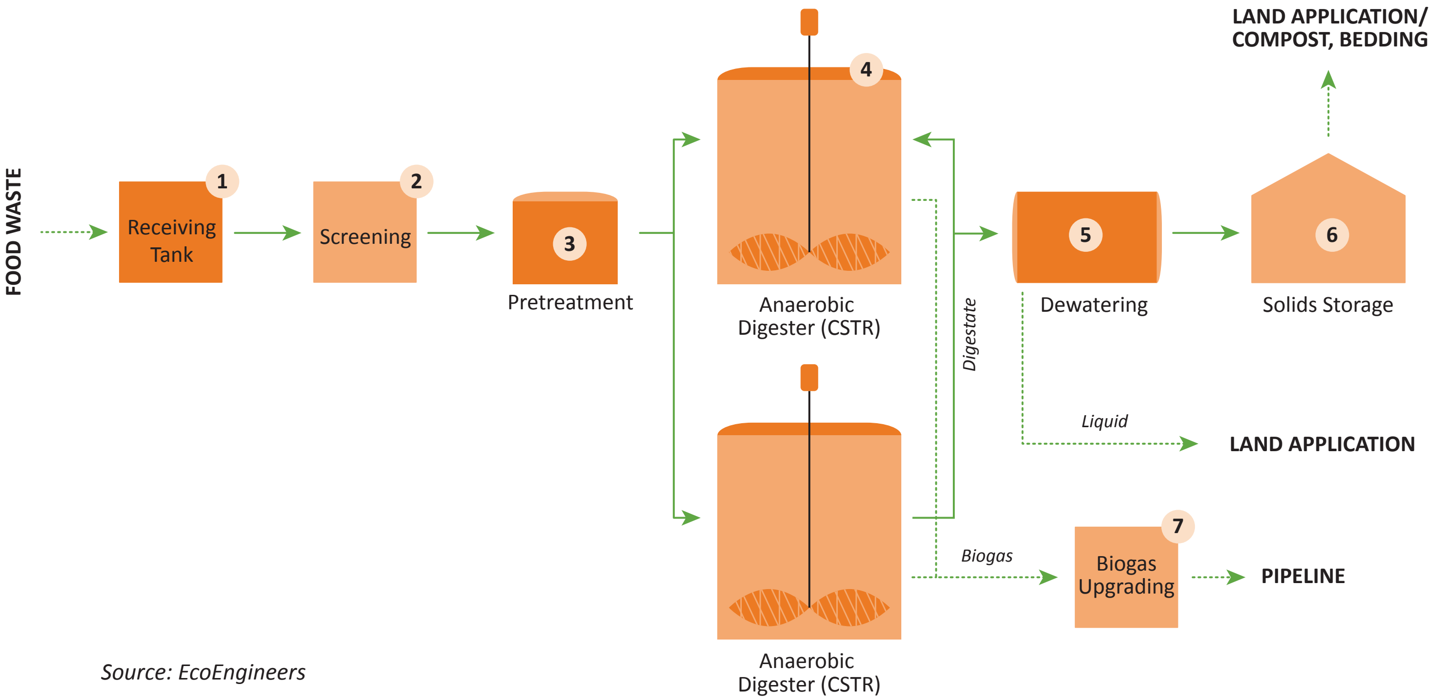
Another important aspect of digester design is the cover. There are two main types of digester covers: fixed and floating. The headspace above the liquid level is filled with biogas (not air), so accommodating changes in liquid level is critical. As liquid levels fall, the headspace pressure decreases, and air cannot be drawn into the vessel. When liquid levels increase, the headspace 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 headspace 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.

3.2 Preliminary Process Flow

A preliminary process flow diagram of the conceptual digester system is shown in Figure 3.

FIGURE 3: PROCESS FLOW FOR ANAEROBIC DIGESTER



Source: EcoEngineers

The feedstock is processed in the pretreatment system until its ready to be sent to the digester. After digestion, the effluent from the digester is dewatered and the resulting liquid can be recycled back for farmland application. 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 removed. 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 3 is described in more detail below.

1. RECEIVING TANK

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

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

b. **Outputs:** Packaged and non-packaged food waste, manure, other organic waste, and contaminants (if not properly separated prior to digester facility)

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

2. SCREENING

The screening process includes a visual inspection of the feedstock to remove any unwanted contaminants, remove indigestible material, and recover bedding material, as applicable. 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, manure, other organic waste, and contaminants (if not properly separated prior to digester facility)

b. **Outputs:** Non-packaged food waste, manure, other organic waste

3. PRE-TREATMENT

A pre-treatment system may help remove packaging material, depending on the type of feedstock, and pre-process waste before feeding it into the digester system. Pre-treatment may also include grinding of the material into smaller pieces, as necessary. The recovered feedstock is then conveyed to the digester system.

a. **Inputs:** Packaged or non-packaged food waste, manure, other organic waste

b. **Outputs:** Recovered feedstock (organics)

4. ANAEROBIC DIGESTERS

There are different types of digester systems that may be used depending on the application. These may include covered lagoons, batch digesters, plug-flow digesters, and continuously-stirred tank reactors (CSTRs). The AD system may be mixed and heated to 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 headspace 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

b. **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 often 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, soil amendment, or animal bedding. The liquid digestate stream from the dewatering system contains high concentrations of nitrogen and phosphorus and is often land applied or requires additional treatment to meet local discharge requirements.

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

b. **Outputs:** Solids, liquid

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 loadout system, so the solids can be loaded onto trucks. This solid material also contains valuable nutrients and can be land applied in accordance with Iowa 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

b. **Outputs:** Dewatered digestate solids

7. LIQUIDS STORAGE

The liquid stream exiting the dewatering process will be conveyed to a tank storage unit. This liquid material contains the majority of the nutrients found in the digestate and can be land applied in accordance with Iowa Department of Natural Resources Environmental Management laws. This stream may also be further treated and discharged as a clean effluent.

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

b. **Outputs:** digestate liquids

8. 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.

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

b. **Outputs:** Condensate, exhaust gas, waste adsorbent media from H_2S treatment

4.0 Biogas Usage Options and Comparative Values

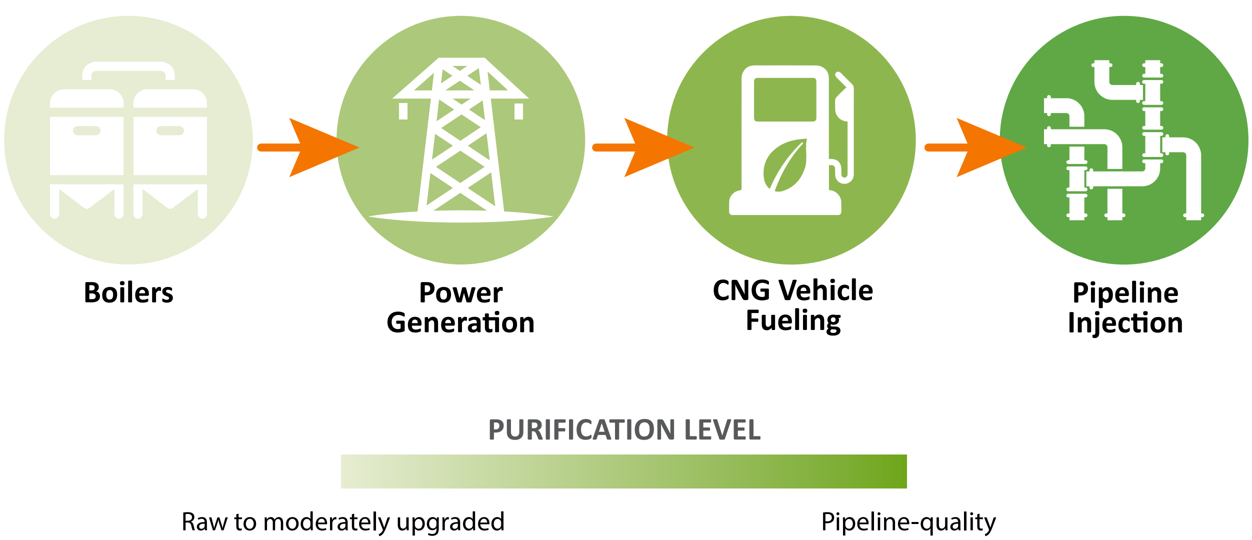
Biogas is primarily a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic materials in the absence of oxygen (anaerobic). Biogas production from the anaerobic digestion of residual organic feedstock is an established process and can be implemented as an effective 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.

Figure 4 shows specific and commercially proven uses for biogas. This includes:

- **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 4: BIOGAS PURIFICATION LEVELS AND ASSOCIATED USES



Source: EcoEngineers

Desired end use for the biogas will dictate the amount of purification, conditioning, or biogas upgrading required. Minimal upgrading is needed for biogas to be used in a boiler for heat production and is typically limited to moisture and hydrogen sulfide removal. To use biogas in a generator for electricity or heat production, further upgrading is required, such as removal of siloxanes. Significant upgrading is necessary to use biogas as vehicle fuel due to vehicle engine specifications. Nearly all non-methane components must be removed, including hydrogen sulfide, siloxanes, oxygen, water, carbon dioxide, and nitrogen. Purification requirements of biogas for pipeline injection are similar to vehicle fuel specifications 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 1. Uses that require significant upgrading (pipeline injection) will incur higher capital investment. The data in Table 1 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.

Disclaimer: Regulations and commodity pricing are subject to change and may be more variable than what is in Table 1. Table 1 shows the common upper and lower bounds.

TABLE 1: BIOGAS VALUES BASED ON USE AND COMMODITY REPLACEMENT VALUES (JANUARY 2021)

		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		$0.12	
Biogas Use	Generator Electricity Production[xix]		$3.86		$7.76
Commodity	LCFS Credit	$100		$215	
Commodity	D3 RIN Credit	$0.50		$3.00	
	CI Score	40 gCO_2e/MJ		-250 gCO_2e/MJ	
Biogas Use	Pipeline Injection-Vehicle Fuel (RINs & LCFS)		$9.99		$109.85

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

5.0 Digestate End Uses

5.1 Overall

Anaerobic digestion is used to process feedstock materials to produce biogas for various end use purposes.

The anaerobic digestion process converts a portion of the organic material into biogas, but it is not 100% efficient and cannot process the inorganic components of the feedstocks. The resulting by-product — the digestate — must be considered. The digestate is high in nutrients, such as phosphorous, nitrogen, and potassium, making it useful for land application as fertilizer for crops, compost, soil amendment, or bedding material.

As such, the digestate can be sold to farms interested in land-applying this material. If digestate is ultimately land-applied, there are typically land application windows (twice per year) within the State of Iowa. Digestate may have to be stored for up to six months, so adequate storage space is critical. Ideally, the digestate is sold and can provide additional economic support to the AD project. However, the ability to sell the digestate and the price is very region- and project-specific.

5.2 Separated Liquids and Solids

The digestate is typically dewatered to save on storage and hauling costs, and to separate the solid and liquid streams.

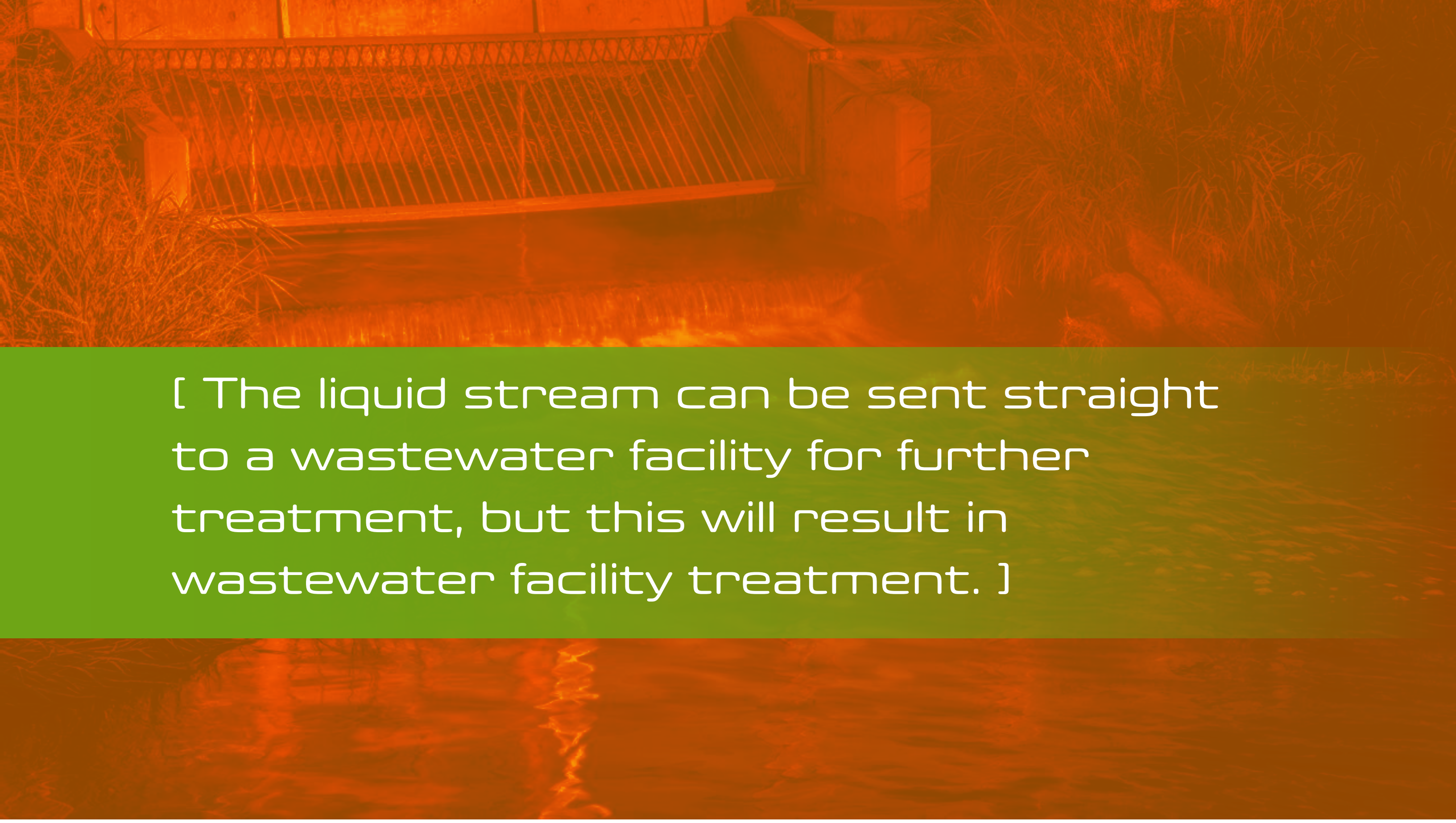
The dewatering process, or liquid-solid separation, is typically accomplished using a centrifuge, screw press, or belt filter press to produce a high-solids byproduct rich in nutrients. Final nutrient concentrations will depend on the feedstock mix, AD system, dewatering technology, and operation. The solids stream existing the dewatering process will be conveyed to a drying system or storage unit. This unit will typically be a covered concrete slab equipped with a loadout system, so the solids can be loaded onto trucks. This digestate stream, high in solids, can then be sold for land application, composting, soil amendment, or animal bedding. The solid stream may also be disposed as waste.

In general, the majority of the nutrients introduced to the AD system will end up in the liquid portion of the digestate, including high concentrations of nitrogen and phosphorus. Dewatering the solid digestate to 30% total solids results in a suitable liquid product for land application. Alternatively, the liquid digestate may require further treatment and the effluent discharged per local and state requirements.

5.2.1 Land Application and Composting

The AD digestate by-product can be sold for land application or compost. A few cities around the country (Seattle, Washington, D.C., Houston, Philadelphia, etc.[xx]) and at least one private company, Magic Dirt, market and sell biosolids commercially. However, it does take time to develop a market for the material.

Both the solid and liquid streams of the digestate may be used for land application as fertilizers. Solid digestate is harder to spread on land, but it is suitable for land application due to its minimal phosphorus concentration. Liquid is more easily spread as a fertilizer through a tanker or injection application equipment. However, due to the possible high concentrations of phosphorous in the liquid portion of the digestate,



[The liquid stream can be sent straight to a wastewater facility for further treatment, but this will result in wastewater facility treatment.]

this may limit its use for land application. It is possible to further treat the liquid stream to remove the phosphorus component through struvite recovery, increasing the ability to land apply the digestate.[xxi] The struvite can then be marketed as a slow-release fertilizer product.

The solid digestate can also be composted. Typically, it takes about 8-12 weeks to compost raw material, but this process can be reduced to about 2-3 weeks when composting digestate, since the material has already partly decomposed in the AD process.[xxii] The resulting compost product can then be sold as a product and land-applied as a fertilizer, supplying nutrients to the soil to enhance crop growth.

5.2.2 Bedding Material

Other than using the solid digestate for land application or composting, this material may also be used "as-is" for animal bedding. The solid digestate may be composted to further remove its moisture content, "making it easier to handle and less messy, while also reducing its odor and ammonia content."[xxiii] It can be economically beneficial for farmers with digester systems to generate their own bedding material. Even if bought externally, this type of bedding is generally less expensive compared to wood-based bedding material.[xxiv] Although selling the solid digestate bedding material to farmers is an option, "relatively little digestate has hit the marketplace thus far in the U.S., primarily because much of the manure-based solid digestate is reused by farmers as cow bedding."[xxv]

5.3 Straight from the Digester

Once the digestate is dewatered, if the liquid digestate is not utilized as fertilizer, it can be processed as wastewater. The liquid stream can be sent straight to a wastewater facility for further treatment, but this will result in wastewater facility treatment. Alternatively, the liquid digestate can be treated at the digester facility to remove the necessary nutrients, then disposed of to a local water source. However, this requires additional capital costs associated with further purification of the liquid stream.

6.0 Incentive Programs

In 2019, 46% of energy-related CO_2 emissions in the United States were from petroleum use, where 33% and 21% were from burning natural gas and coal, respectively. This is due to the transportation sector's high dependence on petroleum fuels, resulting in the most emissions of CO_2 when compared to the industrial sector.[xxvi]

Biogas has a few different commercially proven end uses, including thermal applications, power generation, combined heat and power, and vehicle fuel. They all contribute to the overall reduction of GHG emissions. However, due the level of GHG emissions from the transportation sector, there is particular interest in displacing traditional vehicle fossil fuels.

In particular, biogas upgraded to RNG can be used to displace conventional fossil natural gas in natural gas vehicles. RNG can also be used to displace diesel; however, the cost to convert vehicle engines to RNG is significant and often depends upon availability of government incentives.

Using biogas for a vehicle fuel end use provides the opportunity for participation in the Federal Renewable Fuel Standard (RFS) and in state programs such as California's Low Carbon Fuel Standard (LCFS) program. Participation in these programs can provide a stream of revenue for a project through credit generation. If participation in any of these programs is planned, considering the type of feedstock is critical for the monetary success of the project; different types of feedstocks are not all treated equally under these programs.

The following sections will outline the different classifications under the RFS and LCFS around the type of feedstock used to produce biogas.

6.1 Renewable Fuel Standard (RFS)

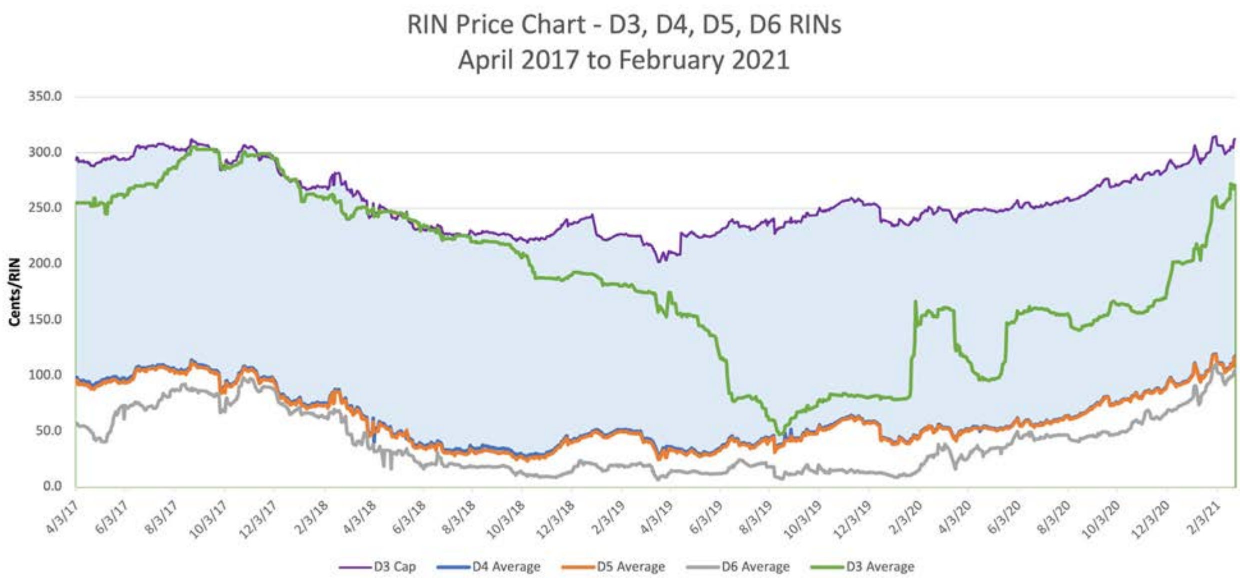
The Federal RFS program was created to incentivize the development of the renewable fuels. The primary policy mechanism the program utilizes is the renewable volume obligations (RVOs), which are set annually and mandate the amount of transportation fuel that must be used in the United States. Congress originally set the traditional low-carbon fuel at 15 billion gallons in the hope of developing advanced and cellulosic low-carbon fuels, but the RVO has since been adjusted annually to reflect actual industry production capacity.

Renewable Identification Numbers (RINs) are a unique number generated to represent a volume of renewable fuel. RINs are classified by fuel types such as biodiesel, ethanol, natural gas, and other approved renewable fuels. RIN classifications, or D-Codes, are further broken down by the type of feedstock and the process used to produce the renewable fuel, along with the calculated reduction of GHG emissions.

RINs are the "currency" of the RFS program. The RIN value, or pricing, is determined based on various volatile market forces, including annual RVOs set by the USEPA, the number of Small Refinery Exemptions (SREs) allowed by the USEPA, changes in administration staff, rulemaking changes, and other regulatory events. Figure 5 (on page 22) shows a graph of RIN price fluctuation over the years.

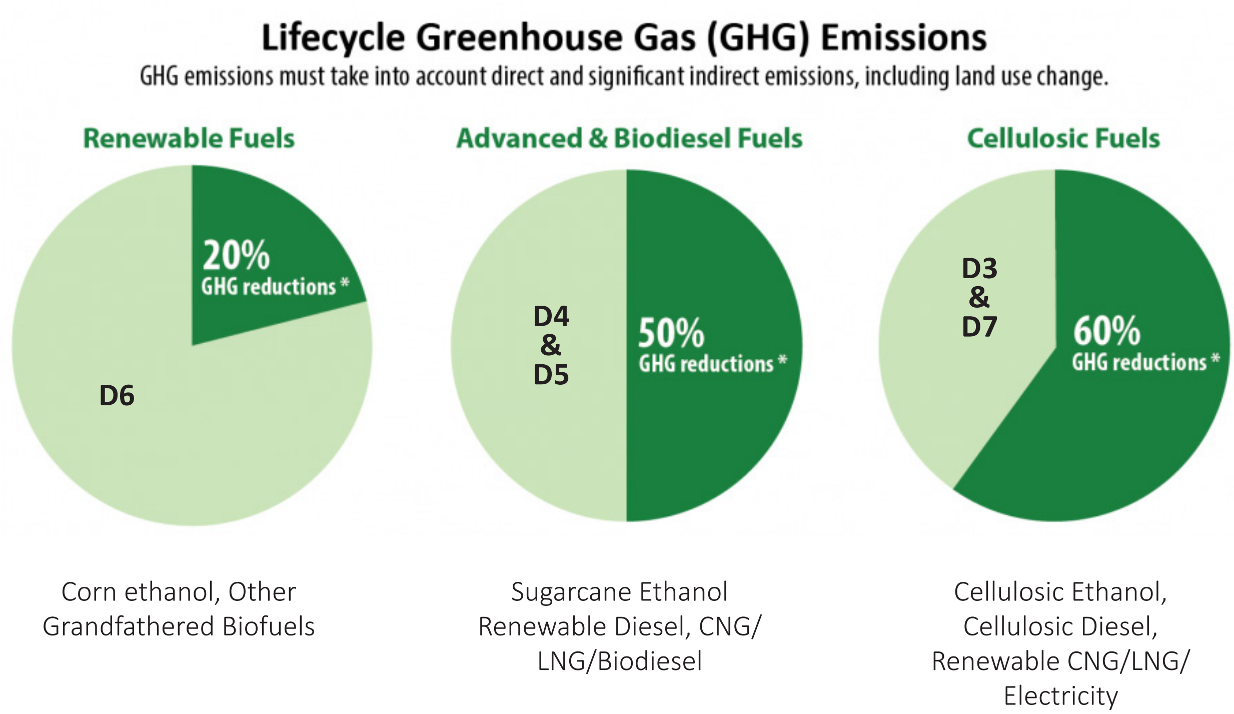
RNG may fall under the "advanced biofuels" category, generating D5 RINs under a "T" pathway, or under the "cellulosic fuels" category, generating D3 RINs under a "Q" pathway. Figure 6 (page 22) shows the various categories of renewable fuels, minimum GHG emission reduction expected for each, and the associated D-Codes.

FIGURE 5: RIN PRICE HISTORY



Source: EcoEngineers

FIGURE 6: RENEWABLE FUEL CATEGORIES AND GHG EMISSIONS REQUIRED



Source: USEPA, compared to a 2005 baseline

D5 RINs are generated by processing "non-cellulosic" feedstock at an anaerobic digester to produce RNG. Non-cellulosic feedstock can include any type of renewable biomass that is not high in cellulosic content (less than 75% threshold of cellulose, hemicellulose, or lignin components). Food waste is typically considered a non-cellulosic type of feedstock.

D3 RINs are generated by processing "cellulosic" feedstock at an anaerobic digester to produce RNG. Cellulosic feedstock must meet the minimum 75% threshold of cellulose, hemicellulose, or lignin components. Examples of cellulosic feedstock include dairy and hog manure, wastewater waste, landfill waste, cover crops, and crop residues from agricultural waste processes. Table 2 provides more information on the two RNG pathways (Q and T) eligible under the RFS.

TABLE 2: RFS PATHWAYS ELIGIBLE FOR BIOGAS (FROM §80.1426)

	FUEL TYPE	NOTE	PRODUCTION PROCESS	D-CODE
Q	Renewable compressed natural gas, renewable liquified natural gas, renewable electricity	Biogas from landfills, municipal, wastewater treatment facility, digesters, agricultural digesters, and separated MSW digesters; and biogas from the cellulosic components of biomass processed in other waste digesters	Any	3 (Cellulosic biofuel)
T	Renewable compressed natural gas, renewable liquified natural gas, renewable electricity	Biogas from waste digesters	Any	5 (Advanced biofuel)

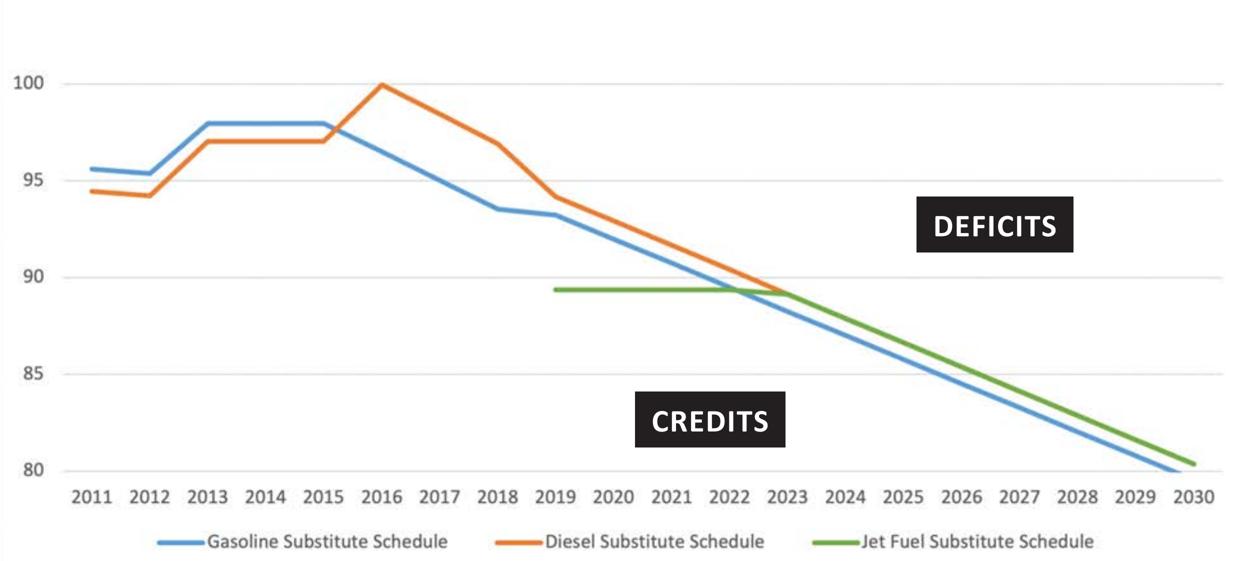
The D-Code of renewable natural gas is essential to project revenue because of the premium value of D3 RINs over D5 RINs. As shown in Figure 5, D3 RIN prices ranged from $0.78 to the current value of $2.60 in February 2021 and from $0.38 to $1.20 for D5 RINs. The premium price of D3 RINs over D5 RINs could increase revenue by potentially millions of dollars each year for a project.

6.2 California's Low Carbon Fuel Standard (LCFS)

California's LCFS aims to meet a 20% reduction in the carbon intensity score (CI) of transportation fuels by the year 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.

Compliance curves have been established for gasoline, diesel, and jet fuel, as seen in Figure 7 (page 24). When a fuel has a CI score lower than the compliance curve for the established fuel it displaces, it generates credits. Fuels with CI scores above the compliance curve generate deficits, and those deficits need to be satisfied by LCFS credits. For example, if the compliance curve is set at a CI score of 90 and RNG is produced with a CI score of 30, then the RNG generates LCFS credits based on that differential. The lower the CI score of the facility, the more LCFS credits generated by the same volume of renewable fuel.

FIGURE 7: LCFS ANNUAL COMPLIANCE CURVE



Source: EcoEngineers

It is more profitable to produce fuel with a low CI score, as the fuel can generate more credits under the LCFS system. It is also more profitable for RNG to displace diesel fuel, compared to fossil natural gas, because diesel's CI is higher than fossil natural gas (greater compliance curve); and, therefore, will generate more LCFS credits. 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 they have no price floor.

There are different pathways an applicant may apply for to participate in the LCFS. Determining which is the applicable pathway depends on the type of fuel produced. The appropriate pathway may also depend on the type of feedstock or process used to produce such fuel. Typically, a Tier 1 pathway application is used for RNG produced from landfill waste, wastewater, organic waste, and manures. RNG produced from the aforementioned feedstocks may fall under a Tier 2 pathway instead if an innovative method, meeting substantiality requirements, is used to produce the RNG. Table 3 (page 25) provides an overview of the different types of fuels and feedstocks that qualify under the LCFS pathways.

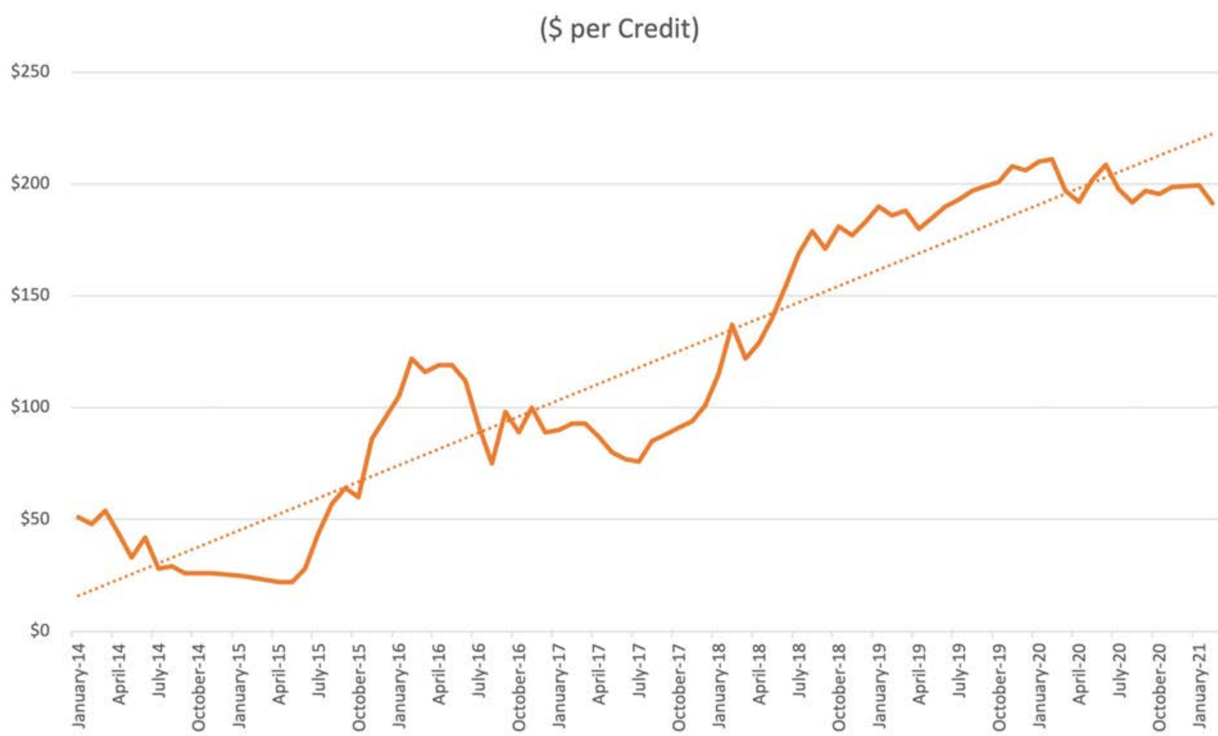
The CI score of the fuel will dictate how many LCFS credits will be generated and, ultimately, the monetary value of the RNG on a per MMBtu basis. The CI score for a project is modeled through a life-cycle analysis (LCA), starting with the production and transportation of the feedstock to the production and distribution of the RNG and, finally, the use of RNG as transportation fuel. Since the production of the feedstock is part of the LCA, different types of feedstocks will contribute differently to the overall CI score of a project. Depending on the feedstock used to produce RNG, RNG has the potential to produce extremely low CI. As seen on Figure 8, based on the fuel the RNG is substituting, the compliance curve for the original transportation fuel will change and impact the number of credits generated.

Figure 8 (page 25) shows the historical price of LCFS credits. Prices fluctuate daily but have remained above $170 since January 2019. With the increasing credit prices, more importance is placed on reducing the CI score in order to generate more credits. It is anticipated that the trend will continue, and there will be continued high demand for low-CI fuels in California.

TABLE 3: LCFS PATHWAY TYPES

LOOKUP TABLE VALUES (§ 95488.5.5 TABLE 7-1)	TIER 1 PATHWAYS (TIER 1 CALCULATORS)	TIER 2 PATHWAYS (CA-GREET 3.0)
CARBOB	**Biodiesel**	**Tier 1 Fuels** using innovative method meeting substantiality requirements: • 5% lower if reference below 20 CI • 1 CI point lower if reference below 20 CI
Diesel	**Renewable Diesel**	
CNG	**LNG, CNG from North American natural gas**	
Propane	**Ethanol** • Starch • Fiber • Sugarcane	**Wet Mill Ethanol**
Hydrogen	**Biomethane** • N.A. Landfills • Anaerobic Digestion of Wastewater • Organic Waste • Dairy and Swine Manure	**Plastic to Fuel**
Electricity • Grid • 100% Zero-CI • Smart Charging		**Pyrolysis Oil**
		Next-Generation Fuels

FIGURE 8: AVERAGE MONTHLY LCFS CREDIT PRICE



Source: EcoEngineers

[Food waste is great to use in an anaerobic digester because it has high biogas yields, and often there are incentives to use it.]

7.0 What Types of Feedstocks Can Be Used to Produce Biogas?

There are many different types of feedstocks that can be used to produce biogas. There are also several commercially proven end-uses for biogas. The desired end use for the biogas will dictate the amount of purification (upgrading) required.

This section will outline the different types of feedstocks commonly used to produce biogas.

7.1 Types of Feedstocks

Biogas is produced by processing different types of organic material. The organic material, also referred to as "feedstock," is fed into an anaerobic digestion system to ultimately produce biomethane. The produced biogas has various commercially proven uses, including thermal applications, power generation, combined heat and power, and vehicle fuel. The following sections provide a description of the most common types of feedstocks used to produce biogas through an anaerobic digestion system, which can ultimately be used to produce RNG.

7.1.1 Dairy and Hog Manure

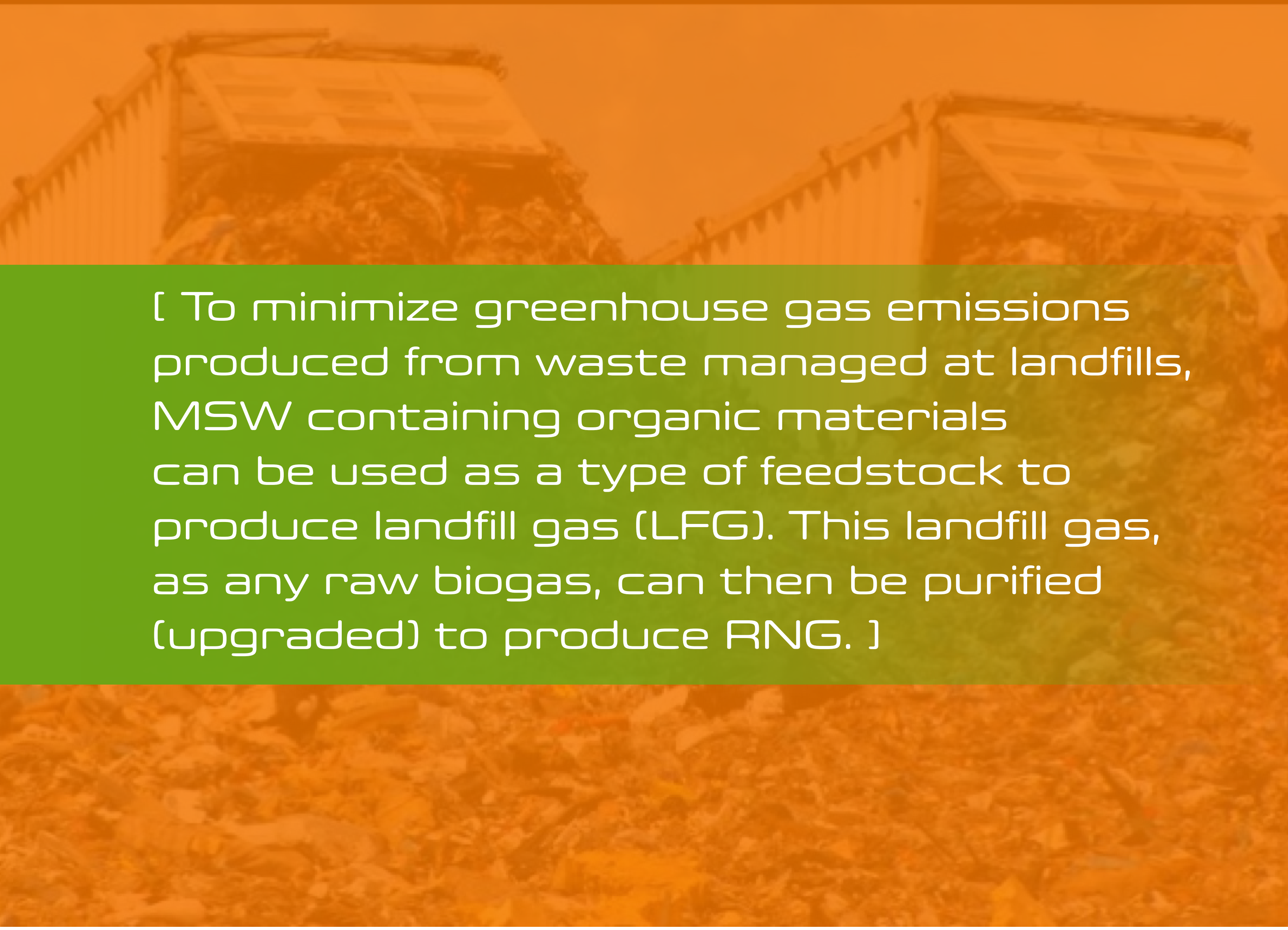
According to the USDA National Agricultural Statistics Service, there were approximately 215,000 milk cows on farms in the state of Iowa as of December 2019, about 2.3% of the national total.[xxvii] However, the USDA says Iowa has the largest inventory of hogs in the U.S.[xxviii] There were about 25.1 million hogs and pigs in the state of Iowa as of December 2019, which is approximately 32% of the national total.[xxix] With such inventory, there is ample opportunity for the use of dairy and hog manure as feedstock within the state of Iowa.

At the farm level, "manure management systems encompass six functions: production, collection, storage, treatment, transfer, and utilization."[xxx] Manure management systems are designed and implemented based on the objective of the system, such as reducing odor, pathogens, and methane emissions, as may be the case with the implementation of lagoon systems.[xxxi] There are also different end uses to manure that are considered in the design of management systems. These end uses may include manure as a source of protein, bedding, or nutrients for land application purposes.

As described earlier, manure may also be used in an AD system to produce biogas. Under the Renewable Fuel Standard (RFS), RNG produced from dairy and hog manure qualifies under a D3 RIN classification due to the manure's cellulosic content. D3 RINs have the highest monetary value in the RFS market, compared to other D-Codes.

Under the LCFS, RNG produced from dairy and hog manure also has the highest monetary value as RNG in the California market due to its extremely low carbon intensity score. This low carbon intensity (CI) score is highly due to the methane avoidance credits that can be generated, which are based on the manure management practices at each farm. For more information on the D-Code classifications and CI score calculation under the RFS and LCFS programs, please refer to **6.0 Incentive Programs**.

Methane is produced and released into the atmosphere at different levels depending on the existing manure management practices used at the farm. When developing an anaerobic digester system, it may be possible to avoid releasing methane emissions to the atmosphere by utilizing manure management practices before the use of the anaerobic system. This is known as "methane avoidance credits" under the LCFS, resulting in ultralow CI.



[To minimize greenhouse gas emissions produced from waste managed at landfills, MSW containing organic materials can be used as a type of feedstock to produce landfill gas (LFG). This landfill gas, as any raw biogas, can then be purified (upgraded) to produce RNG.]

7.1.2 Landfill Waste

Municipal solid waste (MSW) includes a variety of items that fall under different categories, including, but not limited to, plastics, metals, glass, food, wood, paper, textiles, and yard trimmings. MSW management practices can also vary; however, landfill has been and remains the most common method for managing MSW. MSW disposed of at landfills made up approximately 14.1% of the total human-related methane emissions in 2017.[xxxii] Mitigation and other management practices have become more common over the years, including recycling, composting, and energy recovery.

To minimize greenhouse gas emissions produced from waste managed at landfills, MSW containing organic materials can be used as a type of feedstock to produce landfill gas (LFG). This landfill gas, as any raw biogas, can then be purified (upgraded) to produce RNG. Landfill gas can qualify under a D3 RIN classification. It is important to note that though food waste can be disposed of at landfills, it is not considered an MSW. Instead, food waste is considered a high-strength waste, which does not meet the cellulosic threshold required by D3 RINs. For more information on food waste as a type of feedstock, see **7.1.3 Food Waste**.

As more manure-to-biogas projects or other projects with negative CI scores come online, the California LCFS market will continue to grow increasingly competitive for landfill gas projects, making placement that much harder in the next three to five years.

7.1.3 Food Waste

Food waste is generated throughout the United States for several reasons, including spoilage, faulty storage equipment, and over-ordering. Food waste can also occur at different stages of its life cycle, including the production, supply chain, transportation, storage, and consumer levels. Per the USDA, "food waste is estimated at between 30-40% of the food supply. This is based on USDA estimates of 31 percent food loss at the retail and consumer levels. This added up to approximately 133 billion pounds and $161 billion worth of food in 2010."[xxxiii] Food waste is typically placed at landfills where it will produce greenhouse gas emissions, contributing to the total methane emissions from landfills. Per the Iowa Department of Natural Resources 2017 Statewide Waste Characterization Study: "of all the trash sent to Iowa landfills, 20 percent – or 568,197 tons – is food waste."[xxxiv]

An alternative to managing food waste at landfills is use it as a source to produce renewable energy, such as RNG. There are different types of food waste generating sources that may provide feedstock supply for an anaerobic digester project; this includes the restaurant, food wholesale and retail, food manufacturing and processors, healthcare, educational, food bank, and residential sectors, to name a few. Food waste is an advantageous feedstock for anaerobic digestion because it has higher biogas yields than other feedstocks, and it has not gone through a digestion process before. However, all types of food waste are not created equally. Different types of food waste will have different levels of biogas yields. For example, fats, oils, and grease (FOG), or foods high in starch and sugars, can provide high biogas yields, whereas foods high in water content, such as leafy greens or celery, generate lower yields. Ultimately, performing laboratory testing of the types of food waste considered for anaerobic digestion is recommended to estimate accurate biogas production for a project.

Under the RFS, RNG produced from food waste qualifies under a D5 RIN classification, since food waste is considered a "non-cellulosic" feedstock. Historically, D5 RINs have had a lower monetary value than D3 RINs of about $12-23 per MMBTU of RNG. This is due to the cellulosic content of D3, which means that the feedstock is comprised of 75% or more of cellulose, hemi-cellulose, or lignin. It is important to note that co-digesting D5 eligible feedstock, such as food waste, and D3 eligible feedstock, such as manure, would still result in the RNG generating D5 RINs, if used as transportation fuel. The USEPA does not currently have a methodology to attribute the biogas produced to its respective feedstock. All feedstocks processed in the AD vessel must meet the D3 cellulosic definition in order to quality for D3 RINs.

If cellulosic (D3-eligible) and non-cellulosic (D5-eligible) feedstocks are mixed and co-digested, then all biogas produced by the digester would only be eligible for D5 RINs. Testing can be used to determine the cellulosic content of the feedstock if it is unknown.

Under the California LCFS, qualifying food waste feedstocks must have been ready for the consumer. This includes packaged food waste, such as spoilage at grocery stores, restaurant waste, etc and excludes food waste generated in food production facilities that do not go to the consumer. Additionally, projects producing RNG from food waste under the LCFS may qualify for landfill diversion credits. Landfill diversion occurs if the food waste used as feedstock to the anaerobic digester would have been sent to a landfill if not used as raw material fed to an anaerobic digester. 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 between 0 to-75 g CO_2e/MJ, which is attractive in the California market. Instead, projects that use food waste that has not been diverted from a landfill typically have a CI score range of

20-45 g CO_2e/MJ, which is much less attractive in the California market based on current market conditions as of February 2021. More information on carbon intensity impact factors can be found in **9.0 Livestock Carbon Intensity Factors and Impact** and **10.0 Other Feedstock Carbon Intensity Factors and Impact**.

7.1.4 Crop Residue

After crops have been harvested in an agricultural field, crop residues are left in the field. These crop residues, also referred to as stover, includes stalk, stem, and leaf materials left behind in the field from growing corn, sorghum, and soybeans. Crop residue can be removed from the field and used as a feedstock to the production of raw biogas through anaerobic digestion. Crop residue is more commonly used to produce ethanol.

Under the RFS, crop residue used to produce RNG can qualify under a D3 RIN classification. Crop residue can be combined with other D3-eligible types of feedstocks, such as dairy or hog manure. Combining these feedstock materials may be used to increase biogas production, depending on the characteristics of the feedstock, but it may increase capital/operating costs associated with a project, as additional feedstock processing may be needed.

Under the LCFS, the CI score for projects using crop residues vary since it is typically combined with other D3-eligible feedstock materials when producing RNG. For example, CI score of projects combining crop residues with manure will tend to be higher than manure-only projects. Typically, RNG produced from only crop residue may have a CI range between 20-45 g CO_2e/MJ.

7.1.5 Wastewater Solids

Wastewater treatment plants receive wastewater from various sources, including the residential and industrial sectors. Through the treatment process, contaminants are removed from the water, allowing the water to be discharged into streams or for reuse. Wastewater solids, or sludge, is a by-product produced from this treatment process. Typically, through the treatment process, these solids settle and separate from the water. The removed solids include both organic and inorganic material.

There is energy in the organic material that can be recovered through an anaerobic digestion process to produce biogas. It has become more common for municipal wastewater facilities to develop and build an AD process onsite to manage these organic solids.

Under the RFS, biogas produced from wastewater treatment facility digesters qualifies under a D3 RIN classification. Participation in the RFS program with a D3 pathway provides for a high monetary value, compared to other D-Codes. Wastewater plants must not co-digest the wastewater sludge, D3 eligible feedstock, with other feedstock non-D3-eligible materials. Doing so may result in the inability to claim D3 RINs, since the USEPA does not currently have a methodology to attribute the biogas generation to its respective feedstock.

Under the LCFS, projects producing RNG from wastewater material typically have a CI score ranging from 20-45 g CO_2e/MJ. As with any other project participating in the LCFS, the CI score will be dependent on the specific operations at the facility, including the type of feedstock, the energy used in the upgrading process, and the amount of RNG produced. With the estimated CI score of 20-45 g CO_2e/MJ being common for these projects, placement into the California LCFS market may be difficult, especially in future years.

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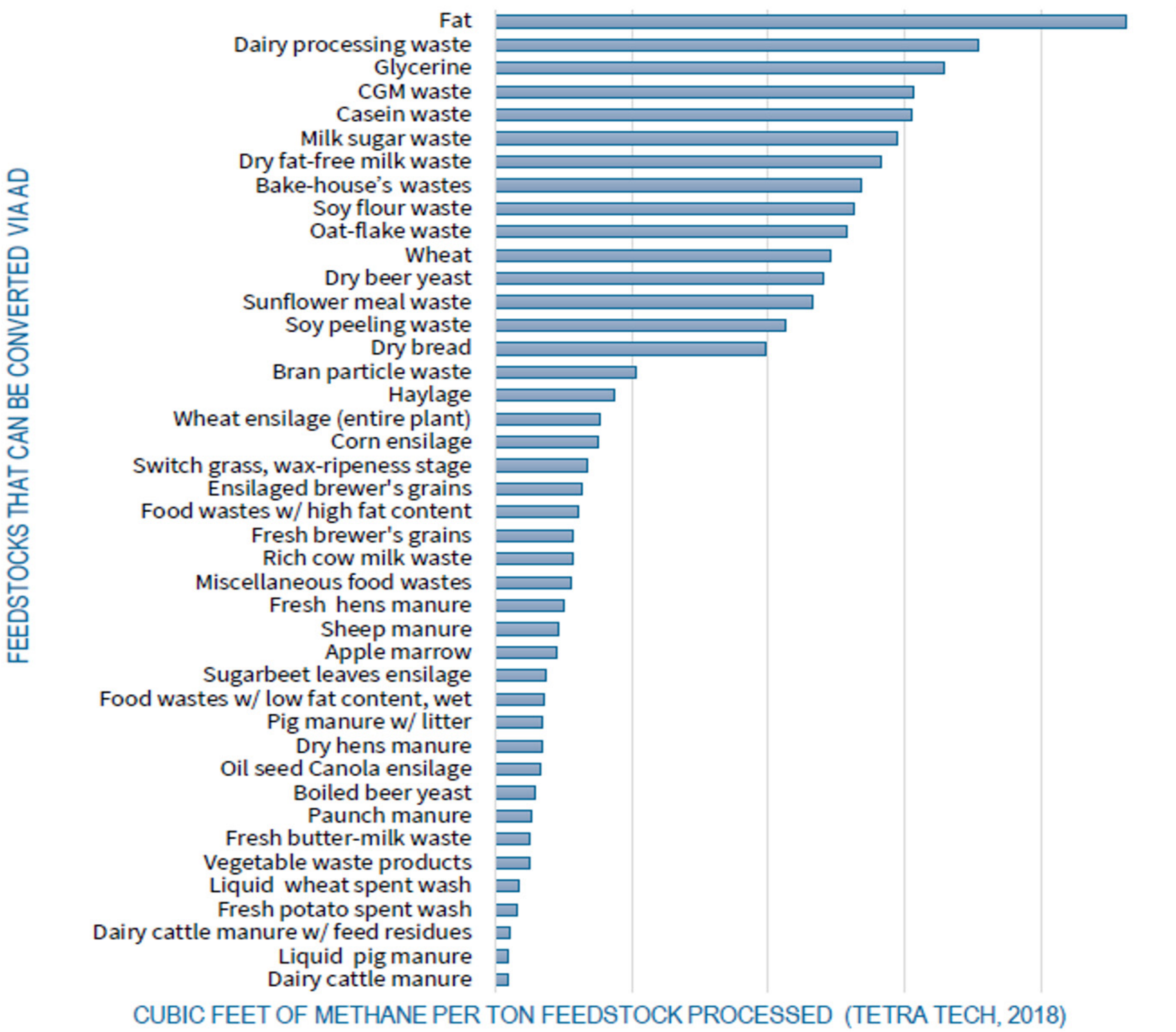
7.1.6 Biogas Yield of Various Feedstocks

Physical and biochemical feedstock characteristics vary by type of feedstock, which affect biogas production yields and the type of digester required. Analyzing a representative feedstock sample in a laboratory is imperative when designing an AD biogas system. Basic and inexpensive testing identifies the total solids (TS) and volatile solids (VS) of a feedstock, providing a baseline to estimating biogas yield. More complex and expensive testing may be completed, including a biomethane potential (BMP) test, to obtain further information about the feedstock biogas potential. It is recommended to complete project-specific testing early on, during the development phase of a project, so the system is designed appropriately for the feedstock procured. This maximizes biogas yield. Testing can also be completed to determine the cellulosic content of the feedstock and determine what D-Code the project is eligible for if participating in the RFS program. Figure 9 below provides methane yields for different types of feedstocks, as reported by the USEPA in the AgSTAR Project Development Handbook.

FIGURE 9: METHANE YIELDS FROM VARIOUS FEEDSTOCKS



Source: TetraTech, 2018

8.0 External Funding Sources for Biogas Projects

As with all large projects, financing and securing capital can sometimes be an issue. Carbon and renewable energy are an area of focus of the federal government, and the United States Department of Agriculture (USDA) is a source of incentives and resources for producers and businesses looking to invest into these types of projects.

Not only are the USDA and its sister agency, the United States Department of Energy (USDOE), good resources to help with sources of capital, but these also offer loan guarantees for new or innovative processes for renewable energy.

The following is a list of programs and resources that individuals or entities creating, participating in, or investing in renewable energy projects should consider.

In these programs, there are essentially three separate ways to secure funding:

1. **Grant**: An outright payment in exchange for a commitment or participation in a program.
2. **Direct loan:** Direct loan from the government or entity that is making the solicitation. In the case of the USDA or other federal program, the loan is from the U.S. Government.
3. **Guaranteed loan:** A loan guarantee is usually a commitment to another lender pledging payment of the debt in the case of risky or unproven technology or application. The private lender receives a federal guarantee that the loan will be repaid.

These three sources of funds are further outlined in the following sections. It is not an all-inclusive list of all available programs, since the availability of a certain program is dependent on available funding and agency priorities within a given year. This is intended as a general guide for individuals or entities to explore while attempting to obtain financial incentives and financing resources. For more information on each of the programs outlined below, please refer to **Appendix A**.

Within local, state, and federal governments, there is a strong dedication to renewable energy projects for rural communities. Anaerobic digesters are a great process for deriving energy from renewable or waste products. This is a dynamic renewable energy area and funding sources are continually changing. As external funding is considered, please note that program deadlines and sources of funds may change with each calendar. For this reason, it is recommended to maintain project information current, including budget, funding, and primary financial information, to ensure applications are completely timely.

8.1 USDA Funding for Clean or Renewable Energy

The USDA is a great resource for those considering a rural renewable energy project. This following listing includes the current available programs under the USDA. Please note these programs are subject to change, as can be the case with many government programs.

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8.1.1 OneRD Guarantee Initiative USDA Platform

The USDA has combined many loan and assistance programs into one area by creating the OneRD Guarantee Loan Initiative in the fall of 2020. With this initiative, the USDA has created one place to make an application for many of their loans and removed unnecessary regulations to increase private investment in rural business and rural economic development projects. This platform was also created to improve customer service and includes the four loan guarantee programs the agency has available. The USDA implemented a standard set of requirements, processes, and forms for all four of these rural development programs. This platform can be accessed by emailing OneRDGuarantee@usda.gov.

The programs on this platform are:

- Water and Waste Disposal Loan Guarantees
- Community Facilities Guaranteed Loan
- Business & Industry Loan Guarantees (B&I)
- Rural Energy for America Program (REAP)

The first place to start with a digester project would be the Rural Energy for America Program (REAP). However, depending on circumstances and the actual project, any program above may offer assistance, either by itself or combined, with a lender in the form of a guarantee and/or a grant.

Rural Energy for America Program Renewable (REAP) Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants

REAP is specifically created for agricultural producers where greater than 50% of their gross income is derived from agricultural operations. Funding is available through the application process for U.S. citizens and private-entity borrowers who can demonstrate that the funds will remain in the U.S. The REAP area for the USDA is tailored to the rural agriculture and business development for the rural sector of the U.S. The loan guarantee and grant program for REAP is as follows:

- Loan guarantees for loans up to 75% of the project
- Grants for up to 25% of the project
- A combination of grant and loan with the combined total not to exceed 75% of the total eligible costs

The amount of funding available for this grant program is set by the Federal Register. This information as well as other questions related to REAP can be found by contacting the State Rural Development Energy Coordinator for your state. Please refer to **Appendix A** for the contact information.

USDA Rural Development Business and Industry (B&I) Loan Guarantee Program

Another resource on the OneRD platform is the USDA Rural Development Business and Industry (B&I) Loan Guarantee Program. Under the Business Programs section of OneRD, there are many grant and loan opportunities that are focused on businesses or business programs that support the creation and preservation of quality jobs in rural areas. The B&I programs are primarily focused on the lender and, specifically, provide guarantees to lenders for innovative rural business development.

These loan guarantees are in place for U.S. businesses, individuals and cooperatives, and the funds must be used in the U.S. The loan interest rates can be variable or fixed and are dependent on the lender. The guarantees are in place for the life of the loan and must not exceed 40 years. More information and details for this can be found in **Appendix A**.

Community Facilities Guaranteed Loan Program

The Community Guaranteed Loan program is another program on the OneRD Initiative Platform. This program is a guarantee program for municipalities and has a particular area for renewable energy systems. The project dollar amount authorized is 100% of the first $200 million, 50% of the next $200 million, and 25% of all amounts exceeding $400 million. See **Appendix A** for more information.

Waste and Waste Disposal Guaranteed Loan Program

If your project is removing or converting solid waste to a renewable resource and you are a non-profit, tribal entity, or public body, you may qualify for a loan guarantee through this program. This program is on the OneRD platform and is only applicable for waste management projects in municipalities or tribal ground or projects that are for waste of public bodies, tribal ground, or non-profit entities. See **Appendix A** for more information.

8.1.2 Other USDA Programs

Outside of the OneRD USDA Platform, investors and developers should look to the following programs for sources of financial assistance from the USDA. These programs are geared toward all sizes of operations and offer options for producers, lenders, and investors.

USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP)

The NRCS is a part of the USDA, where agricultural producers can obtain financial and technical assistance for projects that improve the environment. This assistance is provided to producers based on a ranking system and available funds on a continual basis. The agricultural producer works with the NRCS office or the Farm Service Administration (FSA) to develop an EQIP plan that is tailored to the specific application. Energy projects, such as AD projects producing biogas, are within the scope of this program and could be eligible for grants to assist with gaps in lending.

An additional benefit to this program is the specialized advice specific to natural resources that are provided with the funding. Participation in EQIP requires the participant to adhere to the plan created by NRCS staff or their appointed representatives. EQIP programs and ranking vary by state. See **Appendix A** for more information.

USDA Nature Resources and Conservation Services Conservation Innovation Grant (CIG) Program

The CIG program is another grant program authorized and implemented by the NRCS. This program is competitive and its applicants begin the project, demonstrate viability, and then are awarded a grant based on how the new tool or process ranks versus others. The timing of this grant program and the focus of funding is announced yearly, and the successful awardees may receive several years' compensation from one application. This program is available at national and state levels. See **Appendix A** for more information.

USDA Rural Development Value Added Producer Grant Program (VAPG)

The USDA VAPG is in place to help producers entering into value-added activities. Annually, federal dollars are awarded for applications received prior to a deadline in the middle of March. The federal Register publishes the funding and exact application details every year around November through December. The program is implemented through the Rural Business Cooperative Service Agency and is focused on helping producers build a robust and sustainable rural economy. More details for this program can be found in **Appendix A**.

USDA Rural Development Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003)

The 2008 Farm Bill established the BioRefinery Assistance Program under Title IX Section 9003. This program outlines grants, loans, and guarantees for eligible technologies for operations that produce advanced biofuels. Specific to this program are Loan Guarantees for the development, construction, and retrofitting of commercial scale biorefineries. Applications for a project can be made through the U.S. Department of Agriculture Rural Development. There is a phased approach for financing and technical assistance. Applications are scored according to the criteria as part of the application guide. See **Appendix A** for details on this program.

USDA Rural Development - Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (BAP)

BAP, also known as the Section 9003 Program, provides loan guarantees to assist in the development of advanced biofuels, renewable chemicals, and biobased products manufacturing facilities. This program provides loan guarantees up to 80% of the cost of eligible project costs up to $250 million dollars. Projects are scored for eligibility and borrowers are expected to contribute a significant amount of their own equity for the project.

Eligible projects include the development, construction, or retrofitting of commercial scale biorefineries using eligible technologies. The biorefinery must produce advance biofuel and may:

1. Sell the advanced biofuel that it produces as a biofuel, renewable chemical, or for other non-fuel usage;
2. Process the advanced biofuel into renewable chemicals or other biobased products; or
3. Use the biofuel as a fuel for heat or power in its processes or to generate electricity.

More information for BAP can be found in **Appendix A**.

8.2 D.O.E. Title XVII Innovative Energy Loan Guarantee Program (LGP)

Commonly referred to as LGP, Title 17 program is overseen by the U.S. Department of Energy and is authorized by the Energy Policy Act of 2005. The LGP has since been improved by the American Recovery and Reinvestment Act of 2009. This program was reinstated in January 2020. To qualify for this loan guarantee, a project must "avoid, reduce, or sequester air pollutants or greenhouse gases; employ new or significantly improved technologies and provide a reasonable prospect of repayment." The Loan Programs office has resources available to step applicants thru the process to complete an application and has consultants available for applicants to research and improve their renewable energy projects. Refer to **Appendix A** for more information.

8.3 AgSTAR

Along with the USDA programs mentioned, there are also programs created as a collaborative effort between agencies. AgSTAR is a collaborative program sponsored by the USEPA and the USDA to promote the use of biogas recovery systems to reduce the methane emissions from livestock waste. This partnership is a complete guide for technical assistance and resources for those considering a biogas project. More information about this partnership can be found on their website listed in **Appendix A**.

9.0 Livestock Carbon Intensity Factors and Impact

The following section is an overview of carbon intensity (CI) factors and their relative impact for anaerobic lagoon livestock manure projects to generate low-CI biogas and use as transportation fuel in California. This section will also establish reasonable ranges for the CI of such projects. The most ideal sites are farms with many livestock and no solid separation or lagoon cleanout, so all manure produced remains in the anaerobic lagoons. Major factors regarding CI impact that were analyzed included herd size and type, biogas yield, and manure management practices, including solid separation and lagoon cleanout procedures. Minor factors discussed included digester type, process energy use, and temperature. Baseline emissions, historical farm manure management practices, and biogas yield are the most important and impactful factors in the CI analysis.

Important: Baseline conditions are based on historical conditions at the farm and cannot be changed to improve the farm's baseline. The following sections are intended to demonstrate how baseline conditions impact CI score and aid in estimating the CI score of a project in development.

As a sample analysis, a 10,000-head swine farm was chosen to demonstrate CI impacts and trends for various factors, though a dairy manure project would follow similar trends. The best farm setup with the lowest CI score meets below criteria and will be discussed in the following sections:

- Contains high number of livestock.
- Uses uncovered lagoons to store manure and all manure is sent to the lagoons.
- Does not cleanout, agitate, or remove solids from the lagoons.
- Does not separate solids from the manure before it enters the lagoons.

9.1 Definitions

Below are some definitions to reference throughout this section:

- **Avoided Emission Credit (AEC):** When expected baseline scenario emissions are compared to project emissions, avoided emissions credits are calculated. AEC represent the amount of methane emissions avoided resulting from project installation, such as an anaerobic digester or covered lagoon.

- **Baseline Scenario Emissions:** The greenhouse gas emissions within the project boundary that would have occurred if not for the installation of the biogas control system (BCS).[xxxv]

- **Biogas Control System (BCS):** Commonly referred to as a digester, this is a system designed to capture and destroy the biogas that is produced by the anaerobic treatment and/or storage of livestock manure and/or other organic material.[xxxvi] BCS is also often referred to as the "project."

- **Biogas:** The raw gaseous mixture comprised primarily of methane and carbon dioxide and derived from sources, including but not limited to, the anaerobic decomposition of organic matter in a landfill, lagoon, or constructed reactor (digester). Biogas often contains a number of other impurities, such as hydrogen sulfide, and it cannot be directly injected into natural gas pipelines or combusted in most natural-gas-fueled vehicles. It can be used as a fuel in boilers and engines to produce electrical power. The biogas can be refined to produce near-pure methane, which is sold as biomethane.[xxxvii]

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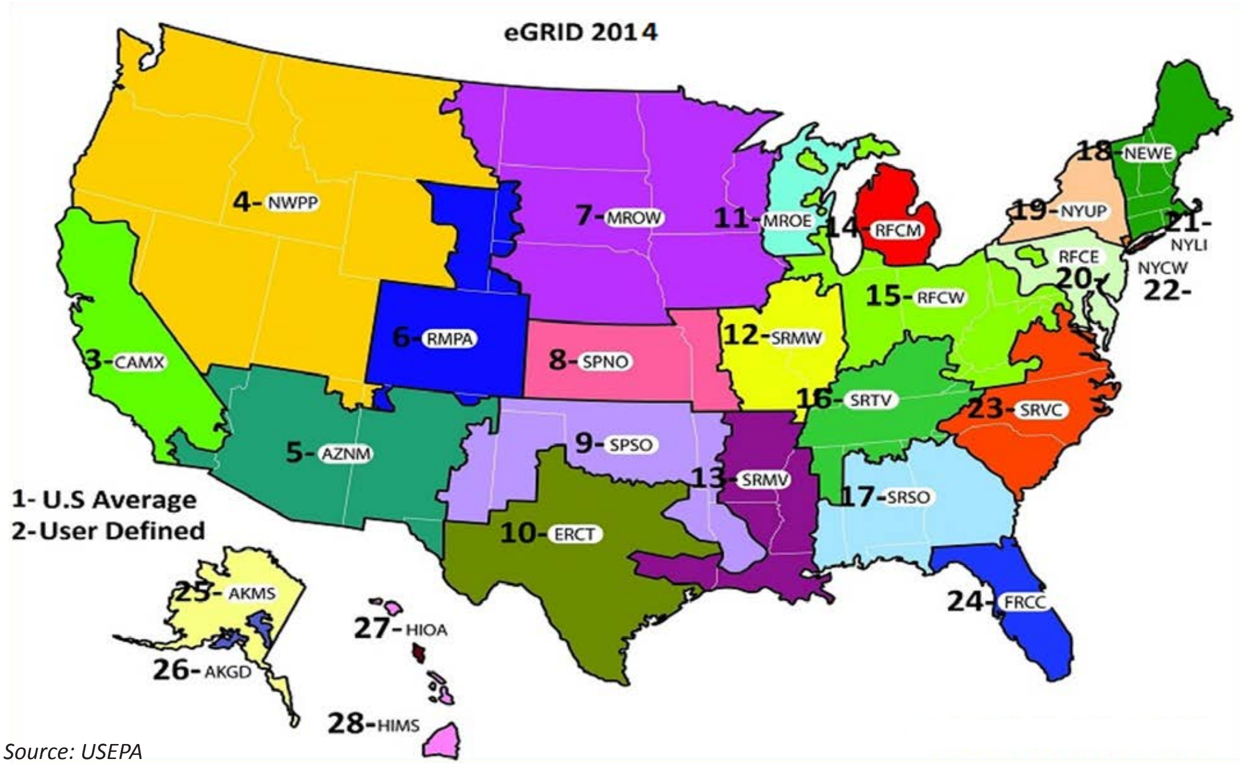
- **Biomethane:** The methane derived from biogas or synthetic natural gas derived from renewable resources. It includes the organic portion of municipal solid waste, which has been upgraded, or purified, to meet standards for injection to a natural gas common carrier pipeline, or for use in natural gas vehicles, natural gas equipment, or production of renewable hydrogen. Biomethane contains all of the environmental attributes associated with biogas and can also be referred to as renewable natural gas.[xxxviii]

- **Carbon Intensity (CI):** The quantity of life-cycle greenhouse gas emissions, per unit of fuel energy, expressed in grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ).[xxxix]

- **Emissions and Generation Resource Integrated Database (eGRID):** A comprehensive source of data on the environmental characteristics for most electric power generated in the U.S.[xl] Figure 10 depicts the eGRID regions for selection in the model.[xli]

FIGURE 10: EGRID SUBREGION REFERENCE FOR GRID ELECTRICAL MIX



Source: USEPA

- **Volatile Solids (VS)**: The organic fraction of the total solids (TS) in a material that will oxidize and be driven off as gas at a temperature of 600°C. Total solids are defined as the material that remains after evaporation at a temperature between 103 and 105°C.[xlii]

9.2 Livestock Manure Assumptions and Base Case Results

To effectively compare the impacts of different factors, a control scenario (base case) was created based on industry experience. A swine farm was chosen to demonstrate trends and impacts on CI for various factors. The following assumptions were used:

- Grow/finish swine produce 2.4 gallons of manure per head per day.

- Manure density is 8.30 pounds of solids per gallon of manure.
- The manure is 6% total solids.
- Manure total solids is 80% volatile solids.
- The baseline manure treatment system is an open lagoon system.
- The lagoon system has one cleanout per year.
- The digester is an enclosed vessel.
- The digester generates 10 SCF per 1 pound of volatile solids destroyed.
- Methane content of the produced biogas is 65%.
- All digester effluent is sent to effluent ponds and not subject to solid separation.
- 30 kWh of electricity is required as process energy to generate 1 MMBtu of pipeline-injection quality biomethane.
- 0.1 MMBtu of natural gas is required as process energy to generate 1 MMBtu of pipeline-injection quality biomethane.
- 0.04 gallons of diesel is required as process energy to generate 1 MMBtu of pipeline-injection quality biomethane.
- The upgrading system has an efficiency of 98% .
- The average annual temperature is 9°C.
- Pipeline distance to California is 1,700 miles.

Note that these assumptions are "typical" values observed through industry observation and pathway applications submitted to CARB. However, any given project may have different values for the parameters listed above. Therefore, the CI ranges provided in this analysis is for reference only, but the general magnitude of certain parameters should not vary greatly. Once a project is up and running, operational data is needed to submit a pathway application for LCFS credit generation. Table 4 shows the breakdown of the CI score for the assumed base case: no baseline or project solid separation and no lagoon cleanouts.

TABLE 4: CI BREAKDOWN OF BASE CASE

STAGE OF LIFE CYCLE	CI (gCO_2E/MJ)	NOTE
AD Handling and Upgrading	29	User Control
Fugitive Emissions	10	Almost Fixed
Biomethane Flaring	1	User Control
Pipeline Transport to California	15	Proportional to Distance
Compression at CNG Station	3	Fixed
Tailpipe Emissions from Vehicle	61	Fixed
Avoided Emissions Credits	-335	Dependent on Baseline vs. Project
Final CI	**-214**	

9.3 Baseline Emissions and Avoided Emissions Credits

For a manure biogas project life-cycle analysis (LCA), there are two important scenarios regarding the management of manure: baseline and project. The baseline scenario identifies manure management practices before the digester is installed; the project scenario looks at the manure management practices after digester installation. Baseline factors are the most important when searching for a potential site because they the main reason a project can achieve an ultralow CI. Also, these project variables are controlled by the project developer.

To determine baseline methane emissions, CARB does not differentiate between dairy cows and hogs. Instead, livestock categories are defined based on the "stage-of-life" (grow/finish, nursery, or breeder for swine; dairy cow, dry cow, and heifer for dairy) and uses the average weight of each stage along with herd size.[xliii] Avoided Emission Credits (AEC) are allocated among the transportation fuel produced, resulting in a reduction in CI of the final product. This makes manure management practices a much more impactful factor than herd size because increasing herd size increases AEC but also increases the amount of biogas injected. This results in no net gain from the AEC. However, in general, a larger facility with increased amount of feedstock usually holds economic advantages because of the "scale effect" on other parameters such as process energy.

It is important to note that the current LCFS regulation only provides AEC for dairy and swine manure. Beef cattle manure, poultry litter, and other manures, even if using a lagoon-based manure treatment system, do not currently qualify for AEC and will likely have positive CI scores.

9.4 Biogas Yield and RNG Production

The biogas yield of a project can have a significant impact of the CI score of a project. The baseline model of a project determines the amount of AEC that a project will receive. The Avoided Emission Credits are then evenly distributed across the total volume of RNG produced from the project. Table 5 shows CI scores with ± 20% varying biogas production.

TABLE 5: CARBON INTENSITY SCORES FOR RECOGNIZED "STAGE-OF-LIFE" SWINE WITH VARYING BIOGAS YIELD

DESCRIPTION	HERD SIZE	BIOGAS YIELD (MMBtu/ HEAD/YEAR)	BASE CASE CI (gCO_2e/MJ)	120% BASE CASE BIOGAS YIELD (gCO_2e/MJ)	80% BASE CASE BIOGAS YIELD (gCO_2e/MJ)
Grow/Finish	10,000	1.57	-214	-166	-286
Nursery	10,000	0.47	-214	-166	-286
Breeder	10,000	2.25	-126	-101	-188

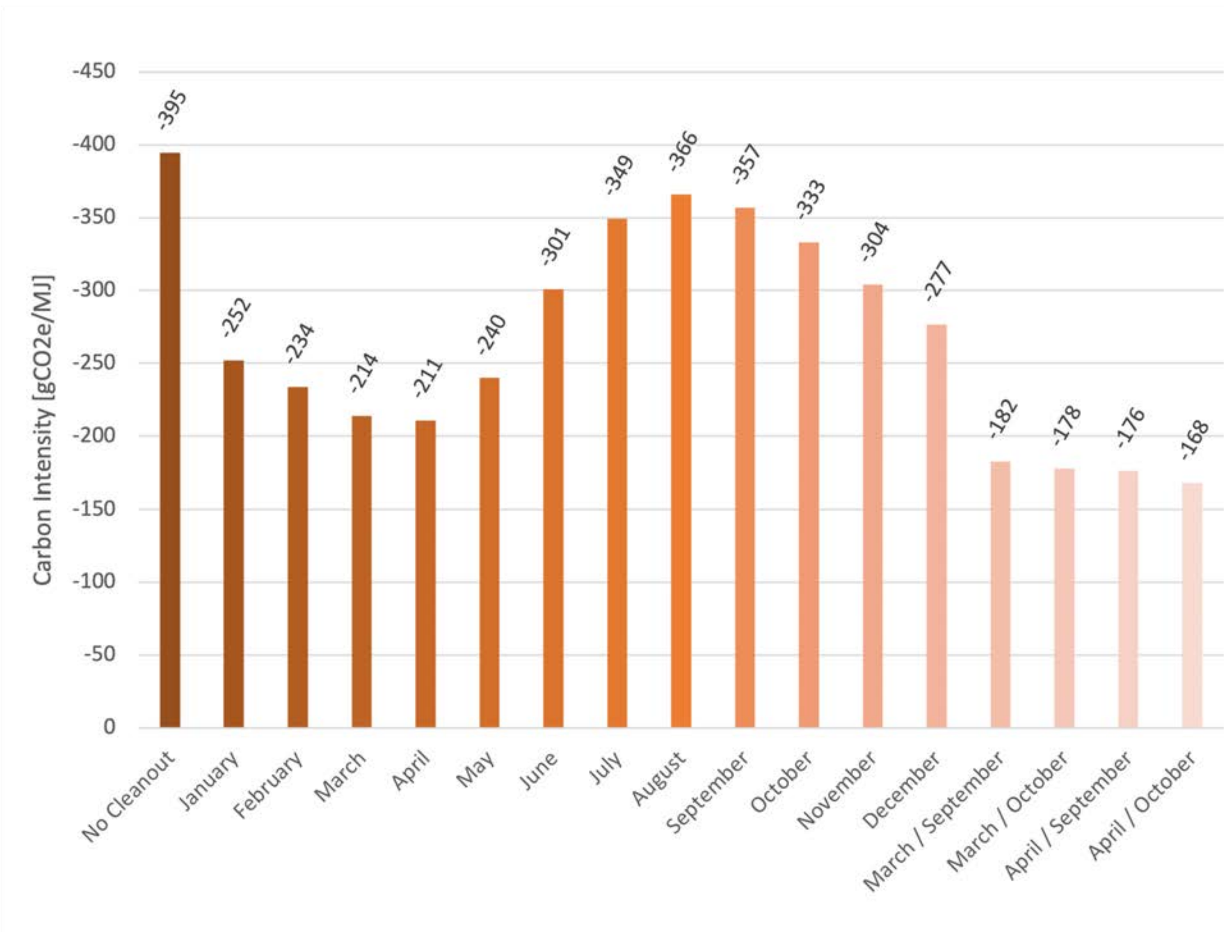
For project developers, biogas yield is usually calculated based on the amount of VS entering the anaerobic digester system without differentiating the swine types that generate such VS. However, in the CA-GREET 3.0 model, manure from different types of livestock may have different biomethane potential and therefore generate different baseline emissions as shown in Table 5. The biogas yield is the theoretical biogas yield for livestock as provided by the California Air Resources Board (CARB), which governs the LCFS. As a result, the same amount of manure from different types of livestock may generate different baseline emissions and may result in different CI values for the biomethane produced.

9.5 Lagoon Cleanout Frequency

Lagoon cleanout is a general term used to describe the activity when farmers attempt to empty the lagoon and clean out the solid buildup from the system. CARB's Tier 1 Simplified CI Calculator for Biomethane from Anaerobic Digestion of Dairy and Swine Manure document defines a cleanout as "System Emptied in Previous Month."[xliv] Another CARB document, Instruction Manual to the Tier 1 Simplified CI Calculator for Biomethane from Anaerobic Digestion of Dairy and Swine Manure, states "... If the month following the complete drainage and cleaning of solid buildup from the anaerobic storage/treatment system, the volatile solids retained in the system from the previous month must be set to zero."[xlv] It is not considered a cleanout if liquid is taken from the top of the lagoon without agitating it and the depth of the lagoon does not fall below 1 meter at the shallowest area.

Lagoon cleanout frequency is an important factor in livestock project LCA. When manure is sent to the lagoon, anaerobic digestion of the manure occurs at the lower levels of the lagoon, which produces methane that is ultimately emitted directly into the atmosphere. When the lagoon is cleaned out, volatile solids are removed, and less methane is generated. A project with no cleanouts will generate the most AEC, resulting in a better CI when the digester is installed. Figure 11 shows the ranges of CI scores for cleanout months. Based on experience, a combination of spring and fall months that are common for biannual lagoon cleanouts are also included.

FIGURE 11: CARBON INTENSITY SCORES BASED ON LAGOON CLEANOUT FREQUENCY



Source: EcoEngineers

Due to the difficulty of quantifying the solid removal for a partial cleanout, a "0 or 100" method has been adopted by CARB for any partial cleanout performed previously. This means that any partial cleanout is considered a full cleanout. This results in a worse CI for farms who perform one or more partial cleanouts a year. CARB is expected to provide more guidance on the determination of lagoon cleanout and may apply a universal cleanout frequency for all the producers. This could make the CI for projects without any cleanouts worse, while making the CI for projects with multiple cleanouts a year better. An update can be found in the LCFS FAQ: Credit Generation for Reduction of Methane Emissions from Manure Management Operations.[xlvi]

9.6 Baseline Manure Management Practices

Different manure management practices may occur at different sites. For a lagoon treatment system, some manure may be diverted from the lagoons. As the fraction of manure is sent to the lagoon decreases, the total amount of AEC generated are reduced and worsen the CI. For example, some farms do not collect all the manure generated because it is not economically feasible, such as for dry lot or pasture, which is common for the dairy industry. Some farms only have a deep pit manure management system, and this is very common in Iowa. Other farms choose to have solid separation before the manure is sent to the lagoons. The separated solids could be used for composting, bedding, or other purposes. Each of these manure management details will impact the baseline CI score for the facility.

Another important factor in the CI score is solids separation between the barn and the lagoon. When a farm has no solid separation before the manure goes into the lagoon system, it will have a better CI score than farms with solid separation. Table 6 contains the CI scores for different solid separation practices with varying percent of manure diverted. The change in CI score is linear to the percent of manure diverted. These scores were calculated based on the assumptions that no solid separation occurs after project installation and that all the solids in the baseline enter the AD.

TABLE 6: CI SCORES FOR DIFFERENT MANURE SOLID DESTINATIONS WITH VARYING PERCENT OF MANURE DIVERTED

PERCENT OF MANURE DIVERTED	CI SCORES FOR VARIOUS MANURE DESTINATIONS (gCO2e/MJ)		
	Pit Storage or Deep Bedding for More Than 1 Month	Solid Storage	Pit Storage or Deep Bedding for Less Than 1 Month
0%	-214	-214	-214
10%	-193	-183	-183
20%	-171	-151	-153
30%	-150	-120	-122
40%	-129	-89	-91
50%	-108	-57	-61

9.7 Project-Based Manure Management Practices

Within the project scenario, solid separation of the digester effluent is a common practice to reclaim solids for use as composting, bedding, or other purposes. A common practice in manure RNG projects is to return the digestate back to the existing lagoon systems at the farm. After the AD is installed, any volatile solids (VS) from the digestate that are reintroduced into the lagoon will create emissions and negatively impact the project CI — similar to the concepts used in determining AEC in the farm baseline analysis. Common industry practice is to perform solid separation on the digester effluent to prevent a portion of the undigested VS from entering the lagoon and thereby improving the CI score.

Table 7 shows the impact of digestate solids separation for scenarios when no lagoon cleanout, June lagoon cleanout, and March lagoon cleanout occurs under the assumption that the separated solids are destined for solid storage. Solid separation from digestate may have significant impact on the final CI, as reflected in the June or March cleanout cases. The reason the "no cleanout" case is not influenced is because the baseline methane emissions are greater than the project production, capping the AEC at the project biogas production.

TABLE 7: IMPACT OF SOLID SEPARATION ON CI SCORE FOR DIFFERENT PROJECT SCENARIOS WITH REMOVAL EFFICIENCY FOR VARIOUS SOLID SEPARATION EQUIPMENT

SOLID SEPARATION	VOLATILE SOLIDS REMOVED	MARCH LAGOON CLEANOUT CI (gCO_2e/MJ)
No Separation	0%	-214
Vibrating Screen	15%	-219
Stationary Screen	17%	-220
Screw Press	25%	-222
Roller Drum	25%	-222
Gravity	45%	-229
Belt Press	50%	-231
Centrifuge	50%	-231

9.8 Additional Factors

Process energy use for biogas processing and upgrading usually impacts the carbon intensity of a project much less than baseline factors presented above. Table 8 shows CI scores with changing process energy requirements for different fossil energy types. The last column in Table 8 is included to show CI score improvements related to eliminating fossil energy in favor of wind, solar, or other technologies that produce heat and electricity with no emissions.

TABLE 8: CARBON INTENSITY SCORES WITH VARYING FOSSIL ENERGY USE

ENERGY TYPE	BASE CASE CI (gCO_2e/MJ)	150% ENERGY USE CI (gCO_2e/MJ)	50% ENERGY USE CI (gCO_2e/MJ)	DISPLACED WITH 100% ZERO-CI ENERGY (gCO_2e/MJ)
Diesel	-214	-214	-214	-214
Natural Gas	-214	-210	-217	-221
Electricity	-214	-203	-225	-236
All	-214	-199	-229	-243

Temperature is another factor for manure digester projects. The methane generated during the anaerobic digestion in the lagoon is directly related to temperature, with higher external temperatures speeding up the production and increasing the amount of AEC. However, since temperatures within the same localized region are relatively consistent, this factor is only impactful when deciding where in the country to search for a project. Temperature can greatly impact digesters like covered lagoons that are not heated or mixed. In northern climates like Iowa, a covered lagoon may not generate enough biogas in the winter months to run the biogas upgrading equipment.

[Combusting unrecoverable biogas (typically via flaring or thermal oxidizer) is a recommended procedure for project developers. Within the LCFS model, flared gas emissions only include the CO_2 emissions involved in the burning.]

Biogas can be upgraded through a variety of different processes including temperature swing adsorption (TSA), membrane separation, and amine scrubbing. Two factors to consider are energy input and biomethane recovery rate. Each type of technology requires process energy. Higher process energy consumption usually results in higher operating costs and emissions. The CI impact for ±50% change in process energy is shown in Table 8. Additionally, each technology provides a certain biomethane recovery rate.

Combusting unrecoverable biogas (typically via flaring or thermal oxidizer) is a recommended procedure for project developers. Within the LCFS model, flared gas emissions only include the CO_2 emissions involved in the burning. If the unrecovered gas is directly released to the atmosphere, it could have significant adverse impact on CI, as methane is a potent greenhouse gas that has 25 times higher global warming potential (GWP) than CO_2. It is recommended that the gas be combusted at the upgrading site because flaring on the farm side is considered an operation out of the system boundary. Flared gas cannot benefit from the RFS program.

The project digester type can either be a covered lagoon or an enclosed vessel. The enclosed vessel can be heated and agitated to increase the volatile solids destruction rate, improve biogas yield, and maintain stable biogas production with minimal seasonal variation, though the capital and operational cost could be high. On the other hand, covered lagoons are able to utilize existing lagoons and usually have lower capital and operational cost. They also have lower VS destruction rate, lower biogas yield, and ups and downs in biogas production due to seasonal variation.

Manure RNG projects using covered lagoons often have significantly better CI scores than heated and mixed-tank based digesters namely because of the lower process energy input and lower RNG yields, which both contribute to a better CI score.

9.9 Digester Project Identification Tools

Table 9 provides rankings from "A-Tier" to "C-Tier" for the key factors for swine farm selection: types and herd size of swine, lagoon cleanouts, and manure management practices.

TABLE 9: FACTOR PRIORITY TIER LIST

FACTORS	A-TIER	B-TIER	C-TIER
Size of Clustered Farms (Grow/Finish equivalent) (Milking Cow equivalent)	• >200,000 • >10,000	• 100,000-200,000 2,000-10,000	• <100,000 • <2,000
Type of Livestock	• Nursery and Grow/Finish Swine • Dairy Cows	• Breeder • Dry Cows • Heifers	• Non-Dairy or Swine Farms
Baseline Manure Management Practices	Lagoon or Liquid/ Slurry system	• Pit Storage below Animal Confinements (>1 Month) • Deep Bedding (>1 Month)	• Other aerobic treatment • Continuous land application • Stockpiling of solids
Baseline Solid Diverted to Other Treatment and Not Entering the Lagoons	None	10%- 20% Manure Removed	>=30% Manure Removed
Lagoon Cleanout Frequency	No Cleanout	One Cleanout	Two Cleanouts
Digestate Solid Separation for "One Cleanout" Projects*	• Centrifuge • Belt Press • Gravity	• Roller Drum • Screw Press • Stationary Screen • Vibrating Screen	No Solid Separation

* This assumes one lagoon cleanout in June to illustrate the impact of digestate solid separation on CI. For more details, refer to Table 7: Impact of Solid Separation on CI Score for Different Project Scenarios with Removal Efficiency for Various Solid Separation Equipment

Table 10 (page 45) shows ranges of CI scores for various factors presented in Table 9. Ranges in the third column, "CI," are provided to show the best- and worst-case scenarios for a certain factor tier when we keep other parameters are kept constant as in the baseline. The last column shows these ranges if the total biogas production fluctuates by ±20%.

Table 11 (page 45) is a quick guide to estimate CI impacts for various other factors identified.

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TABLE 10: IMPACT OF TIER FACTORS' CARBON INTENSITY SCORES WITH VARIATION IN BIOGAS YIELD

FACTOR	TIER	CI (gCO_2E/MJ)	CI FOR ±20% BIOGAS YIELD (gCO_2E/MJ)
Base Case		**-214**	**-166 to -286**
Type of Swine	A	-214	-166 to -286
	B	-136	-101 to -188
Baseline Manure Management Practices	A	-214	-166 to -286
	B	-1.90	11 to -21
	C	111	105 to 121
Baseline Solid Diverted to Other Treatment and Not Entering the Lagoons	A	-214	-166 to -286
	B	-165	-125 to -225
	C	-84	-57 to -123
Lagoon Cleanout Frequency	A	-395	-339 to -395
	B	-214	-166 to -286
	C	-182	-140 to -246
Project Digestate Solid Separation	A	-233	-182 to -309
	B	-223	-174 to -298
	C	-214	-166 to -286

TABLE 11: FARM FACTORS AND ASSOCIATED IMPACT

FACTOR	IMPACT ON PROJECT
Baseline Solid Diverted to Other Treatment and Not Entering the Lagoons (Diverted to Pit Storage or Deep Bedding for >1 Month)	~3 CI Points Worse per Percent Removed
Baseline Solid Diverted to Other Treatment and Not Entering the Lagoons (Diverted to Other Aerobic Treatment System)	~5 CI Points Worse per Percent Removed
Digestate Solid Separation for "1 Cleanout" Projects	~0.6 CI Points Better per Percent Removed
Zero-CI Process Energy	~25 CI Points Better
100% Natural Gas Substituted with Biogas as Process Energy	~50 CI Points Better*
Pipeline Biogas Transportation to California	~5.7 CI Points Worse per 1000 Miles
Trucking Biogas Transportation to California	~6.7 CI Points Worse per 1000 Miles
LCFS Revenue at $200 per Credit	$0.21/CI Point/MMBtu

*Natural Gas use is very region-specific. In warmer climates, natural gas for digester heating will be reduced, and the impact from using biogas will be lower.

10.0 Other Feedstock Carbon Intensity Factors and Impact

Although livestock manure presents the highest economical potential due to avoided emissions, there are other potential feedstocks that can be used, such as wastewater sludge or organic waste. These do not have as many factors impacting the CI score.

10.1 Wastewater Sludge

Wastewater sludge from wastewater treatment plants (WWTP) can be anaerobically digested to produce biogas. For this process, sludge is sent to a digester to produce biogas; the biogas is then upgraded to pipeline specifications and injected. These systems' biggest CI impact is the energy use involved, as there are no avoided emissions in the process. The biogas produced can also be burned in boilers for process heat at the WWTP facility instead of cleaned and injected.

10.2 Organic Waste

Organic waste feedstocks can also be used in a digester, such as food scrap waste, urban landscaping waste, construction and demolition waste, municipal solid waste, diapers, sewage sludge, industrial food processing, pulp and paper, industrial sludge, wood products, and other organic wastes. For these projects, the two most impactful factors are the amount of degradable organic carbon, fraction of volatile residue of the degradable organic carbon, and the landfill diversion fate of the feedstock. Additional minor factors include feedstock transportation distance and upgrading energy required.

Degradable organic carbon (DOC) is the fraction of carbon that is degradable organic fraction and the fraction of degradable organic carbon is the amount of carbon that actually decomposes and is converted to biogas.[xlvii] The higher these values are, the higher the potential yield can be. The following table is lists DOC on a wet basis as provided by CARB:

TABLE 12: DEGRADABLE ORGANIC CARBON BY FEEDSTOCK[xlviii]

ORGANIC WASTE FEEDSTOCK	DEGRADABLE ORGANIC CARBON	FRACTION OF DEGRADABLE ORGANIC CARBON
Sewage Sludge	0.05	-
Construction and Demolition	0.08	-
Industrial Sludge	0.09	-
Food Scraps	0.14	0.64
Yard Trimmings	0.20	0.23
Pulp and Paper	0.20	-
Industrial Food Processing	0.22	-
Diapers	0.24	-
Municipal Solids	0.31	-
Wood and Wood Products	0.43	0.21

[Values for the fraction of degradable organic carbon provided by CARB only include three common feedstocks: food scraps, yard trimmings, and wood products.]

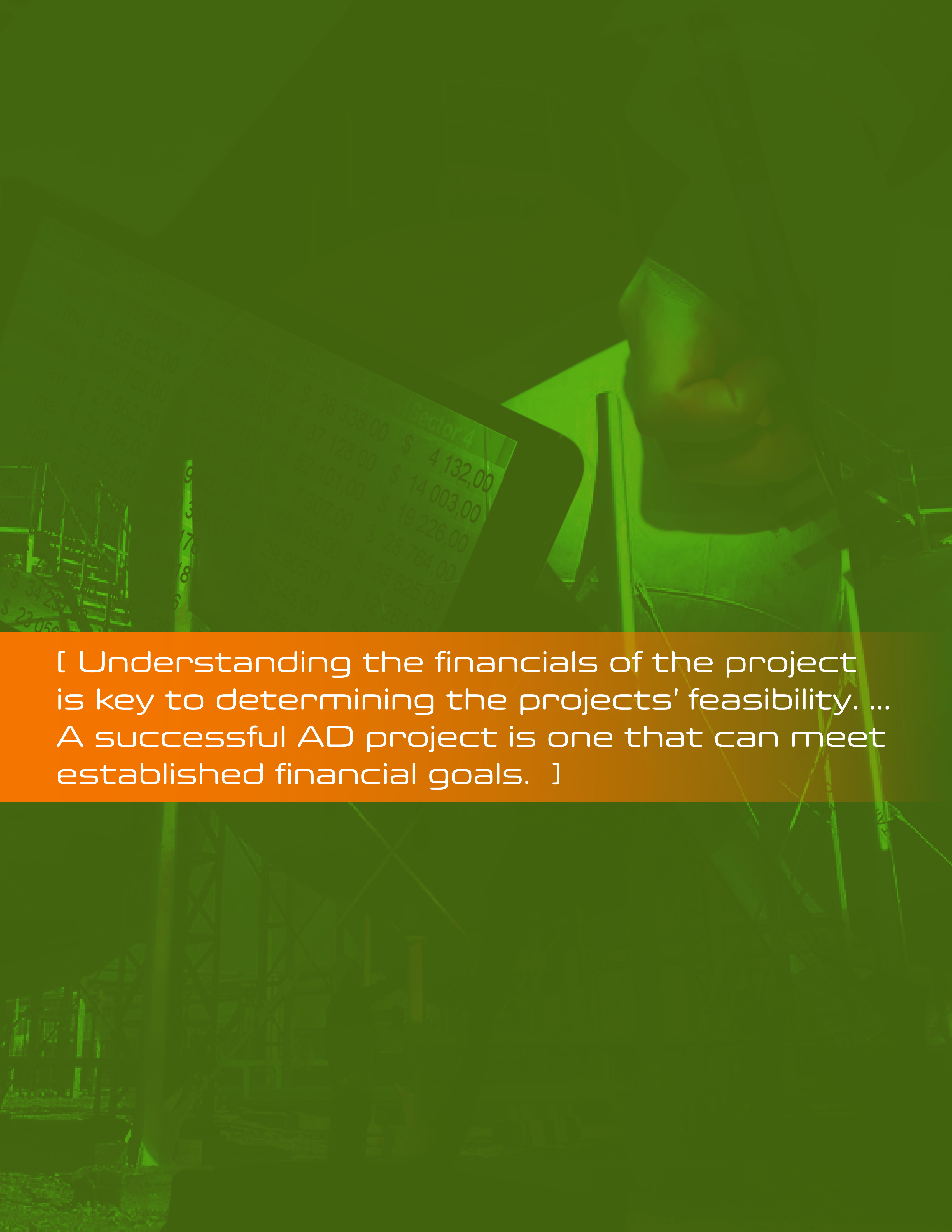
Values for the fraction of degradable organic carbon provided by CARB only include three common feedstocks: food scraps, yard trimmings, and wood products. The following formula can be used to estimate the fraction of degradable organic carbon for other feedstocks. If this formula cannot be calculated, a default value of 0.60 can be used as provided by CARB.[xlix]

$$DOC = F_{DOC} * \frac{\%\ \text{Volatile Solids}}{100\%} * \frac{\%\ \text{Total Solids}}{100\%}$$

Where: F_{DOC} = The fraction of the volatile residue that is degradable organic carbon

% Total Solids = 100%- % Moisture Content

Landfill diversion fate is the other important factor because CARB recognizes avoided methane emissions for anaerobic digestion of organic wastes. The diversion fate is the fraction of other organic waste that would be sent to landfill in the absence of the anaerobic digestion project.[l] The higher the diversion rate, the less organic waste is sent to landfill and more emissions are avoided. CARB has provided diversion factors for food scraps and urban landscape waste built into the calculator, 97.5% and 35.9% respectively. For other organic waste, landfill diversion rates would need to be proven based on common area practices. For instance, if a particular feedstock source under review is sent to the landfill but the norm for that area is that the feedstock is not sent to landfill, CARB would view that feedstock used in anaerobic digestion as having no landfill diversion. Feedstock diversion can improve the CI of the project significantly through avoided emissions.



[Understanding the financials of the project is key to determining the projects' feasibility. … A successful AD project is one that can meet established financial goals.]

11.0 Economic and Financial Factors

Understanding the financials of the project is key to determining the projects' feasibility. The developer must estimate capital costs, annual and operating costs, and expected revenues to ensure the project covers expenses, meets profitability goals, and allows for a quick payback period on capital investment. A successful AD project is one that can meet established financial goals.

11.1 Capital Investment

One of the key items in determining financial feasibility is the estimation of the capital expenses. The capital cost estimate should include all the necessary items required to get the project operational.

Some of the common capital costs associated with building an AD may include the following:

- Land acquisition
- Site demolition and development
- Utility services (electrical, natural gas, water, etc.)
- Civil works (earthwork, site work, etc.)
- Feedstock processing equipment (tanks, mixers, pumps, screening, etc.)
- Anaerobic digestion equipment (tanks, covers, piping, heating, etc.)
- Digestate processing equipment (solids separation, dewatering, storage, etc.)
- Process design engineering
- Equipment installation
- Project controls
- Permitting fees
- Project management
- Consulting and legal
- Contingency
- Working capital

There are some project-specific costs that will be dependent on the end use of the biogas. Below are some of the project-dependent capital costs:

- Electricity generator
- Combined heat and power
- Biogas upgrading system (H_2S removal, CO_2 removal, compressor, etc.)
- Pipeline interconnection
- Regulatory consulting

It is important that the equipment is sized properly for the project. If the equipment is undersized, then the project will not realize the full potential. Material may not get processed or the equipment might not be able keep up with the input. If the equipment is oversized, then the developer is increasing the capital cost of the project with no benefit. However, if the project is expected to grow through the acquisition of additional feedstock from other farms or sources, then it may be beneficial to consider an oversized system at first so it can handle the future production.

A contingency factor is particularly important throughout capital cost estimating, as it provides a buffer for unexpected costs that might arise throughout development. In the early stages of development, a large contingency of 20-30% is needed as the estimated capital costs can be significantly different that the actual costs. As development moves further along, the contingency can shrink to 10-15% because the equipment costs from vendors and design engineers will be firmer.

If unfamiliar with the equipment necessary and the appropriate sizes of the equipment, then it is beneficial to reach out to the equipment vendors for budgetary estimates or a third party with experience to provide a capital cost estimate. The vendor or third party will have the necessary experience to provide a more accurate capital cost estimate.

11.2 Annual and Operating Expenses

The project's operations and maintenance (O&M) costs are the ongoing costs for running the system, which can be daily, annual, or recurring costs throughout the life of the project. Common O&M items are listed below:

- Feedstock payments or royalties
- Labor
- Utilities (electricity, natural gas, water, etc.)
- Maintenance and replacement parts
- On-site spare parts
- Media or chemical replacement
- Digestate disposal
- Regulatory compliance
- Lab testing
- Insurance
- Administrative, legal, and reporting
- Miscellaneous
- Contingencies

The labor costs represent the required labor to operate and maintain the equipment. This typically involves making sure the equipment is operating under the desired conditions and set controls parameters. This involves checking the digester temperature and pH, assuring the systems are functioning, and recording data. The labor will also be required to do any routine maintenance or replace certain broken equipment within reason. During certain equipment failures, it may be required to call the vendor for their expertise. Depending on the facility, the labor may be required to facilitate feedstock reception and processing.

Depending on the size of the facility, this can be done with as few as one person or as many as seven people for very large facilities.

Estimating the use of utilities will be based on the equipment being used and the end use of the biogas. Components such as pumps, motors, compressors, and more will require electricity to run. The equipment specification sheets should provide the average and maximum electricity draw of the equipment to get an estimate of how much electricity will be used by the project. Other items such as the anaerobic digester, flare, and operations building may use natural gas. The project may use water for feedstock or servicing the operations building.

The biogas upgrading and other equipment will require routine maintenance: replacement parts, oil, or media. The H_2S removal equipment will need the media changed out every six months or year, the compressor will need replacement oil to keep it well operating, and other similar items will need to be maintained. These maintenance costs can be annualized for inclusion in the O&M budget. It is also recommended that an O&M reserve fund is included, which can cover unexpected major costs in the case of equipment breakdowns.

Some of the other annual costs include lab testing, regulatory compliance, insurance, and administrative fees. Regulatory compliance can be complex. Occasional testing of the feedstock, digestate, or biogas may be required for regulatory purposes, process improvement, or monitoring. If the biogas or RNG is used as a transportation fuel, compliance can be handled by a third party.

11.3 Project Revenues

Determining the appropriate revenue streams based on the likely markets for the project is key for the overall project feasibility. A lot of the markets around ADs are prone to revenue fluctuations. It is best to use conservative assumptions, as it can help temper expectations when assessing the revenue for the project,. If the project is feasible under conservative assumptions, then the project will likely succeed through most fluctuations in market conditions.

Certain individual revenue streams can be stacked together to increase the total revenue generation for the project. Irrespective of the end use of the biogas, tipping fees and digestate sales are potential revenue streams for all projects. Biogas used as a transportation fuel is eligible for the commodity value of natural gas and to participate in the Federal Renewable Fuel Standard and a state-level low-carbon fuel standard. Biogas-to-RNG projects usually have multiple stakeholders involved (e.g., farms, developers, offtake marketer, investors etc.), but only one party can have claim to the environmental attributes associated with each RNG physical molecule and generate its respective program credits.

Although multiple revenue streams exist for an AD project, not all can be capitalized upon due to the project location and logistics involved. This section will go more in depth into the potential revenue streams, how to assess the amount of revenue, and how to determine the likelihood of realizing each of the individual streams.

11.3.1 Electricity Sales and RECs

One possible source of revenue for an AD project is using the biogas to produce electricity. Many states have a renewable portfolio standard that dictates a certain portion of the electricity in a utility's portfolio come from renewable source, and biogas is sometimes an approved source. Revenue generation from the production of electricity can come from a power purchase agreement (PPA) or the sale of renewable energy credits (RECs). The PPA can be between the project owner and a utility or potentially a municipality, company, or other entity.

RECs are a market-based credit that certifies the producer has generated a megawatt-hour of electricity from a renewable energy source. The project can then sell RECs to a voluntary buyer or utilities who have to meet compliance goals. The revenue from RECs is on a $/MWh basis.

11.3.2 RNG Sales

If the biogas is upgraded to RNG, it can be injected into a natural gas pipeline and be used anywhere in the United States. Once upgraded to RNG, it is indistinguishable from fossil natural gas. Injected RNG will receive the commodity value of natural gas. This is typically measured in $/MMBtu, and the natural gas index is typically between $1.50-3.00 per MMBtu.

Another option is the sale of RNG to a voluntary buyer at a fixed price. As more companies try to meet sustainability goals, there is more focus on buying renewable energy. RNG is a source of renewable heat and can be key to many company or municipality sustainability goals. Due to the renewable nature of the RNG, its sales to a voluntary buyer are often at a higher price than the commodity value of natural gas. Fixed-price contracts have typically been anywhere between $8-15 per MMBtu and can depend on production volumes, location, commercial operations date, or CI score.

11.3.3 RINs

If the biogas produced from the AD is used as a transportation fuel anywhere in the United States, it is eligible to participate in the Renewable Fuel Standard. The RFS was established by Congress in 2005 and provides financial incentives for projects producing renewable fuels like RNG, namely in the form of Renewable Identification Numbers (RINs). Depending on the cellulosic content of the feedstock being processed in the digester, RNG is eligible to produce either D3 or D5 RINs.

RINs are based on the energy content of a gallon of ethanol. The energy of one MMBtu of RNG is equivalent to the energy content of 11.727 gallons of ethanol. This means the one MMBtu of RNG that is used as a transportation fuel will generate 11.727 RINs. The index price for RINs can be found on the USEPA website.

There are brokers who can facilitate the sale of RNG and RINs but will take a percentage of the revenue, typically 10-20%. These brokers can assure that the RNG is used as a transportation fuel and is eligible to produce RINs.

11.3.4 State Program Credits

Several states like California and Oregon have created low-carbon fuel standards, which are complementary to the RFS. Several more states are considering the adoption of similar legislation. The goal of these programs is to reduce the life-cycle greenhouse gas emissions of the transportation fuel pool. This is done by measuring the emissions of the fuel from each project and assigning a carbon intensity score. The CI score is facility-specific and dependent on several factors including electricity and natural gas use, feedstock composition, and fuel production volumes.

If RNG from the fuel is used in a state with a low-carbon fuel standard, then it is eligible to generate credits under the program. Since the these state programs are complementary to the RFS program, a fuel that is used in a state with such as program can generate RINs and state credits. This can add significant value to the project. Right now, California and Oregon are the only states will well-established programs, and their markets are incredibly competitive. Selling RNG into those states may be difficult if the CI score of the project is not low enough.

11.3.5 Tipping Fees

Many industries and organizations that are producing large quantities of organic waste need a place for disposal. These companies will partner with a waste hauler, landfill, or AD project to process their waste and will pay the waste processor a tipping fee to do so. Tipping fees are typically assessed on a per-ton or per-gallon basis and can be a significant source of revenue for a project.

11.3.6 Digestate Sales

The digestate can be separated into liquid and solid portions. The feedstocks being processed by the AD, especially manure, are high in nutrients that end up in the liquid portion of the digestate. These nutrients can be recovered and sold as fertilizer to farmers. The solid portion of the digestate is rich with fiber and can be used as bedding material or soil amendment.

Digestate sales are typically done per unit weight (e.g., $/lb) of the specified nutrient or fibrous material. However, these markets can be difficult to set up and will require contract negotiations with nearby farmers. This source of revenue is not guaranteed and depends greatly on establishing a local market. A common misconception in the development of AD projects is assuming and relying on a significant revenue stream from digestate produced.

There are various factors, such as location and digestate volume, that may provide difficulty or take years to fully monetize on this by-product. Projects can fail to meet financial goals due to unachievable digestate sales projections.

12.0 Developing a Successful Project: Mitigation for Common Risks and Missteps

This section will discuss the critical components to successful execution of an RNG project and how to avoid common mistakes. Below are the key components in the development process of a successful AD project. Each factor can affect timeline, budget, and compliance with the regulations that generate credits and revenue. A successful project begins with the right team and the right project manager on the team.

Working with the right team: Identifying, hiring, and working with the right team may be the most important decision a project developer makes. With new players are entering the marketplace on a near daily basis, the difference in experience could determine whether the project is developed or flounders along the way. Considerations when assembling the team should include:

- **Offtake partner and financial structure:** Most RNG projects cannot work without monetization of the environmental attributes of the RNG. Finding the right offtake partner, whether for transportation fuel or into the voluntary markets, is critical.
- **Technology assessment and biogas upgrading equipment selection:** Working with experienced equipment vendors with proven technology is highly recommended. Ask for references and installation lists and visit other project owners' sites using the targeted technology before making a selection. The biogas-to-RNG space is constantly growing, and new vendors are consistently coming out with new equipment. When millions of dollars of revenue are at stake, proper due diligence in selecting equipment that will continuously meet the pipeline specifications with minimal downtime is very important.
- **Design engineer and contractor selection:** Digesters and upgrading equipment are specialized machinery. Piping material selection, heat tracing or insulation of lines, moisture capture, appropriate controls, and more decisions are crucial to the long-term success of a project. Design issues that cause your system to be down for an extra few days per year can be expensive. Hiring an experienced design engineer is the best mitigation to avoid costly downtime.
- **Renewable energy consultant:** A good renewable energy consultant can act as a reliable project manager to guide the project through all the above tasks and manage the various development phases of the project, all while navigating the complex regulatory environment, helping maximize RNG value, and identifying potential roadblocks or gaps within your project. a good renewable energy consultant's fee can easily be offset with one month of revenue generation.

The right project manager (PM): The cornerstone of success is a central project manager who can competently coordinate the various parts of project development and stakeholder involvement to deliver a project on schedule and on budget.

The PM should have a sufficiently strong grasp of the three key development phases to maintain sight of the overall picture and be able to anticipate and mitigate potential risks, roadblocks, or bottlenecks to the project.

Each development phase constitutes critical activities that shape the success of the project. Figure 12 outlines these activities and are further described in this section.

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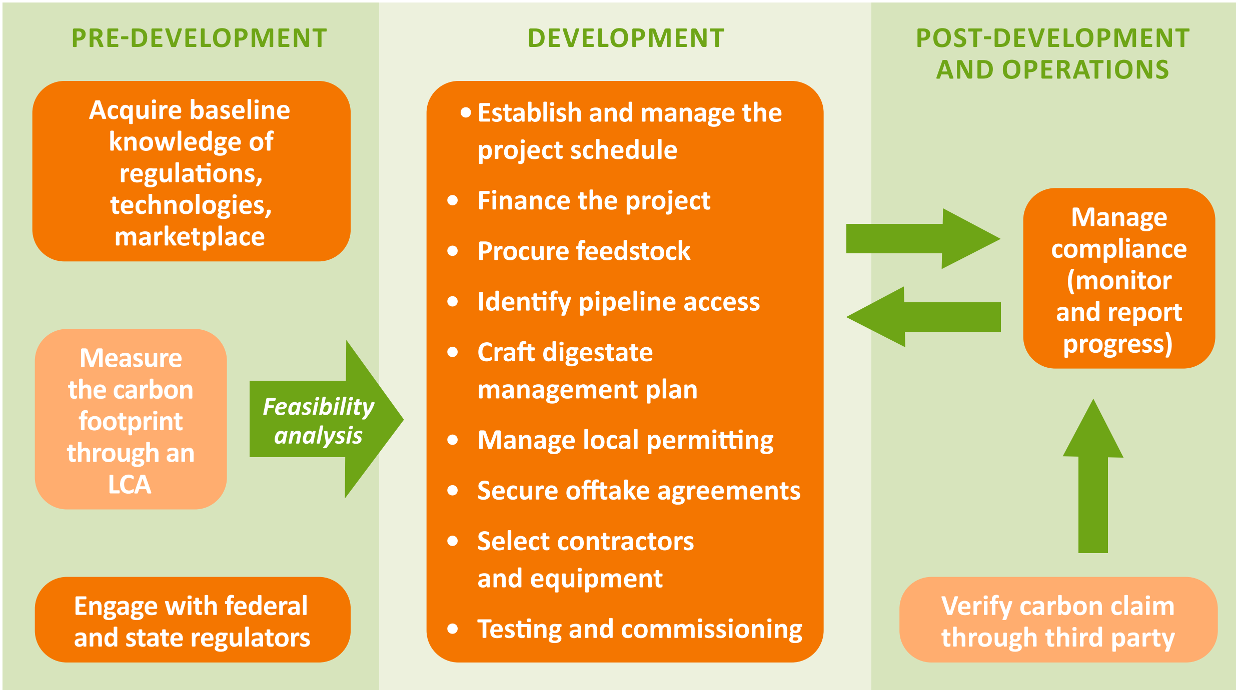
FIGURE 12: THE PROJECT DEVELOPMENT CYCLE



Source: EcoEngineers

12.1 Pre-Development Phase

Before a firm decision can be made to develop a project, there is a pre-development phase that involves gathering preliminary information and conducting a feasibility study. This phase involves the steps outlined in the following sections.

12.1.1 Acquire Baseline Knowledge

Clean energy project owners require a solid grasp of the regulatory requirements that drive value to their projects. Project owners who invest in upfront training and education are better equipped to navigate the complex clean energy regulations and requirements that move their project across the finish line. Most experienced developers are skilled at intuitively understanding if an opportunity is a viable option, but even these developers have to maintain a strong grasp of the regulations and the marketplace to translate their intuition to hard numbers. For those developing a first or second project, the variations in credit prices and changes in the quickly morphing RNG industry prove difficult to put into perspective when considering a new opportunity. After arriving at solid preliminary financial numbers, it is key to understand that there will be changes in the ever-evolving RNG industry. A successful project developer will stay current on new developments and adapt as changes occur in the following three main areas:

- **Regulations:** The primary regulations that drive revenue to biogas projects are the low-carbon fuel regulations that incentivize RNG produced from biogas for use as transportation fuel or thermal energy, as well as raw biogas used to generate electricity or used as process heat. Depending on the end use, a variety of regulations, such as the RFS, LCFS, tax codes, utility regulations, local RPS, etc., all come into the picture for these types of projects.
- **Technology:** AD technologies, gas upgrading systems, pipeline interconnect options, power generation, and natural gas engines are all relatively mature. The right PM will have a sufficiently

[When considering participation into the RFS and LCFS programs, engaging with the regulatory bodies implementing each, USEPA and CARB respectively, may be the best strategy to protect stakeholders' investments.]

strong grasp of the major vendors and options available in the industry to help developers make the right decision for their projects.

- **Marketplace:** AD project revenues are primarily derived from avoided emissions or carbon credits. These markets are evolving very fast and are often driven by regulations; however, there is a rapidly growing voluntary segment that will pay a premium for low-carbon fuels. Understanding the marketplace and how offtake contracts are set up is critical to project success.

12.1.2 Measure the Project's Carbon Footprint through a Life-Cycle Analysis (LCA)

Preliminary carbon modeling (life-cycle analysis or LCA) under applicable regulations is the only way to quantify the emissions reduction resulting from the use of biogas or RNG as a fuel. Although detailed LCA work may be completed by an experienced developer, it is recommended for a third-party expert to complete this modeling. Many financing entities are interested in a third-party's CI report.

The PM should have a baseline knowledge of the inputs and outputs that impact the project LCA and the resultant CI score. The methodology used and the assumptions behind the calculations can sometimes cause a big difference in the final score. As seen earlier, the majority of revenues to AD projects are from the sale of carbon credits. AD projects provide a low-carbon, zero-carbon or even negative-carbon fuel. In today's marketplace, products with a lower-carbon footprint are intrinsically more valuable. In order to develop strong project financials, the assumptions that go into carbon measurement and pricing must be accurate and reliable. This is also crucial to attracting financing.

In addition to standard energy inputs that impact a project's carbon footprint, AD projects have the added complexity of benefitting from avoided methane emissions from manure management or from landfill

diversion. Modeling these avoided emissions credits is an important and sometimes complex upfront effort. Preliminary reliable values for these credits can make a big difference in having greater confidence in the project's pro forma and securing the right financing partner.

12.1.3 Engage with Federal and State Regulators

It is sometimes necessary to secure regulatory interpretations to optimize project revenues or to seek a new regulatory pathway. All regulations and carbon protocols have assumptions and boundaries. The earlier you understand whether your project is within those boundaries or an outlier, the smoother the project development process and greater confidence you will have in projected revenues.

When considering participation into the RFS and LCFS programs, engaging with the regulatory bodies implementing each, USEPA and CARB respectively, may be the best strategy to protect stakeholders' investments. Although the RFS and LCFS programs have regulations set in place that provide the basis for how these programs are implemented, there are different factors to an RNG project that can lead to regulatory complexities. Some of these complexities may include, but are not limited to, the following unique factors of a project:

- Process used to produce RNG
- Process technology
- Type of feedstock
- Co-processing of different types of feedstocks
- Process energy practices
- Carbon capture sequestration (CCS)
- Feedstock practices prior to the project (e.g., landfill use, manure management practices, etc.)

Engaging with the programs' regulators may provide guidance, help understand regulatory risks, and, ultimately, determine the project's viability under these programs. Regulatory engagement can often help facilitate important go/no-go investment decisions.

12.1.4 Feasibility Analysis

If the project has a reasonably confident approval rating and a preliminary CI, an offtake market analysis should be conducted for all outputs: RNG, environmental attributes, and co-products. Having credit market revenue short- and long-term outlooks and estimating capital and operating costs will lead to a preliminary project pro forma and a feasibility test. If the project passes this stage, then it can move to the formal development phase.

12.2 Development Phase

Asset development is the longest phase and involves multiple steps that happen in parallel with feedback loops. Some of the key steps include: Once the carbon footprint is established, a regulatory pathway charted and project pro formas finalized, the project is ready to be built. This stage requires a focused project manager who can oversee the steps detailed in the following sections.

12.2.1 Establishing and Managing Project Schedule

One of the key roles of an effective PM is establishing a project schedule and managing the timeline. The below project schedule is a timeline of the ideal RNG project commissioning process in the case that each step of the project schedule is executed as planned. RNG projects can take 18-60 months from concept to completion. Of the factors that can impact a project timeline, financing can often be the most difficult to overcome. The complexities associated with developing an RNG project that connects to the pipeline can be out of the hands of the project developer. When looking at the success of RNG projects, challenges can provide delays of longer than a year from the expected startup date. However, careful preparation, alignment of project resources, and an experienced project team can lower the possibility of delays. Table 13 outlines an accelerated project schedule achievable by working with experienced project partners.

TABLE 13: EXAMPLE PROJECT SCHEDULE

TASK	COMPLETION TARGET
Decision to Proceed	Month 1
Feedstocks Procured	Month 3
Financing Procured	Month 6
Preliminary Design and Technology Selection	Month 6
Design Engineer Selection	Month 6
Final Design	Month 9
Natural Gas Utility Pipeline Agreement Finalized	Months 11/12
Offtake & Gas Marketing Negotiations	Month 13
Construction and Technology Installation	Month 15
Startup	Month 16
RFS Registration	Month 20
Revenue Generation Begins	Month 20
LCFS Registration	Month 23

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12.2.2 Finance the Project

Developers and financiers who have funded an AD project understand the challenges and lengthy schedule associated with closing. Many project developers may spend years in fundraising mode even for a project that is very lucrative on paper. For an investor, working with established entities who have a proven record in project development, but need financing, could be a mutually beneficial relationship.

12.2.3 Procure Feedstock

Procuring feedstocks in long-term agreements prior to starting project development can be a challenge. Given the value of RNG, compensating feedstock providers for manure and agricultural digesters is often done by alleviating the burden of current feedstock disposal. Selling the overall environmental impact and vision may also be beneficial. Alternatively, a share of the project revenues may be required to secure commitment from feedstock suppliers, as more and more organic waste producers see value in converting their wastes into biogas. Often, project developers obtain letters of intent (LOI) for the exclusive rights to use a feedstock for RNG production. These LOIs outline the general terms of a potential future arrangement between the developer and the feedstock provider. Turning LOIs into formalize feedstock supply agreements can take significant effort.

12.2.4 Identify Pipeline Access

Access to a pipeline helps connect the RNG to its end user for use as transportation fuel. Establishing access to a pipeline may require a new interconnection setup. It is possible the USEPA will approve a new interconnection setup, but it may not be realistic for all projects. If a project has a unique component that has not been approved by the USEPA in the past, there will likely be delays during the registration process. Engaging with the USEPA early in the planning and design process is recommended to avoid delays or having to install additional equipment after the project is fully constructed. Furthermore, the assumption that the nearby commercial pipeline will work with the project in a timely manner may also cause delays and additional problems. It is highly recommended to contact the pipeline early in the process to understand its requirements.

The distance from a project's upgrading facility to an interconnection point may vary. For some projects with a close enough distance, it may be feasible to run piping directly from the upgrading facility to the interconnection point.

Typically, building a pipeline to the interconnection point to a commercial pipeline costs approximately $1 million per mile of pipeline. For other projects, this may not be financially feasible due to the distance between the upgrading facility to the interconnection point.

Another option may be to truck the RNG from the upgrading facility to the point of interconnection. The cost for trucking may be approximately $3-6 per MMBtu of RNG, depending on the hauling distances.

12.2.5 Craft Digestate Management Plan

Digestate handling has been a common fail point for past anaerobic digestion. It is important to understand the management options, plan of action, and associated costs. Project owners often assume markets will develop for the liquid nutrient-rich stream and the dewatered solids, where both streams will end up as additional revenue sources. If a project developer does not plan for this, digestate handling can be a cost center as opposed to a revenue generator — especially for the first few years of a project.

12.2.6 Manage Local Permitting

Local permitting requirements — city, county, state, air quality, and other land-use authorities — are complex and vary state to state. Knowing when to submit these permits and the review time required by the various agencies can alleviate frustrations with the project schedule.

AD and RNG projects may require other permits and approvals from local agencies before construction begins. It is important to check with local agencies for regulations or guidelines on noise, zoning, setbacks, and land use. It is also important to check with local agencies regarding project design, fire safety, electrical, and structural requirements.

The Iowa Department of Natural Resources (DNR) – Construction Permits section is responsible for the review and approval of all pre-construction air permitting in Iowa. However, for projects located in Linn and Polk counties, permits are administered by local air programs. Any project that includes construction of a new facility or modification of an existing facility that emits air contaminants requires authorization from the DNR. Facilities meeting state and federal requirements are issued construction permits and operating permits for ongoing compliance. The Iowa DNR strongly encourages pre-application meetings in order to facilitate review and permitting of large and complex projects.

More information on the permitting processes can be found through the contact information provided in **Appendix B**.

12.2.7 Secure Offtake Agreements

Selecting the right offtake partner is a critical piece in the development of an RNG project. During the pre-development phase, the project developer must explore the potential markets, including the transportation and voluntary market, from which the revenue will be generated. This process includes research and outreach to potential interested offtake partners to obtain a sense of the pro forma of the project through a feasibility analysis.

During the development phase, the project developer will make a final decision on the offtake partner for the project and firmly establish this relationship through a contract agreement. Contract term negotiations may occur through this period.

The right PM for the project will have experience with common offtake relationships in the marketplace and will provide guidance through review of requests for proposal (RFPs), term sheets, and contractual agreements during pre-development and development phases.

Ultimately, is important to establish the right relationship with an offtake partner since the project's monetization will be primarily from the environmental attributes of the RNG.

12.2.8 Select Contractors and Equipment

Experienced contractors and equipment vendors in the RNG sector are critical for maintaining construction schedules, achieving RNG production levels, and selecting equipment that will result in minimal downtimes and consistently meet pipeline specifications. During the pre-development phase, project developers will explore possible contractors and assess different AD and upgrading technologies. During the development phase, these selections will be finalized, contract agreements will be secured, equipment purchases will be made, and construction activities will take place. The right PM will assist in this process by providing insight to common and new technologies available in the industry. The RNG sector is consistently growing, and it is important to perform proper due diligence and explore all possible equipment options to protect the project's investment and revenues.

12.2.9 Testing and Commissioning

The development phase will conclude once construction of the RNG production facility is completed and commissioning takes place. During commissioning, all components of the systems installed will be tested to confirm proper operation. Laboratory testing will be completed on raw biogas and finished RNG samples to ensure chemical properties are met; this is typically done through a certificate of analysis (COA). The COA is part of the commissioning process and also a requirement of the RFS registration process, as it helps ensure the system produces RNG that meets all pipeline-quality requirements to ensure delivery to transportation fuel end users will be possible.

12.3 Post-Development and Operations Phase

Equipment will break, pumps will fail, and feedstock and digestate handling will be more labor intensive than expected, and this will all happen at inopportune times. An experienced operator who knows how to respond, manages the situation, and makes the necessary repairs will be worth the investment. The RNG industry is relatively young, and finding and retaining experienced operators can be a challenge. Post-commissioning operations can be separated into two major areas. One is the physical operations to make sure the equipment and processes are functioning, and the biogas and co-products are being produced. The second is ensuring that the avoided emissions and carbon credits are being generated successfully. This latter is the source of the majority of project revenues and can be divided into the following two steps: compliance management and verification.

12.3.1 Manage Compliance

The first step in compliance management is having a properly registered pathway under the applicable protocols. Next, a document control system needs to be established to make sure that every detail of regulatory compliance under all applicable low-carbon regulations is clearly addressed. Many projects have paid insufficient attention to this very important step and suffered from a loss of revenues. The right PM partner will help navigate the compliance requirements under the different low-carbon programs, starting with initial registration requirements and continuing with a control system to meet ongoing compliance requirements.

To generate credits under the RFS, the project must be registered under a USEPA-approved pathway.

Regulatory engagement must take place for unique projects where either the feedstock, process, or fuel type do not align with any established pathway.

In some instances regulatory guidance will be needed if a project needs to undergo a pathway petition process to seek USEPA approval for a facility-specific pathway. To register the company and facility under the appropriate pathway, an engineering review report must be completed by an independent third party and submitted to the USEPA. The engineering review includes review of relevant documents that represent and document information required pursuant to 40 CFR 80.1450(b)(1), a visit to the facility confirming the accuracy of the information, and a summary report with the independent third-party findings.

Similarly, to generate LCFS credits to sell into the California market, each facility must be registered with CARB. To register, a facility needs a minimum of 90 days of operational data to submit a pathway application using a Tier 1 or Tier 2 calculator, which models the life-cycle analysis (LCA) of the project. The LCA relies on an accurate measurement of carbon usage and greenhouse gas emissions from "cradle to grave" to ultimately calculate the CI score of the project's pathway. The application package submitted to CARB must include the Tier 1/Tier 2 calculator and all required supporting documentation. The application is later verified in person by a verification body through the validation process (see **12.3.2 Verify Carbon Claim through Third Party**).

Participation in the RFS and LCFS include ongoing compliance requirements that must be met to continue to monetize the rewards of generating low-carbon fuels. Maintaining compliance requires regulatory knowledge and effective communication with regulators, as necessary. The following provides an overview of the ongoing compliance requirements for the RFS and LCFS programs:

- **Renewable Fuel Standard (RFS)**
  - RIN Management
  - RIN Generation Protocol
  - Three-year Third-Party Engineering Review Update (see **section 12.3.2**)
  - Registration Updates (as necessary)
  - Reporting
  - Recordkeeping
- **Low Carbon Fuel Standard (LCFS)**
  - Compliance Monitoring Plan (CMP)
  - Registration Updates (as necessary)
  - Annual Fuel Pathway Report
  - Verification (see **section 12.3.2**)
  - Reporting
  - Recordkeeping

> [The regulations are subject to change, which may change the compliance needs of the project. Compliance monitoring is key to the long-term success of a project. Working with an experienced third party may be highly beneficial..]

Once a project developer successfully navigates all aspects of development and the project is operational and generating revenue, compliance for credit generation continues. Ongoing compliance requirements are necessary to ensure validation and verification of the environmental attributes and to protect the investment made in the project. The amount of compliance work can vary and may be as little as sending pipeline injection volumes to a voluntary offtake party; however, it may be much more complex with RIN and LCFS credit generation. The amount of compliance work also depends on the role the project developer intends to fill on the project team.

The regulations are subject to change, which may change the compliance needs of the project. Compliance monitoring is key to the long-term success of a project. Working with an experienced third party may be highly beneficial.

12.3.2 Verify Carbon Claim through Third Party

The final step to protect project revenues is to secure a third-party verification of all environmental claims – in this case, avoided emissions from using low-carbon fuels. Most low-carbon fuels regulations and standards have specified verification protocols. Contracting with a competent third-party verifier and providing them access to your compliance management system will ensure a verified credit and continued cash flow.

Part of protecting an RNG project investment is to ensure ongoing compliance is satisfied, per regulatory requirements. Part of this compliance includes ongoing auditing practices completed by an independent third party, as described below:

- **Renewable Fuel Standard (RFS)**
    - Quality Assurance Program (QAP):
        - The QAP is a voluntary program where independent third parties (a QAP provider) may audit and verify that RINs have been properly generated and are valid for compliance with the RFS.
        - RINs qualified by a QAP provider are designated as "Q-RIN" at point of RIN generation. This "Q-RIN" tag travels with the RIN as it is sold and purchased by downstream parties.
        - The auditor conducts an on-site visit at the renewable fuel production facility at least two times per calendar year and include verification of all QAP elements that require inspection or evaluation of the physical attributes of the renewable fuel production facility.
    - Three-Year Third-Party Engineering Review Update:
        - The USEPA requires that registered facilities/companies update registration information and submit an updated independent third-party engineering review every three years from the initial registration submission. This submission is required by January 31 of the year in which the report is due.
- **Low Carbon Fuel Standard (LCFS)**
    - Validation:
        - CARB requires all LCFS pathway applicants to have a CARB-accredited verifier review the application submitted to certify the pathway. Only CARB-accredited Verification Bodies, such as EcoEngineers, may provide LCFS validation services. The validation process includes a conflict-of-interest analysis and review of the pathway application, including review of the CA-GREET 3.0 model used to calculate the CI score. The verifier also completes a site visit to confirm the information provided by the applicant. Ultimately, the verifier prepares a validation report and statement to submit to CARB.
    - Verification:
        - Starting in 2020, CARB requires pathway holders to have a CARB-accredited Verification Body, such as EcoEngineers, complete a verification process on the approved pathway on an annual basis. The verification process includes a site visit to the facility to confirm the information provided in the approved pathway is accurate. The verification process will take place after the submittal of the Annual Fuel Pathway Report (AFPR), which is due by March 31 each year. The Verification Body will review the information as included in the AFPR submittal, including 24 months of data/documentation supporting the pathway and CI, along with findings through the site visit, to prepare the Annual Verification Report, which is subsequently submitted to CARB.

13.0 Case Study

13.1 Des Moines Metropolitan Wastewater Reclamation Authority

The Des Moines Metropolitan Wastewater Reclamation Authority (WRA) treats 63,000,000 gallons of wastewater and produces up to 1,800 scfm per day of biogas. The biogas was used to generate electricity while the excess biogas was flared. WRA wanted to upgrade the biogas for pipeline injection to renewable natural gas (RNG) and to use resulting revenue through the sale of natural gas and energy credits to offset capital and operating costs at the facility.

DES MOINES METROPOLITAN WASTEWATER RECLAMATION AUTHORITY

After the development of the project, EcoEngineers asked WRA about their experience throughout the process, including challenges encountered and lessons learned. Overall, WRA indicated the biggest challenge was working through all of the regulatory and contractual terms with its legal team. As an organization whose main focus is not the production of gas transportation fuel, the use of multiple gas industry agreements and terminology used for renewable natural gas purchase and sale was a difficult learning experience for WRA.

The RNG's offtake also proved challenging. During the selection of the offtake partner, WRA's biggest hurdle was understanding the requirements of the RNG tariff filed with the state utility commission and how it affects natural gas contracts for the sales of gas. Ultimately, WRA worked with its Board to establish offtake options, risk profiles, and cash flow volatility levels in order to define the optimum deal structure and identify end users for use of the renewable natural gas.

WRA indicated the negotiations of the pipeline interconnect agreement was one of the development activities that took the longest. Since WRA was interconnecting to a utility pipeline without any existing RNG connections, it experienced a lengthy negotiation process to establish the contractual agreement. WRA also identified the permitting process as an activity requiring a substantial amount of time. Specifically, WRA noted coordination issues between itself, the utility and the regulatory board added to the time required.

No prior experience working through this type of permitting process had created challenges for WRA. To navigate the regulatory landscape, WRA relied on consultants to educate and guide its staff through the process.

Successfully taking an RNG project from concept to commissioning requires deep knowledge of clean fuels regulations and fuel and carbon markets. EcoEngineers was tasked as WRA's renewable energy consultant throughout the project — from concept, through design, construction, and startup and compliance management with the federal Renewable Fuel Standard (RFS) and other clean fuel regulations.

The following provides an overview of some of the tasks EcoEngineers assisted WRA with as its regulatory consultant partner through the development of the project:

- Conducted workshops covering regulated clean fuel markets, such as the RFS and LCFS, and voluntary non-regulated markets, the financial risks associated with them, and their ongoing compliance obligations. This helped to establish a baseline knowledge within the WRA team.

[Successfully taking an RNG project from concept to commissioning requires deep knowledge of clean fuels regulations and fuel and carbon markets.]

- Completed a pro forma analysis of project revenues including a revenue sensitivity assessment.
- Reviewed records management of the project and recommended best practices to fulfill compliance expectations. EcoEngineers reviewed the feedstock mix and determined eligibility to generate cellulosic versus advanced biofuel environmental credits (RINs) under the RFS.
- Managed the solicitation and selection process to find offtake options for the renewable natural gas within the parameters set by WRA and its Board.
- Conducted a carbon intensity analysis and registered the project under the RFS program to generate RINs.

Currently, the project is under its post-development phase with a recently approved federal RFS pathway registration. WRA has been producing and selling pipeline quality RNG since Q1 2021.

14.0 Next Steps

The following next steps are recommended for potential project developers interested in pursuing biogas projects:

- Review financing options and grant opportunities.
- Attend a site tour(s) of an existing biogas upgrading installations.
- Engage a renewable energy consultant to act as the project manager during the pre-development, development, and post-development phases of the project.
- Measure the project's preliminary carbon intensity score through a life-cycle analysis.
- Determine potential risk mitigation strategies including financing structures.
- Complete initial feasibility analysis to assess the project's viability.
- Make a go/no-go decision to move forward to develop the project.
- Establish a project schedule.
- Obtain Letters of Intent (LOI) or feedstock agreements from the key feedstock suppliers in the area.
- Collect and analyze additional feedstock samples for lab analysis to confirm biogas generation estimates and co-digestion compatibility.
- 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.
- Develop a digestate management plan.
- Solicit proposals for engineering, procurement, and construction management services.
- Request firm proposals from AD and upgrading system vendors.
- Make final equipment selections.
- Finalize project size, capital cost, O&M cost, and financial pro forma after discussions with feedstock providers.
- Begin the design process of AD and upgrading systems.
- Meet with pipeline utilities to determine optimal interconnection location and to obtain a draft interconnection agreement.
- Meet with potential offtake partners to determine optimal market for biogas and digestate.
- Review local air quality management district permitting requirements to determine pretreatment and tail gas treatment needs.
- Begin construction of the facility.
- Begin the registration process into the RFS and state low-carbon fuel standard programs.
- Complete testing and commissioning activities at the end of construction.
- Maintain ongoing compliance practices to continue participation in the RFS and state low-carbon fuel standard programs.

Appendix A External Funding Resources

RESOURCE	WEBSITE
Water and Waste Disposal Loan Guarantees	www.rd.usda.gov/sites/default/files/fact-sheet/508_RD_FS_RUS_WEPGuarantee.pdf
Community Facilities Guaranteed Loan	www.rd.usda.gov/sites/default/files/fact-sheet/508_RD_FS_RHS_CFGuarantee.pdf
Business & Industry Loan Guarantees (B&I)	www.rd.usda.gov/sites/default/files/fact-sheet/508_RD_FS_RBS_BIGuarantee.pdf
Rural Energy for America Program (REAP)	www.rd.usda.gov/sites/default/files/fact-sheet/508_RD_FS_RBS_REAP_RE.pdf
Rural Business-Cooperative Service State Energy Coordinators	www.rd.usda.gov/sites/default/files/RBS_StateEnergyCoordinators.pdf.
Environmental Quality Incentives Program	www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=nrcseprd1342638
Natural Resources Conservation Service	www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/
Conservation Innovation Grants	www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/
USDA Rural Development Value Added Producer Grant (VAPG)	www.federalregister.gov/documents/2020/12/21/2020-27986/inviting-applications-for-value-added-producer-grants-and-solicitation-of-grant-reviewers
USDA Rural Development - Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003)	www.rd.usda.gov/files/RBS_Section9003Biorefinery_ApplicationGuide.pdf
USDA Rural Development - Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (BAP)	www.rd.usda.gov/sites/default/files/fact-sheet/508_RD_FS_RBS_Biorefinery.pdf
D.O.E. Title XVII Innovative Energy Loan Guarantee Program (LGP)	www.energy.gov/sites/prod/files/2020/01/f70/DOE-LPO-Renewable-Energy-Efficient-Energy-Jan2020.pdf
AgSTAR	www.epa.gov/agstar

Appendix B Additional Contact Information

RESOURCE	WEBSITE	PHONE NUMBER
American Biogas Council	americanbiogascouncil.org Leadership: americanbiogascouncil.org/about/leadership Membership: americanbiogascouncil.org/about/members	202.640.6595
California Low Carbon Fuel Standard	ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard	1.800.242.4450
Iowa Economic Development Authority	www.iowaeda.com	515.348.6200
Iowa Department of Natural Resources	www.iowadnr.gov/InsideDNR/RegulatoryAir/ConstructionPermins.aspx	1.877.AIR.IOWA (1.877.247.4692)
Linn County Public Health Department, Air Quality Division	www.linncleanair.org	319.892.6000
Office of the Governor of Iowa	governor.iowa.gov	515.281.5211
Polk County Air Quality Division	polkcountyiowa.gov/airquality	515.286.3705
USEPA Renewable Fuel Standard Program	epa.gov/renewable-fuel-standard-program	Fuels Program Helpdesk: 1.800.385.6164

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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.

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