On-Farm Biogas Development Handbook:

For Farmers in British Columbia

Version 1




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Acknowledgments

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All information provided in this Handbook was drawn from the author's experience and expertise with on-farm biogas plants. Information presented in this Handbook should be viewed as suggestions and ballpark estimates only. Prior to building an on-farm biogas plant, B.C. farmers should engage an experienced biogas company to ensure soundness of all assumptions and confirm all biogas plant parameters. Hallbar Consulting Inc. and The Research Institute of Sweden will not be liable for any claims, damages or losses of any kind arising out of the use of, or reliance upon, this Handbook.

Date & Version

Version 1 of the On-Farm Biogas Development Handbook for Farmers in B.C. was published in 2020. Updated versions of this Handbook will be published as new information pertaining to on-farm biogas plants in B.C. becomes available. If using this Handbook, please be sure that you have the most recent, updated version.

Author

This Handbook was written by Hallbar Consulting Inc. (www.HallbarConsulting.com) and the Research Institutes of Sweden (www.Ri.Se/en) in collaboration with the B.C. Ministry of Agriculture.

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Glossary of Terms

- **Agricultural Feedstock:** feedstock for a biogas plant produced on-farm (e.g., manure or crop residues).
- **Agricultural Environmental Management Coade of Practive (AEM CoP):** replacement for the Agricultural Waste Control Regulation.
- **Biogas:** renewable methane-rich gas produced by biogas plants.
- **Biogas Plant:** built to produce biogas from feedstocks.
- **Biogas Upgrading:** removal of carbon dioxide and other contaminants from biogas to produce renewable natural gas.
- **Biogas Yield:** amount of biogas produced per unit of feedstock.
- **Co-digestion:** combintation of different feedstock inside a digester tank.
- **Combined Heat and Power Engine:** used to combust biogas to produce renewable heat and electricity.
- **Digestate:** material removed from a biogas plant once useable dry matter has been converted to biogas.
- **Digestate Management:** increasing concentration of digestate nutrients to enable cheaper transportation.
- **Digester Tank:** tank where feedstock is converted to biogas by micro-organisms.
- **Dry Matter:** percentage of feedstock left after all moisture has been removed.
- **Feasibility Assessment:** study that assesses the suitability of a biogas plant for your farm.
- **Feedstock:** organic material, such as manure and food waste, used in a biogas plant.
- **Gigajoule (GJ):** measurement of energy approximately equivalent to 277 kilowatt hours of electricity.
- **Non-Agricultural Feedstock:** feedstock for a biogas plant produced off-farm (e.g., food processing and residential waste).
- **Nutrient Management Plan:** plan to ensure that nutrients are land-applied as required by crops.
- **Pasteurization:** heating to kill bacteria.
- **Simple Payback Period:** years of biogas plant revenues required to match investment and operating costs.
- **Renewable Natural Gas:** renewable replacement for natural gas made from biogas.
- **Retention Time:** number of days that feedstock remains in a digester tank.
- **Sensitivity Analysis:** assessment of how changes to costs and/or revenues impact payback period.
- **Tipping Fee:** price you are paid to accept, or have to pay to acquire, feedstock.

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1. Introduction to Handbook

The On-Farm Biogas Development Handbook (the Handbook) was created specifically for B.C. farmers interested in owning a biogas plant. After reading this Handbook you should understand the basics of how biogas plants work, recognize the key requirements to build and operate an on-farm biogas plant in B.C., and be able to assess the potential for building a biogas plant on your farm. This Handbook is divided into six key sections:

Introduction to Biogas

Provides information about the basic concepts of biogas and on-farm biogas plants, and reasons for considering a biogas plant for your farm.

On-Farm Biogas Plants

Highlights the four main process stages of on-farm biogas plants (feedstock, digester, biogas and digestate management), as well as the key components and aspects of each stage.

Biogas Plant Economics

Contains information to help you determine the costs, revenues and profitability of owning an on-farm biogas plant.

Biogas Plant Development Steps

Lays out the ten key development steps required to take an on-farm biogas plant from idea to construction and operation.

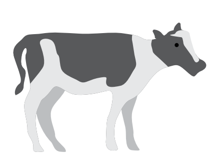
Biogas Self-Assessment Tool

Enables you to easily assess the potential suitability of building and operating a biogas plant on your farm.

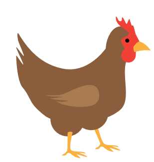
Next Steps

Provides a brief summary of the Handbook and suggested next steps.

Examples are provided throughout this Handbook using a fictitious B.C. farm (Farm ABC). Farm ABC is a dairy farm that produces 9,500 tonnes/year of manure. Farm ABC also has year-round access to 1,000 tonnes/year of poultry manure from a neighbouring farm, 8,000 tonnes/year of mixed food waste and 2,000 tonnes/year of used cooking oil from local food processors.

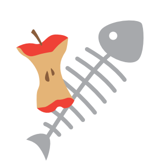


DAIRY MANURE



POULTRY MANURE

USED COOKING OIL



MIXED FOOD WASTE

When you are using the Handbook to assess building your own biogas plant, use your own feedstock values (rather than those given for Farm ABC). Space has been provided in the Handbook to allow you to make these calculations.

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Key Points to Remember

- Biogas is like natural gas, but with a higher water content and more carbon dioxide.
- Biogas can be burnt to produce renewable heat and/or renewable electricity, or upgraded to renewable natural gas.
- Digestate is the material that comes out the back-end of a biogas plant.

2. Introduction to Biogas

Biogas Basics

The basic concept of a biogas plant is very simple; place organic material, such as manure, crop residues, and food waste from food and beverage processing and/or municipalities into a warmed airtight tank and let naturally occurring micro-organisms convert this material (called 'feedstock') into biogas and digestate. The reason tanks must be airtight is because the conversion of organic material into biogas and digestate happens in the absence of oxygen. This is why biogas plants are referred to as anaerobic (defined as in the 'absence of oxygen') digesters.

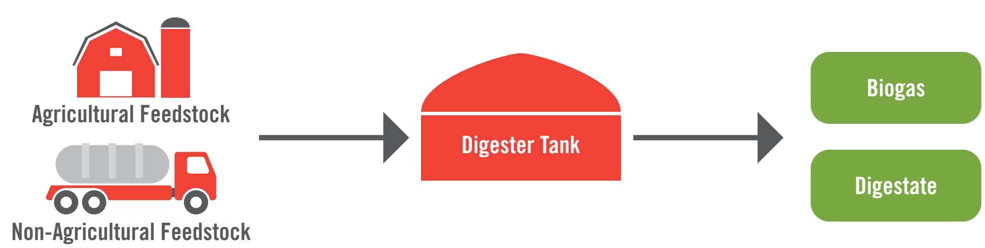
Biogas consists of methane (typically 55% – 65%), and carbon dioxide (typically 35% – 45%), with small amounts of water, hydrogen sulphide, nitrogen and other trace gases. Biogas is like wet natural gas diluted with carbon dioxide. Biogas can be used in multiple ways: it can be combusted in a boiler to produce renewable heat, combusted in a combined heat and power engine to produce renewable heat and electricity, or upgraded to renewable natural gas by removing the carbon dioxide and other impurities. Renewable natural gas can be used as a replacement for natural gas.

In addition to biogas, a biogas plant will also produce digestate. Digestate is the material removed from a biogas plant after micro-organisms have finished converting most of the feedstock's dry matter into biogas. Digestate, which typically has 4% – 8% dry matter, contains almost all of the nitrogen, phosphorus and potassium of the input feedstock, and is considered a good fertilizer. Ideally, digestate is spread on farmland surrounding a biogas plant. If digestate is required to be transported off-site, processing may be required to reduce water content and increase nutrient concentration, thereby reducing transport costs.

Biogas consists of methane, carbon dioxide and small amounts of water, hydrogen sulphide, nitrogen and other trace gases

There are two major types of biogas plants. These are wet biogas plants and dry biogas plants. A biogas plant is defined as 'wet' when feedstock inside the digester tank is pumpable and can be stirred. This means that when all feedstocks are mixed together, wet biogas plants typically have an average dry matter content of no more than 15% – 20% (80% – 85% water). However, and depending upon the type of feedstock, it is possible for wet biogas plants to have an average dry matter content greater than 20%. Therefore, the key distinction of a wet biogas plant is not dry matter, but if the feedstock inside a digester tank is pumpable and can be stirred.

BASICS OF BIOGAS



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Key Points to Remember

- Wet, complete mix biogas plants are the most suitable for B.C. farmers.
- There are thousands of on-farm biogas plants in Europe, the U.S. and Canada (over thirty in Ontario).
- On-farm biogas plants in B.C. can now sell renewable natural gas for up to $30/GJ.
- On-farm biogas plants fit well into most farming operations providing there is sufficient feedstock.

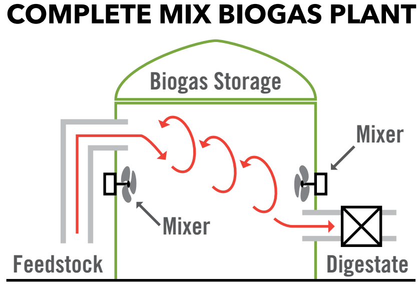
A biogas plant is defined as 'dry' when feedstock inside the digester tank must be shovelled or augured. This means that when all feedstocks are mixed together, dry biogas plants typically have an average dry matter content greater than 15% – 20% (80% – 85% water). The key distinction of a dry biogas plant is not actually dry matter content, but rather if feedstock inside the digester tank must be shovelled or augured.

For this Handbook only wet biogas plants are discussed. This is because when all feedstocks are mixed, on-farms biogas plants typically have feedstock with an average dry matter content less than 15% – 20%. This makes dry biogas plants unsuitable for most farms in B.C.

Even biogas plants that digest poultry manure are typically wet biogas plants. The reason for this is that poultry manure is high in nitrogen and high nitrogen levels upset the microorganisms inside digester tanks, resulting in low biogas production and potential plant failure. Therefore, poultry manure is challenging to digest without mixing it with liquid manure or water. While biogas plants are being designed to run on up to 100% poultry manure, this technology is still widely unproven.

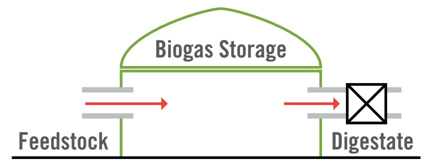
Wet biogas plants are either 'complete mix' or 'plug flow'. Typically, complete mix biogas plants have vertical digester tanks into which feedstock is fed through a pipe on one side and digestate flows out through a pipe on the other side. While inside the digester tank feedstock is mixed.

COMPLETE MIX BIOGAS PLANT



Plug flow biogas plants lay horizontally. Feedstock is fed into a plug flow digester tank from one end, create a 'plug' that is pushed to the other end of the tank.

PLUG FLOW BIOGAS PLANT



For this Handbook only complete mix biogas plants are discussed. This is because complete mix biogas plants are the most commonly used type of on-farm biogas plant when energy production is the primary motivator, such as in B.C. For example, almost all on-farm biogas plants in Canada and Europe are complete mix.

Why Consider Biogas

On-farm biogas plants are not a new technology. Over the past forty years, thousands of on-farm biogas plants have been built in countries such as Germany, Austria, Sweden, Great Britain, Switzerland and Holland. More recently, hundreds of biogas plants have been built on farms in the United States and Canada. Ontario for example, is home to over thirty on-farm biogas plants. In B.C., while there are currently only three on-farm biogas plants, this number is expected to grow rapidly over the coming years.

In March of 2017, the B.C. Government announced the Renewable Portfolio Allowance for renewable natural gas. Under this Allowance, B.C.'s gas utilities (i.e., FortisBC and Pacific Northern Gas) are able to buy renewable natural gas for up to $30 a gigajoule (GJ). This means that for every GJ of renewable natural gas injected into B.C.'s gas pipeline, you could be paid up to $30. This is significantly more than on-farm biogas plants in B.C. were previously being paid, and means biogas plants are now a real opportunity for many B.C. farmers.

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Typically, provided there is sufficient feedstock available, biogas plants fit well into most B.C. farming operations. For livestock farms, biogas plants are typically set-up to take manure prior to long-term storage and field application. For horticultural farms (such as berries, crops and vegetables), biogas plants can take unwanted organic material as it is produced. By converting feedstock into renewable energy that is sold, B.C. farmers can diversify their income and increase farm profitability. For many B.C. farmers, biogas plants could be a beneficial addition to their farm.

> Sadly, there are too many examples worldwide of poorly thought-out biogas plants that cause farmers nothing but trouble

Why Read This Handbook

Biogas plants are complex installations that require considerable research and planning, time and effort to operate and maintain. Also, they are only suitable for farmers with the financial capability to undertake a multi-million dollar investment. Therefore, if you are interested in owning an on-farm biogas plant, you should be aware of the commitment required.

On-farm biogas plants are only beneficial to the farm if they are well thought-out. Sadly, there are too many examples worldwide of poorly thought-out biogas plants that cause farmers nothing but trouble. Therefore, if you are considering building your own biogas plant, it is important that you understand how these plants work and how they can impact your farm.

It is important that you understand the basics of biogas plants. This knowledge will help you understand what is right for both your biogas plant and your farm. After all, long after biogas companies leave, it is you who will be operating and maintaining the biogas plant. Furthermore, any necessary modifications to a biogas plant after construction, for example needing additional tanks, larger equipment or more storage, are typically much more expensive to do than if done prior to or during construction.

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3. On-Farm Biogas Plants

Key Components

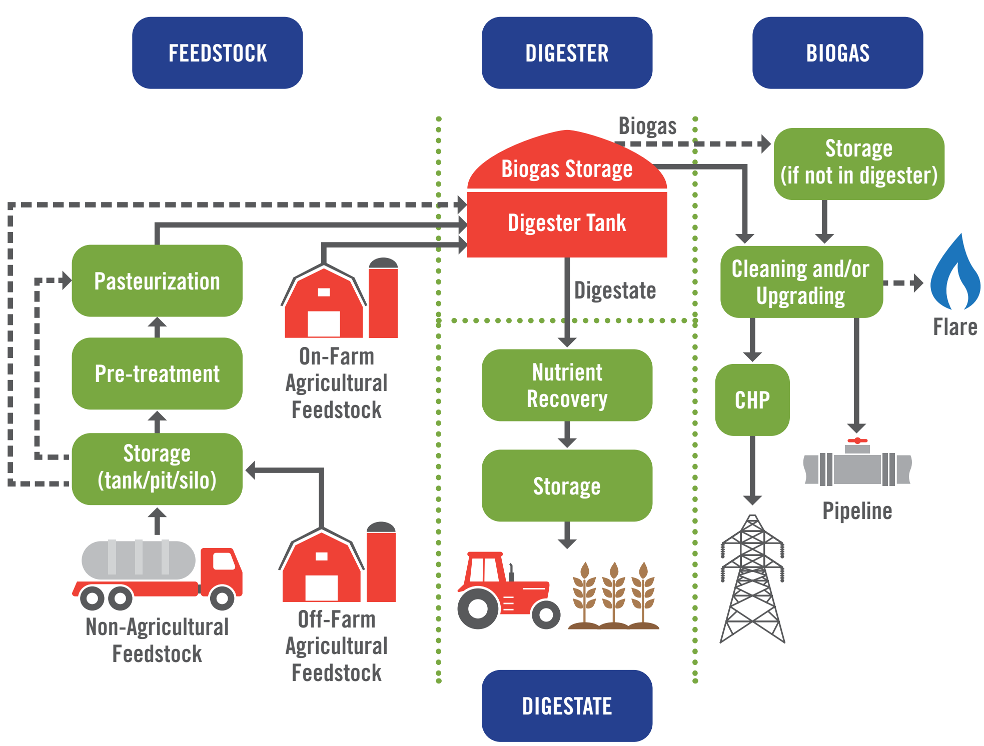
The design of an on-farm biogas plant depends on the type and amount of available feedstock. Because there are many different suitable feedstock, there are, correspondingly, many different biogas plant designs. As such, on-farm biogas plants come in a variety of different shapes and sizes, from very small and technologically simple, to large and complex.

Generally speaking, there is no right or wrong biogas plant design; however, there are poorly and well-designed biogas plants. Well-designed biogas plants take into account the farm's day-to-day operations and future plans for development, type and amount of feedstock available (both today and into the future), nutrient management requirements, lessons learned from other on-farm biogas plants, and local regulations.

Most on-farm biogas plants consist of four process stages:

1. Feedstock, including type of feedstock, biogas potential, required storage and pretreatment;
2. Digester, in which biogas is produced;
3. Biogas, including storage, cleaning and use; and
4. Digestate management.

TYPICAL ON-FARM BIOGAS PLANT



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Key Points to Remember

- Agricultural feedstock are produced on farms (i.e., manure and crop residues).
- While dairy and hog manure produce little biogas, they act as excellent balancers.
- Typically, on-farm biogas plants cannot be profitable using just agricultural feedstock.

Feedstock

Agricultural Feedstock

Agricultural feedstocks are those produced on a farm. The most commonly used agricultural feedstocks are dairy, hog and poultry manure, spoiled silage and crops and crop residues. In some countries, energy crops such as corn and grass are grown for biogas plants. However, these crops come at a cost (they must either be grown on your farm or purchased) and as such, their use and impact on profitability must be carefully considered.

Agricultural feedstock can be 'on-farm', which are produced on your farm, or 'off-farm', which are produced on other farms. When farms are close by or if the feedstock has a high dry matter content, it may be profitable to use agricultural feedstock from neighbouring farms. As of 2018, there is no minimum amount of on-farm feedstock that you must use in your on-farm biogas plant.

Typically, manure only biogas plants are not profitable. The reason for this is that biogas yield from manure is lower than most other types of feedstock. However, if a large amount of manure is available (a very rough estimation would be 40,000 tonnes/year of dairy manure and 5,000 tonnes/year of poultry manure), and if the biogas plant is technologically very simple (i.e., it doesn't require much more than a digester tank, heating system, pumps, mixers and biogas cleaning equipment), a manure only biogas plant could be profitable.

While dairy and hog manure have relatively low biogas yields, they provide a constant supply of micro-organisms and micro-nutrients needed to convert feedstock into biogas. Dairy and hog manure also provide excellent buffering capacity, protecting biogas plants from sudden changes in off-farm and non-agricultural feedstock, and have low dry matter content, allowing for co-digestion of dry feedstock without the addition of water.

Poultry manure has a higher biogas yield than dairy or hog manure. However, poultry manure can be a challenging feedstock due to its high nitrogen content (high nitrogen levels can upset the micro-organisms inside digester tanks, resulting in low biogas production and potential plant failure). Because of this, poultry manure rarely accounts for more than 20% of a biogas plant's total feedstock. While biogas plants are being designed to run on up to 100% poultry manure, this technology is still widely unproven.

> Agricultural feedstock can be 'on-farm', which are produced on your farm, or 'off-farm', which are produced on other farms

Horticultural farms produce crop residues. However, most of this feedstock has relatively low biogas yields and may contain large amounts of grit, sand and/or soil that can cause problems inside a biogas plant. Furthermore, finding a year-round supply of this feedstock may be challenging. A large supply of feedstock once or even a few times a year is of little benefit to a biogas plant that requires feeding every day.

Spoiled silage, spoiled crops and unwanted organic material from feeding or on-farm processing can have high biogas yields. However, even if these feedstock are available year-round, the amount available is typically small; usually under a thousand tonnes a year. Furthermore, because no one plans for their crops or silage to spoil, there is often no consistency of supply.

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Key Points to Remember

- Non-agricultural feedstock are produced by non-farm sources (e.g., food and beverage processing).
- On-farm biogas plants in B.C. are allowed to accept up to 49% non-agricultural feedstock.
- Determine the quantity and composition of available non-agricultural feedstock is very important to the success of your biogas plant.

While biogas plants are able to convert a wide variety of feedstocks into biogas and digestate, straw can be problematic unless finely chopped. This is because straw can clog pipes and is challenging to mix with other feedstock, tending to float to the top of digester tanks.

Furthermore, the micro-organisms inside digester tanks are unable to convert wood into biogas. This doesn't mean that feedstock, such as manure, containing sawdust or small wood chips cannot be used in a biogas plant. It just means that wood takes up space inside biogas plants without providing any benefit in the form of biogas. Feedstock with large pieces of wood should however be avoided as they can cause pipes and pumps to block.

Non-Agricultural Feedstock

Within B.C., on-farm biogas plants are allowed to accept up to 49% non-agricultural feedstock by volume. This means that 51% of all feedstock for your biogas plant must be agricultural (i.e., from a farm). This limit has been set to ensure that on-farm biogas plants in B.C. are sized appropriately for the farm on which they are built.

Non-agricultural feedstock are unwanted organic material produced by non-farm sources, including food and beverage processing, grocery stores, restaurants, hotels, abattoirs and homes (often called green bin waste). These feedstock produce much higher biogas yields than most agricultural feedstock. Profitable on-farm biogas plants typically co-digest some non-agricultural feedstock.

If you are considering owning an on-farm biogas plant, it is important to determine the quantity and composition of non-agricultural feedstock that might be available. After all, it is this feedstock, as well as available agricultural feedstock, which dictates your biogas plant's technology, size and profitability, not the other way around. Knowing both the quantity and type of available non-agricultural feedstock, both today and over the next five to ten years, is very important and should not be underestimated.

When you are sourcing non-agricultural feedstock, the two main options are to work with a waste supply company that will collect and deliver feedstock to your biogas plant, or contract directly with businesses that produce suitable feedstock, such as local food processors, grocery stores, restaurants and hotels. A third option is to contact your local municipality or regional district to discuss their non-agricultural food waste collection programs.

Working with a feedstock supply company is often simpler and requires much less time and effort on your part. Consistency of feedstock can also be greater, although this is not always the case. However, due to requiring payment for the service they provide, feedstock supply companies tend to pay a much lower tipping fee for the feedstock. Furthermore, feedstock supply companies often require you to sign contracts that can limit who you can accept feedstock from. Deciding whether to work with a feedstock supply company or not is an important decision that should be carefully considered.

Feedstock Biogas Yields

Different feedstock have different biogas yields. Biogas yield is very important as it is the sale of biogas that will make your on-farm biogas plant profitable. The *Typical Biogas Yield* graph on the following page shows typical biogas yields for commonly used feedstocks on an as-is-basis (i.e., without any processing to improve biogas yield). As you can see, manure has a relatively low biogas yield, which is why it is rarely used in biogas plants alone except in technologically simple, low cost plants.

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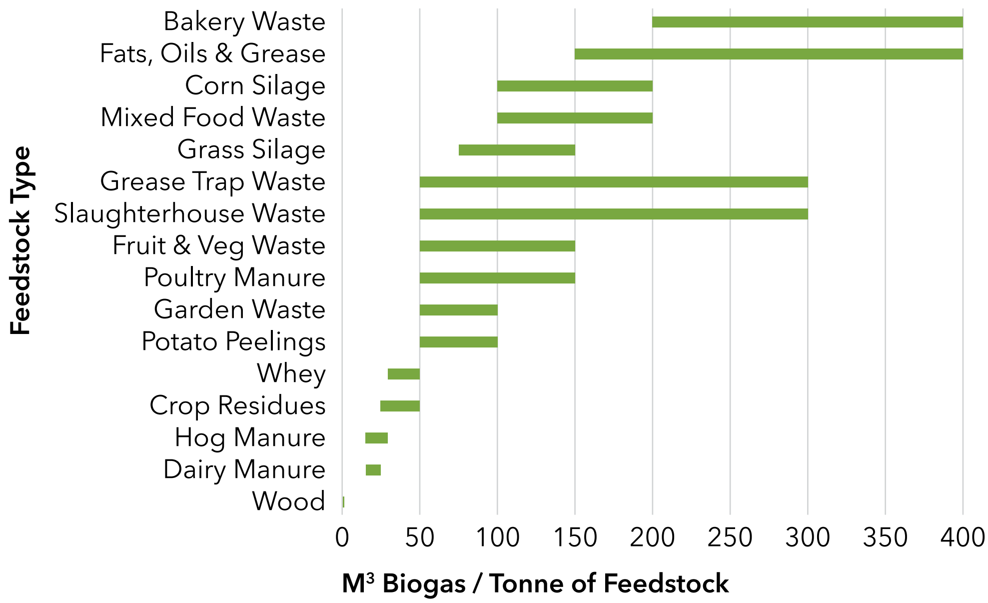
TYPICAL BIOGAS YIELD OF VARIOUS FEEDSTOCKS



It should be noted that actual biogas yield will depend upon a number of variables, including feedstock dry matter content and how long it has been stored for (i.e., freshness), type of feedstock pre-treatment required, and your biogas plant size and temperature. This is why the biogas yields shown are ranges (from low to high) and should be treated as estimations only. With further investigation and testing, it is possible to more accurately estimate biogas yields.

To estimate potential biogas production for a biogas plant on your farm, use the information in the *Typical Biogas Yield* graph above and simply multiply the tonnes of each feedstock you have access to in a year by its estimated biogas yield (m^3/tonne).

Self-Assessment Calculation

Feedstock 1: ________ (t/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 2: ________ (t/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 3: ________ (t/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 4: ________ (t/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 5: ________ (t/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 6: ________ (T/yr)
x Biogas yield: ________ (m^3/t)
= **Biogas prod: ________ (m^3/yr)**

Feedstock 1: ________ (m^3/yr)
\+ Feedstock 2: ________ (m^3/yr)
\+ Feedstock 3: ________ (m^3/yr)
\+ Feedstock 4: ________ (m^3/yr)
\+ Feedstock 5: ________ (m^3/yr)
\+ Feedstock 6: ________ (m^3/yr)
= ____________________ **(m^3/yr)**

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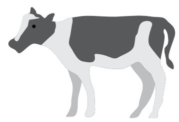
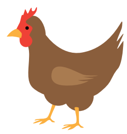
For Farm ABC, estimated biogas yield is 1,865,000 m^3/year, calculated as follows:



9,500 tonnes/year
x 20 m^3 biogas
= **190,000 m^3/year**



\+ 1,000 tonnes/year
x 75 m^3 biogas
= **75,000 m^3/year**

\+ 8,000 tonnes/year
x 150 m^3 biogas
= **1,200,000 m^3/year**

\+ 2,000 tonnes/year
x 200 m^3 biogas
= **400,000 m^3/year**

1,865,000 m^3
of biogas a year

Feedstock Dry Matter

Feedstock dry matter is the percentage of feedstock left after all moisture has been removed. Dry matter is important because the amount of high dry matter feedstock that you can use in a biogas plant (such as poultry manure and some non-agricultural feedstock) is limited by the amount of low dry matter feedstock (such as dairy and hog manure) you can dilute it with.

Remember that for a complete mix biogas plant, the feedstock inside the digester tank must be pumpable and easily stirred. Adding water is an option for reducing dry matter content inside a digester tank. However, water does not produce biogas and adding it will result in more heat being needed to reach required temperature. Therefore, adding water increases the size and cost of your biogas plant without increasing biogas production.

Adding water also results in a greater volume of digestate that you must manage. As with all other feedstock decisions, deciding whether to add water or limit the amount of high dry matter feedstock you accept is a delicate balance that should be carefully considered.

To estimate average dry matter content for a biogas plant on your farm, multiply the tonnes of each feedstock you have access to by its estimated dry matter content, add these together and then divide by total tonnes of feedstock.

Self-Assessment Calculation

Feedstock 1: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 2: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 3: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 4: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 5: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 6: t/year: ________
x Dry matter (%): ________
= ________ **(t/dry matter)**

Feedstock 1: t/year: ________
\+ Feedstock 2: ______ (t/year)
\+ Feedstock 3: ______ (t/year)
\+ Feedstock 4: ______ (t/year)
\+ Feedstock 5: ______ (t/year)
\+ Feedstock 6: ______ (t/year)
= _______ (t dry matter/year)
÷ _______ (t feedstock)
= _______ **% average dry matter.**

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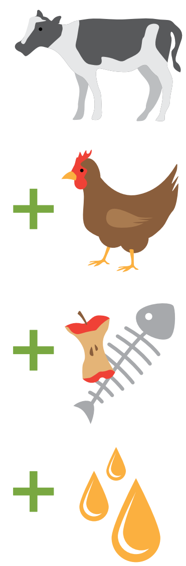
Key Points to Remember

- Dry matter content is important because the amount of high dry matter feedstock you can accept is limited by the amount of low dry matter feedstock you have.
- Non-agricultural feedstock often comes with a tipping fee. This is the price you are paid for the feedstock.
- You may have to pay for very desirable non-agricultural feedstock.

For Farm ABC, estimated average dry matter is 14.5%, calculated as follows:



9,500 tonnes/year
x 6% DM
= **570 tonnes DM**

\+ 1,000 tonnes/year
x 60% DM
= **600 tonnes DM**

\+ 8,000 tonnes/year
x 20% DM
= **1,600 tonnes DM**

\+ 2,000 tonnes/year
x 10% DM
= **200 tonnes DM**

2,970 tonnes/year
÷ 20,500 tonnes
x 100%
= **14.5% dry matter**

Feedstock Tipping Fee

Non-agricultural feedstock often comes with a tipping fee. This is the price you are paid for the feedstock. Tipping fees are usually stated as $/tonne. While usually not as important to the profitability of your biogas plant as biogas yield, tipping fees can be important.

Tipping fees can also provide an indication of a feedstock's biogas yield, cleanliness, and how challenging it will be to receive and manage. Generally, a feedstock that is sought after because of its high biogas yield and low level of contaminants (e.g., plastics) typically comes with a low or no tipping fee, and vice versa. You may even have to pay for feedstock that is very sought after. Therefore, while feedstocks with high tipping fees may seem desirable, they may produce less biogas and may require pre-treatment (i.e., cleaning). Deciding between feedstock quality (i.e., biogas yield and cleanliness) and tipping fee is a delicate balance that should be carefully considered.

Feedstock Storage

You should already have sufficient storage for all feedstock generated on your farm. Additional storage will be required for any off-farm and non-agricultural feedstock you receive. On-farm biogas plants require a regular supply of feedstock to operate efficiently. Additional feedstock storage is therefore necessary to even out feedstock deliveries, ensuring a constant supply of feedstock to your biogas plant day and night, on weekends and during statutory holidays.

Off-farm agricultural feedstock storage can be as simple as pits, silos or bunkers. However, for some off-farm agricultural feedstock and most non-agricultural feedstock, there is potential for nuisance and environmental risk associated with odour and leachate. Therefore, most feedstock should be stored in sealed, odour-tight tanks. All air vented from these tanks should be captured and treated to meet required regulations. Stirring inside these tanks may be required to reduce sedimentation and floating layers. Heating may be necessary to prevent freezing during colder months, and tank insulation may also be a good idea.

Dry feedstock should be stored in silos, bins or pits. Depending upon type of feedstock, these may need to be covered or kept in such a way as to ensure that all odour from storage is captured and treated. Some type of dry feeder will also be required, such as an auger or belt feeder, for delivering dry feedstock to the next step of the process.

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Key Points to Remember

- Biogas plants require a continuous supply of feedstock to operate efficiently.
- It may be necessary to clean your feedstock as it may contain problematic contaminants, such as sand and stones, plastics, glass and metal.
- There are a large number of feedstock cleaning options available, ranging from the simple low cost screens to expensive sophisticated technology.

Feedstock Pre-Treatment

Depending upon the type of agricultural and non-agricultural feedstocks you have access to, it may be necessary to cut, mash or clean them. Cutting and mashing helps to prevent clogging and makes feedstock more pumpable. Depending upon the origin and composition of your off-farm agricultural and non-agricultural feedstock, they may contain problematic contaminants. Some of the most commonly encountered contaminants include sand and stones, packaging material, labels, twist ties, cutlery and rubber gloves. Glass and metal may also be present.

All contaminants should be removed as soon as possible, as they can cause problems for a biogas plant's pipes, pumps and mixers. Heavy contaminants, such as sand and glass, can settle inside tanks, slowly filling them up and reducing their volume. Light contaminants, such as plastic, tend to float, forming thick crusts, which slows biogas production. Furthermore, contaminants, especially plastics, can end up in digestate, reducing its quality and value. Digestate contaminated with small pieces of plastic can be very hard to get rid of.

There are a large number of feedstock pre-treatment options available, ranging from simple low cost screens to expensive sophisticated de-packaging technology. Sand, stones and other heavy contaminants can typically be separated through simple gravity separation. Other contaminants, such as plastic, may require specialized technology.

Generally, the more sophisticated the pre-treatment technology you use, the more contaminated the feedstock you can accept, and the higher the tipping fee you will get paid. However, this is not always the case. Careful consideration must be given to which pre-treatment technology is most suitable based on the type and quality of feedstock you have access to. As with feedstock storage, all air vented from any feedstock pre-treatment system should be captured and treated to meet required regulations.

Feedstock Pasteurization

Pasteurization uses heat to kill bacteria. While pasteurization adds cost, it is recommended to protect your farm and ensure that your digestate is safe to use. The risk of introducing diseases or harmful substances onto your farm should be avoided at all costs.

Most jurisdictions in Canada and Europe require certain types of non-agricultural feedstock to be pasteurized. The B.C. Ministry of Environment and Climate Change Strategy (B.C. Ministry of Environment) provides a list of feedstock that requires pasteurization in their On-farm Anaerobic Digestion Waste Discharge Authorization Guideline. The feedstock on this list, which includes unwanted food from residential, commercial or institutional sources, fat, oil, grease, and unwanted organic material from dissolved air flotation, must be heated to 70°C for one hour or as approved (in Ontario, for example, pasteurization can be at 70°C for one hour or at 50°C for twenty hours).

> Some non-agricultural feedstock requires pasteurization

In Canada, pasteurization is typically done before feedstock is pumped into a digester tank. However, digestate (the feedstock after it leaves a digester tank) may be pasteurized instead. While pasteurizing digestate is typically more expensive than pasteurizing only non-agricultural feedstock (as you have more material to heat), this can be a good idea if you plan to accept manure from other farms. Deciding which

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Key Points to Remember

- Biogas plants require a continuous supply of feedstock to operate efficiently.
- All non-agricultural feedstock should be pasteurized to protect your farm and ensure your digestate is safe to use.
- Digester tanks operate at one of three temperatures; psychrophilic, mesophilic or thermophilic.

option is best for you and your farm will require careful consideration.

Digester

Tank Type & Heating

Digester tanks are typically vertical gas tight insulated tanks made of concrete or steel, placed below or above ground. Digester tanks operate at one of three temperature ranges; psychrophilic (below 25°C), mesophilic (35 – 40°C) or thermophilic (above 50°C). As temperature increases, the required time that feedstock stays inside a digester tank is reduced, resulting in smaller tank size. Biogas yield can also be higher. However, as temperature increases, more heat is required to maintain this temperature, and the biogas plant becomes less stable. Higher temperature biogas plants therefore require more supervision. Most on-farm biogas plants in Canada and elsewhere are mesophilic (35 – 40°C).

To achieve the appropriate operational temperature inside a digester tank, feedstock must be heated. Feedstock can be heated using an external heating source prior to being fed into a digester tank, or heated while inside a digester tank. Heating inside the digester is achieved using elements placed inside tank walls and floors, or by removing a small portion of the material from the tank, heating it with a heat exchanger and returning it back to the tank, or both. Whichever option is selected, it is vital to ensure that sufficient heating is available to maintain the required temperature inside the digester tank; otherwise biogas yield will be negatively impacted.

An on-farm biogas plant can have one or more digester tanks. If there are two or more tanks, these tanks can run in parallel (where each tank receives feedstock). Alternatively, these tanks can operate as a two stage process in series, where one tank feeds into the next. Running digester tanks in parallel reduces risk because if one tank goes down the other is still operational. Running digester tanks in a series typically results in slightly higher biogas yields. Regardless of set-up, a second digester tank adds cost.

However many digester tanks you have, these tanks should be fed feedstock regularly. Therefore, once feedstock is ready, automated feeders are often used to introduce feedstock into digester tanks through a pipe on one side every few hours.

Tank Size

Choosing appropriate tank size is important to ensure all feedstock spends sufficient time inside your digester tank. Generally speaking, and up to a certain point, the longer feedstock stays inside a digester tank (known as 'retention time') the more biogas is produced. However, the longer the retention time, the larger the digester tank, and the greater the cost to build, heat and mix the tank. Therefore, choosing tank size is a balance between obtaining maximum biogas yield and minimizing cost.

Typically, a retention time of 25 to 35 days is sufficient for most on-farm biogas plants. Obviously, if feedstock with slower biogas production rates make up a large portion of your total feedstock, or if the digester temperature is low (25°C), then a longer retention time may be beneficial.

To estimate required digester tank size for a biogas plant on your farm, divide total annual tonnes of all your feedstocks by 365 days, multiply this value by your required retention time. For this example, we are assuming that 30 days retention time is required. Then multiply this value by 1.1 (tank volume is typically 10% greater than active volume). Then convert tonnes to m^3 on a one-to-one ratio (i.e., 1 tonne equals 1 m^3).

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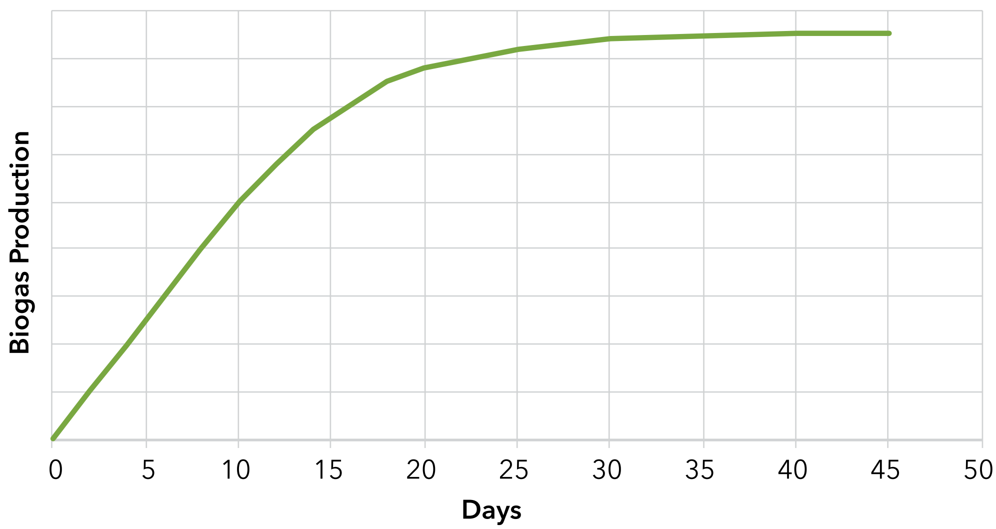
TYPICAL BIOGAS PRODUCTION AS IT RELATES TO RETENTION TIME

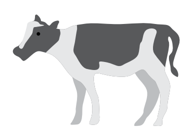


Self-Assessment Calculation

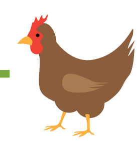
Feedstock 1: ______ (t/year)
\+ Feedstock 2: ______ (t/year)
\+ Feedstock 3: ______ (t/year)
\+ Feedstock 4: ______ (t/year)
\+ Feedstock 5: ______ (t/year)
\+ Feedstock 6: ______ (t/year)
= __________ (total tonnes/year)
÷ 365 days
x __________ (days retention time)
x 1.1
= __________ **(tonnes and m³).**

The reason for calculating digester tank size using feedstock tonnage rather than volume (i.e., m³ or gallons) is that when mixing wet feedstock, such as dairy manure or used cooking oil, with dry feedstock, such as poultry manure or dry food waste, total feedstock volume doesn't equal total volume of feedstock mixed. Therefore, calculating digester tank size using volume can result in overestimation. For example, mixing 20 m³ (approximately 20 tonnes) of dairy manure with 3m³ (approximately 1 tonne) of poultry manure will not result in 23 m³ of feedstock. However, it will result in 21 tonnes of feedstock. As this mix is pumpable with density similar to water (i.e., 1 tonne = 1 m³), 21 tonnes is approximately 21 m³.

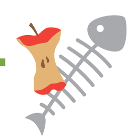
For Farm ABC, estimated digester tank size for 30 days retention time is approximately 1,850 m³, calculated as follows:



9,500 tonnes/year

\+ 

1,000 tonnes/year

\+ 

8,000 tonnes/year

\+ 

2,000 tonnes/year

20,500 tonnes
÷ 356 days
x 30 days
x 1.1
= **1,853 tonnes**
= **1,853 m³**
= **489,511 gallons**

(1m³ = 264.172 gallons)

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Tank Mixing

The importance of mixing in on-farm biogas plants is sometimes underestimated. Mixing (often referred to as 'agitation') is required inside digester tanks to mix new feedstock with existing feedstock, bring micro-organisms into contact with new feedstock, keep feedstock moving (preventing formation of surface layers and sediment inside the tank), ensure higher levels of biogas production, facilitate the up-flow of biogas bubbles, and evenly distributes heat.

Once your biogas plant is operational, changing mixers is difficult and costly. As such, it is often advisable to size mixers larger than initially required, providing you with flexibility around the type of feedstock you can accept. Alternately, you can design your digester tank so that a second mixer can easily be added at a later date.

Mixing can be done mechanically by mixers inside a digester tank, hydraulically by pumps near a digester tank, or pneumatically by blowing biogas into a digester tank. Typically, most on-farm biogas plants use mechanical mixers. These mixers are aimed slightly downwards to create flows near the bottom of a digester tank to prevent sedimentation. To help break-up any surface layers, these mixers are also reversible to pull liquid up into the surface layer and keep it moving.

Mixing can occur continuously or intermittently. Continuous mixing helps with heat distribution and reduces the likelihood of surface layers and sediment inside a digester tank. Intermittent mixing requires less energy. Whether operated continuously or intermittently, mixers should use a variable speed drive to save energy.

Pumps

The transfer of feedstock from storage to pre-treatment and pasteurization, into digester tanks, and for digestate once it leaves digester tanks is done using pumps. Selection of appropriate pumps and pumping technology depends upon the characteristics of the feedstock to be handled, including dry matter content and particle size.

Typically, on-farm biogas plants use the same types of pumps used for liquid manure. As with liquid manure, the formation of plugs at inlets and outlets can be prevented by ensuring a sufficient diameter of pipe. All movable pump parts are also subjected to high wear and must be replaced from time to time. Therefore, pumps should be easily accessible with sufficient working space and installed at a convenient height for maintenance.

The importance of mixing in on-farm biogas plants is sometimes underestimated. Once your biogas plant is operational, changing mixers is difficult and costly

For some pumps, especially those subject to greatest potential for failure and frequent maintenance, such as chopping or cutting pumps, it may be advisable to have a back-up pump in case one pump fails or requires significant maintenance. While a back-up pump may seem a little excessive and will add cost, this cost might seem like a good investment when trying to fix a pump at 4 AM in the middle of winter. Ultimately, the decision for redundancy at your on-farm biogas plant should be based on the additional cost compared to potential lost revenues from downtime.

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Key Points to Remember

- Adequate mixing ensures new feedstock is mixed with existing feedstock, brings micro-organisms into contact with new feedstock, keeps feedstock moving, ensures higher levels of biogas production, facilitates the up-flow of biogas bubbles, and evenly distributes heat.
- Storage is required to ensure a consistent supply of biogas to your biogas equipment.

Biogas

Biogas Storage

Biogas production volume is rarely consistent. To ensure supply of biogas is as consistent as possible to combined heat and power engines or biogas upgrading technologies, temporary storage is required. The simplest storage is a gas tight membrane on top of a digester tank. This membrane, which inflates and contracts as more or less biogas is stored, also acts as a cover for the digester tank. A structure inside the digester tank supports the membrane when there is no biogas inside it. The membrane balloons as biogas fills the storage space.

An alternative option is a separate storage tank, where biogas can be stored at low, medium or high pressure. Low pressure storage typically involves a plastic balloon or tank (typically PVC, polyethylene or polypropylene) that is either housed inside a building to protect it from the weather, or is protected by a second membrane. Medium and high-pressure storage tanks typically involve steel containers and bottles. Medium and high-pressure storage is expensive and operating costs are high due to required energy for pressurisation.

For these reasons, medium and high-pressure storage tanks are only used by on-farm biogas plants when renewable natural gas cannot be injected directly into the natural gas pipeline. When this occurs, the renewable natural gas is stored until it is transported by truck to the natural gas pipeline.

Biogas Cleaning & Use

Biogas is extracted from a digester tank using a pump/blower. When extracted, biogas contains corrosive compounds, such as hydrogen sulphide. Hydrogen sulphide is generally removed using some type of removal (scrubbing) equipment (such as activated carbon or iron sulphide), or hydrogen sulphide levels inside digester tanks are kept low by injecting oxygen or ferric chloride solution. Biogas also contains moisture. This moisture is removed by cooling the biogas, which causes the water vapor to condense into water. Moisture can also be removed by using salts, gels or other media that absorb water as biogas passes through it.

Once hydrogen sulphide and moisture have been removed, biogas can be used. Generally speaking, there are two options for biogas use. These are combustion in a combined heat and power engine to produce renewable heat and electricity, or upgrading to renewable natural gas. A third option is to combust biogas in a boiler to produce renewable heat. However, this is rarely profitable unless there is a year-round demand for all of the heat near to your farm. Once produced, renewable electricity and renewable natural gas can be sold by injecting them into the energy grid.

Combined heat and power engines convert biogas into renewable electricity and heat. Generally speaking, up to 40% of the energy in biogas is converted into electricity and 50% is converted into heat. The remaining 10% is lost. Renewable electricity can be sold to utilities such as B.C. Hydro and fed into the electricity grid. Some of the heat can be used on-site for your biogas plant and farm. If close enough (i.e., within 1 km or so) and if a large amount of heat is required year-round, remaining heat can be sold to local businesses.

Upgrading biogas to renewable natural gas removes carbon dioxide and other impurities to increase the methane content of biogas from approximately 65% to 95%. Renewable natural gas is sold to local gas utilities (i.e., FortisBC or Pacific Northern Gas) and injected into the natural gas pipeline.

There are several technologies available for upgrading biogas to renewable

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Key Points to Remember

- Biogas must be cleaned before it is used in a combined heat and power engine or upgrading equipment.
- Without a suitable powerline or natural gas pipeline close to your farm, it can be very challenging to sell biogas.
- Before choosing a technology speak with other farmers to learn how well it performs and who you can trust.

natural gas. Before choosing an upgrading technology and company to work with, it is always a good idea to speak with other farmers that use the technology. These farmers can tell you how well the technology performs and which technology companies you can trust.

- Membrane upgraders: Biogas is compressed and forced through membranes (hollow fibres bundled together that act like a filter). Because methane molecules are larger than carbon dioxide molecules they don't pass through the membrane wall, instead emerging from the end of the membrane fibre. Membrane upgraders scale well and can be a good option for both small and large biogas plants.
- Water wash upgraders: Biogas is compressed and mixed with water. Carbon dioxide is captured in the water, while methane remains as a gas and is collected. Once saturated with carbon dioxide, water is transported to a low pressure tank where the carbon dioxide is released (similar to opening a soda can) and the water is re-used. Some makeup water may be required to compensate for losses.
- Chemical scrubbing upgraders: Similar to water wash, this technology uses solvents (instead of water) to absorb carbon dioxide, leaving methane as a gas to be collected. Once saturated with carbon dioxide, the solvent is heated to release carbon dioxide and is re-used. Some makeup solvent may be required to compensate for losses.
- Pressure swing adsorption upgraders: Carbon dioxide is separated from methane by adsorbing it onto a surface under pressure. Once the adsorption surface is saturated with carbon dioxide and methane has been removed, pressure is reduced to release the adsorbed carbon dioxide, allowing the surface to be re-used.

Biogas Revenue

When you decide whether to use your biogas to produce renewable heat and electricity or renewable natural gas, the most important consideration is profitability. If your farm doesn't have three-phase power or a natural gas pipeline close by (i.e., typical under 1 km for three-phase power and 3 km for a gas pipeline), it can be challenging to sell your renewable electricity or renewable natural gas. While you could upgrade your biogas to renewable natural gas, compress it and then deliver it by truck, this increases complexity, adds cost, and could negatively impact the profitability of your biogas plant.

> Before choosing an upgrading technology and company to work with, speak with other farmers that use the technology

In 2018, most on-farm biogas plants in Canada sold renewable electricity. However, most on-farm biogas plants in B.C. sold renewable natural gas. One reason for selling renewable natural gas is that typically over 95% of the energy in biogas is sold when it is upgraded to renewable natural gas. This compares to only 40% of the energy in biogas being sold when it is converted to renewable electricity. A second reason for selling renewable natural gas is that B.C. utilities can pay up to $30/GJ.

However, biogas upgrading technologies are more expensive than combined heat and power engines. Therefore, choosing to produce and sell renewable electricity or renewable natural gas is a balance between revenue and cost, and should be considered carefully.

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To estimate revenue from selling renewable electricity from your biogas plant, multiply estimated yearly biogas production by its methane content (typically 65%), multiply this by the percentage of biogas converted to electricity (typically 40%), and then multiply this by the number of kWh produced per m³ of methane (which is 9.97). Finally, multiply this value by the price paid per kWh for renewable electricity. In 2018 the price for renewable electricity in B.C. is approximately $0.10/kWh.

Self-Assessment Calculation

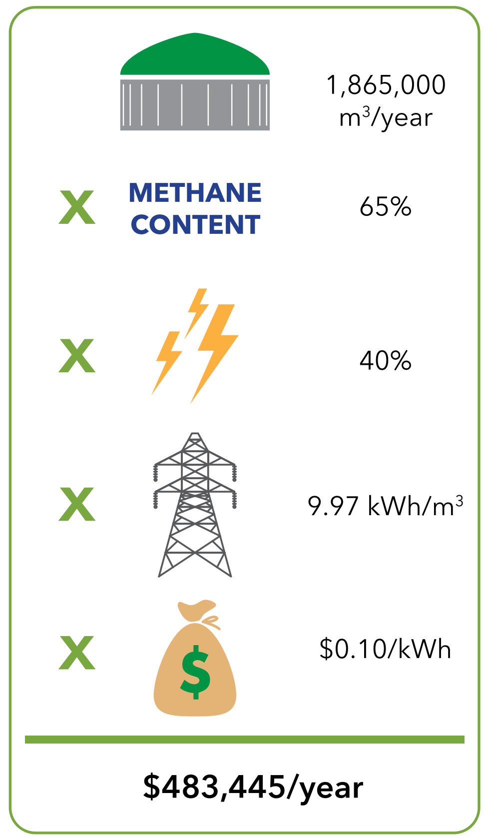
Biogas Production:
___________ (m^3/year)
x _________% (methane content)
x _________% (conversion factor)
x 9.97 kWh/m^3
x $___________ /kWh
(price of renewable electricity)
= **$___________ (revenue/year).**

To estimate revenue from selling renewable natural gas from your biogas plant, multiply estimated yearly biogas production by its methane content (typically 65%), multiply this by the percentage of biogas converted to renewable natural gas (typically around 97% because a small percentage of methane is lost when biogas is upgraded to renewable natural gas.), and multiply this by the number of GJ produced per m³ of methane (which is 0.036). Finally, multiply this by the price paid per GJ for renewable natural gas. As of 2018, B.C. utilities can pay up to $30/GJ for renewable natural gas.

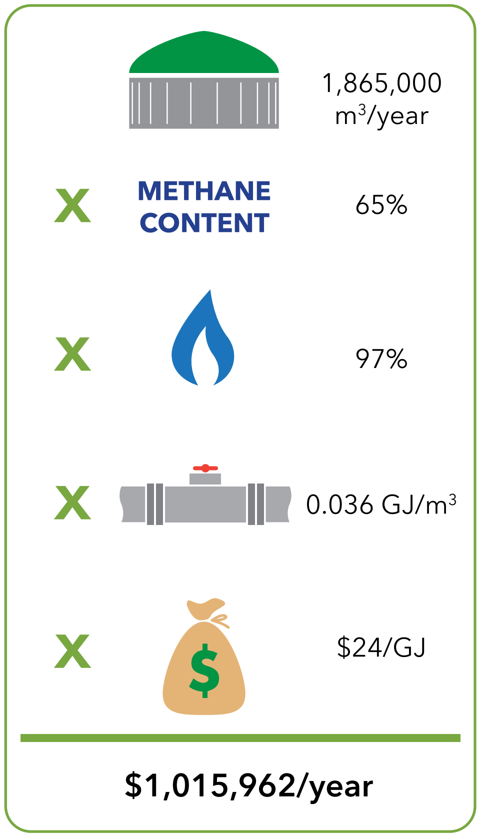
Self-Assessment Calculation

Biogas Production:
___________ (m^3/year)
x _________% (methane content)
x _________% (conversion factor)
x 0.036 GJ/m^3 of renewable gas
x $___________ /GJ
(price of renewable electricity)
= **$___________ (revenue/year).**

For Farm ABC, estimated revenue from selling renewable electricity is $483,445/year, calculated as follows:



For Farm ABC, and assuming the sale of renewable natural gas for $24/GJ, estimated revenue from selling renewable natural gas is $1,015,962/year, calculated as follows:



Biogas Flare

All on-farm biogas plants in B.C. must have a flare. Required for safety reasons, flares are needed in situations where more biogas is produced than can be stored or used by your combined heat and power engine or biogas upgrading technology. This can happen during times of extraordinary high biogas production, or during maintenance and breakdown of combined heat and power engines or biogas upgrading technologies. Flares are also required to burn renewable natural gas that doesn't meet pipeline specification. Ideally, flares are very rarely operational.

Digestate Management

Digestate

Approximately 90% of the feedstock fed into your digester tank will come out the other side at roughly the same rate at which it goes in. Material that leaves a digester tank is called 'digestate'. Digestate, typically has 4% – 8% dry matter, although actual dry matter depends upon type of feedstock fed into the digester tank. Because digestate is typically similar to dairy manure, it can be land applied using the same equipment as used for liquid manure.

Digestate contains almost all of the nitrogen, phosphorus and potassium of the input feedstock (only very small quantities of nitrogen are lost), and is considered a good fertilizer due to its nutrient consistency and availability. Digestate has a lower risk of leaf burn than poultry manure, and has a lower carbon to nitrogen ratio than dairy manure (meaning it has a better short-term nitrogen-fertilization effect), less weed seeds and significantly reduced odour. Finally, due to having less fibre than manure, digestate is easier to mix, pump and spread.

Ideally, digestate is spread on farmland surrounding a biogas plant (typically within a few kms), as this is often the most cost effective way to deal with it. However, for a lot of B.C. farms, especially those in regions where many livestock operations exist on limited agricultural land, this may not be possible. In these situations, some type of nutrient extraction will be required.

Land Application

Before digestate can be applied to farm land, and if your biogas plant accepts non-agricultural feedstock, you will be required by the B.C. Ministry of Environment to develop a nutrient management plan.

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Key Points to Remember

- Approximately 90% of the feedstock fed into your digester tank will come out the other side as digestate.
- Digestate contains almost all of the nutrients of the input feedstock and is considered a good fertilizer.
- All on-farm biogas plants in B.C. require a nutrient management plan.
- When choosing which nutrient extraction equipment is right for you, it is important to determine the exact level of nutrient extraction you require.

Nutrient management plans, which should be updated every twelve months, ensure excessive nutrient loading doesn't occur by requiring that nutrients in digestate are applied to crop fields at the right amount, time and place to protect both ground and surface waters. As part of this plan, you will need to test your soils and digestate for nutrient levels. In addition, expect to test your digestate for heavy metals and pathogens every twelve months or so. Ministry of Environment may also require heavy metal and pathogen analysis as part of an authorization or permitting process. As for when and where digestate is land-applied, expect to follow the best practices and restrictions that apply to livestock manure.

Nutrient Extraction

In cases where the nutrients in digestate are greater than the nutrient needs of your farm, nutrient extraction technology may be required to help you move some of your digestate elsewhere, enabling you to meet a nutrient management plan. As with dairy manure, digestate has high water content (approximately 92% – 96%). This means that the nutrient content per tonne of digestate is low, making transportation costly. Because of this, the objective of nutrient extraction technology is to reduce the volume and increase the nutrient concentration of digestate by removing water as economically as possible. Once achieved, excess digestate nutrients can be exported off your farm and potentially out of the area as cheaply as possible.

When choosing nutrient extraction equipment, it is important to determine the level of nutrient extraction you require by referring to your nutrient management plan (i.e., the amount of nutrients you need to extract from your digestate because they cannot be applied to your farmland). Once this is done, four key questions to ask yourself are:

1. Can the extracted phosphorus, nitrogen or potassium be safely applied to neighbouring farmland?
2. Are there potential users/purchasers for the extracted nutrient product in your area and how much of your product will they take or buy?
3. What is the realistic value of your extracted nutrient product?
4. What amount of time and resources are you willing to commit to nutrient extraction?

Typically, the first step in nutrient extraction is to separate out larger fibre. This can be achieved using liquid-solid separation equipment, such as slope screens or roller presses. Larger fibre can be dried and used for livestock bedding. Once large fibre is removed, the next step is often to remove phosphorus. Most of the phosphorus in digestate is bound to very small pieces of fibre. Therefore, any technology capable of separating out small fibre should be suitable. Two such technologies are centrifuges and flocculation.

> Determine your required nutrient extraction before choosing nutrient extraction equipment

By using high speeds to create centrifugal force, centrifuges separate solids from liquids; extracting phosphorus from digestate into a 20% – 25% dry matter product. Centrifuges are able to extract up to 50% or more of the phosphorus from digestate. Approximately 20% – 40% of the nitrogen and potassium are also extracted. If a binding agent, which cause small fibres to bind together, is used, phosphorus extraction of 90% or higher may be achievable.

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Flocculation uses polymers to bind small fibres together. Once polymer is added to digestate, it is sent to, for example, a dissolved air flotation tank, where bubbles and a skimmer are used to float and capture the clumped small fibre (known as 'flocs'), which is then dewatered with a press. Generally speaking, flocculation is able to extract around 90% of the phosphorus from digestate into a 20% – 25% dry matter product. At the same time, approximately 40% – 60% of the nitrogen and potassium are also extracted.

Once extracted, the 20% – 25% dry matter product can be exported off your farm, and potentially outside the area, whereas the remaining liquid can be applied to local fields as fertilizer. Drying may be required to make the 20% – 25% dry matter product more marketable. However, while this will add value to your digestate, it will also add cost. Whatever decision is made, it is important to determine a suitable, long-term plan for managing any excess nutrients in your digestate.

Struvite precipitation technology can extract phosphorus from digestate and produce better, higher value products than centrifuges or flocculation. The basic principle behind struvite precipitation is that under certain conditions (e.g., high pH) up to 80% of the phosphorus can be extracted from digestate into small crystals. These crystals are desirable because of their small size and high phosphorus level. However, while struvite precipitation technology is being designed to run on digestate, is still widely unproven.

Other nutrient extraction technologies, such as ultrafiltration with reverse osmosis, use membranes to extract most of the nutrients from digestate. This technology produces clean or very low nutrient water, which potentially may be discharged directly into ditches or nearby water bodies, or used as process water. However, this technology is typically more expensive than other nutrient extraction technologies, as it requires significant energy consumption. Furthermore, it is unnecessary for most B.C. farms who will require some of the nutrients to remain in the digestate for their fields.

Digestate Storage

Regardless of the nutrient extraction equipment you choose, you will need sufficient capacity to store your digestate until it is either applied to your land or transported off your farm. Size of required storage will depend upon the amount of off-farm and non-agricultural feedstock you accept. To estimate required additional storage for you digestate, multiply the total annual tonnes of feedstock you have access to (as with digester tank size, calculating digestate storage using volume can result in overestimation) by 0.9 (this is because approximately 90% of the feedstock fed into your digester tank will come out as digestate), divide this by 2 (this is because for this example we are assuming six months storage is sufficient), and then subtract this by the amount of on-farm storage you currently have.

TYPICAL NUTRIENT EXTRACTION PERFORMANCE AND COST

Nutrient Extraction Technology	Typical Extraction Performance		Cost
	Nitrogen	Phosphorus	
Centrifuge	20%	50%	*
Flocculation	50%	90%	***
Struvite Precipitation	20%	90%	***
Ultrafiltration	95%	95%	*****

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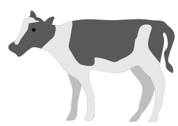
Key Points to Remember

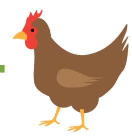
- Whatever decisions you take for digestate management, it is important to have a suitable, long-term plan.
- Expensive technologies that extract almost all the nutrients from digestate are likely unnecessary as some nutrients can be applied on your fields.

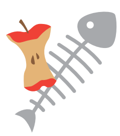
Self-Assessment Calculation

Total Feedstock: __________ (t/year)
x 0.9
÷ 2
- Current Storage __________ (t/year)
= **Required Additional Storage __________ (t/year).**

For Farm ABC, and assuming 4,750 tonnes of current on-farm manure storage, estimated additional storage is 4,475 tonnes, approximately the same size as the farm's current dairy manure storage, calculated as follows:


9,500 tonnes/year

+ 
1,000 tonnes/year

+ 
8,000 tonnes/year

+ 
2,000 tonnes/year

20,500 tonnes
x 0.9
÷ 2
- 4,750
= **4,475 tonnes**
= **4,475 m^3**
= **1,182,170 gallons**

(1m^3 = 264.172 gallons)

Even if Farm ABC were using nutrient extraction equipment, which can reduce digestate volume, required digestate storage will still be larger than current dairy manure storage. Furthermore, Farm ABC will also require additional, separate storage for the extracted nutrients. These nutrients may or may not be stackable depending upon the technology used to extract them.

Other Key Considerations

Footprint

The overall footprint of your on-farm biogas plant will depend upon the amount of agricultural and non-agricultural feedstock you have access to, your choice of feedstock pre-treatment and digestate management technologies, and chosen plant layout. As a general rule of thumb, a typical on-farm biogas plant in Canada requires approximately 1 – 2 acres (0.4 – 0.8 hectares) of land. Furthermore, additional space will be required to build roads for delivery of off-farm and non-agricultural feedstock, and to take digestate away.

Traffic

Off-farm and non-agricultural feedstock will be delivered to your biogas plant by truck. Depending upon feedstock volume and truck size, traffic to and from your farm could increase significantly. For Farm ABC, for example, which accepts 1,000 tonnes/year of poultry manure and 10,000 tonnes/year of food waste, approximately ten trucks/week will come to the farm (this doesn't include any trucks required to remove digestate). Being aware of and sensitive to increased truck traffic is important. If your farm is near a busy road, the impact of increased traffic might be minimal. However, if your farm is on a quiet road or in a residential area, the impact of increased traffic might be significant. This could result in complaints from neighbours.

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Key Points to Remember

- A typical on-farm biogas plant in Canada requires approximately 1 – 2 acres (0.4 – 0.8 hectares) of land.
- Being aware of and sensitive to increased truck traffic is important. Increased traffic might result in complaints from neighbours.
- A good biogas plant location is one that is easily accessible by truck, close to existing infrastructure, and limits potential spread of contamination and disease.

Site Selection

Determining the optimum location for your biogas plant should be based on several parameters. Of particular importance is the ability to connect to the electricity grid or natural gas pipeline. If you are unable to connect to the natural gas pipeline, you could compress your renewable natural gas and transport it elsewhere. However, compression and transportation can be expensive, and, as such, careful consideration must be given to the impact this will have on the profitability of your on-farm biogas plant.

Another important consideration is existing and required roads and infrastructure, particularly with regards to transportation of feedstock and digestate, digestate storage, and biosecurity. A good location for a biogas plant is not only easily accessible by truck and close to existing infrastructure for digestate management, but also one that limits the potential spread of contamination and disease from delivery of off-farm and non-agricultural feedstock to your farm.

Other important considerations include required setbacks from residential buildings and waterways, and geological factors, such as soil characteristics (e.g., soil type and rock content) and the potential for flooding. Finally, it may also be a good idea to make an allowance for potential future expansion. Often, the ideal site for your biogas plant is fairly obvious and requires little thought. However, at other times there can be several choices.

> The overall footprint of your biogas plant will depend upon the amount of agricultural and non-agricultural feedstock you have access to, your choice of feedstock pre-treatment and digestate management technology, and chosen plant layout

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4. Biogas Plant Economics

Like all investments on your farm, a biogas plant must be profitable. While determining exact investment and operating costs, revenue and profitability for your biogas plant requires a lot of work, the following costs and revenues have been provided to give you a rough idea.

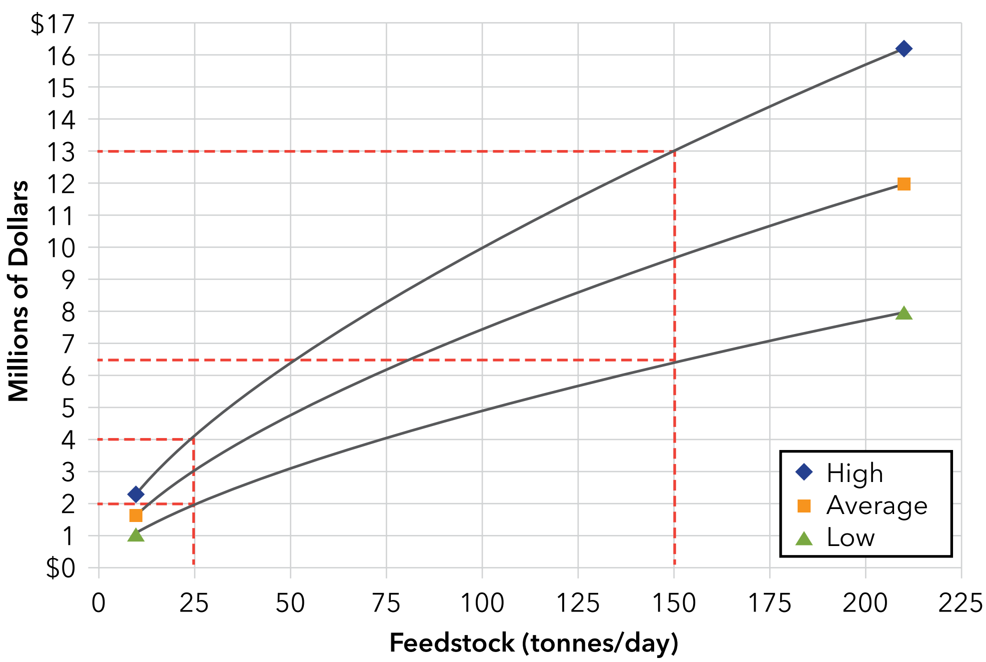
If, after reading this Handbook and completing the Self-Assessment Tool in Chapter 6, you are still interested in building a biogas plant, significant effort must be made to develop a more accurate budget. This should include quotes from suppliers, contractors and engineers, and energy sale and feedstock supply contracts. Only once this work has been completed will you be able to determine if building a biogas plant on your farm could be profitable.

Investment Cost

Estimating the cost of building your biogas plant is complex because it depends upon many variables unique to your farm. These variables include the volume and type of feedstock (both agricultural and non-agricultural) you have access to, type of feedstock pre-treatment and pasteurization technology, size and number of digester tanks you require, how you plan to sell your biogas (as renewable electricity or renewable natural gas), what you will do with your digestate, and the layout of your farm. This is why biogas plants can range from technologically simple and low cost, to complex and expensive.

Typically, as on-farm biogas plants digest more feedstock (are larger), investment cost per unit of biogas produced decreases. This is because small on-farm biogas plants typically require a lot of the same technology as large biogas plants, just at a different scale. Therefore, larger on-farm biogas plants benefit from technology economies of scale (cost savings gained by increased size). This is why large on-farm biogas plants are more likely to be profitable than small on-farm biogas plants.

ESTIMATED TOTAL INVESTMENT COSTS FOR ON-FARM BIOGAS PLANTS IN B.C.



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Key Points to Remember

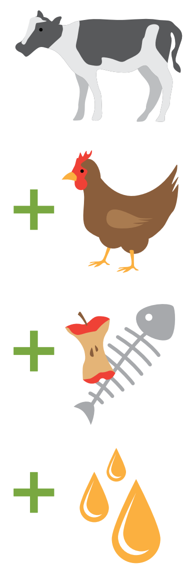
- Technology economies of scale mean that larger biogas plants typically produce biogas at a lower cost per m^3 than smaller biogas plants.
- The cost of building a biogas plant is typically higher if you upgrade biogas to renewable natural gas, accept solid and pumpable feedstock, have high levels of contaminants in your feedstock, and/or require high nutrient extraction.

For example, while total investment cost for a 25 tonne/day on-farm biogas plant is typically in the region of $2 – $4 million, total investment cost for an on-farm biogas plant six times larger (i.e., 150 tonne/day) is typically in the region of $6.5 – $13 million; only three times more expensive. Generally speaking, on-farm biogas plants in B.C. require at least 6,000 tonnes/year of agricultural feedstock and an equivalent amount of non-agricultural feedstock to produce enough biogas to be profitable. 6,000 tonnes/year is the amount of manure produced by approximately 120 milk cows (including dry cows and heifers).

To get a ballpark estimation of the required investment to build your own biogas plant, divide total tonnes of annual feedstock you have access to by 365 days. Use this daily tonnage to estimate your investment cost using the *Estimated Total Investment Cost* graph on the previous page. If planning to buy a combined heat and power engine to produce renewable electricity, you are likely between the lower and average investment cost estimates. If planning to buy biogas upgrading equipment to produce renewable natural gas, you are likely between the average and higher investment cost estimates. The type of feedstock you accept (only pumpable, or solid and pumpable feedstock), the level of contaminants in your feedstock (e.g., plastics), and the type of digestate management equipment you require will also impact investment cost.

If you don't know how much non-agricultural feedstock you have access to, multiply the agricultural feedstock that you have access to by two (this is because 49% of the total feedstock on-farm biogas plants in B.C. can accept is non-agricultural feedstock). It should be noted that investment cost estimations do not include the cost of land, as this is assumed to be available on your farm.

For Farm ABC, and assuming that biogas is upgraded to renewable natural gas, estimated investment cost is approximately $5.5 million, calculated as follows:



9,500 tonnes/year

+ 1,000 tonnes/year

+ 8,000 tonnes/year

+ 2,000 tonnes/year

20,500 tonnes
÷ 356 days
= 56 tonnes/day
= **$5.5 million**

(total investment cost estimated used the *Estimated Total Investment Cost* graph on the previous page).

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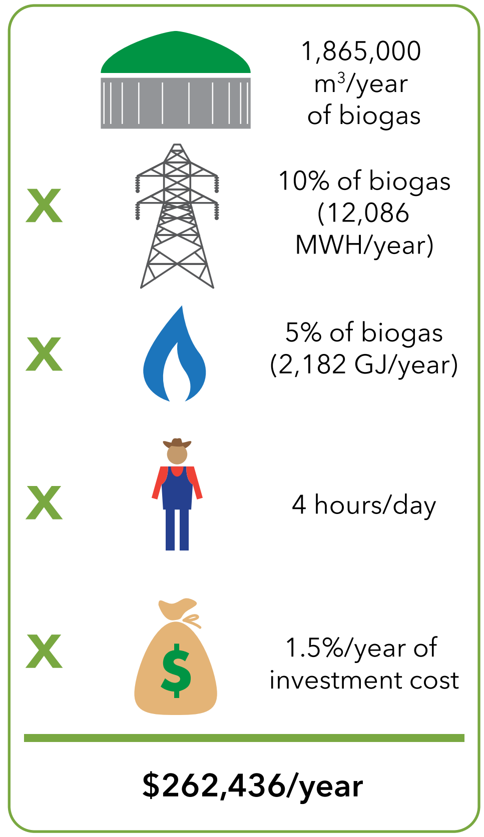
Operating and Maintenance Costs

The cost of operating an on-farm biogas plant tends to be relatively low in comparison to investment cost. However, this does not mean that operating costs are insignificant. Typically, the most important operating costs for an on-farm biogas plant are electricity, heat, labour and maintenance:

- Electricity use, which is required for pumps, mixing, biogas upgrading and digestate management, is typically 4% – 10% of total biogas production. Actually electricity use depends heavily upon if producing renewable natural gas or renewable electricity, type and amount of feedstock, and type of biogas upgrading and digestate management equipment;
- Heat use, which is required for pasteurization, tanks, buildings and biogas upgrading is typically 5% – 10% of total biogas production. As with electricity, actual heat use depends heavily upon if producing renewable natural gas or renewable electricity, type and amount of feedstock, and type of biogas upgrading and digestate management equipment;
- Labour, which is required for day- to-day plant management, is typically 2 – 8 hours/day; and
- On-going maintenance, required for pumps, mixers, pasteurizer, combined heat and power engine or biogas upgrading technology, and digestate management technology, is typically 1% – 2% a year of a biogas plant's investment cost.

For Farm ABC, and assuming 10% electricity use and 5% heat use, labour requirement of 4 hours/day and yearly maintenance costs of 1.5% of investment cost, estimated yearly operating cost is $262,436, calculated as follows:



Estimate	Cost/Year
Electricity use of 12,086 MWH at $100/MWH =	$120,861
Heat use of 2,182 GJ/year at $7/GJ =	$15,274
Labour of 4 hours/day at $30/hour =	$43,800
Maintenance of 1.5%/year of $5.5 million investment cost =	$82,500
Total	**$262,436**

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Key Points to Remember

- Typically, the most important operating costs for an on-farm biogas plant are electricity, heat, labour and maintenance.
- Clean feedstock typically comes with a tipping fee of $0 – $20/tonne, while in some areas you may have to pay for it.
- When estimating digestate revenues, it is often realistic to estimate $0/tonne or even a cost of $10 – $30/tonne.

Revenues

The revenue and cost savings from owning and operating an on-farm biogas plants can include:

- Tipping fees for accepting non-agricultural feedstock;
- Sale of renewable heat, renewable electricity or renewable natural gas;
- Sale or use of large digestate fibre for livestock bedding and digestate nutrients as an organic soil amendment;
- Reduced farm costs, including reduced manure mixing and pumping; and
- Carbon credits.

While non-agricultural feedstock tipping fees can be as high as $30 – $50/tonne, these fees are typically only paid for feedstock contaminated with problematic materials such as plastic. These feedstock, therefore, require expensive pre-treatment equipment to clean them. Clean feedstock that requires no pre-treatment typically comes with a tipping fee of $0 – $20/tonne, while in some areas of B.C. you may have to pay for clean feedstock.

Typically, energy sales are by far the largest revenue generator for an on-farm biogas plant. In 2018, B.C. Hydro paid approximately $0.10/kWh for renewable electricity, while FortisBC and Pacific Northern Gas can pay up to $30/GJ. When you estimate revenues from energy sales, it is important to be realistic. Theoretically, production of any biogas plant is its capacity multiplied by 8,760 (the number of hours in a year). However, as with other technologies, on-farm biogas plants do not operate 100% of the time. Therefore, when estimating energy revenues, it is typical to assume 90% – 95% of theoretically production.

If large fibre is removed from digestate it can be used for livestock bedding. If you have livestock, this will result in cost savings as you will need to purchase less or potentially no bedding. If you don't have livestock, you could sell this bedding to livestock farmers. Typically, the financial benefit of removing large fibre from digestate is small, as the cost to remove the fibre isn't much less than the savings or revenues generated.

> Typically, energy sales will be the largest revenue generator for your biogas plant

Digestate, which has low dry matter and is, therefore, expensive to transport, will ideally be spread on farmland immediately surrounding your biogas plant, potentially requiring you to purchase fewer nutrients. However, in some regions of B.C., especially those where livestock operations exist on limited agricultural land (such as the Lower Mainland), this may not be possible. As such, while digestate is often discussed as a revenue source for on-farm biogas plants, it can be a cost.

For example, while it is possible to use nutrient extraction equipment, such as a centrifuge, flocculation, or struvite precipitation to increase the nutrient concentration and value of your digestate, the cost of doing so is often greater than any revenue you might receive. As such, when you estimate revenues from digestate sales, it is often considered realistic to estimate $0/tonne or even a cost of $10 – $30/tonne to remove unwanted digestate from your farm.

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An on-farm biogas plant can result in cost savings for your farm. For example, digestate (especially after large fibre removal) is easier to mix and pump than manure. This means mixing isn't required as often, and power required for pumping is reduced. It also means that operating and maintenance costs can be lower due to the removal of problematic large fibre. The ability to pump digestate through smaller diameter pipes over greater distances is also greater than with manure. However, while these are all potential benefits to your farm, actual cost saving are often very small.

Carbon credits are generated when a project, such as an on-farm biogas plant, reduces the amount of greenhouse gas emissions entering the atmosphere. Carbon credits can be sold to anyone trying to reduce their greenhouse gas emissions. In B.C., carbon credits associated with the production of renewable energy become the property of the utility once you sell them your renewable electricity or renewable natural gas.

There are carbon credits associated with manure management and off-farm feedstock. These carbon credits could be sold. However, carbon credits must be audited to ensure they are accurate. The cost to audit carbon credits can be higher than the revenue received from selling them. Therefore, any potential revenue from carbon credits should be very carefully estimated before including in your revenue estimates.

For Farm ABC, and assuming that biogas is upgraded to renewable natural gas, a tipping fee of $15/tonne, 95% up-time (5% downtime for maintenance and repairs), a renewable natural gas sale price of $24/GJ, digestate management costs of $5/tonne, no on-farm savings and no sale of carbon credits, estimated yearly revenue is $1,022,914, calculated as follows:

Estimate	Revenue/Year
Tipping fee for 10,000 tonnes of non-agricultural feedstock at $15/tonne =	$150,000
Sale of 40,215 GJ of renewable natural gas at $24/GJ =	$965,164
Digestate management of approximately 18,000 tonnes at a cost of $5/tonne =	-$92,250
On-farm cost savings =	$0
Carbon credit sales =	$0
Total	**$1,022,914**

Profitability

There are many different ways to calculate the profitability of an on-farm biogas plant. At this stage, and due to uncertainty associated with estimating investment cost, operating costs and revenues, a good way to assess the profitability of your biogas plant is to estimate payback period. Payback period is the number of years it takes to recover your investment. In other words, payback period measures the number of years you must receive revenue from your on-farm biogas plant before these revenue are equal to the investment and operating costs.

For Farm ABC, and assuming an investment cost of $5.5 million, yearly operating costs of $262,436/year, and yearly revenues of $1,022,914/year, estimated payback period is 7.2 years.

Generally speaking, and because on-farm biogas plants operate for at least twenty years, a payback period of eight years or less should be a good investment. However, any payback period calculations at this stage are ballpark estimations only. This is because not only are investment cost, operating costs and revenue estimates uncertain, but payback period assess-

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ment is very basic. For example, a more complete profitability assessment takes into account important additional variables, such as interest on loans, depreciation, insurance and taxation.

Sensitivity Analysis

Whenever you assess the profitability of your on-farm biogas plant, it is important to conduct a sensitivity analysis. A sensitivity analysis assesses how potential changes to your cost and revenue estimates impact the profitability of your biogas plant. In other words, it illustrates which costs and revenues have the greatest impact on profitability. For example, when assessing your on-farm biogas plant, it is important to assess how the following changes might impact profitability:

- Tipping fees: what if tipping fee falls from $15/tonne to $5/tonne?
- Biogas production: what if biogas production is 10% lower due to lower quality feedstock or lower than expected operating time?
- Energy sales: what if the renewable natural gas sale price is $22/GJ instead of $24/GJ?
- Investment cost: what if the biogas plant costs 10% more to build than estimated?
- Digestate management: what if you are able to sell unwanted digestate, meaning digestate management costs are $0/tonne?
- Labour requirements: what if labour requirement is only 2 hours/day instead of 4 hours/day?
- Electricity requirement: what if electricity requirement is only 7% of total biogas production instead of 10%?

ESTIMATED PAYBACK PERIOD

Year	Investment Cost	Operating Cost	Revenue	Cash Flow	Balance
0	-$5,500,000	$0	$0	-$5,500,000	-$5,500,000
1	$0	-$262,436	$1,022,914	$760,479	-$4,739,521
2	$0	-$262,436	$1,022,914	$760,479	-$3,979,043
3	$0	-$262,436	$1,022,914	$760,479	-$3,218,564
4	$0	-$262,436	$1,022,914	$760,479	-$2,458,085
5	$0	-$262,436	$1,022,914	$760,479	-$1,697,607
6	$0	-$262,436	$1,022,914	$760,479	-$937,128
7	$0	-$262,436	$1,022,914	$760,479	-$176,649
8	$0	-$262,436	$1,022,914	$760,479	$583,829
9	$0	-$262,436	$1,022,914	$760,479	$1,344,308
10	$0	-$262,436	$1,022,914	$760,479	$2,104,787
				Payback =	**7.2 years**

Key Points to Remember

- While on-farm biogas plants can result in cost savings for farms, these saving are often small.
- Generally speaking, a payback period of eight years or less shows that an on-farm biogas plant could be a profitable undertaking.
- A sensitivity analysis illustrates which costs and revenues have the greatest impact on the profitability of your biogas plant.

For Farm ABC, the following table shows impacts to payback resulting from these changes. Understanding which variables will have the greatest impact on profitability (i.e., change payback by the greatest amount of years) is important as this shows where your biogas plant is most vulnerable, as well as highlights where your focus should be.

PAYBACK SENSITIVITY ANALYSIS

Potential Change	Payback
Tipping fee falls from $15/tonne to $5/tonne =	8.3 years
Biogas production drops by 10% =	8.3 years
Sale of renewable natural gas is only $22/GJ instead of $24/GJ =	8.1 years
Investment cost is 10% higher than estimated =	8.0 years
Digestate management cost falls from $5/tonne to $0/tonne =	6.4 years
Labour requirement drops from 4 hrs/day to 2 hrs/day =	7.0 years
Electricity requirement drops from 10% of energy production to 7% =	6.9 years

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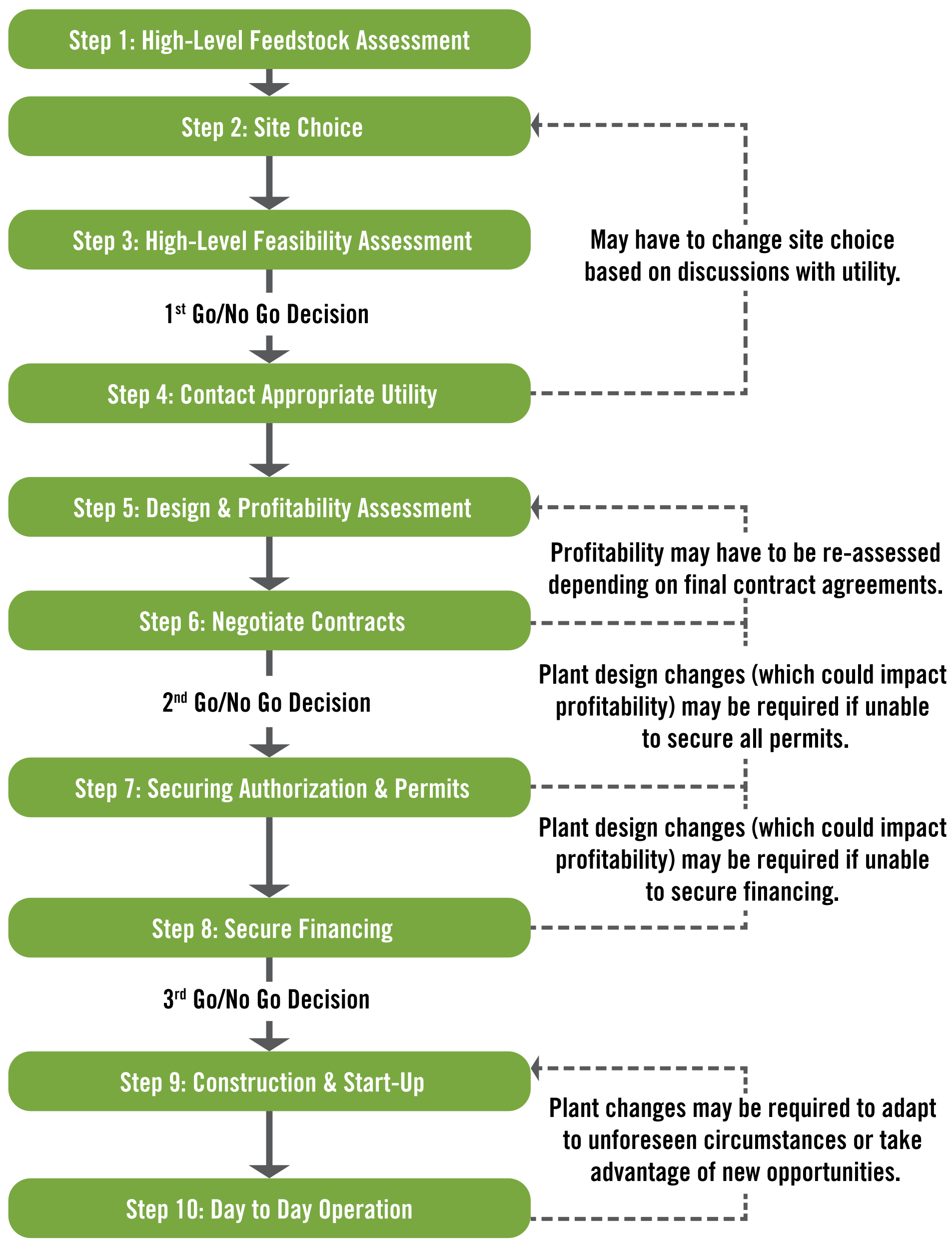
5. Biogas Development Steps

While every biogas plant is unique and will therefore require its own specific approach, there are certain development steps that almost all on-farm biogas plants in B.C. will have to complete. If completed correctly, these steps will greatly increase the chances of building a successful biogas plant on your farm.

The objective of this chapter is to explain these development steps so that you better understand what is required to take a biogas plant from idea all the way through to construction and operation. As every on-farm biogas plant will be site specific, the following development steps may not be all that are required. Furthermore, some of these steps may be completed simultaneously, while others may have to be repeated as new information becomes available.

DEVELOPMENT STEPS FOR ON-FARM BIOGAS PLANTS IN B.C.



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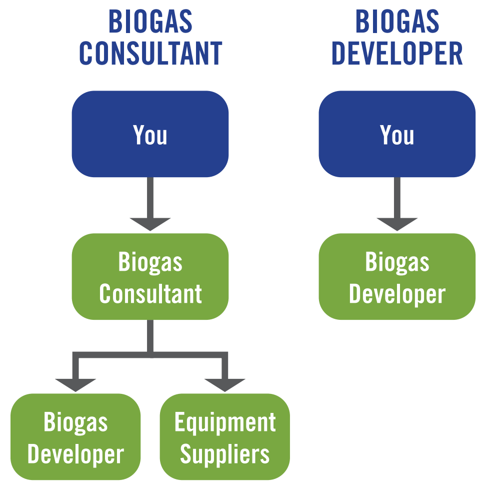
Depending upon available time and finances, you may want to complete some of the early development steps yourself. However, at some point you will need to hire a biogas company to help you. While there are many different types of biogas companies, typically these companies can be classified as either consultants or developers.

Biogas consultants help with planning, design and development of biogas plants. Typically, because biogas consultants don't supply equipment, they can identify the equipment you require based on price, performance and best fit. Biogas consultants can also help write contracts with equipment suppliers and developers. Biogas developers plan, design and build biogas plants. Developers often choose to use their own equipment.

Choosing the right biogas consultant or developer to work with greatly improves your likelihood of success. Therefore, before deciding whether to work with a biogas consultant or developer, you should assess them to see who is best for you by asking the following questions:

- Do they have previous experience with similar types of biogas plants (i.e., on-farm biogas plants), or is their experience with municipal or wastewater treatment biogas plants?
- Do they have local biogas experience (i.e., are they experienced working in B.C.), or is there experience from working in other Canadian provinces or other countries?
- Do they have the capacity required to help you with your biogas plant?
- Do they have any references you can contact directly?

WORKING WITH A CONSULTANT OR DEVELOPER



Step 1: High-Level Feedstock Assessment

Feedstock availability will dictate your biogas plant's size, technology choice and profitability. Therefore, knowing the quantity and type of available feedstock, both today and over the next five to ten years, is an important first step. Until you have a rough idea of the feedstock that is available to you, it is impossible to know if you should build your on-farm biogas plant. The two types of feedstock are:

- Agricultural: produced on farm, such as dairy, hog and poultry manure, spoiled silage and crop residues. Agricultural feedstock can be 'on-farm', which means it is produced on your farm, or 'off-farm', which means it is produced on other farms; and
- Non-agricultural: food waste produced by non-farm sources, such as food and beverage processing, grocery stores, restaurants and municipalities (e.g., green bin waste).

When assessing agricultural feedstock, you should first determine the amount and year-round availability of feedstock produced on your farm. If this amount of feedstock is insufficient, or if you want to work with

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Key Points to Remember

- Biogas consultants and developers can help you take your biogas plant from idea to operation. Choosing the right company to work with is very important.
- Feedstock will dictate the size, technology choice and profitability of your biogas plant.

other farms, you should speak with your neighbours (typically farms no more than 10 – 15 km away for dairy or hog manure, and up to 100 km away for poultry manure and crop residues) to determine the amount and year-round availability of feedstock on their farms.

Once this is done you need to determine if there is any suitable non-agricultural feedstock available in your region. Ideally, the amount of non-agricultural feedstock available should match the amount of agricultural feedstock you have access to. However, this isn't always necessary as on-farm biogas plants can be profitable with less non-agricultural feedstock. When you assess non-agricultural feedstock, the following questions should be considered:

- Which types of feedstock are available in your region (e.g., fruit and vegetable waste, mixed food waste, fats, oils and grease, bakery waste)?
- What quantities of feedstock are available in your region?
- Will the feedstock come with a tipping fee (i.e., will you be paid to accept it) or will you have to pay for it?
- Is this feedstock available on a regular basis (e.g., daily or weekly) year-round?
- How long will this feedstock be available for (e.g., next one, two, five or ten years)?
- Is the feedstock free from potential organic (e.g., branches and other woody material) and non-organic contaminants (e.g., plastic, glass and metal)?
- Does the feedstock come from multiple sources or a single source?

When assessing availability of non-agricultural feedstock, the three main options are to work with a waste hauler that collects feedstock, hire a biogas company (either consultant or developer) to conduct research on your behalf, or conduct the research yourself by contacting food and feed companies and waste management authorities in your region. Each of these options have their own benefits and costs that you should consider carefully.

While waste haulers will have good information on type, quantity and availability of feedstock, they will only know about the feedstock that they handle. A biogas company may be able to complete a fuller assessment of available feedstock, but will likely charge you for this service. Conducting your own research will cost nothing, but will take up valuable time.

> Ideally, the amount of non-agricultural feedstock available should match the amount of agricultural feedstock you have access to

When you assess non-agricultural feedstock availability, there is always a balance between resources committed to finding information and the certainty of information collected. Availability of non-agricultural feedstock doesn't just vary throughout the year, but what is available today might not be available in a few years (when you need it). Therefore, no information will ever be completely accurate. As such, you should only commit enough time and resource to feel confident you have a rough idea of potentially available non-agricultural feedstock in your region.

Alternatively, if this information is too challenging to collect at this point, you

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Key Points to Remember

- When selecting a site for your biogas plant it is important to consider site-specific circumstances, permitting requirements and your neighbours.
- A high-level feasibility assessment will help you determine if a biogas plant might be appropriate for your farm.

could assume that there is sufficient (i.e., equal to the agricultural feedstock you have access to) non-agricultural feedstock available in your region. However, this assumption greatly increases the risk that your high-level feasibility assessment could be inaccurate.

Depending upon quality of information collected, feedstock assessment should only take a few weeks. Depending upon who carries out most of the work (i.e., a waste hauler, a biogas company, or if you do it yourself), this step will require little to moderate effort on your part, and should cost no more than five thousand dollars.

Step 2: Site Choice

Once you have completed your feedstock assessment, you should choose a suitable site on which to build your biogas plant. When selecting a suitable site, it is necessary to consider not only site-specific circumstances that may impact construction costs, such as existing infrastructure, utility connection point and subsoil, but also permitting requirements and your neighbours. The following questions should be considered before choosing a site for your biogas plant:

- Does the site have easy access to existing infrastructure, such as the natural gas or electricity grid, to enable sale of energy, and roads to enable transportation of feedstock and digestate?
- Is the site large enough for your biogas plant, including all necessary buildings, equipment and roads (most on-farm biogas plants in Canada require at least 1 or 2 acres, if not more)?
- Is the site relatively close to your agricultural feedstock production or storage, and to the land on which you will spread your digestate?
- Is the site located a suitable distance from residential areas, and from lot lines, water supply intakes, watercourses and other sensitive features?
- Is the site relatively flat, not located in a potential flood affected area, and does it have suitable subsoil for construction?
- Is the site located so that off-farm feedstock (both agricultural and non-agricultural) will not come into contact with feed or animals on your farm (i.e., causing a potential biosecurity risk)?

Determining a suitable site for your biogas plant should only take a few days or weeks. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself), site selection will require little to moderate effort on your part, and should cost no more than a few thousand dollars. If choosing a site off your farm, site selection can be much more challenging, expensive and time consuming to complete.

Step 3: High-Level Feasibility Assessment

The next step is to conduct a high-level feasibility assessment to determine if a biogas plant might be appropriate for your farm. One way to do this is to complete the Self-Assessment Tool in Chapter 6. Alternatively, you can search for biogas assessment tools on-line, or hire a biogas company to help you.

Assessing if a biogas plant is appropriate for your farm is as accurate as the information you use. Typically, the more effort put into getting accurate information, the more accurate your feasibility assessment will be. However, as with feedstock assessment, no matter how much effort you put in, there will always be some level of uncertainty. As such, you should only commit enough time and resources to feel confident that your high-level feasibility assessment is reasonably accurate.

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If you don't have accurate information on the biogas potential of available non-agricultural feedstock, you could assume that the average biogas production of this feedstock is 160 m^3/tonne. However, this assumption greatly increases the risk that your high-level feasibility assessment could be inaccurate.

Depending upon quality of information collected, a high-level feasibility assessment should only take a few weeks or months. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself), this step will require little to moderate effort on your part, and should cost no more than fifteen to twenty thousand dollars.

Once your high-level feasibility assessment is complete, this is your first go/no go decision point. If a biogas plant looks appropriate for your farm, you should continue to the next development step. If a biogas plant doesn't look appropriate for your farm, you should consider stopping.

Step 4: Contact Appropriate Utility

Depending upon the type of renewable energy you plan to sell, you will need to contact your local natural gas (if selling renewable natural gas) or electricity (if selling renewable electricity) utility to discuss a contract for selling the energy. During these discussions, your utility will let you know if it is possible to inject renewable energy onto their grid.

If selling renewable natural gas, your natural gas utility will need to know:

- If you want to sell them biogas or renewable natural gas;
- The proposed location of your biogas plant;
- The potential volume of biogas or renewable natural gas that you plan to produce; and
- Who will own the biogas plant.

Your natural gas utility will let you know whether the proposed location of your biogas plant is suitable for injection into the natural gas pipeline, if the volume of biogas or renewable natural gas you want to sell is acceptable, and if your biogas plant meets their program cost threshold. Your natural gas utility will also let you know the required quality specifications (i.e., heating value, moisture and hydrogen sulphide content) for injecting renewable natural gas into their pipeline.

> If selling renewable natural gas, your utility will need to know if you want to sell them biogas or renewable natural gas

If your biogas plant meets the necessary requirements, your natural gas utility will proceed with a more thorough evaluation. There is currently no cost associated with this evaluation.

If you are unable to inject renewable natural gas into the natural gas pipeline, for example, due to being located too far from the natural gas pipeline, or the pipeline being unable to accept your renewable natural gas, it may be possible to compress your renewable natural gas and transport it elsewhere for sale. However, compression and transportation will add cost, so careful consideration must be given to the impact this will have on the profitability of your biogas plant.

If planning to sell renewable electricity, you should contact B.C. Hydro to request a meeting. The purpose of this

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meeting is to review the rules of the B.C. Hydro program you wish to sell to. The two main program options as of 2018 are the Micro-Standing Offer Program (for biogas plants with an estimated electrical output of 100 kW to 1 MW) and the Standing Offer Program (for biogas plants with an estimated electrical output greater than 1 MW).

During this meeting with B.C. Hydro, you will discuss interconnecting to the electricity grid. This starts with submitting an interconnection request, followed by B.C. Hydro completing a screening study. This study will provide an estimated cost for any interconnection equipment or grid upgrades that will be required. These costs, which must be paid for by you, will depend upon your biogas plant's location and size, and can be substantial. If you are selling to the Standing Offer Program, a system impact and feasibility study will also be required. You must pay the cost of the screening, system impact and feasibility study.

As of 2018, B.C. Hydro was not accepting applications to sell renewable electricity until a review of its programs has been completed. It is not known when this review will be complete.

Determining if it is possible to inject your renewable energy onto the grid should only take a few weeks (for biogas and renewable natural gas) or months (for renewable electricity). However, if a system impact and feasibility study is required for selling renewable electricity, this could take several months or more. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself) and which utility you work with, this step will require little to moderate effort on your part, and could cost anywhere from a few thousand (for biogas and renewable natural gas) to a hundred thousand dollars or more (for renewable electricity).

Step 5: Design & Profitability Assessment

At this stage, and if you haven't done so already, you will likely need to engage the services of a biogas company to determine the most appropriate technologies and design for your biogas plant. Technology choice and biogas plant design, which could include feedstock pre-treatment, pasteurization, biogas cleaning and use, and nutrient management, should be based on type and amount of feedstock you have access to, both now and in the future, the specifics of your farm, and local regulations. This design should also take into account any of your preferences, such as level of automation, redundancy and equipment suppliers.

At this stage, and if you haven't done so already, you will likely need to engage the services of a biogas company

Sometimes biogas companies copy the design and equipment choices of previously built biogas plants. This approach, called 'cookie cutting', is used to save cost. However, while this approach saves cost it can mean that not enough attention is paid to specific differences between farms. Whenever possible, biogas plant designs should be farm specific. Therefore, your biogas plant should be designed to suit your farm's specific needs and conditions, not the other way around.

If you do not understand why any decisions are made during the design of your biogas plant, be sure to ask. Trusting a biogas company to make the best decisions for your farm can be risky as these companies often promote their own technology, even when it is not the most appropriate for

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Key Points to Remember

- Secure firm quotes for equipment and installation to ensure an accurate profitability assessment.
- When assessing the profitability of your biogas plant is it important to use conservative estimates.

you. Biogas companies also may not fully understand your farm's day-to-day operations or any long-term plans you might have for your farm. Therefore, it is your responsibility to be actively involved in the decision-making process and conduct the necessary due diligence to ensure that each decision is right for both your biogas plant and your farm.

As part of the design step, detailed process, mechanical, electrical, and civil engineering will be required to generate drawings and establish specifications for all components of your biogas plant. All materials/compounds to enter and leave your biogas plant (i.e., feedstock, digestate, emissions and chemicals) will also be identified and quantified.

Once your biogas plant has been designed to a level at which you are able to secure firm quotes for equipment and installation, the profitability of your biogas plant should be re-assessed to determine if a biogas plant is still appropriate for your farm. To assess profitability you will need to create a detailed financial model that should include, but not be limited to, the following conservative revenue and cost estimates:

- Renewable energy sales (i.e., renewable heat, renewable electricity or renewable natural gas);
- Feedstock tipping fees and/or feedstock delivery costs;
- Other realistic revenue/savings for your biogas plant or farm (e.g., bedding, digestate or carbon credit sales);
- All equipment and structure costs (firm quotes as much as possible);
- Site preparation costs (e.g., electrical upgrades, roadway construction and earth works);
- Digestate management costs (if any);
- Utility interconnection costs to sell renewable energy (if any);
- Operating costs (e.g., heat, electricity and all other required consumables);
- Labour costs (including any work you intend to carry out yourself; your time is not free);
- Maintenance and repair costs, plus a small contingency for unforeseen costs; and
- Soft costs (e.g., project management, engineering, insurance and financing), which can quickly add-up and account for 10% – 20% of investment cost.

> Once your biogas plant has been designed, profitability should be re-assessed

Designing your biogas plant and assessing its profitability could take anywhere from a few months to a year or more (depending upon the number of design changes required). Regardless of who carries out most of the work (i.e., a biogas company or if you do it yourself), this step will require a moderate to significant effort on your part, and will cost at least a few hundred thousand dollars.

Step 6: Negotiate Contracts

During the design and profitability assessment of your biogas plant, you should negotiate contracts. When negotiating contracts, it is often advisable to seek help from a third-party biogas company or professional to ensure that these contracts are written as beneficially for you as possible. Typically, it is unadvisable to rely on

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Key Points to Remember

- Tipping fee is typically linked to feedstock quality; the higher the biogas yield or lower the contaminants, the lower the tipping fee.
- All contracts should include clear and concise performance guarantees and performance guarantee measures.

those selling you goods and services to write the contract. Furthermore, it is also advisable to ensure that all contracts include clear and concise performance guarantees and performance guarantee measures.

Performance guarantees are clauses written into contracts to specify the standards that developers, equipment suppliers and contractors must meet, and the procedure to follow if the agreed upon standards are not met. Performance guarantee measures are methods and frequencies for collecting, analyzing and measuring performance to determine if the agreed upon standards have been met. For example, for a feedstock supply contract, this could be:

- Performance guarantee: acceptable range of contaminants (typically on a volume basis);
- Performance guarantee measure: agreed upon sampling method for measuring contaminants in the feedstock every month (to be carried out by an independent third party); and
- Procedure: removal of feedstock that contains excessive contaminants (i.e., more than amount agreed upon) free of charge within a 12 hour period.

The most important contracts for an on-farm biogas plant are feedstock supply, energy sale, digestate, and equipment and service contracts.

Feedstock Supply Contracts

Feedstock supply contracts, for off-farm or non-agricultural feedstock, are necessary to ensure a long-term, constant supply of feedstock for your biogas plant. Within these contracts some important points include:

- Term: this should be sufficient to supply your biogas plant with feedstock for at least the first few years, if not longer. This should also include rules for contract renewal.
- Quantity: this should state tonnage of feedstock to be delivered to your biogas plant, as well as minimum and maximum quantities delivered within a certain timeframe (e.g., one week). This should also include the time when feedstock shouldn't be delivered (e.g., 7pm to 7am and/or weekends).
- Quality: this should specify acceptable ranges for biogas production, contaminants, dry matter and possibly nutrient content. Defining an acceptable range (e.g., 1% – 3% contaminants by volume) will ensure quality levels are known and consistent. This should also include rules and responsibilities for sampling feedstock quality, dealing with feedstock that isn't within the agreed upon acceptable range, and what to do if you are unable to accept feedstock due to temporary issues with your biogas plant.
- Tipping fee: this is often linked to feedstock quality. Typically, the higher the biogas yield or lower the contaminants in the feedstock, the lower the tipping fee and vice versa. In some circumstances, for example, if it has a very high biogas yield and is very clean, feedstock may not come with a tipping fee. Instead you may have to accept it for free, or even pay transportation costs.
- Exclusivity: a feedstock supplier may require that you only accept feedstock from them. Before agreeing to this you should consider what other feedstock might be available.
- Termination: grounds for contract termination should be clearly spelled out. Typically, contracts are terminated when inferior feedstock (e.g., lower than agreed upon biogas yield or higher than agreed upon contaminants) is consistently delivered.
- Type and source: In some circumstances (e.g., with off-farm agricultural feedstock), it may be good to specify the type (e.g., dairy manure) and source (e.g., which farm) of the feedstock.

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Energy Sale Contracts

An energy sale contract should be negotiated with the appropriate utility. A long-term contract will secure long-term revenue for your biogas plant, and is usually required to obtain financing. Within this contract, some important points include:

- Term: this should be sufficient to support financing for the life of your biogas plant. A typical term is 15 – 20 years. The rules for contract renewal at the end of the term should also be stipulated.
- Price: this should be sufficient to ensure long-term profitability of your biogas plant, and may include a price escalation clause. A price escalation clause guarantees an increase in price paid for your energy due to changes, such as inflation.
- Quality: this should specify the desired properties of the biogas or renewable natural gas that you will sell, including methane content, hydrogen sulphide levels, moisture content, carbon dioxide and sulphur content. This isn't necessary if selling renewable electricity.
- Quantity: this should specify the quantity of renewable electricity (kWh), biogas (m^3) or renewable natural gas (GJ) you will sell to the utility. If you are selling biogas or renewable natural gas, your utility may stipulate a maximum quantity that you can sell. The maximum quantity may vary between summer and winter months, and time of day.
- Termination: while grounds for contract termination should be clearly spelled out, these should be very limited.
- Assignment: this should specify if the contract can be assigned, for example, to your heirs or partners.
- Responsibility: this should specify who is responsible for different aspects of your biogas plant (e.g., digester tanks, biogas upgrading equipment and grid interconnection equipment).
- Access: this should specify the access that the utility will have to your farm, including which areas and at what times.
- Title and warranty: this should specify when responsibility of the electricity, biogas or renewable natural gas transfers to the utility.

> A long-term energy contract will secure long-term revenue for your biogas plant, and is usually required to obtain financing

Digestate Contracts

Digestate contracts, for digestate you will not use on your farm, may be necessary to meet the requirements of a nutrient management plan. Within these contracts some important points include:

- Term: this should be sufficient to ensure your biogas plant has long-term plans for all of the digestate nutrients not needed on your farm. Ideally, this will be for at least five years.
- Quantity: this should state expected tonnage of digestate and/or range of nutrient content to be delivered.
- Quality: this should specify an acceptable range for digestate quality. Typically, the most important quality parameters are visible impurities (e.g., pieces of plastic), dry matter (as this will dictate type of spreading equipment required), and nutrient content (i.e., nitrogen, phosphorus and potassium). Because feedstock greatly impacts digestate nutrient content, the agreed-upon acceptable range should be fairly broad.

Key Points to Remember

- The maximum quantity of biogas or renewable natural gas that you can sell may vary by month and/or time of day.
- Your energy sale contract should specify when responsibility of the electricity, biogas or renewable natural gas transfers to the utility.

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- Fee: this is linked to digestate quality. Typically, the lower the impurities or higher the dry matter and nutrient content, the higher the fee (and vice versa). In areas with high livestock densities and plentiful nutrients, it may be challenging to receive any fee for digestate. Instead you may have to give it away, or even pay transportation costs.
- Termination: grounds for contract termination should be clearly spelled out. Typically, contracts are terminated when inferior digestate (e.g., higher than agreed upon contaminants or lower than agreed upon nutrient content) is consistently delivered.
- Standard: in some circumstances, your digestate may be required to meet a certain standard or specification. While these can seem arduous, they can also help you to get a higher price for your digestate.

Equipment & Service Contracts

Equipment and service contracts are necessary to ensure that terms of delivery are clearly understood. Within these contracts, some important points include:

- Scope: this should specify exactly what is being supplied, including which equipment type, whether the equipment will be delivered to the farm gate or site of your biogas plant, and who will be responsible for assembly/construction, installation, commissioning and training.
- Term: this should specify dates by which equipment must be delivered and/or installed and commissioned. This should also specify compensation for lost revenue due to delays.
- Price: this should specify the exact price for the equipment and/or services supplied, including all taxes, delivery, travel costs, service hours, training, and any other related costs.
- Equipment specifications: this should clearly define all equipment specifications, including type, make, model, performance, capacity, volume, materials, temperature, speed and retention time.
- Payment: this should specify the payment schedule for all equipment and/or services supplied. Typically, payment will be based upon delivery of equipment or progress of work. Final payment should not take place before the end of any warranty period.
- Warranty period: this should specify the period of time during which faulty equipment or construction, if the fault occurs through no fault of your own, must be repaired or replaced by the supplier. You should try and negotiate as long a warranty period as possible.
- Termination: this should specify any reasons for contract termination, such as your inability to secure permits or financing.
- Maintenance: this should specify any maintenance contracts for specific pieces of equipment, such as feedstock pre-treatment equipment, pumps, agitators, combined heat and power engines or biogas upgrading units, and nutrient extraction equipment. These contracts should also include a timeframe (e.g., days) within which replacement parts must be installed.

> The time and effort required to secure all necessary permits for your biogas plant should not be underestimated

Contract negotiations should only take a few months. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself)

and the number of contracts, this step will require little to significant effort on your part, and could cost anywhere from a few thousand to fifty thousand dollars or more.

Once contracts are negotiated and profitability assessment is complete, this is your second go/no go decision point. If the results of your profitability assessment look good, you should continue to the next development step. If the results do not look good, you should consider stopping. Alternatively, if you feel improvements can be made to the design of your biogas plant, these changes should be made and the profitability of your biogas plant re-assessed. Whenever you are assessing the profitability of your biogas plant, make sure that your assumptions and estimates are conservative. Wanting your biogas plant to be profitable isn't the same as it being profitable once built.

Step 7: Securing Authorization & Permits

This step in the process involves securing approvals and permits for your on-farm biogas plant. Because this step can take a while to complete, it is strongly recommended that you contact the necessary regulatory agencies of your intention to build an on-farm biogas plant as soon as possible. This usually takes place once you know the biogas plant may be profitable and you have decided to proceed. The agencies you should notify include:

- The Agricultural Land Commission (ALC);
- The B.C. Ministry of Environment; and
- Your local government.

These agencies require information about feedstock, engineering plans and digestate management plans. You are highly encouraged to review the agricultural environmental regulations, if you haven't done so already, to find out current requirements.

Your local and regional government has jurisdiction over various permits that may be necessary for your on-farm biogas plant including building permits, business licensing and possibly air permits. Furthermore, you must contact your local government to determine if a zoning amendment for the site of your biogas plant is required, as well as if any amendments are needed to their solid and liquid waste management plans. A zoning amendment was needed for the first two on-farm biogas plants in B.C. If a zoning amendment is required for your proposed site, an application for this amendment should be made to your local government as soon as possible. If an amendment is required to your municipality's solid or liquid waste management plans, you must apply for this amendment as directed.

You must contact your local government to determine if a zoning amendment for the site of your biogas plant is required

The next step in the authorization and permitting process is to contact the ALC and the B.C. Ministry of Environment to follow the most current authorizations and permitting process.

Under the *Agricultural Land Reserve Use, Subdivision and Procedure Regulation*, biogas plants In the Agricultural Land Reserve (ALR) are not considered a permitted farm activity or permitted non-farm use. The ALC is responsible for approving all non-farm uses within the ALR. Therefore, if the site of your biogas plant is within the Agricultural

Key Points to Remember

- Currently, the approval process for on-farm biogas plants in B.C. is an undefined and inconsistent.
- If your biogas plant is within the Agricultural Land Reserve you will have to submit an application for non-farm use.
- You may be required to re-zone the site of your biogas plant.

Land Reserve you must submit an application for non-farm use. This application should be submitted to your local government. Your local government will review your application and if authorized it will be forwarded to the ALC for a decision. The ALC may schedule a site visit to your farm as part of their review process.

The B.C. Ministry of Environment requires that all wastes discharged to the environment from prescribed industries defined in schedules 1 and 2 of the Waste Discharge Regulation require authorization to discharge under:

- A regulation;
- A code of practice, or
- A permit, approval or operational certificate as authorized by the B.C Ministry of Environment.

Biogas plants in B.C. are required to obtain a site-specific Permit, Approval (maximum of 15 months) or Operational Certificate under the Environmental Management Act to discharge to the environment, regardless of feedstock (100% agricultural or mixed on and off-farm). Depending on the intended use, the land application and/or management of digestate may be authorized under the same authorization or under the Agricultural Environmental Management Code of Practice (AEM CoP).

To initiate the process of obtaining an authorization, review the Standard Application Process to obtain a new Permit, Approval or Operational Certificate. All authorizations for biogas plants (Permit, Approval or Operational Certificate) will be processed as a "Routine Application for a new Permit, Approval or Operational Certificate."

Information on the Standard Application Process can be accessed from: https://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization/routine-application-process

The Standard Application Process for biogas plants includes the following steps:

1. Submit a Preliminary Application Form to the B.C. Ministry of Environment;
2. The B.C. Ministry of Environment will arrange a pre-application meeting to discuss your proposed biogas plant and requirements for your Final Application Package. After this meeting, the B.C. Ministry of Environment will send an Application Instruction Document that identifies technical information and public consultation required.
3. You must collect all required information and prepare a technical information report. A Public Consultation Report will also be required. Public consultation requirements for a new permit are outlined in the B.C. Public Notification Regulation.
4. Once the Final Application Package is complete, this can be submitted to the B.C. Ministry of Environment.
5. The B.C. Ministry of Environment will assess your information and issue a permit if it is determined your biogas plant will not have a significant impact on the environment or that proposed mitigation and treatment technology is sufficient to reduce potential impacts.

Contact the B.C. Ministry of Environment for further information on the authorization application process.

Please note, if your proposed biogas plant is located within Metro Vancouver, you are encouraged to contact the Metro Vancouver Office as soon as possible to determine permitting and other regulatory requirements. Metro Vancouver has been delegated authority to manage air quality within its boundaries by the B.C. Ministry of Environment.

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In addition to a site-specific permit, provisions under the AEM CoP including the land application or composting of digestate may be required. The site-specific authorization for the biogas plant may contain additional requirements, over and above what's stated in the AEM CoP.

A nutrient management plan will be required for the land application of digestate regardless of the source of feedstocks. Nutrient Management Plans (NMP) ensure excessive nutrient loading does not occur by requiring that nutrients in digestate and the receiving environment be considered prior to applications. An NMP must be reviewed and updated every 12 months.

> It is recommended that nutrient management plans are reviewed and updated every 12 months

The B.C. Ministry of Environment determines the criteria for maximum application rates of all nutrient sources that are to be applied on agricultural land, including digestate. The regulatory limits are described in the AEM CoP. Specifically, application rates for nitrogen and phosphorus are not to exceed agronomic limits.

Phosphorus limits in the AEM CoP are scheduled to become more stringent over time, meaning less phosphorus may be applied to land over time on fields with high soil phosphorus levels (for any given crop). In addition, it must be ensured the digestate will not increase the potential for phosphorus loading on farms. If nutrients must be exported to mitigate phosphorus loading, transfer agreements may be needed as part of the NMP.

In addition, the AEM CoP includes record-keeping requirements for application of nutrient sources to land (including digestate), and the B.C. Ministry of Agriculture recommends that record-keeping reports be submitted annually after the NMP is implemented.

The B.C. Ministry of Environment assesses NMPs to determine if there is sufficient land and storage capacity for nutrients. Some criteria that the B.C. Ministry of Environment require NMPs to include are:

1. Nitrogen and phosphorus application rates are within regulatory limits;
2. A farm's ratio of crop phosphorus inputs to crop phosphorus removal will not increase; and;
3. Nutrients not used for land application will be exported; If exporting nutrients off your farm, you may be required to secure transfer agreements with whomever will accept these nutrients. These agreements need to include the location, volume, and proposed dates for the nutrients being transferred.
4. Record-keeping requirements for land application of nutrient sources including digestate.

Additionally, you may be asked by the B.C. Ministry of Environment to conduct digestate sampling for heavy metals and pathogens if you are using non-agricultural feedstocks. The B.C. Ministry of Environment will prescribe the frequency of the sampling requirements.

Based on the authorizations required and the regulatory agencies involved, obtaining authorizations could take up to 8 months for medium complexity and 12 months for high complexity applications from the time the Final Application Package is received. Depending upon who carries out the work (i.e., a biogas company or if you do it yourself) and the authorizations required, this step will require little to significant

Key Points to Remember

- It is advised to engage your chosen lender as early as possible to educate them about your biogas plant.
- Before deciding which financing option is best for your biogas plant consult with your accountant.
- Proper project management is essential to avoid any conflicts and unnecessary delays.

effort on your part and could cost anywhere from ten thousand to a hundred thousand dollars or more.

Step 8: Secure Financing

During the permitting process, you will need to secure financing for your biogas plant. Due to the importance of financing and cost involved in progressing to this step, it is advised to engage your chosen lender as early as possible (potentially as early as development Step 3). This engagement will help to educate your lender about on-farm biogas plants, and will enable you to secure the funds necessary to reach this development step.

When you are securing financing, be sure to shop around. Different lenders have different comfort levels with on-farm biogas plants, and offer different options. For example, while one lender may require double the asset value to loan (so for every dollar you borrow you need two dollars in assets), another may only require the asset value to match the loan. Other lenders may be interested but unable to accommodate the size of the loan you require.

> When you are securing financing, be sure to shop around. Different lenders have different comfort levels with on-farm biogas plant

Typically, there are four financing options for on-farm biogas plants. These can be used even if you plan to co-own the biogas plant with other farmers (e.g., as a co-operative). Before you decide which option is best for you, it is important to consult your accountant:

- Recourse Debt Financing: probably the most commonly used for biogas plants, this is when a lender provides financing based on farm assets, such as quota or land, and estimated revenues from the biogas plant. Therefore, when deciding to finance a biogas plant, lenders examine expected financial performance of both your farm's assets and your biogas plant. Typically, the underlying economics of your farm will determine the willingness of lenders to finance your biogas plant.
- Non-Recourse Project Financing: while currently uncommon for on-farm biogas plants, this is when a lender provides financing based on your biogas plant's assets and expected revenues. Therefore, when deciding to provide financing, lenders examine your biogas plant to determine its ability to repay debt. Due to perceived risks, on-farm biogas plants have historically experienced difficulty securing this type of project financing. However, this may change as more on-farm biogas plants are built. This type of financing requires a separate company (special purpose entity) to house the biogas plant and its assets. It is this company that enters into a financing agreement with a third-party lender, keeping all farm assets separate and safe.
- Third-Party Financing: this is when a third party owns all or a stake of your biogas plant. This can be a good idea if the third party is the biogas company that builds your biogas plant or a supplier of equipment or feedstock, as this ensures they remain committed to your biogas plant after it is built. This is a useful option when you are unable to raise required financing, or are unwilling to invest some or all of the equity yourself. Third-party financing can encompass many different structures. For example, you could lease all parts of the biogas plant's assets that you don't own from the third party and retain all or part of the biogas plant's revenue. You could

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charge the third party rent and an operator's fee, or you could sell the third party feedstock and buy the biogas and digestate.

- Vendor Financing: this is when an equipment supplier provides you with the financing to purchase their equipment. This financing usually takes the form of deferred loans, which depending upon the agreement with the vendor, may or may not accrue interest. This is a useful option when you are unable to raise the required financing for your biogas plant, but do not want a third party to own a stake.

On-farm biogas plants that present a strong business case, have limited risk and secured long-term revenues should be able to secure financing. One way to assess the financial strength of your biogas plant is to calculate its debt coverage ratio. Debt coverage ratio is a measure of operating income (i.e., revenue after all operating expenses) to debt. In other words, it measures your biogas plant's ability to meet its debt payments. Most lenders require a debt coverage ratio of 1.5 to 2.0 or more. This means that yearly revenue from your biogas plant after operating expenses should be 50% – 100% greater than yearly loan payments.

Securing financing should only take a few months. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself), this step will require little to moderate effort on your part, and cost no more than a few thousand dollars.

Once all permits and financing are secured, this should be considered your final go/no go decision point. While you have invested significant time and money to reach this point, if you still have concerns about the profitability of your biogas plant, you should consider stopping (at least until these concerns have been addressed). If you don't have any concerns you should continue to the next development step.

Step 9: Construction & Start-Up

Depending upon your chosen approach, construction (including purchase of all equipment) and commissioning may involve working with one or more companies. For example, if the biogas developer you are working with supplies a turnkey installation (i.e., all engineering, purchasing, construction and commissioning is carried out by one company), the approach will be very different than if you are working with a biogas consultant, equipment suppliers and local contractors.

> Construction and commissioning may involve working with one or more companies

When you are deciding which approach to take, it is important to consider the amount of effort you want to put in. For example, if you want someone else to design and build your biogas plant while you manage your farm, consider a turnkey installation. However, if you want to be more involved, you should consider working with a biogas company for certain aspects of your biogas plant, taking charge of other aspects yourself (e.g., digestate management), and/or working with a local contractor. The options are endless.

Regardless of the approach you take, proper management is essential to ensure equipment procurement and construction are well timed to avoid conflicts and unnecessary delays. Engineering supervision is also necessary to ensure that construction is completed in accordance with your biogas plant design and legal requirements. All companies involved in the construction of your biogas plant

Key Points to Remember

- During start-up, it may take several months to reach maximum biogas production potential.
- Biogas plants require two to eight hours a day or more for day-to-day operations.
- Operating costs can be as high as 50% of total revenue.

should have a clear understanding of the following:

- Who is responsible for supplying which equipment and materials;
- A clear plan for construction in phases and corresponding timelines of the required work, including start date, end date, and any other key dates with corresponding deliverables and/or milestones;
- Who is ultimately responsible for overseeing construction and ensuring that all installations are in compliance with specifications and legal requirements; and
- The communication structure to discuss progress, possible difficulties and modifications.

Once construction is complete, pre-operational verifications must be performed to ensure all equipment is properly installed. After verification, your biogas plant can be started. Start-up will begin with feeding feedstock into your biogas plant, heating digester tanks to operating temperature, monitoring the function of all equipment, including pumps and mixers, and keeping a record of temperature, biogas yield and flow rates.

During start-up, the biological process inside your digester tank will begin working. At least initially, biogas production will be low. The methane content of your biogas may also be low. Over the next few months, biogas production and methane content should gradually increase to its maximum potential. However, reaching maximum biogas potential can take several months. You should ensure you aren't required to repay any loans for at least the first few months of operation.

It is advisable that start-up of your biogas plant is carried out, or at least supervised, by the biogas company that designed your biogas plant. During the start-up phase, whoever will manage the biogas plant on a day-to-day basis should receive instruction for operation, maintenance and safety procedures. It is extremely important that whoever receives these instructions seeks clarification for anything they do not understand.

Typically, the biogas supplier will hand over operational responsibility of your biogas plant at the end of the start-up period. Therefore, it is your responsibility to ensure that during start-up your biogas plant is operating in accordance with agreed upon performance guarantees, such as biogas yield, uptime and throughput. Handover shouldn't occur until you are satisfied that the biogas plant is operating as expected.

Construction and start-up could take anywhere from several months to a year or more. Depending upon who carries out most of the work (i.e., a biogas company or if you do it yourself), this step will require little to significant effort on your part, and will cost anywhere from a few million to ten million dollars or more.

> Start-up should be carried out, or at least supervised, by whomever designed your biogas plant

Step 10: Day-to-Day Operations

Successful operation of your biogas plant will ultimately depend upon how hard you push it, how variable and clean your feedstock is, and level of automation. Day-to-day operations of a biogas plant typically include:

- Coordinating feedstock deliveries, performing inspections, and logging all off-farm and non-agricultural feedstock;
- Monitoring temperature and fill

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levels inside tanks;

- Adjusting tank mixing intervals to ensure mixing is effective and to prevent formation of surface layers and sediment;
- Measuring biogas yield and composition (i.e., methane, carbon dioxide, hydrogen sulphide and nitrogen) to assess biogas plant health; Inspecting all pipes and pumps, checking displays;
- Inspecting all equipment, pipes and pumps, and checking displays; and
- Co-ordinating digestate removal.

To ensure the various components of your biogas plant remain optimally functional, a maintenance schedule should be followed. You will also have to perform unplanned repairs. While you may be able to perform some of these repairs yourself, others will require an expert.

Although every on-farm biogas plant will be different, equipment most susceptible to unplanned maintenance or repairs are biogas upgrading units and combined heat and power engines, dry feedstock feeders, pumps and agitators. Having access to spare parts to maintain and repair equipment is key to avoiding lengthy downtime.

Biogas plant optimization and modifications may also be required to improve performance. For example, despite best efforts, your biogas plant may not perform as intended (e.g., mixing equipment may not be sufficient to prevent formation of surface layers, or feedstock pre-treatment equipment may not clean non-agricultural feedstock sufficiently), or available feedstock may change. If these occur, you may be required to operate your biogas plant differently, or even install new equipment.

The day-to-day operation of your biogas plant will require two to eight hours a day. Actual labour requirements will depend upon a number of factors, including type of off-farm and non-agricultural feedstock, type of feedstock pre-treatment and nutrient extraction technology, and overall level of automation. Make no mistake, on-farm biogas plants require on-going work, and the importance of committed staff is vital.

> On-farm biogas plants require on-going work, and the importance of committed staff is vital

Depending upon who carries out most of the work (i.e., if you hire someone or if you do it yourself), this step will require little to significant effort on your part, and operating costs of your biogas plant will be approximately 20% – 60% of total revenue (depending upon required level of nutrient recovery).

EXAMPLE OPERATING COSTS

Cost	Typical % of Revenue
Electricity	5 – 15%
Heat	2 – 4%
Labour	4 – 8%
Service & Maintenance	10 – 20%
Nutrient Management	0% – 20%+
Miscellaneous	1 – 10%

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6. Biogas Self-Assessment Tool

One way to determine if a biogas plant is appropriate for your farm is to hire a biogas company. However, hiring someone for advice before knowing if your farm is a good candidate for a biogas plant isn't ideal. Instead, it is a good idea to first conduct your own assessment to better understand the suitability of your farm.

The following is a Self-Assessment Tool (the Tool) developed for you to determine if your farm may or may not be a good candidate for a biogas plant. Work through all five sections of the Tool answering every question yes or no. Every question you answer with a 'no' you score 1 demerit. For every question you answer with a 'yes' no demerits are given. If the answer to a question could be yes and no, answer no. If you are unsure of the answer to a question, answer no. Because the number of 'no' answers negatively impacts the assessed suitability of your farm, effort should be made to answers every question as accurately as possible and to avoid default 'no' answers. Otherwise, even if your farm is a good candidate for a biogas plant, it may be assessed as unsuitable.

> It is always a good idea to conduct your own assessment to understand the suitability of your farm before hiring a biogas company

SELF-ASSESSMENT TOOL LEGEND

- **N** No = 1 demerit.
- **N** Maybe = 1 demerit.
- **Y** Yes = 0 demerits.
- **N - STOP** No, Stop = biogas plant unlikely to be appropriate for your farm.

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Section 1: Agricultural Feedstock

Before you complete Section 1 of the Tool, collect as much information as possible about the agricultural feedstock you have access to. This is organic material produced on farms, such as dairy, hog and poultry manure, spoiled silage and crops, crop residues and unwanted feed. Agricultural feedstock can be produced on your farm and neighbouring farms.

Q1: Does your farm produce at least 6,000 tonnes/year of feedstock? [Y → Q5; N → Q2]

Q2: Do nearby dairy, hog or horticultural farms (within approximately 10 – 15 km) or poultry farms (within 100 km) produce agricultural feedstock that you could use in your biogas plant? [Y → Q3; N - STOP]

Q3: When combined with your own feedstock, does this give you a total of at least 6,000 tonnes/year of agricultural feedstock? [Y → Q4; N - STOP]

Q4: Not including potential transportation costs, is the agricultural feedstock from nearby farms available free of charge? [Y → Q5; N → Q5]

Q5: Does your farm consistently produce feedstock year-round? [Y → Q9; N → Q6]

Q6: Does your farm consistently produce feedstock for at least 5 or 6 months of the year? [Y → Q7; N → Q7]

Q7: If you are using agricultural feedstock from nearby farms, is this produced year-round? [Y or N/A → Q9; N → Q8]

Q8: Is agricultural feedstock from nearby farms available for at least 5 or 6 months of the year? [Y → Q9; N → Q9]

Q9: Is the agricultural feedstock from your farm (or neighbouring farms) free of large amount of contaminants, such as grit, sand and soil? [Y → Q10; N → Q10]

Q10: Is the estimated average dry matter content for all agricultural feedstock you plan to use lower than 15%? [Y → Q11; N → Q11]

Q11: Do you feel confident that all agricultural feedstock from your farm and any neighbouring farms will be available for the next five to ten years? [Y / N → Add up all demerits]

Add up all demerits __________

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Once you have worked through Section 1: Agricultural Feedstock, sum up the number of demerits you scored. The potential suitability of a biogas plant for your farm based on available agricultural feedstock is as follows:

- 0 Demerits = in terms of agricultural feedstock, your farm appears to be a good candidate for a biogas plant. While you may choose to use agricultural feedstock from other farms, this is likely not necessary.
- 1 – 2 Demerits = in terms of agricultural feedstock, your farm should be a good candidate for a biogas plant. While there may be a few challenges, these shouldn't be too difficult or expensive to overcome.
- 3 – 4 Demerits = in terms of agricultural feedstock, your farm may or may not be a good candidate for a biogas plant. There are several challenges that may or may not be too difficult or expensive to overcome.
- 5 Demerits+ = unless you can find more or alternative agricultural feedstock that is more appropriate, your farm is likely not a good candidate for a biogas plant. There are too many challenges that are probably too difficult and expensive to overcome.
- Stop = unless you can find more agricultural feedstock, you should probably not build a biogas plant on your farm. The amount of agricultural feedstock determines the amount of biogas you can produce. Without at least 6,000 tonnes/year of agricultural feedstock, it will be difficult to build a profitable on-farm biogas plant in B.C.

Section 2: Non-Agricultural Feedstock

Before you complete Section 2 of the Tool, collect as much information as possible about the non-agricultural feedstock you have access to. This is food waste produced by non-farm sources, such as food and beverage processing, grocery stores, restaurants, hotels, abattoirs and municipalities (often called green bin waste). Non-agricultural feedstock should be produced within the region your biogas plant will be located. For questions 4 and 8 use the *Typical Biogas Yield* graph on page 12.

Q1:
Are you willing to bring non-agricultural feedstock, such as food processing, grocery store and restaurant waste, onto your farm?
Y ↓ — N - STOP

Q2:
Are there at least 6,000 tonnes/year of non-agricultural feedstock available in your region?
Y → Q6 — N ↓

Q3:
Are there at least 4,000 tonnes/year of non-agricultural feedstock available in your region?
Y → Q6 — N ↓

Q4:
Is estimated average biogas yield of all non-agricultural feedstock at least 200 m^3/tonne?
Y → Q6 — N ↓

Q5:
Are there at least 2,000 tonnes/year of non-agricultural feedstock available in your region?
Y ↓ — N ↓

Q6:
Is the non-agricultural feedstock available year-round?
Y → Q8 — N ↓

Q7:
Is the non-agricultural feedstock available for at least 6 months of the year?
Y ↓ — N ↓

Q8:
Is estimated average biogas yield of all non-agricultural feedstock at least 100 m^3/tonne?
Y ↓ — N ↓

Q9:
Is the non-agricultural feedstock generally free from contaminants, such as plastic, glass and metal?
Y ↓ — N ↓

Q10:
Does the non-agricultural feedstock come with a tipping fee (i.e., will you be paid to accept it)?
Y ↓ — N ↓

Q11:
Does the non-agricultural feedstock come from at least two or three sources (i.e., not a single source, such as a large food processor)?
Y → — N →

Add up all demerits ___________

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Once you have worked through Section 2: Non-Agricultural Feedstock, sum the number of demerits you scored. The potential suitability of a biogas plant for your farm based on available non-agricultural feedstock is as follows:

- 0 Demerits = in terms of non-agricultural feedstock, your farm appears to be a good candidate for a biogas plant.
- 1 – 2 Demerits = in terms of non-agricultural feedstock, your farm should be a good candidate for a biogas plant. While there may be a few challenges, these shouldn't be too difficult or expensive to overcome.
- 3 – 4 Demerits = in terms of non-agricultural feedstock, your farm may or may not be a good candidate for a biogas plant. There are several challenges that may or may not be too difficult or expensive to overcome.
- 5 Demerits+ = unless you can find more or alternative non-agricultural feedstock that is more appropriate, your farm is likely not a good candidate for a biogas plant. There are too many challenges that are probably too difficult and expensive to overcome.
- Stop = unless you have access to at least 40,000 tonnes/year of agricultural feedstock, or are willing to bring non-agricultural feedstock onto your farm, you should probably not build a biogas plant. Without at least 40,000 tonnes/year of agricultural feedstock or some non-agricultural feedstock it will be very difficult to build a profitable on-farm biogas plant in B.C.

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Section 3: Location

Before you complete Section 3 of the Tool, collect as much information as possible about the site on which you plan to build your biogas plant. This site could be anywhere on or off your farm. Typically, most on-farm biogas plants are located near the barns. However, this is not always the case.

Q1: Do you have at least 2 acres (0.8 hectares) of land on which to build your biogas plant? — Y ↓ / N ↓

Q2: Is the chosen site within close proximity to where you store your agricultural feedstock (e.g., within a few hundred metres)? — Y ↓ / N ↓

Q3: Is the chosen site easily accessible by truck (i.e., are roads to your site suitable for daily truck use) year-round? — Y ↓ / N ↓

Q4: Will your neighbours be ok with the increased traffic to and from the chosen site to deliver and collect feedstock and/or digestate? — Y ↓ / N ↓

Q5: Is the chosen site relatively flat (i.e., for every 100 feet of horizontal distance, does the elevation change by very little)? — Y ↓ / N ↓

Q6: Is the chosen site in an area that isn't prone to flood? — Y ↓ / N ↓

Q7: Does the chosen site have a low water table (e.g., if you dig a 2 – 3 metre pit does it only very slowly fill with groundwater)? — Y ↓ / N ↓

Q8: Are the neighbours upwind (taking into account the prevailing wind) of the chosen site? — Y ↓ / N ↓

Q9: Is the chosen site at least 30 metres away from residential buildings, lot lines, water supply intakes and watercourses? — Y ↓ / N - STOP

Q10: Can all off-farm feedstock be transported to the chosen site without coming into contact with feed or animals on your farm (i.e., causing a potential biosecurity risk). — Y ↓ / N ↓

Q11: Do you own the site on which you plan to build your biogas plant? — Y → / N →

Add up all demerits ___________

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Once you have worked through Section 3: Location, sum the number of demerits you scored. The potential suitability of a biogas plant for your farm is as follows:

- 0 Demerits = your chosen site appears to be a good candidate for a biogas plant.
- 1 – 3 Demerits = your chosen site should be a good candidate for a biogas plant. While there may be a few challenges, these shouldn't be too difficult or expensive to overcome.
- 4 – 6 Demerits = your chosen site may or may not be a good candidate for a biogas plant. There are several challenges that may or may not be too difficult or expensive to overcome.
- 7 Demerits+ = unless you can find an alternate site that is more appropriate, your farm is likely not a good candidate for a biogas plant. There are too many challenges that are probably too difficult and expensive to overcome.
- Stop = unless you can find an alternate site that is at least 30 metres away from residential buildings, lot lines, water supply intakes and watercourses, you will probably not be allowed to build your biogas plant.

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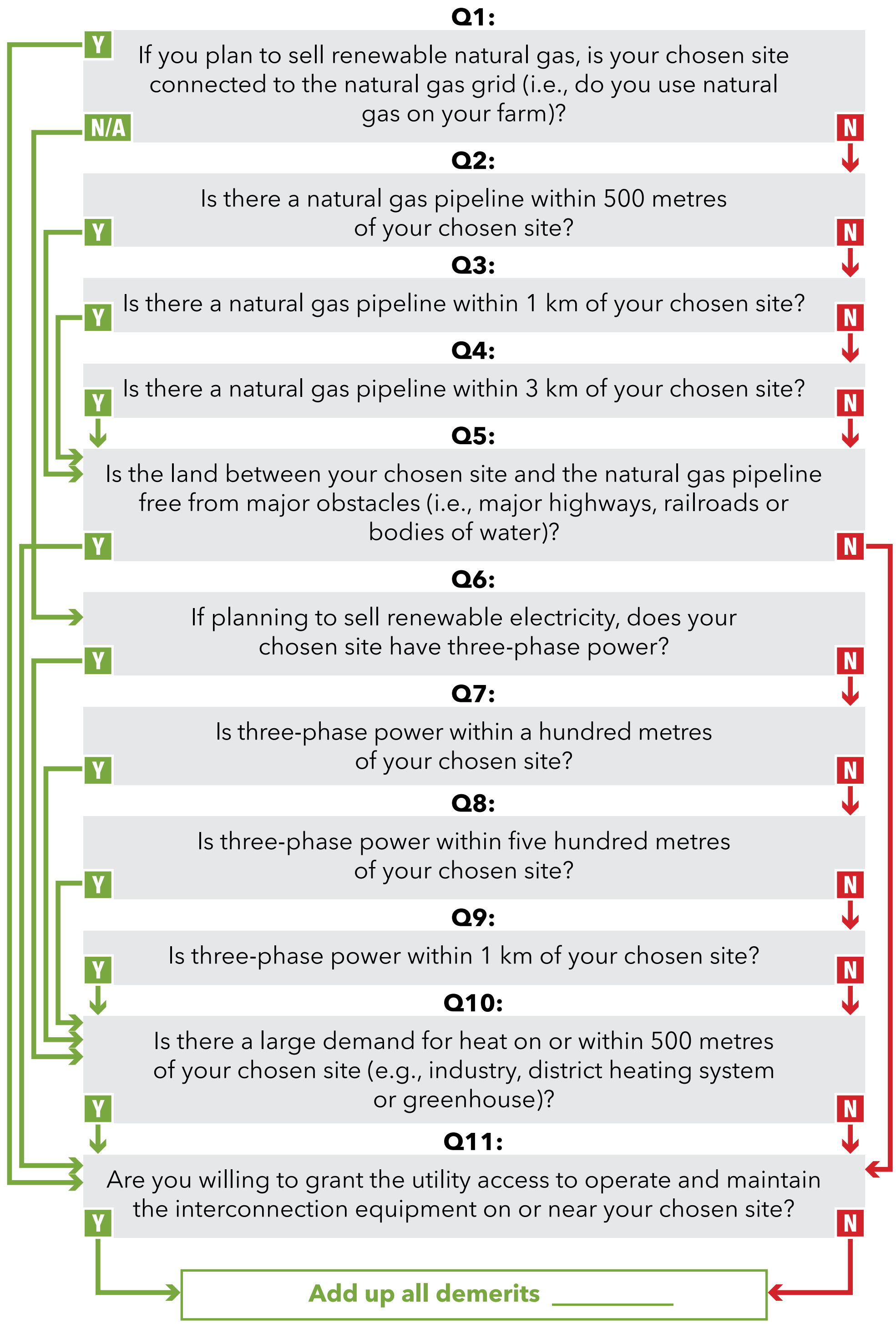
Section 4: Utility Infrastructure

Before you complete Section 4 of the Tool, decide if you want to sell renewable natural gas or renewable electricity, and collect as much information as possible about the appropriate energy utility infrastructure on or near the chosen site for your biogas plant.



Once you have worked through Section 4: Utility Infrastructure, sum the number of demerits you scored. The potential suitability of a biogas plant for your farm based on chosen site utility infrastructure is as follows:

- 0 Demerits = in terms of utility infrastructure, your chosen site appears to be a good candidate for a biogas plant.
- 1 – 2 Demerits = in terms of utility infrastructure, your chosen site should be a good candidate for a biogas plant. While there may be a few challenges, these shouldn't be too difficult or expensive to overcome.
- 3 – 4 Demerits = in terms of utility infrastructure, your chosen site may or may not be a good candidate for a biogas plant. If you plan to sell renewable natural gas, these challenges shouldn't be too difficult or expensive to overcome. If you plan to sell renewable electricity, these challenges may be too difficult or expensive to overcome.
- 5 Demerits+ = unless you can find an alternate site that is more appropriate, your farm is likely not a good candidate for a biogas plant. There are too many challenges that are probably too difficult and expensive to overcome.

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Section 5: Profitability

Before you complete Section 5 of the Tool, convert your estimated yearly biogas yield (using the Typical Biogas Yield Graph on page 12) into GJ or kWh (see page 21 and 22). Also estimate investment cost (using the Estimated Investment Costs graph on page 27). If you plan to sell renewable natural gas or if you scored high in the previous sections, pick an investment cost between the high and average cost estimate lines in the graph. If you plan to sell renewable electricity or if you scored low in the previous sections, pick an investment cost between the low and average cost estimate lines in the graph.

Q1: If you are selling renewable natural gas (RNG), and if sold for $22/GJ, will yearly revenues account for at least 20% of estimated investment cost? (Y → Q7; N/A → Q4; N → Q2)

Q2: If you sell your RNG for $26/GJ will yearly revenues account for at least 20% of estimated investment cost? (Y → Q7; N → Q3)

Q3: If you sell your RNG for $30/GJ will yearly revenues account for at least 20% of estimated investment cost? (Y → Q7; N → Q7)

Q4: If you sell your renewable electricity for $0.10/kWh will yearly revenues account for at least 20% of estimated investment cost? (Y → Q7; N → Q5)

Q5: If you sell your renewable electricity for $0.10/kWh will yearly revenues account for at least 15% of estimated investment cost? (Y → Q7; N → Q6)

Q6: If you sell your renewable electricity for $0.10/kWh will yearly revenues account for at least 10% of estimated investment cost? (Y → Q7; N → Q7)

Q7: Are you willing to invest the millions of dollars necessary to build an on-farm biogas plant? (Y → Q8; N → Q8)

Q8: Does your farm already have infrastructure that can be used for agricultural feedstock and digestate storage? (Y → Q9; N → Q9)

Q9: Do you, or do the farms you plan to take feedstock from, purchase phosphorus and nitrogen for field application? (Y → Q10; N → Q10)

Q10: Is your farm in a region of B.C. with few dairy or poultry farms? (Y / N)

Add up all demerits ________

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Once you have worked through Section 5: Profitability, sum the number of demerits you scored. The potential suitability of a biogas plant for your farm based on profitability is as follows:

- 0 Demerits = in terms of profitability, your farm appears to be a good candidate for a biogas plant.
- 1 – 2 Demerits = in terms of profitability, your farm should be a good candidate for a biogas plant. While there may be a few challenges, these shouldn't be too difficult or expensive to overcome.
- 3 – 4 Demerits = in terms of profitability, your farm may or may not be a good candidate for a biogas plant. There are several challenges that may or may not be too difficult or expensive to overcome.
- 5 Demerits+ = unless you can change your biogas plant, your farm is likely not a good candidate for a biogas plant. There are too many challenges that are probably too difficult and expensive to overcome.

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Section 6: Self-Assessment Results

Once you have worked through all five sections of the Tool, answering every question yes or no, sum the total number of demerits you scored. Based on your total score, the potential suitability of a biogas plant for your farm is as follows:

- 0 – 5 Demerits = your farm appears to be a very good candidate for a biogas plant. There seems to be no or very few challenges to building a profitable biogas plant on your farm.
- 6 – 10 Demerits = your farm appears to be a good candidate for a biogas plant. While there are a few challenges to building a profitable biogas plant on your farm, these challenges are likely typical for most on-farm biogas plants in Canada.
- 11 – 15 Demerits = your farm could be a good candidate for a biogas plant. While there are several challenges to building a profitable biogas plant on your farm, these challenges shouldn't be too difficult or expensive to overcome.
- 16 – 20 Demerits = your farm may or may not be a good candidate for a biogas plant. There are quite a few challenges to building a biogas plant on your farm. Depending upon what these challenges are, they may or may not be too difficult or expensive to overcome.
- 21 Demerits+ = your farm is likely not a good candidate for a biogas plant. There seems to be too many challenges to building a profitable biogas plant on your farm.

If you scored 10 demerits or less, and especially if you scored five demerits or less, you should consider moving ahead with your biogas plant. Typical next steps include contacting the appropriate utility to discuss an energy supply contract, designing your biogas plant, and assessing your biogas plant's profitability using a detailed financial model. You may choose to hire a biogas company to help with these steps.

If you scored 11 – 15 demerits, you might want to consider moving ahead with your biogas plant. If you choose to move ahead, a good next step is to contact the appropriate utility to discuss an energy supply contract, especially if you scored poorly in the utility infrastructure section of the Tool. It may also be advisable to conduct more research to determine how difficult and expensive the challenges you face will be to overcome.

If you scored 16 – 20 demerits, you may or may not want to consider moving ahead with your biogas plant. However, before you move ahead, it is advisable to conduct more research to determine if the challenges you face will be too difficult and expensive to overcome. If you scored 21 demerits or more, you probably shouldn't consider moving ahead with a biogas plant.

Whatever you scored, you should remember that the Tool is only a first-level assessment of the potential suitability of a biogas plant for your farm. Many factors influence whether your farm is a good candidate for a biogas plant, and it is not possible to include all these factors in this Tool. Therefore, the results of your self-assessment should only be seen as an indication as to whether or not you should consider investing more time and money into assessing the suitability of a biogas plant for your farm.

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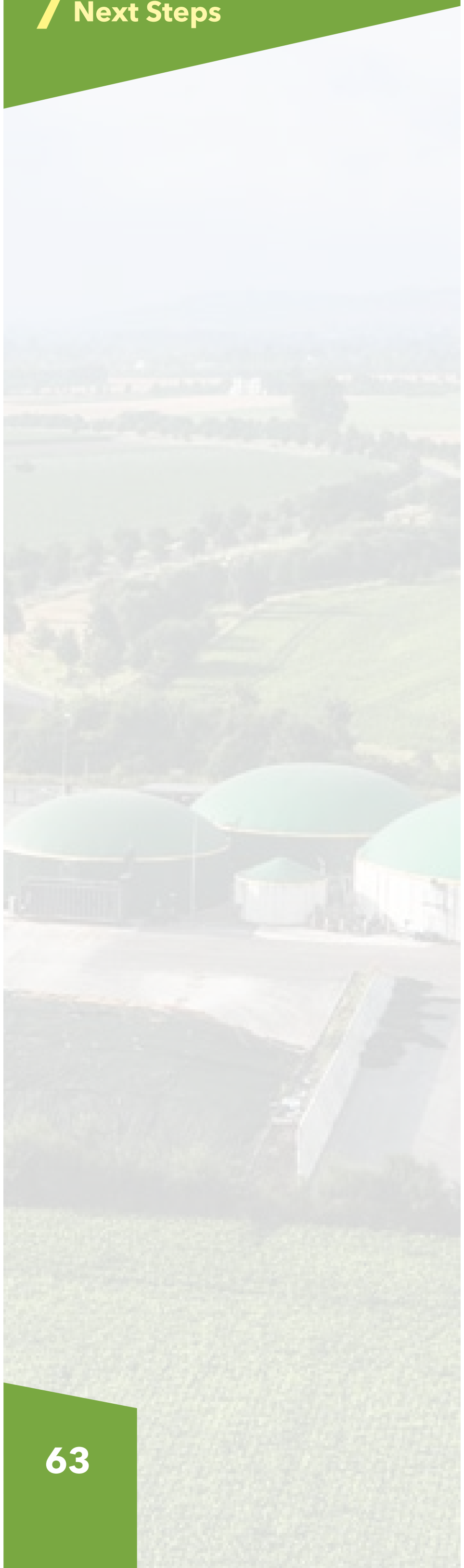

7. Next Steps

Having read this Handbook, you should now understand how biogas plants work, be aware of what is required to build and operate your own on-farm biogas plant in B.C., and know the potential suitability of a biogas plant for your farm.

If the potential suitability of a biogas plant for your farm looks promising and you aren't put off by the required effort and cost, you are ready to begin completing the development steps listed in Chapter 5 of this Handbook. At some point during these development steps, you will need to hire a biogas company. There are many different biogas companies working within B.C., Canada and the United States. Furthermore, European biogas companies also undertake projects in North America. For this reason, it is not possible to provide a complete list of biogas companies here.

Instead, you should research biogas companies yourself. Some useful sources of information include the Canadian Biogas Association, the American Biogas Council, the B.C. Agriculture Council, and the B.C. Ministry of Agriculture. You should also contact any appropriate producer associations, including the B.C. Dairy Association, the B.C. Food Processors Association, and the Sustainable Poultry Farming Group, to ask about any information or useful contacts they might have.

During your research, it is important to remember that while people can suggest biogas companies to work with, they cannot tell you which companies are suitable for your needs. Therefore, it is your responsibility to assess these companies before choosing which one to work with. This assessment should include whether they have previous experience with on-farm biogas plants, whether they have local biogas experience, and where they are located. You should also contact any references they provide.

During your search for a biogas company, and before completing too many development steps, it is advisable that you visit at least one on-farm biogas plant. On-farm biogas plants can be toured throughout B.C. and Canada, the US and Europe. Ideally, the biogas plants you choose to visit will be similar in scale, feedstock type, and biogas use as your own, although this isn't vital. Whatever biogas plants you choose to visit, be sure to speak with the operator to gain valuable insight and experience into owning and operating your own biogas plant.