Canadian Anaerobic Digestion Guideline:

Food and Organic Waste Processing Facilities

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Prepared by:

Canadian Biogas Association

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Foreword

While composing the *Canadian Anaerobic Digestion Guideline: Food and Organic Waste Processing* may have only taken the better part of a year, I dare say that this document is a product of more than forty years' worth of priceless hands-on experience. The Guideline, prepared by highly experienced members of the Canadian Biogas Association, brings together decades of practical, and real-world experience about how to design, build, and operate digesters. Every contributor to this book has "gotten their boots dirty," so to speak.

Building on the experience of the municipal sewage anaerobic digestion community, the first farm-based anaerobic digesters in Canada are credited to Prof. H. Lapp at the University of Manitoba who worked on hog-manure digesters in the 1970s.[1] I remember well my mentor Ray Stickney telling me of his early work with the first cattle-based digester system built in 1979 at Roslyn Park Farms in Ontario.

Although digester owners and operators back then were undoubtedly optimistic, it didn't take long for that initial optimism to die down as they faced one challenge after another. Within the decade, those digesters – the first of their kind in Canada – were shut down and scrapped.

For almost 25 years, the biogas industry in Canada lay dormant until a small group of intrepid farmers took up the challenge and constructed next-generation digesters in the early 2000s. This handful of digester operators formed the Canadian Biogas Association in 2008. Equipped with better technology and renewed enthusiasm, they went through years of growing pains to bring us where we are today – a group of over 135 CBA members stretching from British Columbia to Newfoundland, all focused on building the food and organic waste biogas sector in Canada.

This Guideline is a distillation of lessons learned over those years, most of them hard-earned and expensive. It's the first-ever guideline for food and organic waste anaerobic digesters in Canada, and it was written so that future digester developers, owners, and operators can learn from the challenges of the past. Forty years after the Roslyn Park digester, I'm extremely proud to say that the existence of this guideline document is a sign of how far our biogas sector has come. As a low-carbon, or even carbon-negative, fuel source, the future of biogas is now brighter than ever.

In closing, I'd like to express my utmost appreciation for all the people who contributed their knowledge to this document – the folks who worked through the 3 a.m. foaming problems of the early digesters, the pioneers of the '70s and '80s, and the leaders of the 2nd generation of digesters in the 2000s. It was a tough and grueling road to get here, but we've finally made it. This document is as much a product of your hard work as it is a tribute to your contributions to the Canadian biogas sector.

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Waterloo, Ontario, 2019

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[1] Van Die, P., 1987. *An Assessment of Agriculture Canada's Anaerobic Digestion Program*, Engineering and Statistical Research Branch, Agriculture Canada Research Branch, Report No. 1933.

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Disclaimer

While this technical guide is written to provide detailed information, it should not be construed as legal advice. Readers should note that considerations for developing and operating anaerobic digestion facilities vary greatly based on size, type, and location. Information presented in this document should be evaluated and interpreted by the reader at his or her own risk.

Readers are strongly encouraged to seek out technical experts in the biogas industry to address their own applications.

The authors, editors, and subject matter contributors of this document will not be liable for any claims or losses of any kind arising from the use of, or reliance upon, this information.

Glossary

Airport Zoning Regulations (AZR) – Restrict the heights of buildings, structures, and objects (including tall exhaust stacks and natural growth, such as trees) on **regulated land**. There are also specific restrictions on land use for organic waste management, because these uses can cause a bird hazard. Legislation allowing for Airport Zoning Restrictions is found in section 5.4 of the *Canadian Aeronautics Act*.

Anaerobic Digestion (AD) – The biodegradation or decomposition of organic matter by naturally occurring microorganisms in an oxygen-free environment. As a result of this biodegradation, the microbes generate **biogas**. The biogas generated through anaerobic digestion can be used primarily to 1) fuel electrical generators, or 2) it can be further processed into renewable natural gas. The **digestate** may also be used as a nutrient-rich soil amendment most commonly in agricultural and horticulture operations.

Biogas – A gaseous by-product of the anaerobic digestion process. The major components of biogas are methane (CH_4) and carbon dioxide (CO_2). Biogas normally consists of 50-60 percent methane.

Biological Nutrient Removal (BNR) – A general type of wastewater treatment process that can treat nitrogen, phosphorus, or both biologically. For AD facilities, this typically refers to a wastewater treatment process that treats ammonia in effluent to achieve compliance with sanitary sewer or other discharge limits.

Biological Oxygen Demand or Biochemical Oxygen Demand (BOD) – A laboratory test for determining how much oxygen biological microorganisms use up in a body of water over a period of time. The oxygen is used to oxidize organics and other waste materials. The standard test duration in most regulations is a five-day test, referred to as the BOD_5.

Biomethane – another term used for Renewable Natural Gas, see Renewable Natural Gas.

Biomethane Potential (BMP) – A laboratory test for determining how much biogas and how much methane a certain **feedstock** can generate under ideal laboratory conditions. This test assesses the suitability of organic waste streams for anaerobic digestion and biomethane production.

Biosolids – are the organic materials resulting from the treatment of sewage sludge. Biosolids are nutrient-rich and are often recycled as a fertilizer and soil amendment. Biosolids originate from sewage treatment processes and are NOT included within the scope of this guideline document.

Bovine Spongiform Encephalopathy (BSE) – Informally called mad cow disease, this is a fatal disease of cattle. Residuals from cattle slaughter that may contain BSE infected materials are called Specified Risk Materials (SRM) and are subject to regulation by the Canadian Food Inspection Agency (CFIA). SRM is a prohibited feedstock unless preprocessed in a CFIA approved treatment system.

Buffer Zone – An area of land between different land uses, used to separate the two and help avoid potential conflicts.

Capacity – The maximum power or amount of material that a machine or system can optimally produce or process. The capacity of electrical generating equipment is generally expressed in kilowatts (kW) or megawatts (MW) of electrical power. Renewable natural gas (RNG) systems can express their capacity in terms of normal cubic meters per hour (Nm^3/hr) of raw biogas or Gigajoules per year (GJ/year) or million

British thermal units per year (MMBtu/year) of produced RNG. The AD processing capacity is usually expressed in cubic meters or tonnes (1,000 kilograms) of unprocessed feedstock per day.

Carbon Intensity (CI) – is the emission rate of carbon relative to a unit of production or activity. This value is a score for a facility that is created by modeling a full life cycle analysis of the project, including feedstock, biogas upgrading, coproducts, energy consumption, finished fuel delivery, and many other factors. The Carbon Intensity is used in relation to the sale of RNG to California and other jurisdictions. For an AD facility, this could be carbon emissions per tonne of organic waste processed or carbon emissions per GJ of energy produced.

Chemical Oxygen Demand (COD) – A laboratory test that measures the amount of organic matter in a sample. The COD is the total amount of oxygen required to chemically oxidize the organic material in a sample. This is one way to measure the fuel value of feedstock. In the digester, a portion of the feedstock COD is converted to biogas. The amount of methane produced per kilogram of COD converted in the digester is constant, regardless of the type of feedstock.

Continuously Stirred Tank Reactor (CSTR) – Refers to a type of anaerobic digestion system that runs at a steady state with continuous flow of materials into and out of the process. A CSTR is a theoretically perfectly well-mixed tank whereby the output is the same as the contents of the tank.

Circular Economy – An economic system where, ideally, waste does not exist. In practice, the value of products and materials is maintained for as long as possible. Waste is minimized and resources including nutrients continue to re-circulate within the economy, to be used again to create further value.

Co-generation – see **Combined Heat and Power (CHP)**.

Combined Heat and Power (CHP) – The sequential production of electricity and capturing the thermal energy for beneficial use, from a common fuel source. For example, in an anaerobic digestion system the biogas may be burned in an engine that drives an electrical generator to produce electricity. The heat generated by the engine can be captured and used to heat the digester or used for other useful applications.

Digestate – A solid or liquid that results following the treatment or biodegradation of organic matter in an anaerobic digestion facility. Digestate may be used as a beneficial soil amendment or fertilizer, most commonly in agricultural and horticultural operations.

Effluent – The liquid or gas discharged from a process or a chemical reactor. The effluent from an anaerobic digester is commonly called **digestate**. A common usage of the term effluent is to refer to the liquid discharged from an anaerobic digester facility. This effluent may be from a wastewater treatment facility that treats the watery portion of the digestate.

Emission Summary and Dispersion Modelling (ESDM) Report – A study required by provincial environmental regulators that covers an assessment of air pollution emissions from a facility and how they disperse. The regulations list specific requirements for the study. This report is prepared by a qualified professional.

Feedstock – Any input material which is converted to another form or product. The desired feedstocks for anaerobic digestion systems include food and agricultural wastes, manure, source separated organics, and other biodegradable organic material.

Fats, Oil, and Grease (FOG) – A laboratory test that measures the total amount of fats, oils, and greases in a sample. FOG concentrations in a feedstock or in the digester are measured to allow the digester operator to understand the composition of their feedstock and maintain stable digester health.

FOS / TAC – Similar to the Ripley Ratio, the FOS/TAC is the ratio of the volatile fatty acid to total inorganic carbon concentrations. From the German Flüchtigen Organischen Säuren (FOS), a measure of the volatile fatty acids and the Totales Anorganisches Carbonat (TAC), the total inorganic carbon.

Grid – The electrical or natural gas transmission and distribution system that links sources to customers. Electrical power plants are linked to customers through high voltage transmission lines. Natural gas customers are linked to gas sources through the gas transmission and distribution pipelines.

Long-Chain Fatty Acids (LCFAs) – A laboratory test that measures the amount and type of different organic fatty acids, for example, palmitic acid and oleic acid. LCFA concentrations indicate the amount of saturated and unsaturated fats in a feedstock or in the digester and allow for the digester operator to understand the composition of their feedstock in order to maintain stable digester health.

Municipal Solid Waste (MSW) – All types of solid waste generated by a community including households, commercial businesses, and institutions. **Source Separated Organics** are one type of municipal solid waste.

pH – A measurement of the intensity of the alkaline or acidic strength of water. Values normally range from 0 – 14, where 0 is the most acidic and 14 is the most alkaline and 7 is neutral.

Pressure Swing Adsorption (PSA) – Is a type of technology used in biogas upgrading or refining systems to remove CO_2 from a biogas stream.

Regulated Land – a general term referring to any land that is covered by regulations. Land use regulations can originate at the federal, provincial, or municipal level.

Renewable Natural Gas (RNG) or **biomethane** – A biogas which has been upgraded to a quality that meets the quality requirements for injection into the natural gas grid. RNG is similar to fossil natural gas and typically has a methane concentration of 95 percent or greater.

Sensitive Receptors – Are specific locations where people or other living things reside that may have an increased sensitivity to potential discharges. Typically, increased sensitivity results from age or health, for example, schools, day-care centers, hospitals, and nursing homes. A sensitive or endangered species can also be a sensitive receptor.

Sludge – Is a slurry mixture of water and solids. Sludge can be of different consistencies, although most sludges are typically considered to be pumpable.

Social License – Refers to a community's general attitudes and opinions towards a project. The term Social License refers to the overall level of community acceptance, and not a formal regulatory approval process or document.

Source Separated Organics (SSO) – Organic waste that has been separated from other waste by the waste generator, generally under a program (for example, a municipal green bin program). Typically, SSO includes food waste, both avoidable and unavoidable, non-recyclable paper such a tissue and paper-toweling, and may contain leaf and yard waste. A minority of municipal green bin programs also allow diapers, pet waste, and sanitary products. The composition of each SSO stream is unique to the input components collected in the respective program.

Specified Risk Material (SRM) – Refers to specific organs and other material left over from cattle slaughter that may contain BSE infectivity. Special guidelines are in place for this material to prevent BSE from entering the human food chain, including the production of animal feed, pet food, and fertilizers. SRM is a prohibited feedstock unless preprocessed in a CFIA approved treatment system. Refer directly to appropriate CFIA references for the precise technical definition of SRM materials and SRM management protocols.

Vector and Vermin – A vector is an organism that can transmit infection. For example, insects such as fleas, flies, and mosquitoes can be vectors. Rodents are generally considered “vermin”, and these can serve as hosts for vectors; for example, a disease carrying flea (vector) living and moving on a rat (vermin) host.

Volatile Solids (VS) – Volatile solids is a laboratory measurement whereby the solids that are lost, or “burned off”, on ignition of dry solids at 550° Celsius are measured. The volatile solids measurement is a simplified way to estimate the organic matter, and hence the fuel value, of a specific feedstock. The amount of methane produced per kilogram of VS in the feedstock depends on the type of feedstock.

Volatile Fatty Acids (VFAs) or Short-Chain Fatty Acids (SCFAs) – A laboratory test that measures the amount and type of organic acids, for example, acetic acid (commonly called vinegar) in a sample. Organic acids are produced by microbes during the early part of the anaerobic digestion process. These organic acids are also produced in silage from sugars and other carbohydrate sources. Volatile fatty acids are volatile, which means that they will volatilize in air, depending on temperature. If released into the air, VFAs can be quite odourous.

Abbreviations

ACH – Air Changes per Hour

AD – Anaerobic Digestion

AZR – Airport Zoning Regulations

BOD – Biochemical Oxygen Demand

BMP – Biomethane Potential

BNR – Biological Nutrient Removal

BSE – Bovine Spongiform Encephalopathy, informally called "mad cow disease"

CFIA – Canadian Food Inspection Agency

CHP – Combined Heat and Power

CI – Carbon Intensity

C:N ratio – Carbon to Nitrogen Ratio

COD – Chemical Oxygen Demand

CSTR – Continuously Stirred-Tank Reactor

DM – Dry Matter

ESDM – Emission Summary and Dispersion Modelling

FOS / TAC – from the German Flüchtigen Organischen Säuren (FOS) / Totales Anorganisches Carbonat (TAC)

FOG – Fats, Oils, and Grease

GHG – Greenhouse Gas

GJ – gigajoule

HAZOP – Hazard and Operability study

kWh – Kilowatt-Hour

LCFA – Long-chain fatty acids

MMBtu – million British thermal units

MSW – Municipal Solid Waste

NPK – Nitrogen, Phosphorous, Potassium

OU – Odour Unit

PPM – Parts per Million

PSA – Pressure Swing Adsorption

RNG – Renewable Natural Gas

RR – Ripley Ratio

SBR – Sequencing Batch Reactor

SME – Subject Matter Expert

SSO – Source Separated Organics

TA – Total Alkalinity

TS – Total Solids

VFA – Volatile Fatty Acids

VOC – Volatile Organic Compound

VS – Volatile Solids

Executive Summary

The Canadian Biogas Association (CBA) has prepared the Canadian Anaerobic Digestion (AD) Guideline: Food and Organic Waste Processing Facilities to assist stakeholders in the siting, design, approval, and operations of AD facilities that process food and other organic waste materials in Canada. Biogas and digestate are by-products of the AD process that have demonstrated beneficial use in local communities.

There is currently a shortage of renewable fuels available on the scale needed to address climate change. Much of the emphasis of decarbonization to date has focused on the electricity grid but electricity only accounts for about a quarter of Canada's greenhouse gas emissions. Industry, heating, transportation, and agriculture all require their own solutions.

Biogas provides a versatile, low-carbon fuel that can be used to generate electricity or be upgraded to produce vehicle fuels or a renewable natural gas substitute. Further, unlike other sources of energy that deplete natural resources to produce energy, AD facilities replenish our natural resources. AD facilities transform organic wastes into valuable energy and digestate, which is natural, nutrient-rich, soil amendment that replenishes our soil health.

Anaerobic digestion is a model of the circular economy – methane emissions from food and organic wastes are valorized rather than emitted into the atmosphere, low-carbon energy replaces fossil fuels, and digestate is returned to the soil to provide nutrients and organic matter for crop production – completing the loop. Anaerobic digestion and biogas are powerful tools in the fight against climate change, reducing both methane and carbon dioxide emissions, as well as providing a drop-in replacement fuel useful in many applications.

"As a low-carbon fuel source, biogas offers immediate solutions to environmental, climate and waste management issues impacting our local communities and businesses."

– Jennifer Green

The siting, approval, and operation of AD facilities present many fundamentally different issues when compared to other facilities. Hence, the codification of current experience provides helpful guidance to all parties.

The AD Guideline describes recommended control measures for land use planning considerations, such as site selection considerations, and best management practices for the design and operation of food and organic waste AD facilities. The AD Guideline reflects current legislation and describes best management practices in Canada.

The content of the AD Guideline was developed by technical and subject matter experts in the anaerobic digestion and biogas industry through practical and informed experience.

1.0 Introduction

Anaerobic digestion (AD) is a proven and well understood technology in Canada with more than a hundred operational facilities across the country. Each of these facilities produce renewable power in the range of 20 kW to more than 2,000 kW. Anaerobic digestion is an effective means to process food and organic waste materials that results in the production of not only low-carbon fuel with meaningful greenhouse gas (GHG) emission reductions, but also the return of circular return of nutrients to the land through the production of soil enhancing digestate. GHG reduction is achieved through the capture and utilization of biogas to produce usable energy such as 1) Renewable Natural Gas (RNG), 2) heat, and 3) electricity. **Table 1.1** provides an overview of some of the ways in which AD can align with environmental, economic, and social goals of governments across the country.

Table 1.1 – The Benefits of Anaerobic Digestion

Environmental Benefits	Renewable Energy Benefits	Agricultural Benefits	Socio-Economic Benefits
• Sustainable waste and resource management • Air and water quality improvements • Reduced GHG emissions • Reduction of odours as compared to unprocessed manure • Reduced reliance on fossil fuels and artificial fertilizers • Reductions of pathogens	• Stable baseload energy • Energy security and diversity of supply • Energy can be utilized on-site • Helps achieve renewable energy targets	• Rural economic development • Increased soil health and productivity • Increased biodiversity of soil organisms • Diversification of farm economy	• Capital investment • Job creation • Regional economic development

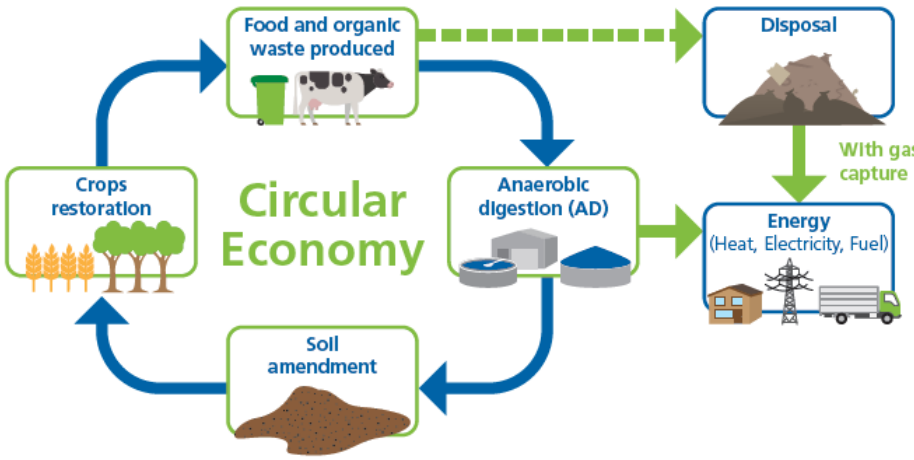
Anaerobic digestion is a biological process whereby organic material is broken down by micro-organisms in a controlled, oxygen-free environment. AD results in the conversion of organic materials into 1) biogas, a renewable source of methane-rich gas, and 2) digestate, a nutrient-rich material that includes valuable plant nutrients such as nitrogen, phosphorus, and potassium (NPK). A schematic summary showing a more detailed outline of the AD process is provided in **Appendix A**.

Biogas is a renewable source of methane, the main ingredient in natural gas. It can be used for heating and cooling, or to generate electricity that can be used on-site or fed into the distribution grid. It can also be refined into RNG that can be injected into the natural gas distribution or transmission pipelines and/or compressed and used as a vehicle fuel. The entire system, including the energy generating components, is typically referred to as a biogas facility.

As illustrated in **Figure 1.1**, the biogas industry in Canada is helping to close the loop by anaerobically digesting organic waste materials, avoiding disposal in landfills, and converting them to low-carbon energy and soil amendments to fuel our circular-economy.

1.1 Purpose

Figure 1.1 – Anaerobic Digestion – A Key Part of the Circular Economy



The purpose of this AD Guideline is to assist stakeholders in the deployment of AD facilities in a manner that improves outcomes and ensures environmental sustainability. It includes recommended planning, siting, design, operational, and risk management practices for AD facilities that process food and organic waste.

1.2 Objectives

The CBA's objectives in developing this Guideline are to:

- Create a clear outline of best practices for biogas projects;
- Assist developers and stakeholders with the regulatory process and remove barriers to support growth in the green economy;
- Inform proponents to minimize or prevent, the exposure of any person, property, plant or animal life to adverse effects associated with the operation of food and organic waste AD facilities; and
- Provide a reference document for the design, approval, and operation of safe and efficient AD facilities.

1.3 Scope

This AD Guideline applies to facilities across Canada that anaerobically digest food and organic waste materials – including new and existing municipal, commercial, and farm-based facilities. Landfill gas systems and anaerobic wastewater treatment processes are not specifically addressed in this AD Guideline.

The scope of this AD Guideline applies only to the AD facility itself and does not include best practices for downstream upgrading and utilization of the biogas or digestate.

The application of the AD Guideline is intended for use by developers, operators, government entities, and any organization or individual with an interest in, or a role to play in, developing, siting, or operating AD facilities.

2.0 Legislation, Approvals and Standards

In Canada, resource recovery and waste management are important areas of governmental focus aimed primarily at protecting public health, the environment, and preserving natural resources. Food and organic waste is a major part of the country's waste management stream, representing roughly 40 percent by weight. The oversight of the management of these wastes involves various government bodies at the federal, provincial/territorial, and municipal levels.

Federal responsibility is generally focused on the management of waste that could impact other jurisdictions and hazardous materials. It also applies to waste management on federal lands, in federal facilities, and on First Nations' land.

Agriculture and Agri-Food Canada, through the Canadian Food Inspection Agency (CFIA), administer the national Fertilizers Act and the fertilizer registration program. Digestate may be, but is not always, managed under the Fertilizers Act in Canada. Digestate producers may choose to market their product as a Fertilizer under the requirements of this legislation. In all cases however, such a decision would have to be taken in the context of other environmental approvals issued for the facility by the local provincial environmental regulator.

For instance, Fertilizer (as registered under the Act), is explicitly recognized in the Province of Ontario within the provincial Nutrient Management Act, and as such Fertilizer is explicitly permitted for application to the land. Producers in Ontario have used this recognition to secure formal permission from their local environmental regulators to use this Fertilizer registration as their approved method of marketing their digestate.

Not all provinces provide this regulatory connection, and consequently, producers should engage with their local environmental regulator before pursuing this strategy.

Provinces and territories are generally responsible for setting most rules and responsibilities related to resource recovery and waste management in Canada. These include regulations that generally apply to the siting, development, and operation of AD facilities. Regulations created by provincial and territorial governments generally apply to:

- Collection and transportation of wastes;
- Limits on the types and quantities of feedstock and/or feedstock ratios that can be received for processing. For example, quantity or ratio of manure vs. non-manure feedstocks or off-farm vs. on-farm feedstocks. These limits can also include specific mandates regarding testing and pre-clearance of feedstocks;
- Health and safety requirements;
- Digestate and nutrient management to regulate the storage and application of nutrients on land, including agricultural land;
- Environmental protection and permitting to regulate waste management activities, including anaerobic digestion facilities, and discharges to air, land, and water; and
- Renewable energy generation.

While waste management requirements are mandated by the provincial government, local governments often deliver them. Local governments play a key role in delivering and administering residential waste management programs, ensuring their official plan and bylaws are in keeping with provincial direction, and are ultimately responsible for issues related to residential waste in their communities. Local governments achieve much of the residential waste management through service delivery, bylaws, and zoning requirements. **Appendix B** provides an overview of the relevant regulations by jurisdiction.

This document is intended only as a general guide to applicable environmental laws administered by government entities. AD facilities may be subject to other federal, provincial, or municipal laws and policies that may require additional permits or approvals from other agencies. It is important to engage with regulators early during the development of the project. Since regulations may be under active review during the timespan of the project, there is the potential for regulations to change between the project inception and its completion.

3.0 Planning and Siting Considerations

Proper site selection can affect the success of any AD project. Site selection ensures optimal outcomes and avoids the potential for adverse effects and other potential problems by careful planning early in the development process. General considerations along with specific site design criteria for selecting an appropriate site are discussed in this section. Specific site design criteria are presented in **Section 4.0**.

Several technical, social, environmental, and economic factors will help to shape decisions on site planning. Proponents should consider the following:

- Minimizing adverse impacts on surrounding land uses, especially land uses considered sensitive based on use or environmental characteristics, through a combination of design, operational practices and separation distance;
- Conformity with the surrounding landscape including similar business operations and the facility's potential visual significance;
- Compliance and conformity with the municipal official plan and local zoning by-laws;
- Adequate space within the site for consideration of setbacks, easements, and other encumbrances as well as all operations, including seasonal storage and stockpiling of both inbound and outbound materials as well as maintenance activities;
- Watershed planning and protection of surface and groundwater, along with other natural features;
- Ensuring convenient access to transportation routes; and,
- Access to feedstock materials, end markets, and realistic market demand for digestate and biogas.

Consideration can be given to developing AD sites on old landfills, brownfield redevelopment sites, or other lands that are challenging to otherwise be productive. Additional approvals may be required to develop projects on some of these possible redevelopment sites.

3.1 Separation Distances and Buffer Zones

At the planning stage of a project to develop a new AD facility, or to modify an existing facility, it is critical to consider measures that together will minimize the potential of the new or modified facility to adversely impact adjacent land uses. Potential impacts that must be considered include air quality, especially odour, surface and ground water, noise, vibration, light, appearance, traffic, vermin and vectors, dust, and litter.

In all but the rarest of circumstances it is unrealistic to plan to rely solely on separation distance to minimize potential impacts, as well it is equally unrealistic to plan to rely exclusively on facility design and operations measures. Successful operating AD facilities have demonstrated that a combination of design features and operational practices planned according to the buffer zones and separation distances between the AD facility and adjacent land uses can effectively minimize the potential for adverse impacts.

Buffer zones and separation distances allow for natural attenuation of emissions from the AD facility and thereby reduce the impact on adjacent land uses. Buffer zones and separations distances vary in their ability to attenuate specific types of emissions depending on their unique characteristics with respect to topography, vegetation, elevation, prevailing wind speed and direction.

Adjacent land uses are also unique to each new or modified AD facility project and must be assessed in terms of the expected sensitivity to potential impacts from the facility. Particular attention must be paid to land uses which are considered to be sensitive receptors. A **sensitive receptor** can be a home, dwelling, school, daycare facility, hospital, long-term care facility, elderly housing, place of worship, cemetery, major retail or office establishments, or an environmentally sensitive area. Certain regulations in Canada include specific definitions for “sensitive receptor” that may include additional property uses than those listed.

When considering which neighbours to treat as a sensitive receptor for planning purposes, it is important to remember that any individual can be potentially impacted by an emission originating from an AD facility and report that emission to the pertinent ministry or agency. Note that people have differing odour sensitivities and that the degree of impact may vary.

The AD facility operator usually does not have control over future development on neighbouring properties. Therefore, facilities should be sited with a maximum possible buffer zone between the plant buildings, process tanks, air emission discharge points (for example, odour treatment exhaust stack) and the property line.

Planning of the new or modified AD facility must, therefore, ensure that design features and operational practices to abate odour and other emissions (further discussed in **Section 7** of this Guideline) effectively minimize the frequency and intensity of the emissions such that the natural attenuation provided by buffer zones and separation distances is not overwhelmed. Highly-engineered odour abatement systems allow even large-scale food and organic waste AD facilities to be located in urban areas relatively near to sensitive receptors, as compared with other waste processing facilities.

Table 3.1 is provided to represent the relationship between key design features and operational characteristics of AD facilities and separation distance requirements.

Table 3.1 – Major Factors That May Increase or Decrease the Required Separation Distances

Type of Facility	Distance to Nearest Sensitive Receptor
Fully enclosed AD facility, incorporating a ventilation design with a high number of air changes per hour (ACH), with all receiving, loading, and operating areas under negative pressure, and with all building and process air being collected and treated prior to discharge.	Shortest, with distance increasing with size of facility
AD facility that is not fully enclosed or collects and treats only a portion of, or none of, the building and process air, and accepts and treats only crop residues from agricultural operations.	Longer than above
AD facility that is not fully enclosed, but collects and treats all process air (which includes all air that contacts materials in storage or in process), and accepts and treats materials other than crop residues from agricultural operations.	Longer than above, with distance increasing with size of facility
AD facility where none of the building or process air is collected and treated, and accepts and treats materials other than crop residues from agricultural operations.	Longest distance, with distance increasing with size of facility

In addition to the facility size and type, the factors in **Table 3.2** should also be considered in determining suitable separation distances as part of the facility planning and design process.

Table 3.2 – Additional Factors Influencing the Required Separation Distances

Factors that <u>REDUCE</u> the Need for Separation Distance	Factors that <u>INCREASE</u> the Need for Separation Distance
Sensitive receptors located upwind from facility, relative to prevailing winds	Sensitive receptors located downwind from facility, relative to prevailing winds
Completed site specific emissions, including odour dispersion, screening or modelling to determine the minimum separation distance required	No site-specific emissions dispersion screening or modelling to determine the minimum separation distance required
Favourable topography and vegetative buffer, for example, variable terrain and trees	Unfavourable topography and vegetative buffer such as flat, open terrain and no vegetation
Receipt of lower-odour feedstock, for example higher carbon materials like crop residues	Receipt of feedstock with greater odour-generating potential, for example higher nitrogen materials like food waste and diapers. or materials that have undergone longer storage and shipping times, for example residential source separated organics.
High degree of odour containment and control from receipt to finished product	Low degree of odour containment and control from receipt to finished product
Effective odour treatment	Lack of effective odour treatment
Well-demonstrated as successful facility design and odour control system based on reference installations	Innovative and commercially unproven facility design and odour control system
Flexibility and redundancy in facility design and operations to account for operational upsets and changing feedstocks or conditions	Limited design and/or operations flexibility
Low population density, and no particularly sensitive receptors, such as hospitals, nearby	High population density or close proximity to particularly sensitive receptors such as hospitals

Facility proponents are strongly encouraged to consult with the local land use and environmental authorities early in the facility planning stages, prior to site selection, to identify whether zoning bylaws or other land use policies make specific requirements for separation from residential or other land uses and whether limits for odour or other potential impacts are established. Typically, proponents will be required to demonstrate that the new or modified facility will not cause adverse impacts as part of the application for approval, or an amendment to existing approval. This no-adverse impacts with respect to potential odour emissions can be demonstrated through odour dispersion modelling based on site specific information on facility odour emissions, the characteristics of the buffer areas and separation distances and meteorological data.

Odour dispersion modeling can estimate a zone of impact around the facility, usually considered to be an area around the new or modified facility within which the odour emissions from the facility are estimated to exceed 1 Odour Unit (OU). Knowledge of the existing or potential land uses within the zone of impact is critical for evaluating the suitability of a potential site or the adequacy of design and operational measures for odour abatement. Caution should be exercised when interpreting the results of odour dispersion modeling since they provide no guarantee that receptors outside of zone of impact will not experience or report an adverse odour impact.

3.2 Proximity to Feedstock Sources and Product End-Markets

The distance that haulage vehicles travel to and from an AD facility, or the length of a pipeline or electricity line required to be installed, can considerably increase or decrease both costs and emissions related to the project. These costs can have a significant impact on the financial sustainability of the AD facility.

In some areas, the proximity to rail transportation can be a significant factor in siting an AD facility and facilitating the shipment of both feedstocks as well as nutrient-rich digestate.

3.3 Conformity with Surrounding Land Uses

The operational and visual significance of an AD facility on the landscape should be considered when selecting a potential site. An AD facility requires activities of an industrial nature as well as buildings and structures of similar characteristics. The significance of the visual impact will depend on the size of the operation, where it is located, and the current local context. For example, during the nighttime the light from a burning flare may be a nuisance to local residents which requires a shrouded flare be used instead of an open-burning style flare.

Careful site selection, adaptation of the infrastructure (i.e., architectural design and layout), and landscaping to provide visual screening can help to minimize perceived impacts.

3.4 Compliance with Land Use Policies

Prior to selecting and purchasing a site, proponents must be familiar with regulatory requirements and guidelines as applicable, including land use planning, environmental approval, and public engagement considerations at the municipal, provincial, and federal levels.

Early in the facility planning stages, prior to site selection, facility proponents are strongly encouraged to consult with their local municipal, conservation authority, and provincial regulator offices, and, where applicable, the relevant federal government department – these consultations are very useful to identify site-specific planning and land-use considerations, including separation distances and other site restrictions.

- **Municipal:** Municipal by-laws can place restrictions on the development of land within or adjacent to areas identified as possessing:
  - Natural heritage features or potentially containing archaeological sites;
  - Environmentally sensitive designated areas, such as wetlands; and
  - Areas of natural or scientific interest.

  Proponents should consult with the municipality early in the planning process to identify the required land use planning processes and approvals needed to ensure the facility is appropriately sited within a specific community.
- **Conservation Authorities:** Several provinces have conservation authorities, sometimes referred to as conservation associations or conservation departments. These conservation authorities may regulate watersheds and other environmentally significant areas for the purposes of flood control and environmental conservation. Online mapping is generally available from the conservation authorities to help determine if a portion of a potential site is regulated by, or adjacent to land protected by, a conservation authority.
- **Provincial:** Proponents must comply with provincial laws. Proponents should demonstrate compliance with applicable standards and that they will not cause an adverse effect, as part of the application for provincial approval (where required). Provincial regulations protecting land use in agricultural lands may be relevant. In some provinces and territories, a specific authorization to construct or operate may be required.
- **Federal:** Where Crown Land is involved, proponents should ensure compliance with any federal requirements for development. Proponents of AD facilities to be located near an airport should contact Transport Canada for guidance. Transport Canada has developed Airport Zoning Regulations (AZR) regarding the use of land around airports that may impact aircraft navigation and safety. For example, the Airport Zoning Regulations prevent tall structures or land uses that may attract birds, since both of these can be a hazard for aircraft. Transport Canada, or the local airport authority acting on behalf of Transport Canada, can oppose a proposed development at the planning approvals stage if it is not in compliance with the AZR. Transport Canada has the authority to enforce compliance or to cause the shutdown of a facility they believe is a significant hazard.
- **Aboriginal:** First Nations may identify traditional land use, cultural, or spiritual sites of significance that could require consultation and additional considerations. If a proposed AD facility may impact the rights and treaty rights of Aboriginal peoples, as defined by the *Constitution Act, 1982*, then the proponent must consult. Guidance on these consultations is often available, such as the Ontario government's, "Aboriginal Consultation Guide for preparing a Renewable Energy Approval (REA)."

3.5 Developable Area

It is important that the site selected is large enough to allow for the design of the AD facility and all operational requirements. The operational requirements should include allowances for both regular, routine maintenance as well as infrequent major maintenance activities that may require space for truck turning and temporary crane installations.

Some portions of a site may be restricted to development. For example: setback constraints, easements, or other encumbrances dedicated to the municipality or local conservation authority. Parking, surface water management, utility right-of-way, and other requirements of the zoning designation may also take away from the area available for the AD facility.

3.6 Traffic Considerations

On-site and off-site traffic can have an impact on an area surrounding an AD facility. If not actively managed, trucks can generate noise, track mud and waste on and off the site, create dust, deposit litter onto roadways, and be a potential source of odour.

A significant increase in traffic volumes, including the potential for queuing of vehicles waiting to enter a site, results in the potential for public conflict and is prohibited under approvals from some provincial regulators. Development of a new road network, or the use or modification of an existing one, and the associated costs of these decisions are site selection considerations. In addition, area roads may be subject to truck road bans or seasonal load restrictions.

On-site roads need to be a functional network that is adequate for haulage vehicles, employees, maintenance, and other traffic is important to minimize on-site queuing, noise, excessive dust, and for ensuring traffic safety and access for emergency vehicles such as fire trucks.

In addition to directions and signage to the site location, specific on-site traffic factors that a proponent can consider include the following:

- Consideration of existing operations, site use, and traffic patterns should be considered if the AD facility will be co-located at an existing facility or waste-transfer site;
- Consideration of peak on- and off-site traffic volumes in designing site layout and traffic features, and in scheduling deliveries and outbound haulage to minimize the number of vehicles on the site at one time;
- There should be no queuing of vehicles on public roads waiting to enter the site;
- Adequate space for vehicles to queue ahead of weigh scales, material unloading and loading area, and for making left- or right-hand turns out of the site back on to public roads thereby minimizing interference with the flow of on- and off-site traffic to the extent possible;
- Adequate space for maintenance vehicles to pull out of traffic and park near the AD facility and equipment access points;
- Adequate space, outside of traffic lanes, for filled and empty trailers to be swapped if needed;
- Adequate space for trucks to turn, and reverse as needed, without interfering with traffic flow;
- All traffic movement in the same direction, to the extent possible, to minimize traffic conflicts and potential for collisions;

- Limits on speed and idling with posted signs, to minimize noise, dust, and other nuisance issues, and to minimize the potential for collisions;
- Ensuring vehicles exiting the facility are clean and are not tracking mud or odorous materials across on-and off-site roadways.

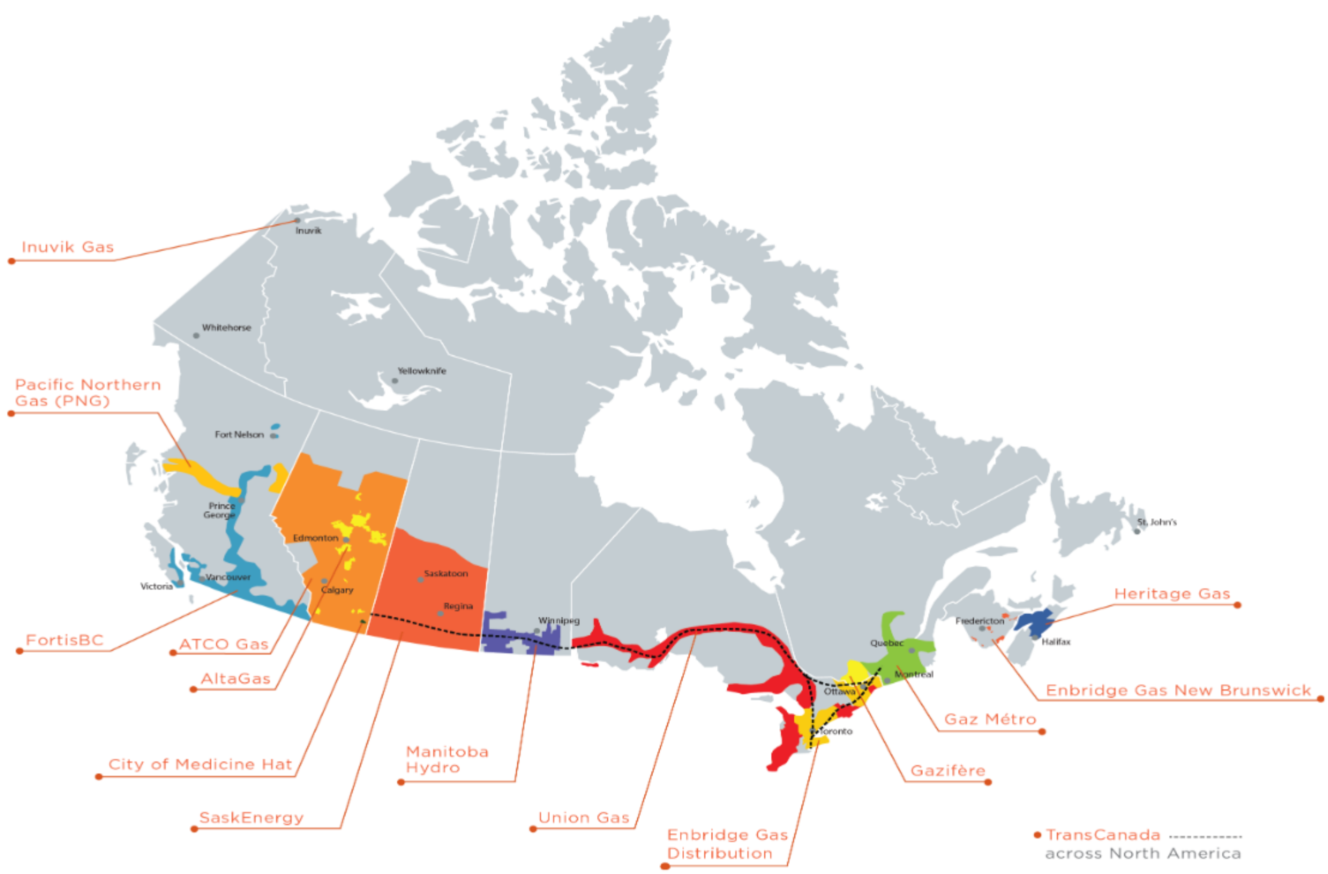
3.7 Access to Utilities and Services

The need for electricity, natural gas, potable water, storm water, sanitary sewer, and telecommunications services at the AD facility can be critical factors in the site selection process.

Both the distance to the utility connection point and the available capacity should be assessed when evaluating candidate sites. Potable water for fire protection and process needs should both be considered as it is often fire protection that dictates required water service requirements. Note that some sites, such as rural farm-based AD facilities, do not have storm and sanitary sewer services and don't require these services for facility operation.

If required to access renewable energy markets, it is important to ensure that the electricity or natural gas grids have the capacity to accept or store the electricity or RNG that will be generated by the AD facility. It is possible that energy grids may be constrained in areas thereby limiting the ability to connect a project. For example, the natural gas pipeline capacity may be limited by downstream demand that can be minimal in the summer months, a time when energy demand at an AD facility is also minimal. Grid capacity is important from both quantity and quality perspectives.

Figure 3.1 – Canadian Natural Gas Pipeline System
(Source: **Renewable Natural Gas Technology Roadmap for Canada**, CGA, December 2014)



One should not assume the closest utility line is the line that will have the capacity to accept the renewable energy. Only the local utility can confirm the connection point, and this typically requires a connection impact assessment or capacity study of some kind before a final determination can be made.

Proponents are encouraged to consult with their local utility agency early in the planning process to confirm the proposed connection point, local line capacity, and identify the planning processes and approvals required. The time required to complete the necessary studies and obtain approval from the utilities can be significant, often requiring 12 to 24 months to complete.

AD facilities also generally require access to high-speed internet to support automation and remote monitoring of the facility, including notifications of warnings or alarms. This internet access can be a challenge in more remote or rural settings with limited access to reliable high-speed internet infrastructure.

3.8 Other Environmental Considerations

Organics processing facilities should not be sited in areas known to experience flooding due to the potential for contamination from feedstock and other contaminants if flooding occurs. Provincial and municipal authorities often prohibit the development of waste management facilities in areas at risk of flooding due to extreme storm events.

The potential for uncontrolled releases has led to a number of provinces establishing minimum setback distances from streams, rivers, lakes, oceans, and wetlands to prevent the possibility of unintentional contamination. Wetlands are largely recognized as sensitive habitats, and thus development of organics processing facilities near these habitats is restricted in most jurisdictions. Sources of potable water should also be protected from potential contamination, and some provincial and local regulations define required setback distances from potable water sources, often at least 150 metres. A protective vertical buffer, or an engineered secondary containment protection, should be maintained between surface activities and any bedrock or groundwater sources as a defense against the potential for contamination. Spill control protocols need to be developed and implemented for management of potential spills.

The makeup of soil at the site should be identified and considered when preparing for management of snow and surface water runoff. Winter snow stockpiling areas and the potential for impacted melt water and stormwater should be considered and managed, as required.

4.0 Site Design and Operating Considerations

This section introduces important considerations for the physical design of AD facilities – considerations that will normally be incorporated into the application for a provincial approval to construct or operate.

Information required in support of such an application may include the following:

- **Site description:** location, zoning designations and adjacent land uses, distance and locations of sensitive receptors, physical site setting and geology, drainage and hydrogeology, local wind patterns;
- **Facility design and layout:** sources, types, and estimated quantities of feedstock and amendment material, facility design, capacity, equipment, site access, security;
- **Facility operations**: operating parameters, processing description, process monitoring, calibration, and process control;
- **Quality assurance:** feedstock quality, on-site testing, cross-contamination prevention, final product sampling and analysis;
- **Biosecurity:** if a common carrier transport truck is used to collect or deliver materials from multiple farms, there may be interest from the farmers to ensure the vehicles are washed between locations to maintain their biosecurity programs and avoid possible cross-contamination of livestock operations;
- **Maintenance program:** description of the program that will be implemented to track and document that preventative and predictive maintenance is performed to manufacturer's recommendations;
- **Nuisance control:** for odour, litter, birds, vectors and vermin, dust, noise and traffic;
- **Contingency plans:** feedstock shortages, feedstock overages, seasonal fluctuations in feedstock and digestate storage needs, disruption in off-site digestate storage, market disruptions, labour disruptions, equipment malfunction, power failures, extreme weather including wind or ice storms;
- **Emergency response planning:** fire, spills, flooding;
- **Documentation:** manual and electronic record keeping and reporting;
- **Site closure:** plans to manage the end-of-life or end-to-operations at the site to ensure the site is not encumbered with long-term environmental liabilities. This plan can include for the clean-up and removal of all waste at the site, washing equipment and disposal of wash wastes, and checking for soil contamination if outdoor storage of waste is used;
- **Odour Impact Assessment**: an odour impact assessment study should be used to determine the extent of odour control and setback distances required. Odour control and setback distances can be selected to ensure impacts on the specific surrounding land uses are below acceptable thresholds. Acceptable thresholds are typically set by provincial regulators. An odour impact assessment considers the type of odourous chemical compounds at the site, their concentration, and the meteorological dispersion of odour through typical wind patterns.

The assessment can assist in the development of an odour management and control plan. This report is prepared by a qualified professional;

- **Emission Summary and Dispersion Modelling (ESDM) Report:** a study required by provincial environmental regulators that covers an assessment of air pollution emissions from a facility and how they disperse. The regulations list specific requirements for the study. This report is prepared by a qualified professional;
- **Hydrogeological Assessment Report:** a study often required by a local conservation authority or provincial regulator that covers the hydrogeological conditions of a site and may be required if no engineered spill containment is prepared for the facility. This study can include the groundwater, local wells, aquifer recharge areas, and the nature of the soils in the local area. This report is prepared by a qualified professional;
- **Acoustic Assessment Report:** Noise can be generated by vehicles or mobile equipment entering, leaving, or operating at the AD facility, as well as by fixed equipment such as a biogas-fueled engine powering electrical generation equipment. An acoustic assessment can be completed to determine the extent of noise abatement required. Proponents should check with their municipal governments and provincial environment ministries to ensure that they are complying with any local noise control by-laws and regulations. Measures that can be used to reduce noises from a facility include:
    - Limit hours of operation or coordinate operations with adjacent activities;
    - Limit traffic to and from the facility to specific hours of the day;
    - Properly maintain all equipment; and
    - Specify and purchase equipment with noise reduction design features (such as mufflers and sound enclosures). Consider locating fans and other equipment away from the nearest point of reception.
- **Stormwater and Site Drainage Study:** This engineering study predicts the expected rainfall during both routine and extreme weather events and models the drainage from the site during these situations. This study can reveal the volume of stormwater that must be considered during the site design and managed during the facility operation to prevent flooding or washing roadways. Managing stormwater to ensure pits, dry-wells, and sumps are not flooded during extreme weather are important attention points during the facility design. The discharge of stormwater may require an Approval. Note that stormwater discharge Approvals are for non-impacted runoff and do not include leachate from outdoor storage areas.
- **Feedstocks:** The type of feedstocks will drive the design, size, and type of many AD facility components. The AD facility components most influenced by the type of feedstock accepted include but are not limited to: feedstock receiving and storage areas, pre-processing equipment, the AD system, and digestate management systems. AD facility operators must ensure that the blend of feedstock mixtures in their operation is nutritionally balanced and will produce the expected quantity of biogas needed to meet its operational goals.

  The changing nature of the feedstocks can be a challenge for the preprocessing system. The facility designers are encouraged to be specific about what the facility can, and cannot, accept. For example, are paper packaging or diapers acceptable in the SSO and to what extent? Are metal cans and plastic packaging from spoiled food products acceptable? Design flexibility should be considered to allow for future changes. For example, newer 'compostable' plastics need to be managed as part of the feed stream. Similarly, changes to SSO collection practices and the portion of single family versus multi-residential sources will influence the ability to collect the cleanest possible organics stream.

Feedstock and digestate management methods should minimize the creation of microplastics and small foreign matter particles which are not easily removed. Digestate end-users and/or regulators may have foreign matter content limits.

- **Renewable Energy Off-take Requirements:** Connecting a facility to a utility to be able to sell the electricity, gas, heat or other form of energy created can be one the most complex pieces of a project. During design, it is important to understand where the delivery point is, the interconnection and quality requirements, and the contractual requirements imposed by the utility or energy purchaser.

  Due to the regulations surrounding the natural gas utility, there can be specific regulatory challenges to the use of RNG. For example, in some areas there is no legal ability to pass on the higher cost of RNG to customers who wish to buy it. Similarly, if biogas is designated by local regulators or the utility in some areas as a "waste", then this designation can impede its use.

- **Digestate Use**: The ability to manage and market digestate is a key aspect of an AD project. Design for adequate storage and handling of digestate for each usage pathway, including land application, fertilizer, and compost. Contingency planning for alternate digestate storage and uses is recommended to allow for future changes in market conditions or other circumstances. For example, an exceptionally wet year can delay or slow seasonal land application campaigns.

  Every organics processing facility needs to be able to rely on a robust and reliable program to market the digestate or digestate-derived product that it produces. This requires a realistic understanding of the market demand for the product, and what the customers' quality expectations are. Likewise, product quality standards and testing are commonly included in environmental approvals provided for the operation of biogas facilities. Failure to plan effectively and realistically for marketing of the end product can quickly create problems, as it is generally difficult to create storage for more than a few months' worth of digestate production;

- **Design According to Code:** An AD facility should comply with all regionally relevant codes, design requirements, applicable building codes, local jurisdictional building codes, environmental, and safety requirements. Specifically, the CSA Code B-149.6-15 governs the design and construction of AD facilities and sets the minimum standards in Canada. Following this Code will ensure the safe and compliant design and operation of the AD facility. Components such as pressure relief valves are required by code and should be operational.

4.1 Required Preliminary Design Information

The specific design requirements for each AD facility will vary depending on the project. However, for almost all projects, certain preliminary information about the location of the facility must be considered for the design as noted below. Specific information related to site selection can be found in **Section 3.0**.

- **Site Survey:** It is important to have a clearly defined site and to understand the landscape and topography to be able to best design the facility;

- **Site Plan:** The site plan for an AD facility will consider the factors listed below to ensure that the site layout of the AD facility is best able to manage the unique location of the facility. For more information on siting, see **Section 3.0**.
    - Preparation is planned and undertaken based on the geotechnical aspects of the site, coupled with the design layout and grading plan;
    - Incorporation with any existing facilities on the site;
    - Site layout to facilitate odour management. For example, in urban areas it may be preferred to locate tanks indoors and locate the office near the front of the facility. The placement of building doors and the ventilation exhaust stack may take into consideration the location of nearby sensitive receptors; and,
    - Stormwater and feedstock area leachate management.
- **Identification of Surrounding Neighbours and Points of Potential Impact:** Odour control is of primary importance and prevention of nuisance odours allows the project to operate without affecting neighbours. It is important to understand the area in which the project is being built as the surroundings can impact the design and location of equipment to reduce noise and odour impacts and the need for abatement and the potential for regulatory action and enforcement;
- **Geotechnical Report:** Required to ensure the structural design is adequate for the land on which the AD facility will be constructed and for spill containment management purposes;
- **Site Zoning and Site Plan Approvals:** Understanding site zoning and site plan approval requirements allows the designer to account for these factors in the design and avoids unnecessary re-design and cost. Refer to **Section 3.1** for more information on site selection considerations;
- **Site Power Requirements and Existing Utilities:** Understanding the site's power requirements, the existing utilities, and the costs of these utilities will impact the design of the system to potentially be able to reduce capital and operating costs. The AD facility can be operated by a variety of power sources including using electrical power and heat generated from biogas, purchased from the electrical grid, or purchased from the natural gas grid;
- **Nutrient Management Requirements:** Understanding the local nutrient management requirements is necessary to i) ensure the environmental protection of the land to which digestate is applied, and ii) inform the level of treatment that digestate receives. Logistical planning is also necessary to ensure feedstock and digestate handling and storage facilities correspond to market access constraints and allowable/applicable land application rates to manage volumes. It is suggested to consult a professional agrologist or other professional licensed in the jurisdiction of the project regarding land application plans;
- **Existing Site Conditions (if applicable):** Incorporating new processes and equipment that meshes with existing operations is a key consideration. The existing operations should be complemented not interrupted;
- **Social License:** The success of an AD facility depends on acceptance from the local community. This acceptance highlights the need for community consultation and effective communication plans and messaging at different project stages. Following all local jurisdictional and

environmental requirements is a method of helping to ensure community acceptance. For example, building permits and any other local permits for the AD facility are likely to be granted when following local requirements;

- **In-Out Bound and Site Traffic:** As identified in **Section 3**, it will be necessary to design an AD facility to effectively manage in-bound and on-site traffic needs. Consider any restrictions if the facility is co-located, for example, at existing landfill. Some jurisdictions have different noise guidelines for truck traffic at landfills;
- **Mass and Energy Flow Analysis:** Analysis of potential available feedstocks and design requirements to maintain an appropriate nutrient blend and active biology need to be assessed. It is important to ensure that the anticipated feedstocks will:

  a. Produce adequate biogas for the requirements of the energy offtake agreement;

  b. Meet the heat and power requirements of the facility if the biogas is not being sold; or

  c. Be digested safely together to meet the waste management requirements of the AD facility if biogas production is not the driving factor of the project.

  An analysis of the mass flow will also be used to ensure that storage volumes, areas, or vessels are sized adequately to provide the required capacity or residence time for the process. These storage vessels include items such as pre-treatment requirements (for example, pasteurization and/or hydrolysis, if proposed), sizing of the anaerobic digester, and storage of digestate prior to land application or further treatment. A process flow diagram is an engineering drawing that documents all the mass flows within the process. Particular care is required when designing AD systems that include a recycle component, for example the recycle of digestate or treated wastewater to hydrate fresh feedstocks can cause the buildup of dissolved or fine particulate materials over time that can impair the biological digestion process. Consultation with a technical expert is recommended for designing systems that include recycle streams.

  An analysis of the energy flow, tracking the mass and temperature of the material in the system, will also be useful to determine the heating or cooling requirements at different points in the system. For example, the energy required to warm a cold feedstock to achieve pasteurization (if required) or to maintain the target temperature within the digester in a cold climate can be significant. Similarly, the digester effluent may be too warm for effective aerobic wastewater treatment. An energy flow diagram is an engineering drawing that documents all the energy flows within the process. Particular care is required when designing AD systems that include a recycle component, for example the recycle of warm digestate or treated wastewater to hydrate fresh feedstocks.

  After the mass and energy flow analysis is completed, a piping and instrumentation diagram (P&ID) can be developed to identify and document the equipment required to construct the project.

- **Biogas Utilization:** Determining how you intend to use the biogas is a critical design factor. This end use for the produced biogas can be to heat a boiler, used in a combined heat and power (CHP) unit, or upgraded to produce RNG.
- **Fire Department Outreach:** It is recommended that during design of an AD facility and following its construction, that the operator engage with the local fire department. The local fire

department engagement can ensure the site plan includes access for emergency response vehicles and access to water to be used in fire suppression. Following construction, inviting the fire department to visit the facility ensures they are familiar with its operation, hazards, and contingency planning such as access routes and source of firefighting water. This site visit allows for an introduction to specific components like the flare, the use of which may be a common and expected occurrence at the facility during start-up and commissioning. Ensuring that the local fire department understands the AD facility and how it operates is mutually beneficial should their assistance ever be needed.

4.1.1 Preliminary Design for Feedstock Management

AD facilities can receive liquid and solid organic waste materials, sometimes intermixed with other non-biodegradable materials such as plastic food packaging. Feedstock without nonbiodegradable materials such as plastic packaging are referred to as being “clean”. These organic waste materials are collectively referred to as ‘feedstock’.

Understanding the preliminary design requirements for the proper storage, pre-processing, and input of feedstock to the digestion process is essential for consistent facility operation.

- **Feedstock Types:** In the broadest of terms, feedstocks can be characterized as:
    - **Clean Liquids:** such as livestock manures, process wash waters, fats, oils and greases (FOG), and pumpable food processing sludges, all of which will be delivered to an AD facility via piping or in tank trucks;
    - **Clean Solids:** such as vegetable peels, spent grains, and other solid wastes from the food processing sector that are entirely free of non-biodegradable materials such as plastic and glass, all of which will be delivered to an AD facility in solid waste hauling trucks;
    - **Source-Separated Organics (SSO):** which are co-mingled with other nonbiodegradable contaminants such as plastics, glass, ceramics, and metals. This category is unique in terms of seasonal trends in quantity and composition, delivery schedules, and for the variety of contaminant materials. These solid wastes will be delivered to an AD facility in solid waste hauling trucks or collection vehicles;
    - **Leaf and Yard Waste:** which may be collected separately or co-mingled with SSO. High solids anaerobic digestions systems can process this type of waste; and
    - **Contaminated Solids:** such as commercial solids and liquids, which include non-biodegradable materials (for example, packaged food products and supermarket wastes), and which require de-packaging or further treatment. These solid wastes will be delivered to an AD facility in solid waste hauling trucks.

  There can be many complex physical, chemical, and biological variables to consider when developing a proposed digester feedstock recipe. Mixing different wastes together may produce unforeseen results and interactions. A failure to understand all the implications of these variables can lead to negative impacts on the AD facility biology and biogas production efficiency. When new feedstock types are considered, proponents are encouraged to consult independent experts who have a deep familiarity with the biological needs of an AD facility.

- **Feedstock Transport, Storage and Feeding:** Feedstocks often arrive at an AD facility in large trucks. Design to allow for quick and efficient unloading of feedstock is important to minimize spills and odours associated with unloading feedstock and to decrease the time spent delivering materials to reduce the potential for traffic on-site. A provision for storage and staging of feedstocks is required to ensure a consistent flow of feedstock to the digester system, thereby maintaining consistent biology within the AD process. The best way to encourage healthy biological stability in an AD facility is to consistently feed regular, smaller amounts, of well-mixed feedstocks.

  Provisions must be made to store inbound liquid and solid feedstocks as appropriate. Liquid wastes can be pumped into aboveground tanks or discharged by gravity into receiving pits. Ideally, any liquid storage vessel should be equipped with some type of mechanism to provide for mechanical agitation, so that the stored material can be mixed and remain homogenous. Heating may be desired in liquid storage tanks. At minimum, solid materials should be stored on an impermeable surface, such as a concrete pad, designed to allow capture and handle runoff in an appropriate manner. The solids storage should be sheltered from precipitation to avoid the generation of a feedstock leachate which requires collection and treatment or disposal. Consideration should be given to the scale of the expected feedstock storage needed, so that any expected surges in received feedstock can be accommodated with ease, while still allowing for ready handling of the materials and regular turnover of accumulated wastes.

  If the AD facility is being constructed in an area that is sensitive to odours, then a high level of attention to odour management is recommended to reduce potential odours produced by the feedstock. For example, in urban settings, this is likely to mean that 1) all feedstock unloading must be fully enclosed inside of a building envelope, 2) feedstock storage is also fully enclosed, 3) negative air pressure is provided inside the building and building exhaust air is ducted to an odour control system, and 4) the use of protocols and control interlocks keeping all vehicle and personnel access doors closed except when the door is in active use.

- **Feedstock Pre-Processing:** Feedstock pre-processing refers to all operations that might need to take place between the initial receipt of feedstocks and the actual addition of prepared feedstocks into the AD process. Depending on the application, feedstock pre-processing can include a broad range of activities, including the following:
  - Blending of different feedstocks;
  - Feedstock conditioning through:
    - Liquification of solid feedstocks by mixing with water or other liquid feedstocks for wet-digestion systems; or
    - Pre-shredding or grinding solid feedstocks into smaller particles for high-solids digestion systems. High-solids digestion systems may also need the addition of water if the solid content rises above their upper limit;
  - Removal of foreign or non-biodegradable materials such as plastics, glass, ceramics, and metals from feedstocks using screens to capture these materials upfront; and,
  - Pasteurization of feedstocks and/or use of a hydrolysis process, if required or proposed.

  Some design considerations for feedstock pre-processing should include:

- **Feedstock Consistency:** Ensuring the greatest possible consistency of feedstock should be considered in design since anything that can be done to blend or homogenize feedstocks before injecting them into an AD facility is supportive of stable biology. In practice, this might include blending different liquid feedstocks before injecting into the AD process. Blending feedstocks prevents any shock-loading effect on the process biology that might result from injecting a single, unusual feedstock, in isolation. For wet digestion it is common to mix solid feedstocks with either other liquid feedstocks, or water, or digestate to render it into a slurry before injecting the materials into the AD process. In some cases, solid feedstocks are directly injected into the AD process, requiring some pre-shredding or size reduction to ensure ready mixing into the liquid digestate within the AD process once the solids feedstocks are introduced. In high-solids systems the pre-shredded solid feedstocks are added directly to the digester;
- **Contaminant Removal:** AD facility design should consider if non-biodegradable contaminants such as plastics, glass, metals, ceramics, and grit require removal before the feedstock enters the AD facility, after the AD facility, or a combination of the two approaches. This item is discussed in more detail in **Section 4.2**; and
- **Pathogen Reduction & Pasteurization:** The need for pasteurization or other pathogen reduction methods can depend on the type of AD technology, feedstock, use of outputs, and regulatory jurisdiction. For example, pasteurization is sometimes specifically required by regulators in circumstances where a broad range of pathogens from raw meat feedstocks are expected or SSO is processed which contains human waste such as soiled diapers, used incontinence products, or used sanitary products. If pasteurization is required, pasteurization can be implemented before, within the digester, or after the AD process. It is possible that the regulator may require regular pathogen testing of the digestate. A typical pasteurization strategy requires material to be heated to 50°C for 20 hours or 70°C for one hour.

  In addition to pasteurization, other pathogen reduction technologies such as aerobic composting, alkaline stabilization, or other methods can be used.

4.2 Main Components of AD Facility Design

AD facilities are an arrangement of equipment selected and tuned to process a very specific material composition before and after the digester. The equipment used to create an AD system is identified as pre-processing, digestion, and post processing, including dewatering and in some cases wastewater treatment.

The main components involved in an AD facility design include:

- **AD Types:** Anaerobic digestion processes can be classified by their:
    - operating temperature;
    - solid vs. liquid consistency; and
    - the number of stages used in the digestion process.

  The time required for the digestion process to occur is highly dependent on the feedstock and the biodegradation environment within the digestion process.

- **AD Temperature Ranges:** Anaerobic digestion can take place in any of the three broadly defined temperature ranges:
    - Low-temperature (psychrophilic): (<25°C);
    - Mid-temperature (mesophilic): (30-42°C); or
    - High-temperature (thermophilic): (>48°C).

  In general, the biodegradation process is faster at higher temperatures so that a higher-temperature process implies a shorter residency times is needed within the digestion process. Thermophilic digestion of mixed food wastes can take as little as two weeks for the digestion process to take place; whereas psychrophilic processes can take up to three months. Canadian AD facilities have typically been constructed using a mix of mesophilic and thermophilic processes. Thermophilic temperatures increase the rate of VS and COD destruction. This faster rate results in a smaller reactor size being required and provides pasteurization and pathogen reduction as compared with a mesophilic digestion system. The faster digestion rate in a thermophilic also results in the process potentially becoming unstable faster than at modest temperatures in mesophilic processes. In Canada, most AD facilities have selected the improved stability of the mesophilic process.

  Several factors need to be considered when selecting the ideal temperature regime for a given project. **Table 4.1** compares higher-temperature and mid-temperature systems. Determining the appropriate temperature regime for a given AD facility will require an analysis of the available feedstocks, and a compromise between maximizing biogas yield while maintaining economic viability.

  Note that both mesophilic and thermophilic processes can produce the exact same biogas yield from a particular feedstock—the thermophilic process generates the biogas faster.

Table 4.1 – Comparison of Mesophilic and Thermophilic Digestion Systems

Mesophilic Digestion Systems (30 – 42 °C)	Thermophilic Digestion Systems (> 48°C)
Benefit • Bacterial population more robust and adaptable to changing input conditions • Lower energy input to maintain temperature • Less sensitive to nitrogen levels in the feedstock • Less intensive monitoring and control needed	**Benefit** • Higher temperatures advance the biological process for higher rates of gas production; smaller retention times are possible • Pasteurization in the digester • Higher throughput rates
Drawback • Lower rates of gas production rate; larger retention time needed to achieve the same rate • Lower throughput rates • Resulting digestate may require further processing	**Drawback** • Higher construction costs for heat resistant material • Higher energy input to heat to thermophilic temperatures • More sensitive to nitrogen levels of feedstock • Require more intensive monitoring and control

- **Facility Heating Options:** It is important to consider the heating requirements of the pasteurization process, the digester vessels, process water tanks, processing buildings, and any other areas within the AD facility. It is also equally important to consider energy efficiency within the facility including measures such as insulating the digesters and other tanks, heat recovery, and the use of biogas for heating. Calculating the seasonal heating or cooling requirements is part of the facility energy flow analysis during the early stages of the planning and design work.

  Heating can be provided to the AD facility through a variety of methods. In most smaller digesters, cast-in-place tubing is installed directly in the digester floor and/or walls for process heating. Some digesters recirculate hot water through stainless steel piping that contacts the digestate inside the digester tank. For larger digesters, recirculating the digestate though external heat exchangers is commonly used. The source of heat can be from a biogas- or natural gas-fired boiler, or waste heat from a compressor or CHP co-generator.

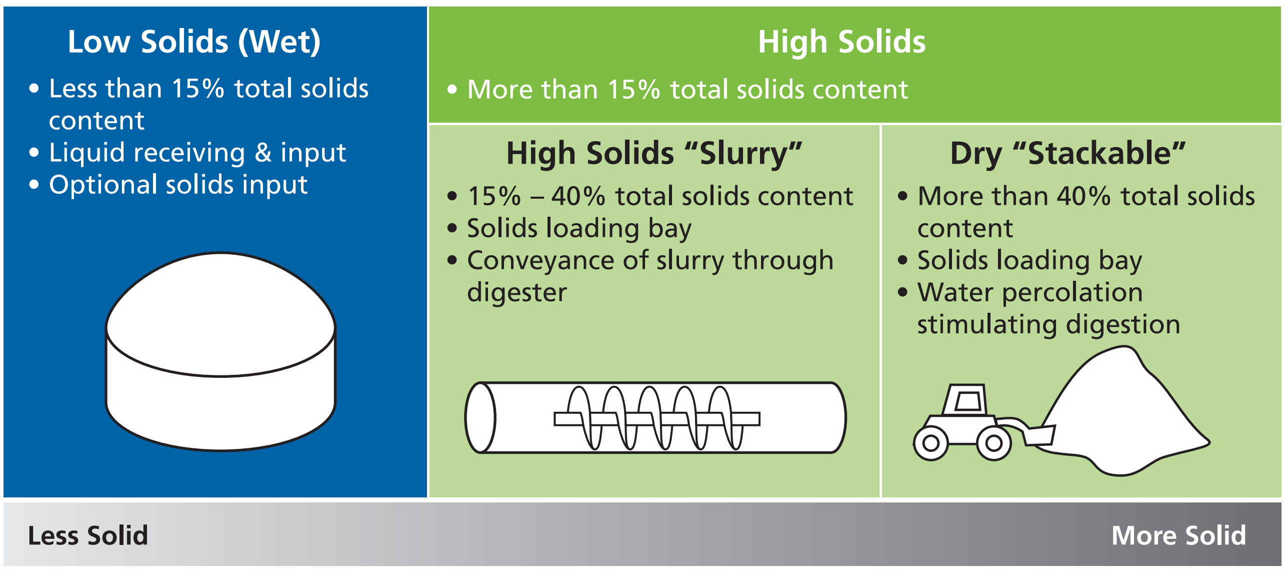
  This use of in-digester or cast-in-place heating is an example of the overlaps that occur between construction trades. Depending on the scope of work defined in the contract, the heating tubing could be installed by the mechanical contractor or the tank structural contractor.

  The heating control system governs the distribution of heat throughout the AD facility and controls the heat inputs to maintain target temperatures within the various AD processes. A combination of flow control valves, variable speed pumps, temperature measuring thermocouples, and a programmable controller are used to design and achieve optimum control. Consistent temperature control is needed to maintain stable biology and consistent biogas production.

- **High-Solids and Low-Solids AD systems:** Anaerobic digestion processes can be categorized by the solid-liquid consistency of the digestate generated by the process:
  - Low-solids or "wet" process with total solids (TS) content less than 15 percent;
  - High-solids slurry process with TS of greater than 15 percent; and
  - "Dry" or "stackable" process with TS greater than 40 percent.

  A "dry" or "stackable" anaerobic digestion process is a type or subset of high-solids anaerobic digestion.

Figure 4.1 – Types of Anaerobic Digesters by Solids Content



These types of digesters are separated based on those three categories:

- **Low-Solids or Wet Digestion:** Wet digestion processes contain less than 15 percent total solids (150,000 mg/L), although typically most wet digestion systems operate with a total solids content of < 12 percent (120,000 mg/L). These AD processes typically are constructed using well-mixed storage tanks. Anaerobic lagoons are another example of a wet digestion process. Wet digestion uses low TS slurries to allow for continual agitation of the digestate to achieve complete mixing within the AD process. Mixing is used to prevent settling of heavy solids and grit and to prevent floating crust formation from light fractions;
- **High-Solids Slurry Digestion**: High-solids slurry digestion processes are used for systems operating at between 15-40 percent dry solids (150,000 – 400,000 mg/L or 150,000 – 400,000 mg/kg). These processes often operate as a high-solids slurry within plug flow reactors or high solids digesters, which can be either vertical or horizontal. Vertical plug flow reactors utilize minimal amounts of agitation, sufficient only to slowly move the material from the top towards the bottom of the digester vessel. Vertical plug flow tanks often have a conical base to facilitate digestate removal. Horizontal plug flow reactors operate on the same principal as vertical plug flow reactors but utilize a

relatively long and slender horizontal cylindrical digester vessel with widely spaced paddle arms; and

  - **Dry Digestion:** Dry digestion or "stackable" processes typically operate at more than 40 percent dry solids (>400,000 mg/kg). Dry digestion uses percolation bunkers or dry digesters, similar in design to composting vessels, but are operated in an anaerobic environment. Typically, an additional supply of leaf and yard waste amendment is required to process SSO in order to achieve high TS levels.

  The primary difference between these systems is the type of mixing required to manipulate the increasingly viscous material. For example, gas mixing is only suitable in a low-solids wet digestion process, whereas percolation bunker reactor digestate is typically loaded and unloaded with earth-moving equipment such as front-end loaders.

- **Mixing Flow Regime:** Mixing is required within a digester for many reasons. Mixing ensures that the untreated organic material is blended, kept in suspension, and homogenized. Mixing helps to achieve uniform temperature within the digester and brings the anaerobic biomass into intimate contact with the untreated organics. Good mixing achieves a uniformity of solids concentration throughout the digester.

  There are various available mixing technologies from gas injection systems, to mechanical mixing, some of which include the following:

  - **Gas Mixing** – involves using a gas compressor to recirculate a fraction of the digester biogas and inject that biogas near the bottom of the reactor. The biogas bubbles then rise through the digestate and mixing the contents. Gas mixing is only suitable for low solids digesters.
  - **Vertical Linear Mixing** – a flat disk located deep inside the tank that is held by a vertical shaft. The shaft is then moved up and down by a drive located at the top of the tank, similar to a plunger action.
  - **Hydraulic Mixing** – uses an arrangement of nozzles and pumps to pull digestate from digester tank and pump it back into the digester at a high speed. The flow pattern can be used to cause the digester contents to move in a circular pattern.
  - **Mechanical Mixing** – uses a mechanical mixing impeller, driven by a motor. The motor may be directly coupled to the mixer shaft or may use a gearbox or pulley system depending on the design of the mixer, the mixer speed, and torque requirements. Mechanical mixers are the most common style for smaller, wet digesters. These mixers can be fully submersible, with the motor and impeller within the digester, or they can be mounted with the motor external to the digester and the drive shaft passing through the digester wall. High-solids digesters often use a horizontal mechanical agitator moved by a drive located outside the vessel.

    Maintenance work and ease of access should be considered when determining the type of mixer preferred for a particular project.

- In addition to continual mixing, some wet-digester designs incorporate a self-cleaning tank. Self-cleaning tanks are designed to accommodate small amounts of dense "heavies" and floatable contamination and utilize surface skimmers and/or bottom scrapers to move the contaminants to a collection point for extraction.
- **Single and Multi-Stage Anaerobic Digestion Processes:** Anaerobic digestion follows a four-stage biological process. These processes can occur in one or more vessels. In a single-stage AD system, the entire biological digestion process takes place in a single vessel. Since all the processes are carried out in the same place, these systems are generally lower cost and easier to maintain than a multi-stage AD system. There are many types of single-stage digesters including well-mixed Tank Reactors and Plug-Flow Digesters, which are discussed below.

  The premise of a multi-stage, also called multi-phase, AD system is to optimize the conditions for individual biological reactions within different vessels. There are numerous process configurations with different vessels operating at different temperature and pH ranges in an attempt to maximize the biogas production and degradation rates, while lowering the cost, and allowing for stable operation. Multi-stage systems can incur a higher capital cost and, depending on the configuration, may be more complicated to operate.
- **Contaminant Removal:** Non-biodegradable contaminant levels in food waste and SSO tend to vary depending on the municipality's SSO collection system. Non-degradable material can sometimes reach high contaminant levels of 15-25 percent. Therefore, AD technologies selected to process SSO must also be designed to process both the average and the wide range of feedstock quality expected.

  Pre-processing of organics involves contaminant removal prior to sending the feedstock or organic-rich slurry for further pre-processing, if required, and then anaerobic digestion. Pre-processing technology that helps reduce contamination levels in SSO slurries include pre-shredding, screening, an extrusion press, or a hydraulic pulper. The technology used depends on the contamination characteristics and the digester technology used. Additional pre-processing equipment further refines the organic feedstock prior to digestion, as needed. Additional pre-processing steps may include removing remaining contamination, altering total solids (TS) levels, or fragmentation.

  Contaminant removal prior to the digestion process is crucial for the overall maintenance of a digester, as plastics and other light contaminants can collect at the surface of the digester over time and create a thick, surface-crust layer that impacts digester performance. Similarly, grit and heavy contaminants can form a solid layer at the bottom of the digester and accelerate mechanical wear of pumps, valves, piping, and agitators. Allowing for the removal of these contaminants during the design stage will be an important part of the project planning.
- **Process Water Management (on-site treatment vs. discharge):** Process wastewater generation depends on the selection of AD technology, and in particular depends on the digestate management plan, the TS content, and carbon to nitrogen (C:N) ratio of the digesters. In many cases, digestate can be land applied without further processing. If the AD facility design calls for the creation of a wastewater stream, then that process wastewater can be treated on site by installing a wastewater treatment plant. Alternatively, it can be discharged to the sanitary sewer if the wastewater complies with local by-law limits. Some of the by-law limits may allow for

over-strength surcharges, which means if one exceeds the local wastewater by-law limits, they must pay for excess discharges.

On-site treatment of process wastewater should aim to minimize the use of potable water purchased from the municipal supply. Biological nutrient removal (BNR) treatment is a general name for a type of aerobic biological treatment process that can refer to nitrogen and/or phosphorus removal. For AD facilities, BNR processes are usually focused on biological nitrogen removal; phosphorus is commonly treated chemically. In the AD process nitrogen is not created or destroyed; a large part of the nitrogen present in the feedstock is converted into an ammonia-ammonium form.

While most BNR treatment configurations are technically achievable following centrifuge treatment of the digestate, they all require a large treatment volume and some added complexity to the operation of the system.

- **Odour Control/Treatment:** Odour control and treatment systems must be integrated with the rest of the AD facility to maintain a safe environment for workers, to prevent off-site odour impacts, and to comply with the requirements of the environmental permits. Typical odour control options are detailed in **Section 7.3**.
- **Biogas Upgrading Equipment:** Biogas upgrading equipment is required to produce RNG for injection into the local utility pipeline. This RNG can be transported, stored, and ultimately used as vehicle or engine fuel. This upgrading is required to remove the large volume of carbon dioxide (CO_2) that is naturally produced along with methane. Upgrading is also required to remove hydrogen sulfide (H_2S) and other undesired gases such as VOCs from the biogas. A less-stringent form of upgrading, focusing on hydrogen sulfide removal can be used to partially clean or 'sweeten' the biogas before it is burned in a direct-fired boiler or engine.

  The RNG recovery rate from biogas is dependent on the specific suite of treatment technologies selected and how they are combined into an overall upgrading system. Individual upgrading process steps typically recover 96 to 99 percent of the methane in the input. Overall system yields, which usually involve several processes used sequentially, are typically in the 90 to 95 percent range for methane production. The final methane content required in the upgraded RNG is dependent on the pipeline injection specifications required by the local utility provider.

  Note that the RNG injection criteria set by the individual local utility providers may be adjusted based on the capacity and flowrate of their distribution pipeline receiving the RNG. Conversely, some utilities do <u>not</u> alter the RNG injection requirements regardless of the capacity and flowrate of their distribution pipeline receiving the RNG.

  Biogas upgrading systems for RNG may consist of the following subsystems and functions, with the order of the different processes depending on the technologies selected:

  - Initial raw biogas compression;
  - Desulfurization for hydrogen sulfide (H_2S) removal. Desulfurization can be coarse or fine depending on the flow rate and inlet hydrogen sulfide concentration;
  - Dehydration for moisture removal;

- Pre-treatment to remove non-methane organic compounds, organic halides, and siloxane removal;
- Intermediate pretreated gas compression;
- Carbon dioxide (CO_2) removal;
- Nitrogen (N_2) removal and/or oxygen removal;
- Final RNG compression;
- Flare – biogas and RNG must be burnt in a waste gas burner (also called a "flare") if it cannot be injected into the pipeline because of quality or flow restriction reasons;
- Off-gas treatment – the waste gases from RNG upgrading can include carbon dioxide with trace residual gases such as hydrogen sulfide or other gases. This gas may require further treatment, as through, for example, a thermal oxidizer before being discharged to the atmosphere; and
- Storage – depending on the design of the overall system, storage of the raw or partially upgraded biogas, or the final RNG may be used.

There are various carbon dioxide (CO_2) removal techniques used with biogas. These CO_2 removal technologies remove the CO_2 from the biogas; ultimately, the CO_2 is commonly discharged to the atmosphere as "tail gas". The most common carbon dioxide removal technologies are as follows:

- **Water Washing** – a water scrubbing process that takes advantage of CO_2's greater solubility in water compared to CH_4. This high solubility is also true for H_2S, meaning that the water washing unit may remove the need for desulfurization earlier in the upgrading process. In this process the CO_2 is dissolved in water under high pressure. Downstream, the pressure is released, and the CO_2 is discharged to the atmosphere before the water is recycled.
- **Chemical Scrubbing** – is similar to water washing, except chemical scrubbing agents such as aqueous amine solutions or solvents such as polyethylene glycol blends are used instead of water as the scrubbing fluid.
- **Pressure Swing Adsorption (PSA)** – is based on the adsorption of CO_2 on to a solid media under elevated pressure. Common adsorbent materials are activated carbons, and natural and synthetic zeolites. These systems are used to separate CO_2, H_2S, and H_2O via physical properties; the adsorption materials can be blended or customized to address different biogas compositions. The adsorbent materials are regenerated by a sequential decrease in pressure which results in the adsorbed CO_2 being released and discharged to the atmosphere before the column is reloaded at higher pressure.
- **Membrane Separation** – operates on the principle of solution diffusion through a non-porous membrane and is used for CO_2 removal. The membrane does not have pores, and as such does not separate on the basis of molecular size. Rather, it separates based on how well different compounds dissolve into the membrane and the speed at which they diffuse through it.

- **Monitoring and Controls System Design:** The control system enables the sequence of operations at the AD facility to function properly including safety aspects. The control system philosophy and architecture are usually decided early in the project definition stage. The control of equipment, for example a pump, can have local controls at the pump, a manual control at a motor-control centre, and an automatic control mode where the pump is operated according to programmable control logic. The programmable logic controller (PLC) will usually interface with a supervisor control and data acquisition (SCADA) computer).

  The supervisory computer often provides a system overview screen and an interface for the operator to view and control the equipment. The systems are automatically controlled through the sequence of operations programming within the PLC. When necessary, the system can be switched to manual operation, normally for start-up or troubleshooting. The sequence of operations for the control system is provided by the designer and implemented by the contractor or the technology provider. Often, the electrical contractor provides the controls system as well.

- **Trades and Services**: It is important to retain professionals who have technical expertise and are licensed, competent, reputable, and credible in their field of training. Specific trades that will be required include:
  - **Piping Work:** Pipes interconnecting buildings and process areas are often installed underground to minimize the amount of pipe supports required. For the safety and convenience of the operators of the AD facility and those coming onto the AD facility for any reason, it is important to ensure that piping is designed with truck traffic and operational use in mind.
  - **Mechanical Work:** Mechanical work includes the heating system, mixers, pumps, valves and ventilation. The mechanical work is often the most complex portion of an AD facility. Mechanical systems must be completed as per design including appropriate gaskets and hardware.
  - **Electrical work:** Once all other work is installed, the electrical contractor provides power to all the components of the AD facility. The electrical work must be complete including local disconnects for motors, as well as appropriate shielding of wire and explosion-proof equipment, where required.

5.0 Commissioning and Starting Up an AD Facility

In preparation for commissioning and start-up of an AD facility, an operation and maintenance plan for the facility should be completed and reviewed with the commissioning and operations personnel. This pre-planning will ensure that the operation, monitoring and equipment calibration, and maintenance procedures for the facility are properly understood and adhered to during commissioning and start-up.

Once the facility starts accepting feedstock, there is potential for odour, noise, and vector/vermin impacts. An AD facility is unique in that once the biological processes are initiated, they must be maintained and receive feedstock on a regular basis throughout the commissioning and start-up period. While not in full operation, certain key operational procedures must be implemented prior to facility start-up to ensure odours and vermin do not get out of control before the project is ramped up to full production.

An AD facility is a living organism and as such the start-up period is very important to ensure healthy biological conditions to promote stable biodegradation and reliable biogas production.

Start-up often proceeds in several stages, includes:

- Clean water testing and leak testing of pumps, tanks, and equipment;
- Calibration and tuning of all instruments and control systems;
- Filling the anaerobic digester(s) and reception tanks as per the designer's instructions;
- Ramping up the heating process, bringing the process to the design temperature;
- Then the biological start-up can begin by seeding and feeding the digester until steady-state operational conditions are met; and
- If using an odour control air biofilter, biological sulfur removal process, or biological wastewater treatment system, then the continuous operation of these living processes should be maintained to ensure that the microorganisms in these systems survive and their effectiveness is maintained.

The start-up phase of the AD facility is complete when the facility is running at steady-state feedstock processing capacity and all key process indicators and output end materials are meeting the appropriate quality specifications.

It might be necessary for the AD facility to be seeded or inoculated with a large volume of anaerobic bacteria for the anaerobic digestion process to be initiated. Biological start-ups without an active seeding plan can take 4 to 12 months to complete. It is not necessary to completely fill the new digester with seed material from an existing digester, although this can greatly reduce the start-up time required.

Note that external seeding does not apply to farm-based AD facilities. Livestock manure often contains the correct bacteria to start the process. The reception of additional feedstocks can occur once the AD facility is filled to an adequate level to be mixed, heated, and inoculated.

It is recommended to avoid prematurely storing feedstock during start-up as it is likely to putrefy while being stored and can lead to odours. Once the AD process vessels are full enough to be mixed and heated, the process temperature in the biological reactors should be increased by no more than one degree Celsius per day until the operational temperature is reached. Heating at a higher rate can “shock” the bacteria. As the target steady-state temperature of the digester is reached, the AD facility should begin to produce biogas.

After steady-state temperature is reached within the AD facility, the operating chemistry is within the digester confirmed to be stable, and biogas is being produced with at least 50 percent methane content, the operator can begin adding more feedstock to the AD facility. The introduction of additional feedstock should be done in such a way as to allow the bacteria to acclimate and adjust. Failure to do so can lead to a slow and sometimes unsuccessful start-up or operation.

If the AD facility uses co-digestion, or the digestion of a diverse feedstocks, care must be taken to ensure the various feedstocks are compatible and that they provide a balance of nutrients to support the digester biology. The process designer or a technical expert may need to be consulted during this phase to offer guidance and microbiological support.

During start-up of the AD facility, the operator should plan on making more frequent than usual observations of the plant operation and note how the system reacts to different feedstocks. The most basic tools for monitoring the digester operation are: i) pH meter; ii) a titration analyser – this can be manual or use a semi-automated machine, and; iii) a biogas quality tester. These tools are discussed in more detail in **Section 6.0**.

6.0 Operating an AD Facility

The operation of an AD facility will be determined by the types of organic feedstocks fed to the AD facility, the environment created for the anaerobic bacteria, and by its desired outputs, for example the end-use for the biogas and digestate produced. This section of the guideline will provide an overview of the AD process and generally describe technology options and best management practices for each of the unit operations that might be used in an AD facility.

6.1 AD Facility Operational Considerations

Several factors must be considered when operating an AD facility. At its heart, an AD facility is a bacterial process and the conditions must be maintained within the AD vessels to maintain and promote the good health and growth of the desired anaerobic bacteria.

6.1.1 AD Biological Conditions

An AD facility will host a diverse population of living microorganisms that are dependent on the conditions created in the digestion vessel for their health. Failure to meet the biological needs of those organisms at all times will inevitably impair the digester's microbial health, result in process problems, and possibly even process failure.

Providing a consistent feedstock and maintaining consistent conditions within the AD facility will lead to stable biological health resulting in stable process performance and reliable biogas production.

Key elements to achieving stable and reliable biogas production include the following:

- A consistent and stable supply of raw feedstock materials;
- A combination of feedstocks that when considered on a total mixed ration (TMR) basis provides an appropriate blend of macronutrients;
- Appropriate levels of trace metal micronutrients. Trace metals can be added to a feedstock blend or recipe to ensure a healthy microbial population and to avoid nutrient deficiency inhibition. An excess of certain metals, for example copper, in the feedstock will result in toxic inhibition of the bacteria in the digester and poor biogas production;
- An oxygen-free environment within the digester, this is also very important for safety reasons;
- The preferred range of moisture content appropriate for the type of digester vessel and mixing equipment used;
- Digester operating temperature maintained in the desired range. This digester temperature control usually requires artificial heat input to maintain the target temperature under all weather conditions.;
- Consistent pH in the desired range;
- A reliable mixing or stirring regime; and
- Active monitoring, management, and control of potentially-inhibiting factors such as the build-up of ammonia or salts within the digester.

The operator must carefully manage these conditions because small deviations in any of the previous aspects can have significant impacts on the operation and create unwanted by-products such as digester foam or a mineral precipitate called struvite.

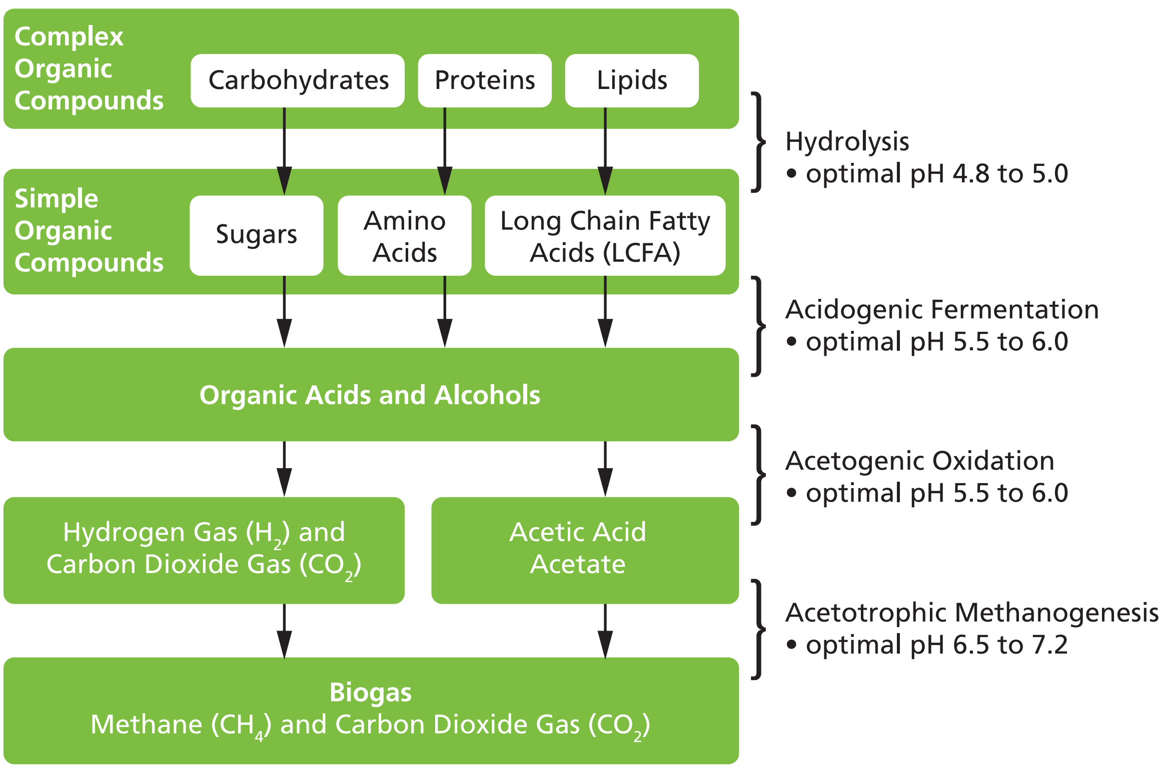
6.1.2 AD Biological Process and Key Factors

The biological anaerobic digestion process includes four distinct stages. To convert the feedstocks to methane, the raw material must pass through all four stages, and these must be in succession. If any one of the four stages is inhibited, then the entire process will fail. The four stages are:

1. Hydrolysis;
2. Acidogenesis or Fermentation;
3. Acetogenesis; and
4. Methanogenesis.

These four stages are shown in **Figure 6.1**.

Figure 6.1 – Chemistry of Food and Organic Waste Breakdown by Anaerobic Digestion



Most AD facilities in Canada operate as wet-digestion processes within cylindrical digester tanks. These are most commonly operated as single-stage digesters, all four biological processes simultaneously within that single environment. However, this single-stage digestion process involves making compromises since the organisms responsible for each of these processes actually respond best under differing environmental circumstances.

Some AD facilities are constructed with multiple stages to separate the steps and provide different environments within different vessels in the process chain. For example, most methanogenic organisms (those which are the ultimate producers of the methane in the biogas) thrive in a pH environment of 7.0 to 8.0 and are severely inhibited at a pH of less than 6.0. Yet the initial steps in the AD process are acid-producing, and can drive the pH below such levels, especially if high levels of fresh feedstock in the mix lead to robust fermentation activity by those families of organisms.

If a digester becomes overloaded by too much readily digestible feedstock, rapid fermentation and the production of organic acids can result. If the overloading is severe, then the fermentation acids can overwhelm the ability of the rest of the feedstock to maintain the digester pH within the usual range and the digester becomes acidic, or 'sours'.

Maintaining a balanced pH range that will serve all participating organisms well is a critical management parameter if a single-vessel approach is used. Regular monitoring of the digester pH, the quantity of organic acids, and the buffering capacity of the digestate to resist changes in pH are important to understand the stability of the digestion process. A rapid change in pH can impair the methane producing bacteria, which can then result in the faster build-up of organic acids and the faster pH drop.

In addition to the buildup of organic acids over time, the digester operator should also be aware of the possible build-up of other potentially inhibitory compounds within the digester. This buildup of inhibitory material is a particularly important consideration when digestate or water is recycled within the facility. The buildup of material can occur very slowly, sometimes over a 12 to 24-month period.

Both slowly biodegradable and non-degradable components can build up in a digester over time. For example, digesters can accumulate a floating 'crust' layer consisting of very slowly degrading materials such as woody fibres from straw or other agricultural residues. The accumulation of fats, oils, and grease (FOG) materials can be a concern and potentially give rise to foam within the digester. Long-chain fatty acids (LCFAs) are specific types of fat that can be inhibitory to the digester bacteria if allowed to accumulate. Example non-degradable compounds of concern include soluble materials, for example ammonia and salts such as sodium and potassium. The build-up of soluble salts can contribute to the formation of a hard scale on piping, heat exchangers, and other equipment as well as accelerate corrosion of metal parts.

In an anaerobic digester, soluble nitrogen exists in two main forms: the ammonium ion (NH_4+) and ammonia (NH_3). The ammonia form is more toxic to living organisms. Ammonia, when present inside an AD facility at higher concentrations, can be inhibitory to the process, and affect methanogenic organisms. Ammonia toxicity can be an issue with feedstocks that contain significant amounts of organic nitrogen, such as protein-containing feedstocks, SSO that includes waste meat, diapers, and incontinence products, and manure.

Table 6.1 outlines typical process parameters for AD systems, although specific systems are able to operate outside these typical values.

Table 6.1 – Typical Process Parameters for Anaerobic Digestion

Parameter	Typical Range		
	High Solids		Low Solids
	Dry or Stackable	Slurry	Wet
Solids content (TS)	>40% (400,000 mg/L)	Between 15% to 40%	<15% (150,000 mg/L)
pH	6.5 to 8.3		
Alkalinity (mg/L)	More than 100, up to more than 20,000 mg/L as CaCO3		
VFAs (mg/L)	Less than 4,000, with some systems running less than 100 mg/L as HAc		
Temperature (°C)	Mesophilic digesters: 30 to 42°C Thermophilic digesters: 50 to 60°C		
Retention Time (days)	14 to 40		
C:N Ratio	30:1		
Ammonia (mg/L)	Less than 3,000 mg/L as N		
Sulfide (mg/L)	Less than 50 mg/L as S		

6.1.3 Digester Loading Rate

Of all the process factors which influence the performance of the anaerobic digestion process, it is the organic loading rate that is the most important. Organic loading to the digester can be expressed in terms of the daily mass of VS or COD fed to the digester. The loading rate appropriate for any particular digester will depend on both the nature of the feedstock and the specific digester technology being used.

A feedstock such as municipal SSO will contain complex organics such as solid whole vegetables, meats, and fats. This SSO material will biodegrade more slowly within the digester and so a low loading rate is appropriate. In contrast to SSO, a simple feedstock such as a food processing plant's washwater containing dissolved sugars can be fed to a digester at a much higher rate because the organics are very quickly biodegraded within the digester.

On a VS basis, design loading rates for wet mesophilic digester can vary from 2.0 to 8.0 kg VS per m^3 of reactor volume per day; with a typical value for mixed food-waste systems being 4.0 kg VS/ m^3-day. If the feedstock is measured as COD, the loading rate can vary from 0.3 to 30 kg of COD per m^3 of reactor volume per day with a typical value for mixed food-waste systems being 6.0 kg COD/ m^3-day.

6.1.4 Trace Metal Micronutrients

The presence of trace metal micronutrients, for example iron, nickel, cobalt, selenium, molybdenum, and tungsten, are as important for biological health as macronutrients such as nitrogen, phosphorus, and calcium. There is an ideal range for each micronutrient, with both too high and too low concentrations providing an opportunity to inhibit the biology of the process. Specialists can evaluate the trace metal concentrations in a given AD facility and provide advice where problems are suspected.

Most AD facilities have a well-balanced feedstock blend and do not require trace metal supplements.

The form of the trace metals in the digester can be an important factor determining their bioavailability. If trace metal deficiency is suspected, then consideration of the chemical interactions within the digester and their impact on the bioavailability of these micronutrients should be considered.

6.1.5 AD Facility Testing

Standardized and consistent testing is critical to understanding the current state of an AD facility, and to predict potential operating challenges in time to prevent them. Some tests can be performed on-site and give operators an overview of the health of the system, such as the pH and titration with the calculation of the ratio of organic acids/alkalinity concentration. Different measurements of this ratio, called the Ripley Ratio or RR, are used in the industry.

The natural pH of the digester will depend on the feedstock. Industrial anaerobic digester systems often perform well at a pH near 6.8, while municipal sewage digesters perform between 7.0 and 8.0, and many farm-based digesters operate well with a pH between 7.8 and 8.2. For most digester operators, the magnitude of the pH value is less important than the stability of the pH value.

The titration of a digestate sample with a strong acid such as sulfuric acid (H_2SO_4) can be used to estimate the organic acids and buffering capacity in the digester. This value of the organic acids is called the "volatile fatty acids (VFA)" the buffering capacity is measured by the "total alkalinity (TA)". This ratio of organic acids / total alkalinity, or VFA/TA is also called the Ripley Ratio (RR). The Ripley ratio is very similar to the German "FOS/TAC" ratio some digester operators use. A RR of less than 0.25 usually indicates stable operation.

Note that these titration methods (RR and FOS/TAC) are only estimates—the VFA estimates the "food" in the digestate. However, this titration VFA reading can: i) give false values depending on the ammonia concentration in the digestate, and; ii) cannot detect the build-up of ammonia, fats, or long-chain fatty acids in the digester.

When performed consistently, testing can also be an early warning system for changing conditions that could eventually lead to process upset, or even complete process failure.

Further laboratory testing can also be scheduled to provide more detailed information about the composition of the substrate, such as volatile fatty acids and long-chain fatty acid profiles, nitrogen or ammonia content, salinity and specific salt measures, and other important control parameters. Ultimately it is up to the operator to interpret and analyze these results, as each AD facility is a living organism and will have different operational values than the next depending on facility design.

Regular and consistent testing is important so that test results can be compared against previous results to identify slowly changing conditions and overall process trends. Testing can take several forms, with some parameters being monitored daily, and some parameters being tested only four times per year. The frequency of testing depends on the facility design and overall retention time, the nature and consistency of the feedstock, and the observed biogas production.

Daily or twice-a-day pH, titration, and biogas testing can be required during the critical first weeks of the biological start-up. Over the first year of operation, the operations staff will identify the rate at which the digester parameters change, and they can reduce the testing frequency accordingly. In general, for a well-mixed, single stage, wet digester, a testing frequency of at least ten tests per retention time is a suggested minimum testing frequency. For example, if the digester has a 30-day retention time, a program of basic testing (pH, RR, biogas) once every three days is suggested as a minimum initial frequency.

Several online instruments are available to provide continuous monitoring of the digester pH and temperature, and the biogas quality. Online meters to continuously monitor the bacterial respiration are under development.

A larger suite of digester parameters measured in offsite laboratories, for example, solids, alkalinity, VFAs, LCFAs, total-nitrogen and ammonia, and COD can be measured once per retention time as an initial estimate. A fully comprehensive set of samples that include macronutrient, trace metals, and salts can be measured up to four times per year.

If there is a change in the biogas production or a new feedstock is added to the digester, then more frequent sampling is recommended. If the biogas production falls unexpectedly or there are any signs of foam formation, immediate additional testing is recommended to identify the cause of the disturbance.

In general, operators are encouraged to secure samples of all potential feedstocks that are unfamiliar to the AD facility or not well understood or already characterized, and submit those samples for laboratory analysis with an accredited lab familiar with the needs of AD facilities and the nature of feedstock materials. This laboratory testing will help to ensure that there are no inhibitory materials in the sample that could impair the biology of the AD process or contaminate the final digestate with any undesirable substance.

Feedstock samples should be tested for heavy metals concentrations to verify they are within regulatory limits. Laboratory testing will also determine the energy value of the feedstock through a biomethane potential (BMP) test so that its utility to the operation can be determined. The BMP test provides an assessment of methane production potential, and biogas production curves that can be used to check for the presence of possible latencies, inhibitors, and compatibility with the inoculum used.

The detailed analysis of the BMP production curves can show the operations staff how long a certain feedstock takes to be converted to biogas. For example, with many feedstocks in a single-stage mesophilic digester, the majority of the biogas is not produced until 2 to 4 weeks after the material is added to the digester. Because of this normal lag in biogas production, excellent records of the digester feeding from several weeks ago are important for the operators to understand the biogas production being observed today.

6.2 Digestate Management and Post-Processing

After the feedstock has undergone the anaerobic digestion process to generate biogas, a residual material referred to as digestate remains. This digestate still contains virtually all of the macro and micronutrients that were found in the original feedstocks. In wet AD facilities, the digestate will be a low-solids organic liquid.

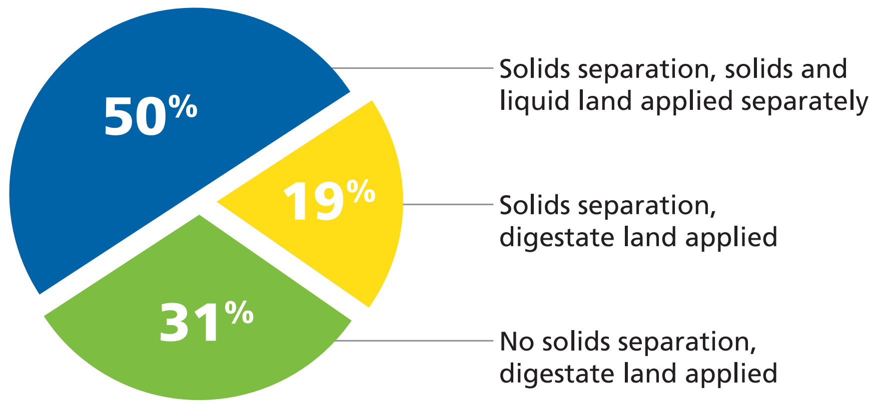
The nutrient rich digestate has value as a fertilizer and/or soil amendment. Managing digestate is a crucial aspect of project planning, particularly in areas with nutrient overloading issues.

6.2.1 Digestate Pathways

There are a number of pathways that can be considered for the use and marketing of digestate in Canada. Attention should be paid to specific regulatory considerations that may be relevant in some provinces. The vast majority of digestate produced in Canada today is stored and then applied to adjacent farmlands as a soil amendment.

Figure 6.2 presents the results of a 2018 survey of 26 operating agricultural digestion facilities across Canada and shows that 69% of those agricultural facilities surveyed use some form of solids separation. In agricultural operations, recovered fibre solids from AD systems can be used as bedding material.

Figure 6.2 – Use of Digestate from Canadian Agricultural AD facilities (2018)



This direct land application of digestate is the most economical approach due in part to most Canadian AD facilities being co-located on farms or near agricultural areas and land application does not require digestate treatment. Digestate treatment may add significant capital and operational costs to an AD facility, depending on the project specific details.

Agricultural operators take care to balance the application of nutrients such as nitrogen and phosphorus with the nutrient uptake of the crops. In some areas, the removal of excess nutrients, such as phosphorus, may be necessary where the overall nutrient loading is an issue. For instance, in the Fraser Valley area of British Columbia, digestate is transported away from the digesters to avoid overloading the capacity of the land in the local area.

In addition to agricultural digesters, non-agricultural digesters can also direct much of the digestate for reuse as a fertilizer or soil amendment.

There are no pan-Canadian regulatory standards for digestate quality. In general, each province has its own approach towards the regulation and control of digestate application to land. Digestate use is an issue that should be addressed in the context of securing approvals to construct and operate an AD facility.

Post-processing of the digestate, for example screening to remove large or non-biodegradable solids may be required in some instances. Post-processing can also include solid-liquid separation processes to recover valuable material such as non-degraded fibre from the digestate.

Where an AD facility uses manure that includes straw or other slowly biodegraded fibrous bedding material as a significant feedstock, much of that fibrous mass will have resisted degradation in the digestion process and will still be significantly intact at the end of the process. It is common practice in farm-based AD facilities to process the digestate through a screw press or similar device to separate and recover the fibrous residue from the liquid digestate. This fibrous residue can be used as livestock bedding material, however proper storage and application of the bedding material is required.

If the AD facility applies, the Federal Government may also register the use of digestate as an agricultural fertilizer, under the provisions of the *Fertilizer Act.* In some jurisdictions, approval of digestate as a Fertilizer under the Act exempts that product from other, additional approvals. Regardless of the digestate end-use and product classification, government approvals will still likely be required for operation of the digestion facility.

Since 2015, digestate has been accepted for use in certified Organic Farming in Canada and is listed as a 'permitted substance', which may be employed in the operation of Certified Organic farms. Organic certification is performed by private, 3rd parties and is independent from any government registrations and/or approvals. To access this market, digestate producers would have to approach one of the approved organic certifying agencies, which operate in their Province and apply to have their particular digestate certified for this purpose.

One other avenue for the management of digestate is to consider it an intermediate product only, and to then ship the digestate for further processing at a downstream facility. For instance, de-watered digestate can be trucked to a licensed aerobic composting facility, for additional processing to allow the material to be turned into a final compost product. The blended material, the co-composted output, product is then marketed under local regulatory regimes for compost.

6.2.2 Digestate Storage and Dewatering

In general, it should be noted that most jurisdictions prohibit the application of soil amendments, including digestate, during prescribed winter periods and provision must be made for either on-site or off-site winter storage of digestate, in whatever form it is produced. Storage requirements are often described in number of days of storage, accounting for rainfall in the area. It is important for digestate to be handled and stored to prevent odour concerns and recontamination with other materials onsite.

Because of its large volume, digestate can be costly and impractical to store for lengthy periods of time, or to haul it any significant distance. If low-cost winter storage and nearby farmland is not readily available, post-processing of the digestate using a dewatering process may be required. The resulting smaller quantity of dewatered solids then become more efficient to transport and store as necessary. However, the de-watering process can be costly and result in the production of large quantities of ammonia-rich wastewater, which must be disposed of or treated, possibly using one of the BNR-type wastewater treatment processes.

This wastewater could be recycled back into the process, for instance to blend with solid digester feedstocks. However, special attention is required whenever recycling materials within the digester facility is considered. Recycled water returns solids, nutrients, and dissolved compounds such as salts to the process, thereby increasing the loading of these materials on the digester. Wastewater for on-site reuse should be treated to remove most nutrients, to prevent ever-increasing concentrations of those nutrients from accumulating and becoming toxic to the process biology. High-quality wastewater treatment processes to remove nutrients and salts are available but can also be costly. The accumulation of increasing concentrations of potentially inhibitory levels of ammonia, trace metals, potassium and other salts, and other compounds can occur over a period of 12 to 24 months.

Removing solids from digestate can begin with simple thickening, proceed to dewatering, and advance to drying. In a drying process, the dewatered digestate is taken all the way to the production of a dry, stable, granular product, if desired.

6.3 Use of Biogas

Most AD facilities are designed to produce biogas, and the sale of energy produced from raw biogas is commonly the primary economic driver for building an AD facility. Some municipal SSO digestion systems were originally envisioned as SSO treatment facilities and the biogas was simply flared—this practice is no longer recommended.

Raw biogas is generally a mix of 50-65 percent methane, 40-50 percent carbon dioxide, and a range of other constituent gases in smaller proportions, including hydrogen sulfide, water vapour, nitrogen, and oxygen. Additional contaminant gases such as terpenes, VOCs, and siloxanes can present as trace gases. Common energy applications for biogas include:

- The production of electricity, by burning the biogas in specially-designed internal combustion engines harnessed to large electrical generators. These units are described as CHPs, because they also produce thermal (i.e., heat) energy as a by-product;
- The production of pipeline-grade natural gas, commonly referred to as RNG or biomethane, by scrubbing the raw biogas to remove impurities to achieve almost pure methane. RNG can be directed into the natural gas grid and/or used to fuel CNG fleets; and,
- To consume the biogas directly as boiler fuel in specially-designed, dedicated or dual-fuel boilers built to work with this fuel (i.e., in stationary applications).

In general, it is not economical to transport raw biogas any significant distance, so the equipment required to produce energy from the biogas should be located on the same site or in close proximity. This local energy generation creates a need for the energy market to be accessible to the location chosen either through ready access to a natural gas pipeline or to high-voltage transmission/distribution lines required to transmit the energy to market. This access to the energy market is a key consideration in selecting and confirming the site for the AD project.

The potential developer of an AD project needs to consult directly with the relevant local utility to ensure that the available local infrastructure has sufficient capacity to take away the energy produced, 24/7, and on a year-round basis. The presence of local utilities does not necessarily imply that sufficient year-round capacity will be available.

Regardless of the energy pathway chosen, there will never be a perfect match between the biogas output from the AD facility and the ability of the energy pathway to utilize it, from hour to hour and day to day. For example, a brief disturbance to the electrical grid during a lightning storm can cause a digester electrical supply to be disconnected from the electrical grid for a period of time until the system is reset. Similarly, maintenance work on a natural gas pipeline can cause the gas utility to stop accepting RNG until the work is completed. These energy grid interruptions can last minutes to days.

Biogas storage is typically built into the design of an AD facility to buffer variation in biogas generation rate and to ensure a constant supply to the energy conversion system. Biogas is often flared when the energy network is unavailable.

6.4 Management of Inorganic Residuals

AD facilities that accept feedstock commingled with food packing and other inorganic materials such as plastics, glass, ceramics, and other materials, should have specialized equipment to separate these contaminants from the digestible organics. Because many feedstocks can also contain pathogenic bacteria such as *E. coli*, *Salmonella*, or other human pathogens from used diapers and incontinence or sanitary products, great care is required to ensure operator safety when performing maintenance on any part of the system or equipment. See **Section 8.0** for further discussion of risk management and safe operation of AD systems.

Removing non-digestible materials from feedstock will create a continuing stream of inorganic materials, which must be handled, stored, and ultimately disposed of as part of the operation. Usually, these inorganic residuals will still include entrained water and at least small amounts of organic matter adhering to the material and are likely to be odourous. All aspects of handling, storing, and disposing of these inorganic wastes should be included in the facility's odour management plan. Storage of these materials at the facility should be large enough to facilitate efficient trucking for disposal, while remaining small enough to minimize the need to manage odours.

Canadian experience, to date, with attempting to recover recyclable or other valuable materials from this stream of inorganic contaminants has not been successful, and consequently, these materials are generally trucked to landfill for disposal.

6.5 Prevention of Emergency Situations

Site operators should develop and maintain detailed contingency plans for identifying, preventing, and dealing with non-routine and emergency situations at AD facilities. For example, these plans can cover: stormwater runoff from feedstock storage areas; noise; dust; litter; odour complaints; fire; power outages; emergencies; and, gas leaks or venting, such as methane and hydrogen sulfide.

It is not unusual for a digester facility to use a back-up power supply to maintain critical site operations and odour control facilities in the event the main CHP system or primary power supply is interrupted. Similarly, the facility designer may include an allowance for a propane or natural-gas-fired boiler to maintain the digester's operating temperature during an interruption of the CHP or primary heat supply.

Some contingency plans are required under environmental regulations and permits, while others are required under occupational health and safety regulations, and others are good management practices at digestion facilities. Operators should check their local regulations for the type of contingency plans that are required. A copy of these contingency plans should be kept at the site and all operations staff trained on the contents of the plans; written documentation of this training should be recorded, and a plan made for record retention. The plan would normally be required to be implemented as soon as a problem is discovered.

For additional safety measures, it is suggested that small facilities consider using a lone-worker monitor when there are few people working on different areas of the facility.

6.6 Preventative Maintenance and Spare Parts

To ensure the AD facility continues to operate effectively and safely, a robust maintenance and spare parts plan is required. Some spare parts are critical to the facility operations, for example, certain pumps, agitators, contaminant removal equipment, and odour control or environmental systems.

Spare parts for both planned and unplanned outages can be both expensive and have a long lead time. Facility management can evaluate the cost of keeping spare parts in inventory and the risk and consequences of an unplanned outage.

The source, location, and reliability of spare parts supply are factors for consideration is selecting an equipment or technology provider. In many cases the cost of critical spare parts can be justified when considering the consequences of lost production and the risk of an odour discharge while waiting for a part to be fabricated and shipped to the facility.

6.7 Operator Training

AD facility operators are encouraged to attend high-quality training courses to facilitate their understanding of process operations and to obtain hands-on experience. Training is recommended to provide new operators with the resources and tools they will need to safely operate an AD facility. As part of the development of the AD project, a detailed understanding of the AD-specific processes and systems, and the corresponding staff training needs is required. From this detailed understanding of the training needs the training plan should be developed.

AD service providers, consultants, and technology provider can provide site-specific training customized to individual facilities.

A number of resources are available that operators should consider for safe operation. A partial list is shown below, including but not limited to:

- Anaerobic digestion process fundamentals and biological safety;
- Feedstock management;
- Management of vectors, vermin, and other wildlife (including bears in some areas);
- Gas safety including both methane, carbon dioxide, and hydrogen sulfide;
- Energized equipment lock-out and tag-out;
- Confined space;
- Working at heights; and
- Emergency response, including first aid, and firefighting.

The facility designer and other experts should be consulted to ensure the appropriate training is identified and training plans are created.

6.8 Environmental Considerations

The following environmental considerations must be taken into account from an operational perspective to ensure a clean and safe facility. Good housekeeping and the maintenance of a neat and orderly site also contributes to reduced odour concerns.

- **Litter:** Litter, primarily in the form of plastic and paper, can be present in loads of waste materials used as feedstock. Light-weight materials can be blown off feedstock trucks or blown around the site by the wind and result in an unkempt appearance and complaints from neighbours. Litter may also be caused by plastic residues blowing from open digestate storage tanks or areas. Litter can also be tracked around and off-site by vehicles moving around and leaving the facility. Measures to reduce litter from a facility that should be considered on a site-by-site basis include:
    - Refuse to accept loads from uncovered vehicles;
    - Receive and process feedstock in an enclosed area;
    - Exercise care during processing and screening of organic waste, particularly during windy days if done outdoors;
    - Collect on-site and off-site litter promptly, for example by conducting a daily manual pickup;
    - Ensure that litter and other waste materials at the site are stored in proper closed containers and disposed of on a regular basis;
- **Dust:** Dust is generated from truck traffic on gravel roads and parking areas. Also truck traffic can generate dust on paved roads dirtied by vehicles leaving the site. Dust control measures that should be considered include:
    - Paving on-site roads, parking, and truck storage areas;
    - Using on-site road sweeping equipment to regularly collect dust from the site;
    - Wetting dry, dusty, on-site gravel roads;
    - Ensure vehicles leaving the site use a wheel wash to minimize tracking of dirt onto public roads; and
    - Clean roads regularly, including refreshing gravel if that is the case.
- **Vermin and Vectors:** Raw organic waste and waste food attracts a variety of vermin and vectors including insects, rodents, birds and other wildlife. Once established, vermin and vectors can be very difficult to remove, and may pose a public health problem.

  Wildlife may be attracted by the food and shelter available at an AD site. Flies are attracted to decomposing material, and mosquitoes may breed in pools of water on the site. Possible trouble areas at an AD facility include:
    - Receiving and storage areas;
    - Processing areas, run-off and low-lying areas within a facility that hold standing material or water;
    - Feedstock truck parking and empty roll-off bin storage areas;
    - Site perimeters; and
    - Roadways.

Measures that should be considered to control vermin and vectors at a site include:

- Promptly incorporating wastes (particularly food wastes) into active processing;
- Consider covering feedstock storage areas or storing within buildings;
- Active management of run-off and collection ponds;
- Regular cleaning of receiving areas;
- Using pest control and traps for vermin as required, and
- Appropriately-fenced enclosures at sites likely to attract larger wildlife such as coyotes and bears.

7.0 Odour Prevention, Control, and Treatment

Odour control must be considered in all stages of planning. Managing odour is often a key requirement of receiving a local permit to operate an AD facility and successful odour management is critical to a successful AD operation.

Failure to comply with permitting requirements can result in penalties and in extreme cases facility closure. Moreover, poor odour management systems can pose a safety risk if hydrogen sulfide or other dangerous gases are escaping. More information on preventing, identifying and managing dangerous gas leaks can be found in **Section 8.1**.

7.1 Sources of Odour

Every aspect of operating an AD facility has the potential to produce odour. An odour emissions model should include the following sources to identify the potential for significant odour emissions:

- **On-site Traffic:** Trucks used to deliver feedstock and remove digestate from the facility may discharge odours when they drive around the plant and are stationary while being unloaded and loaded. The storage of empty trucks and roll-off bins, if not thoroughly cleaned, can be a significant odour source;

- **Odours Associated with Active Work at the AD facility:** During working hours, odours will be generated as new material is moved onsite, shredded, mixed, or otherwise handled will result in odours being generated. If this work is done outside, or in a facility without effective odour control, the odour generated from the feedstock processing will result in an odour release from the facility.

  Odours can be generated at the site from natural processes not directly related to the AD process. For example, the accumulation of water in a stormwater pond and the subsequent natural biodegradation of algae during hot weather can result in odours.

  Similarly, partially empty feedstock or preprocessing tanks can contain a substantial amount of odourous air in the headspace prior to being refilled with fresh feedstock. As a raw material tank is quickly filled by a feedstock truck, the odourous air is rapidly pushed out of the tank—this can quickly overwhelm an odour control system if this situation is not fully considered in its design;

- **Odours Associated with Ongoing Storage and Material Pre-Processing:** Storage and pre-processing of organic feedstock material that has not yet been added to the AD process or the storage of digestate in an uncontrolled environment after processing will create continuous sources of odour;
- **Flare:** The waste gas flare can be activated to burn biogas when the engine or upgrader is shut down or excess biogas is produced. Odour emissions will occur when the flare is in operation due to the combustion products;
- **Fugitive Odours:** Biogas leakages can also be a source of odour. Avoiding leaks and using closed buildings and tanks are among the most important ways to reduce fugitive emissions. Poorly constructed buildings and failure to maintain closed doors in feedstock storage and/or pre-processing or post-processing buildings can lead to fugitive odour emissions.; and
- **Housekeeping:** Handling and processing organic waste materials or digestate will inevitably lead to the accumulation of small amounts of organic residues on equipment, walls, and floors inside an AD facility. A failure to continually clean and remove these residues will lead to odours.

For working and continuous sources of odour, the best mitigation is to minimize the amount of time that organic waste material is in contact with the atmosphere. This can be achieved by timing deliveries to minimize the amount of organics in outdoor storage and having a plan for active digestate management and removal. In more urban areas, the presence of any organic material handling outside may be enough to cause complaints from nearby residents. In this case, it may be necessary to handle all organics inside of facilities with negative pressure air treatment systems (described in **Section 7.3**).

As general housekeeping practices, facilities should be designed to collect and treat stormwater runoff and leachate from outdoor feedstock or digestate storage areas, and regular maintenance and cleaning activities must be undertaken as needed.

Odours are caused by volatile chemicals in the air being detected by scent receptors in humans. Odour chemistry is complex. In general, the most common classes of chemical compound that give rise to odour concerns are i) reduced sulfur compounds in the feedstock and digestate, ii) volatile fatty acids such as butyric acid, which is an intermediate compound in the AD biodegradation process, and iii) nitrogen compounds in the feedstock and digestate. A summary of odourous compounds can be seen in **Table 7.1**.

Table 7.1 – Potential Odourous Compounds Found at AD Facilities

Compound	Source	Smell
Inorganic sulfur (hydrogen sulfide)	Leachate, biosolids	Rotten eggs
Organic sulfur (mercaptans)	Wastes stored in anaerobic conditions	Rotten eggs
Organic sulfides	Composting	Manure
Inorganic nitrogen (ammonia)	High nitrogen feedstock (e.g., poultry manure)	Urine
Organic nitrogen (amines)	Composting	Fishy
Fatty acids	Wastes stored in anaerobic conditions	Vinegar
Aromatics/butyric acid	Anaerobic digestion	Sour milk

7.2 Design and Operations to Reduce Odour

Facility design is an important factor in effectively maintaining control of odour. Design elements that should be considered include:

- Enclose all odour-creating material and handling activities within a negative pressure environment that captures and collects all potentially odourous air and forces it through the odour control system or where not practical using air currents;
- Enclose significant odour sources (for example manure, residential SSO, etc.) in tightly fit enclosures to reduce contact with air;
- Design the facility ventilation with due consideration of the number of air changes per hour (ACH) provided by the ventilation system, and the air face velocity at doors;
- Connect all doors associated with process buildings to an alarm system which alerts operators in the event doors are left open;
- Create partitions within buildings to reduce airflow and drafts and to isolate the more odorous activities;
- Utilize interlocks between personnel doors, truck doors, and facility receiving areas to control the number of doors that are open at one time;
- Make vehicle entry points to process building accessible via fast acting roller shutter doors that open and close on a pressure switch; and

- Design with flexibility for the expected characteristics of the process. Use a flexible design that can handle predicted upsets such as excessive feedstock being delivered or reduced production capacity.

These design features are mostly oriented towards large-scale AD facilities operating near odour sensitive regions, in general, urban areas. Operations in less sensitive regions can often maintain good relations with neighbours through less sophisticated means. AD facilities in rural areas should focus on good handling practices and reducing the amount of feedstock being stored in the open air before being fed to the system.

All digesters should include plans and design options for upset conditions when feedstock accumulation can outpace digester capacity. These plans should include seasonal factors such as odour generation during hot summer months.

To reduce odour in handling the following should be considered:

- Minimize storage of feedstock on site and institute operational protocols to ensure material is processed in the approximate order of receipt;
- Do not accept more feedstock than can be managed by the existing receiving area;
- Perform regular preventative maintenance of equipment and all building surfaces to minimize equipment breakdowns and ensure that odourous materials are not allowed to accumulate in the facility.

7.3 Odour Control Systems

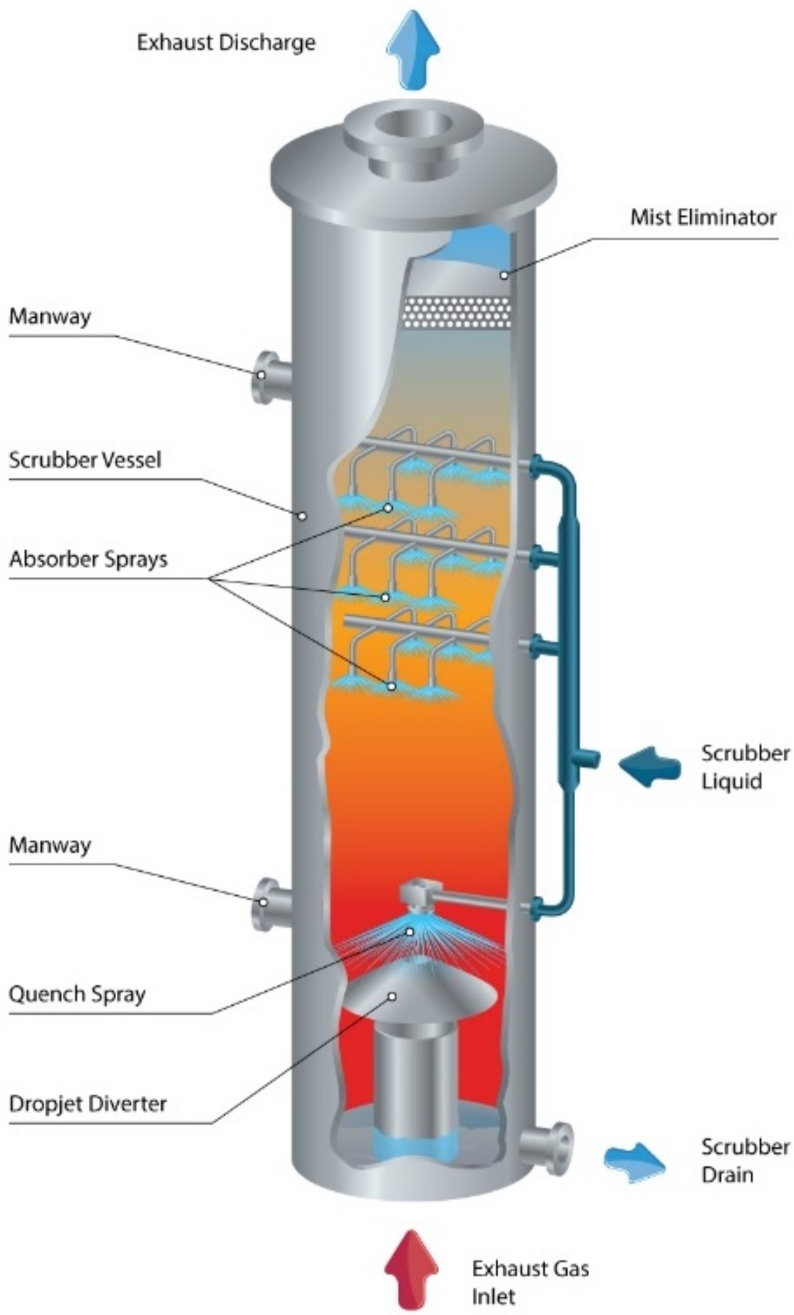
With odour control, the major design consideration is control of air circulation. This starts with the collection point for organic waste materials. Organic waste materials left in an unenclosed area, especially on a warm day, will degrade quickly and create a significant amount of odour.

A benefit of AD is that air is not circulated in the actual processing vessels, in contrast with aerobic composting facilities, and that the finished digestate has had many of the odour-causing compounds degraded.

The first step in odour control is isolation of the organic waste material from the building environment. Once this is achieved, the control of odour has two parts. The first component is containment within the building that accepts and processes the organic waste material. This is achieved through the design of the ventilation system to achieve and maintain 1) a negative pressure regime within the building containing organic waste storage and handling, 2) the appropriate face-velocity on doors and entranceways, and 3) the appropriate number of air changes per hour for each room.

The second component is the removal of odours from the ventilation system before the air is discharged to the atmosphere. The requirements of odour abatement systems are dependent on the chemical composition of the process air stream and the location of the nearest sensitive receptors.

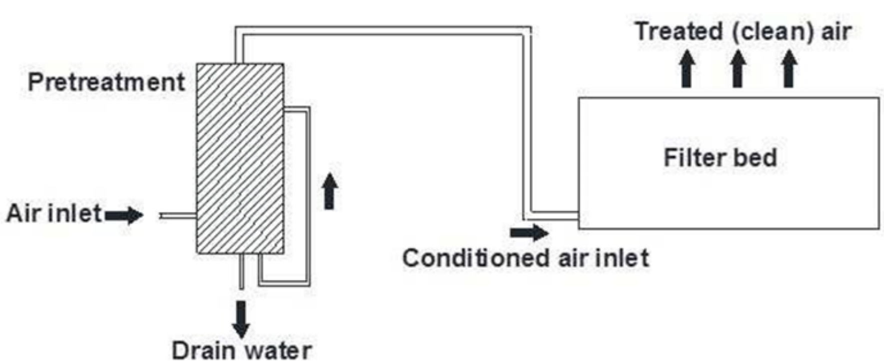
Figure 7.1 – Wet Scrubber (Source: https://www.ipeadvisor.com/wet-scrubber)



Odour abatement systems should be designed utilizing technologies that mitigate the specific odour causing compounds present within the process air, and conservatively designed for the odour loading expected during peak odour generation events. The odour treatment technology must reduce the odour compounds in the emitted air to below the threshold anticipated to cause nuisance odours to nearby sensitive receptors as determined through air dispersion modelling. Selecting a specific odour treatment system for a facility should be undertaken with the aid of a qualified professional. Depending on the characteristics of the process air, the use of multiple technologies within an odour treatment train may be necessary for effective odour mitigation. The following technologies are identified for use within an odour abatement system:

- **Wet Scrubbers:** Odorous air is passed upwards through a packed or misting tower, usually two to four metres tall with several stages, while water rains down and contacts the odours air (**Figure 7.1**). Odorous compounds are dissolved into the water, which can include the addition of acid or caustic chemicals or chemical oxidizers. The water or water-chemistry solution is slowly drained off as it saturates and is processed to neutralize the dissolved compounds. Wet scrubbing is effective for sulfur and ammonia removal. The space requirement is relatively small and at high flow rates wet scrubbing is cost effective. The disadvantages of wet scrubbing include the cost to treat the acid or caustic process fluid, freezing in cold environments, and the requirement for periodic cleaning.
- **Carbon Filters:** Typically used for removing hydrogen sulfide, carbon filters can potentially be used for other odorous compounds (**Figure 7.2**). Odorous air is passed through a tower or drums with a carbon media that adsorbs odorous agents. Depending on the size of the filter and concentration of odorous compounds, the carbon media will need to be replaced every two to 18 months. Carbon filters tend to be very space efficient and simple to operate. The disadvantage of carbon filtration is periodic media replacement and moisture sensitivity. Carbon filters are not effective at removing ammonia.

Figure 7.2 – Carbon Filters



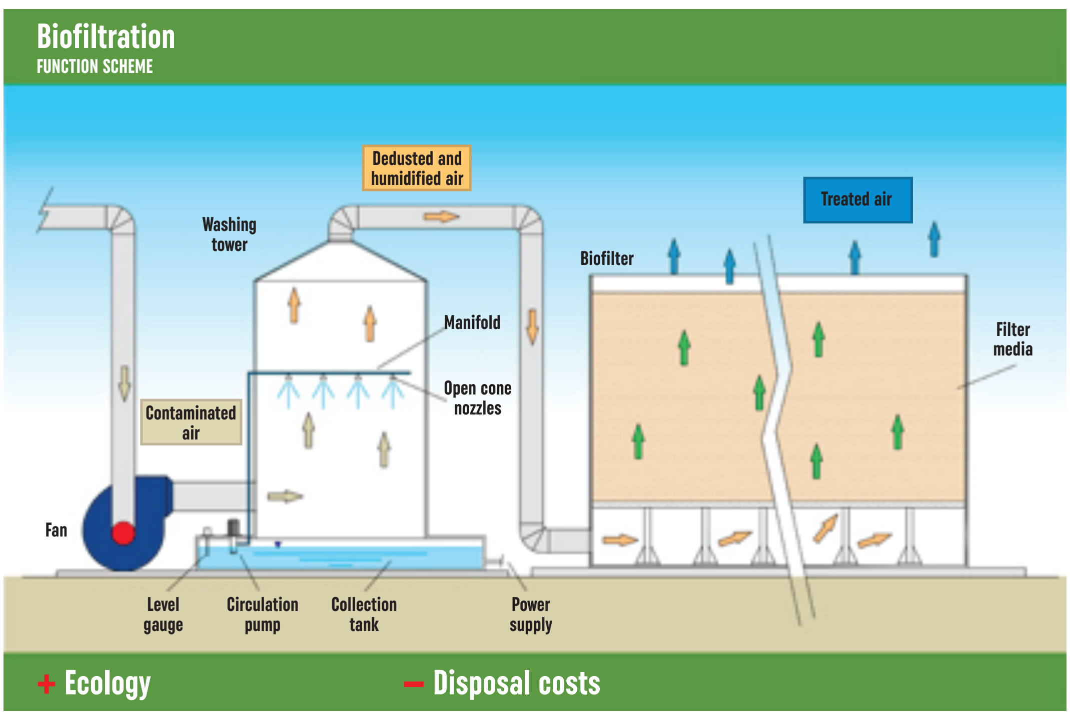
- Carbon filters should be equipped with continuous breakthrough monitoring that is located within the media bed, or after each media bed in the case where multiple filters operate in series, to ensure breakthrough is detected before odourous air breaks through the filter. The diagram [above] illustrates a typical configuration for carbon filter systems that allows for the changeout of media without releasing odour to the environment;

- **Bioscrubbing:** Bioscrubbing operates in a similar fashion to wet scrubbing, except the odorous compounds are reduced by a community of microorganisms that metabolize the compounds. A well-designed system requires less maintenance and operational expenses than a wet scrubber. A biological system can also adapt to changes in the relative concentrations of odour compounds as microbe populations will increase proportionally to the presence of compounds that they can metabolize. The disadvantages of a bioscrubber are a larger space requirement and the need to maintain a stable biological system. Moisture and temperature control are needed to maintain a stable biological system, as are the provision of nutrients;

Biofilter: Biofiltration consists of a pre-treatment step to remove particulates and aerosols, as well as warm and humidify the incoming odourous air stream. The air then passes over a media onto which a biological community of microorganisms has grown. These microbes then metabolize the odour compounds (**Figure 7.3)**. A well-designed system requires less maintenance and operational expenses than a wet or biological scrubber. In some instances, a biofilter can be used as a polishing step following a wet chemical scrubber.

The biofilter system can also adapt to changes in the relative concentrations of odour compounds. The disadvantages of a biofilter are a larger space requirement to achieve the required contact time, called the "empty bed contact time (EBCT)" and the need to maintain a stable biological system. Moisture and temperature control are needed to maintain a stable biological system, as are the provision of nutrients;

Figure 7.3 – Biofilter and Biofiltration (Source: http://grtdarma.com/fr/p.asp?p=biofiltre-biofiltration)



- **Electro-oxidation, Photoionization, and Ionized air oxidation:** Are different technologies that use oxygen and water vapour in the air to create highly-reactive oxygen molecules to chemically oxidize the odourous compounds from the AD facility. These systems use electricity to power chemical reactions using a combination of electrical fields, ultraviolet (UV), a corona discharge, and a catalyst to break down odour-causing molecules. The odourous air passes through a reaction chamber where it is exposed to a high-energy environment that creates free radicals that immediately begin oxidizing the odour-causing molecules. These systems have a small footprint and do not rely on flowing water or other liquids to operate. As a result, oxidation and ionization-based equipment often have a relatively small footprint. The energy demand of the system can be a drawback as is the need for maintaining the cleanliness of the reaction chamber;
- **Thermal Oxidation:** Thermal oxidizers are used industrially to destroy odourous volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Thermal oxidizers use heat to degrade odour-causing molecules. As a result, thermal oxidizers require a source of fuel which can be biogas, natural gas, or electricity. This fuel requirement will add additional operational cost. A thermal oxidizer can also be used to destroy methane emissions that may be entrained in the exhaust of a biogas upgrader. In this case, the amount of additional fuel required to operate the thermal oxidizer may be reduced and overall greenhouse gas emissions may be further reduced.

8.0 Contingency Planning, Safety, and “Spill” Response

AD facilities include a number of hazards that range from nuisance to life-threatening. Some hazards are common among industrial and agricultural sites, such as the use of rotating equipment and large vehicles. Some concerns are unique to AD and biogas, such as flammability, explosion risk, toxic gases, and entry into confined spaces. Provincial regulators have ultimate authority over the requirements for safe work practices and mitigation.

This AD Guideline provides only a high-level overview discussion of safety concerns, focusing on AD facility-specific issues and general considerations for mitigating these hazards.

AD facility operators are strongly encouraged to seek the guidance of a safety professional in identifying potential risks and appropriate mitigation efforts at their specific site. A formal review using a Hazard and Operability (HAZOP) review, Process Safety Management Review (PSMR), or similar methodology is recommended.

Attention should be paid to these issues, including workplace safety regulations and protocols that may apply in your jurisdiction.

See **Section 6.7** for a list of training resources for operators.

8.1 Toxic Gases

Depending on the feedstocks used, biogas can contain hydrogen sulfide (H_2S) from levels of 10 parts per million (ppm) to more than 10,000 ppm. Sulfur is most commonly found as part of high-protein feedstocks and this sulfur is liberated as dissolved sulfides and gaseous H2S during the biodegradation process.

Hydrogen sulfide is deadly. Hydrogen sulfide is a flammable, corrosive, and colourless gas that is highly toxic and requires special training. Hydrogen sulfide has a greater density than atmospheric air and will, under most environmental conditions, sink and accumulate in low-lying areas, sumps, pits, drywells, and basements. At first, low levels of hydrogen sulfide have a strong smell like rotten eggs, however people suffer from olfactory fatigue and sustained exposure to low levels of H_2S can eliminate the sense of smell, disguising how much danger is present. A high concentration of H_2S cannot be smelled as it instantly overwhelms a person's sense of smell.

Smelling H_2S at an anaerobic digestion facility is an indication of a larger problem—namely there must be a biogas discharge, which also contains potential flammable or explosive methane. After taking appropriate protective measures, the source of the H_2S should be investigated and any leaks repaired.

A guide to hydrogen sulfide concentrations can be found in **Table 8.1**.

Table 8.1 – Hydrogen Sulfide Concentrations
(Source: https://www.ihsa.ca/WebHelp/OHSA_and_Regs.htm, December 2014)

Concentration (ppm)	Symptoms	Notes
1	Smell of rotten eggs	
5	Strong smell	
10	Overpowering smell	Time-weighted average limit
15	Nose/throat irritation, coughing	Short-term exposure limit
100	Nose/throat irritation, coughing	Immediately dangerous to life and health
150	Instant loss of smell	
200	Pulmonary edema	
>500	Death	

Controlling toxic gases starts with knowing where in the process these gases reside and isolating these processes. Hydrogen sulfide will normally be found from the point of generation within the AD process vessels, to the point where it is removed from the biogas stream. The areas and piping where hydrogen sulfide is present should be clearly labelled. If properly designed, maintained, and operated gastight, the operation of this equipment is safe.

The next level of protection after isolation, keeping the biogas containing equipment physically away from people and enclosed areas, is engineering controls. Engineering controls include the use of area gas monitors and properly designed gas handling and relief systems.

The last lines of defense for staff are training, procedures, the use of personal gas monitors, and personal protective equipment—these should never be a substitute for appropriate facility design and maintenance. The systematic use of regularly calibrated personal gas quality monitors is recommended. When working on site, all persons working in areas where dangerous gases might be present should have a personal gas monitor and be adequately trained on the dangers, impacts, and proper mitigation strategies for any potential hazards.

Concentrations of hydrogen sulfide in process air streams should be considered in the design of odour abatement systems in order to mitigate release to the atmosphere. Acceptable emission rates will vary dependent on localized environmental conditions.

8.2 Confined Spaces

Confined space entry is regulated by each Province's safety board and local requirements MUST be followed. In an AD facility, a variety of areas such as the input storage tanks, digester vessels, odour scrubbers, and any other gas clean-up towers may be considered confined spaces.

AD facility operators are strongly encouraged to seek the guidance of a safety professional in identifying potential confined spaces and preparing appropriate management plans and procedures at their specific site.

If work is to occur in a confined space, for example for clearing solid debris from a digester vessel, the confined space access and rescue plan and documentation must be prepared, reviewed, and sign-off completed as required under provincial regulations. The appropriate staff training and documentation is also required.

The use of dry-type digesters requires special attention to the issue of confined spaces and operators working with wheeled loading equipment to load or empty the dry digestion vessels. It is important to understand when the area is considered a confined space, and when it changes and it is not considered a confined space.

Not following the regulations and taking appropriate safety measures can result in death as well as criminal prosecution and jail time for managers and supervisors.

The following are examples of general safety guidelines that must be met; this is not an exhaustive list:

- The confined space has a ventilation system that is engaged before an operator enters;
- The conditions in the confined space must be tested before entry and the presence of dangerous gases, or a low concentration of oxygen determined;
- The operations within the confined space and their potential to create a hazard considered, for example running gas-powered skid-steer equipment inside a digester tank can create a carbon monoxide hazard;
- The use of a safety monitor and rescue staff outside the confined space, with continuous visual and auditory contact with the workers inside;
- Removal of material that may generate a toxic atmosphere must be cleared as a first priority of the work crew;
- A rescue plan must be completed and understood by all involved prior to the work.
- The confined space must be isolated and all related equipment and processes locked-out. For example, pumps that could fill the tank and mixers within the tank must be locked out.

8.3 Fire

Methane, the major component of biogas, is flammable at mixtures of 5-15 percent methane in air. Methane mixed with air can also form an explosive mixture. The presence of high carbon dioxide content may increase the amount of dilution with air required for flammability, but this depends on the relative concentrations of methane and carbon dioxide.

Regardless, fire poses a risk to the operation of an AD facility generating and handling biogas.

During start-up, as biogas is first being generated within the digester and air is being displaced through the biogas system, there is the potential for hazardous biogas-air mixtures to form.

In normal AD facility operation, there should not be biogas-air mixtures anywhere in the process. Care is required for the use of active air injection into AD systems as a means to control the hydrogen sulfide concentration in the biogas.

There are two main ways to monitor and reduce the risk of air infiltration:

1. Continuous monitoring of oxygen levels in biogas. Oxygen should be a negligible (<0.4 percent) component of biogas. If the concentration of oxygen increases, this is a warning sign of air-biogas mixing and an indicator that air infiltration is occurring. Many digesters have a significant headspace above the digesting material that may contain an air/biogas mixture if there is a leak.
2. Routine maintenance checks for leaks or damage to pipes. Visual inspections and biogas leak audits confirm that there is no entryway for air.

Appropriate fire-monitoring equipment such as smoke detectors or fire eyes should also be considered.

To prepare for the risk of fire, a risk management and emergency response plan should be created. This plan should indicate which areas are of greatest concern and identify any hazards that moving in these areas may present. This plan should be communicated to the local fire department, allowing them to understand the unique risks of fire suppression at the AD facility. All facilities should maintain an ongoing communication with the local fire department after the design stage and offer tours to ensure their familiarity with the site.

Most AD facilities will have temporary storage of biogas on site in the form of a membrane gasholder. On-site gas storage should not present an explosion risk with regular maintenance and monitoring to avoid air infiltration and ignition sources such as heat and sparks. As part of a safety assessment program, consideration should be given for the worst-case scenario: where would a biogas leak be most likely, what would be affected, could anything else be ignited within the vicinity?

Most regulations have an exclusion zone around gas storage areas to minimize this risk. Flares, compressors, and other ignition sources should be located a safe distance from gas storage.
A well-designed site layout can be an effective means to reduce the risk of explosion and fire.

It is recommended to strictly enforce a no-smoking policy within a fixed distance of the entire AD facility perimeter.

8.4 Vehicle Management

AD facilities will often have large vehicles entering the site to deposit feedstocks and/or collect digestate. Work vehicles such as forklifts and trucks will also be used in normal operation. Facilities should have appropriate signage and a clearly marked area for vehicles to move, with enough room for the turning radius of vehicles that will be on site. The operation of service vehicles and the required visibility and personal protective equipment for operators on site is defined in Provincial worker safety regulations.

8.5 Spill Response and Secondary Containment

A contingency and emergency response plan must be prepared for the facility and all workers shall be trained on the emergency response protocol. The plan shall be reviewed on a regular basis and updated as required. Critical components of a comprehensive contingency and emergency response plan include, but are not limited to the following:

- A list of site personnel responsible for the implementation of contingency measures and various emergency response tasks, and their training requirements;
- A list of equipment and materials required for the implementation of the contingency measures and the emergency situation response, including a site plan displaying the location of the items on the aforementioned list;
- Maintenance and testing program for equipment required for the implementation of the contingency measures and the emergency situation response;
- Procedures to be undertaken as part of the implementation of the contingency measures and the emergency situation response;
- Names and telephone numbers of waste management and service companies available for emergency response; and
- Notification protocol, with names and telephone numbers of persons to be contacted, including the Owner, the Site personnel, the local Fire and Police Departments, the local Medical Officer of Health, required Environmental Regulatory Agency, and the Ministry of Labour.

The preparation of the contingency and emergency response plans should identify the possible incidents that could give rise to an emergency situation. Preventative and control measures to minimize the occurrence or impacts of these situations should also be identified. As an example, the following lists common possible situations where procedures and actions to be taken should be included in the plans:

- Incoming feedstock does not meet the applicable quality criteria;
- Outgoing residuals fail to meet the required criteria;
- Current disposal options for the outgoing residuals, rejected feedstock, and the digestate become unavailable;
- The plant is unable to maintain normal airflow conditions;
- A breakdown of the equipment at the site, including the odour treatment system, results in emissions to the atmosphere resulting in public complaints;

- Complaints require the implementation of additional odour control measures;
- Complaints require the suspension of waste processing activities at the site;
- The digestate fails to meet the criteria required by the receiving site;
- Power failure;
- Flood, fire, ice storm, and wind storm;
- An emergency shutdown and start-up of equipment at the site, including the odour abatement system; and
- Labour or transportation disruptions.

9.0 Communication

Public education is an important investment in gaining public understanding and support for AD projects. A good communication plan can help to mitigate the 'Not in My Backyard' (NIMBY) response experienced by some past digester projects. It is important to communicate the safety, odour control, environmental, and economic benefits of biogas to communities located near these large projects. Some communities initially may not have a deep understanding of the safety, low nuisance designs, and significant benefits of modern biogas projects. Historical design or operating challenges may cause some people to see the nuisances from such facilities as more prevalent.

9.1 Public Education and Consultation Considerations

The public consultation process should aim to increase support for the AD facility development by providing adequate opportunity for public and stakeholder input, questions, and concerns to be listened to and addressed. Communities and businesses that will be affected by the AD facility should be contacted and engaged in the process.

Table 9.1 below provides an overview of tools commonly used for public consultation and communication and identifies benefits and drawbacks for each. This table was compiled based on stakeholder interviews, jurisdictional reviews, and project team experience. It is recommended that project developers employ multiple tools during the site selection process and develop an appropriate consultation program appropriate to each specific case. The depth of engagement and timeframe employed will vary depending on the project.

Table 9.1 - Public Consultation and Communication Tools

Tool	Description	Benefits	Drawbacks
Letter of Notification to Interested Parties	All known stakeholders, including provincial and municipal agencies, general public, neighbouring regional districts, First Nations, current solid waste management or residual organics processing facilities, contractors and haulers, large waste generators, environmental organizations, and possible purchasers of end-product, should be identified and contacted to inform them of the intended project. The notification letter should inform on the general aspects of the project, potential benefits and drawbacks to stakeholders, opportunities for input, and projected timeline for the project.	Letter has personalized effect and is not likely to be missed.	May not be able to identify all stakeholders, and anyone who is not directly contacted will miss the information.
Stakeholder Meetings	Meetings provide a good face-to-face opportunity to present the project to stakeholders and provide an opportunity for input or questions.	Face-to-face interaction gives more opportunity for discussion.	Can be costly depending on location of stakeholders. May not be able to identify all stakeholders, and anyone who is not directly contacted will miss the information.
Website	Creating an easily-accessible webpage is a useful way to provide access to information for anyone interested. The website should provide details about the project, including timeline and how it will impact the community, and inform on events or methods for public participation and input on the project. Public meetings and engagement events can also be advertised through large event-sharing sites such as Eventbrite.	Easy for anyone to access the project details from anywhere.	People must already be aware of the project to find the website; advertisement is needed to direct internet traffic.
Community Survey	Community surveys are an effective method for gauging the general opinion of groups affected by the project. A survey could ask about the public's satisfaction with the status-quo waste management services and acceptance of options for improvement. A well-written survey can also be used to educate the participants on the technology and benefits of organic waste	Can reach large numbers of the public and gauge results based on location, age group, etc. Generates easily comparable data.	Cost-effective questions may not give the public a satisfactory chance to provide input, for example multiple-choice questions do not leave room for unforeseen

Tool	Description	Benefits	Drawbacks
	processing. A survey can be online, by phone, at a booth, door-to-door, or a combination of these.		answers but are low cost to aggregate and analyse.
Public Meetings	Meetings for public engagement provide an opportunity to collect public input and gauge community acceptance of the project options.	Ideal opportunity for people who are interested in the project to learn more, ask questions, and join the discussion. Can facilitate in-depth engagement such as collaborative planning or mixed-stakeholder technical committees.	Can be difficult to organize or costly. May only engage most vocal or oppositional.
Open Houses	Venue for public engagement to provide information on the project, answer questions, and gather public feedback.	Can create a positive environment with meaningful flow of information in both directions between project staff and the public. Equitable participation – less likely for most vocal or oppositional to dominate dialogue.	Can be difficult to organize or costly. Limited level of engagement compared to public meetings.
Social Media Promotions	Describing the project goals, strategies, and impacts through easy-to-understand material on social media is an effective way to provide high-level education on the project. Infographics and short videos spread through local Facebook groups or on Twitter are effective methods, and online question and answer sessions can be held on local forums. Meetings can be advertised through Facebook and Twitter.	A free method to reach a large amount of people, particularly younger generations.	May not reach some demographics.
Public Media Releases	Public engagement events and meetings can be advertised through local radio and news stations, and news of the project's progress can be announced.	Effectively reaches local populations.	Can be costly for advertisements. Must identify which media types are relevant to a given community and varying demographics.

10.0 Monitoring, Sampling and Documentation

10.1 Monitoring/Sampling

Continuous monitoring of process parameters discussed in **Section 6.1.5** is critical to maintaining a healthy population of biomass in the digesters to optimize stable biogas generation and feedstock processing. Daily review of feeding and operating data is important for early detection of potential biological or chemical issues in the digesters or digestate. Data is essential to allow plant operators to make adjustments necessary to ensure optimal biological conditions are maintained and for diagnosing any issues such as reductions in biogas generation rates.

10.1.1 Odour and Nuisance Monitoring

- **On- and Off-site Monitoring:** On-site monitoring should include daily routine monitoring by facility staff to identify nuisance situations such as odour, noise, litter, and dust. Although, it is important to note that employees who are regularly exposed to odours can become de-sensitized. On-site monitoring can provide useful feedback on the effectiveness of site management activities and process control measures. Odours and other instances of excess nuisance should be noted in the daily site log, the causes analyzed, and corrective actions recorded to prevent repeat occurrences.

  If nuisance odour, noise, litter or dust problems have been identified, for example through public complaints, it may become necessary to increase the staff monitoring frequency and determine if changes to operational practices are required.

  A program of periodic sampling and analysis of the odour treatment system performance is strongly recommended. Odour treatment performance can include untreated air, partially treated air, and the final air emissions. If odour problems are identified, the odour concentration of the input air, and at each stage of the treatment process, can be measured to determine whether the removal efficiency of the treatment system is within an acceptable range.

  Ambient sampling and analysis of odour to determine specific ambient odour concentrations is impractical. However, ambient odour monitoring can be used to estimate the off-site odour impact. Off-site odour impacts can also be verified by the frequency and number of complaints received from near-by residents. Residents should be provided with a contact phone number at the facility should they detect odour attributed to the anaerobic digester operations.

  Facility management should be prepared to respond quickly and definitively to odour complaints.

- **Monitoring of Meteorological Conditions:** An on-site weather station can be useful for day-to-day operations to identify unfavourable and favourable meteorological conditions. The on-site weather station is also useful for recording wind direction and speed to assist with responding to an odour complaint. Potential odour releasing activities, such as facility maintenance activities, should be avoided during unfavourable meteorological conditions that minimize natural dispersion. Often, meteorological conditions during the early morning and early evening are most stable and can tend to concentrate odours at ground level. Therefore, it may be preferred to conduct certain operations at mid-day when the atmosphere tends to be more turbulent and provides better odour dispersion. However, the schedule of neighbouring businesses or residences should also be taken into consideration as it may be advantageous to conduct certain operations outside of normal business hours or when neighbours are not present.

When all odour generating sources are assessed, odour dispersion modelling is encouraged to be used to identify unfavourable, or 'worst case' meteorological conditions.

10.2 Documentation

The facility operator should establish and maintain records of the daily operations at the facility and produce monthly and annual reports from this information. These records include public complaints. Documentation and reporting is a best management practice for on-farm systems as well, ensuring that records are completed on a regular basis.

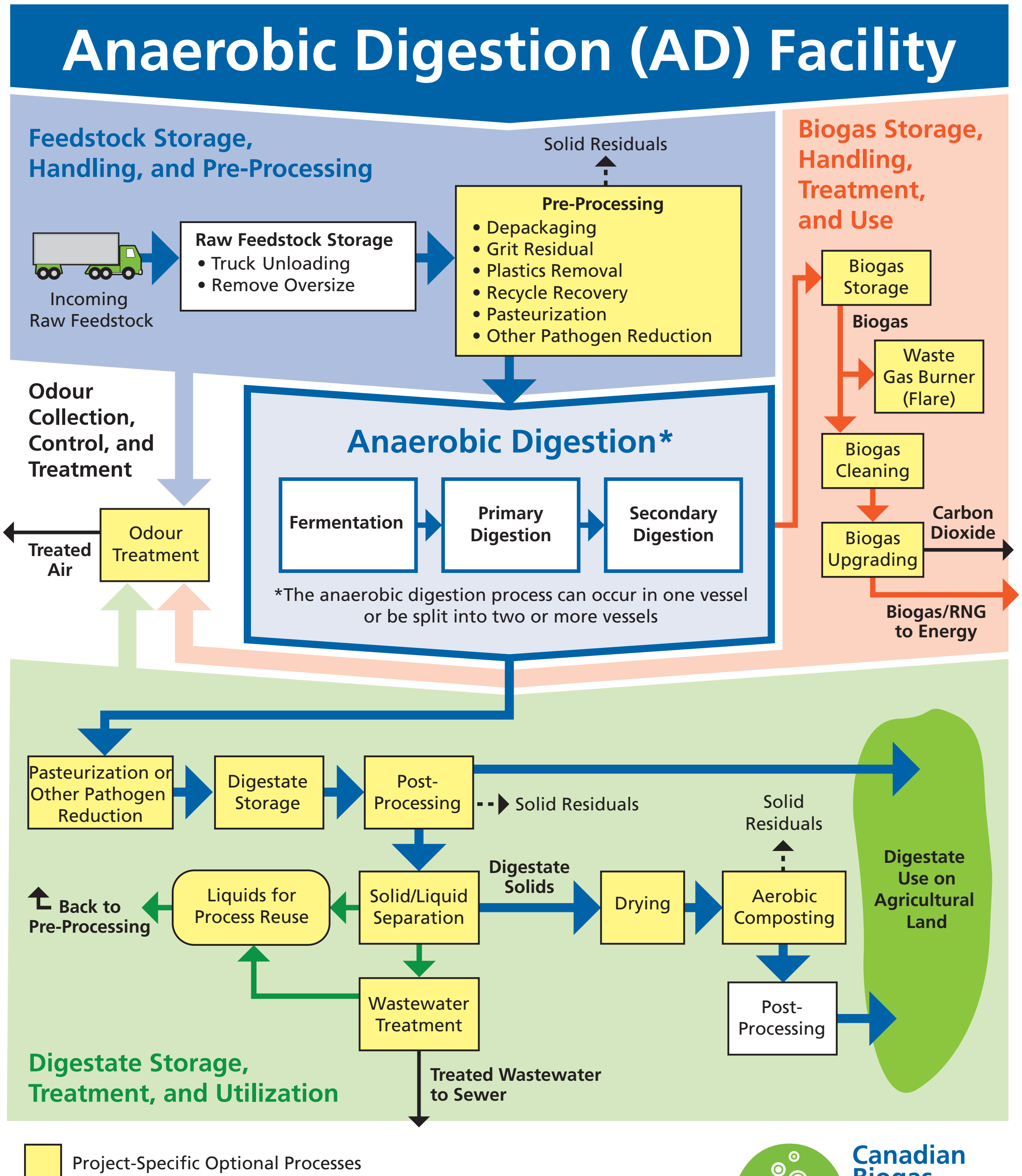
The conditions of the environmental approval will typically list the type of information required to be kept on-site for at least five years and for the information to be organized in the form of an annual report. The environmental ministry or agency may require, through a condition in the approval, that this annual report be submitted each year and possibly also submitted to a public liaison committee. In any case, all reports must generally be made available to ministry staff on request.

Some of the information that is encouraged to be collected includes, but is not limited, to the following:

- Source, type, quality, and quantity of feedstock and amendment materials received;
- If more than one type, or end-market, of digestate is being produced, operational procedures clearly demonstrating that the materials are kept separate at each stage of the process, and daily tracking of each batch or stream;
- Process operating information such as temperatures and retention times recorded manually, if necessary, or as part of the supervisory control and data acquisition (SCADA) computer system;
- Preventative maintenance and lifecycle repair records to demonstrate the facility is being properly managed and maintained;
- Quantity of digestate and residues produced, and the quantity and destination of digestate and residue removed from the facility;
- A log of all feedstock and digestate sampling events, with sufficient detail to clearly identify the source of all samples taken;
- All results of analytical testing from laboratory reports or certificates of analysis of digestate and feedstock; and
- A log of all complaints received, and corrective action taken to abate problems. Detailed complaint reports, especially for odour complaints, can be useful to determine the source of odours. For example, cross-referencing complaints with process steps or site deliveries may identify a recurring issue and suggest a possible solution.

Appendix A

Schematic of Generic Anaerobic Digestion Facility, showing several optional project- and feedstock-specific processes



Appendix B

Summary of Regulations

Province	Regulations	Notes	Website
Federal	Federal Fertilizers Act	Digestate may be registered as a fertilizer under the Federal Fertilizer Act. Digestate designated as a fertilizer by the CFIA is regulated under the Federal Fertilizers Act.	https://lois-laws.justice.gc.ca/eng/acts/F-10/page-1.html
BC	Environmental Management Act Chapter 53: Pt 2 Prohibitions and Authorizations, Pt 3 Municipal Waste Management, Pt 6.1 Division 2 Management of GHG at Waste Management Facilities	General Waste Management regulations for BC. No specific mention of AD.	http://www.bclaws.ca/civix/document/id/consol12/consol12/03053_00
	B.C. Reg. 18/2002: Organic Matter Recycling Regulation	Governs production, distribution, storage, sale and use of biosolids and compost.	http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/18_2002
AB	Environmental Protection and Enhancement Act: Waste Control Regulations	General Waste Management regulations for Alberta.	http://www.qp.alberta.ca/documents/Regs/1996_192.pdf
	Alberta Regulation 267/2001:Nutrient Management	Requirements for nutrient management application.	http://www.qp.alberta.ca/documents/Regs/2001_267.pdf
	Alberta Agricultural Operation Practices Act	Land application of digestate should meet allowable nutrient permitted by this Act.	http://www.qp.alberta.ca/documents/Acts/A07.pdf
SK	Environmental Management and Protection Act: Waste Management	General Waste Management Regulations for Saskatchewan.	http://www.qp.gov.sk.ca/documents/english/Chapters/2010/E10-22.pdf
	The Agricultural Operations Regulations	Requirements for land application of manure.	http://www.publications.gov.sk.ca/freelaw/documents/English/Regulations/Regulations/A12-1R1.pdf

MB	M.R 37/2016 Waste Management Facilities Regulation	General Waste Management Regulation for Manitoba.	https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=37/2016
	Nutrient Management Regulation		https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=62/2008
QC	Environment Quality Act chapter Q-2, r.13 Regulation Respecting Solid Waste		http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2013
	Agricultural Management Regulations		http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2026
	Organic amendments - Digestate from Biomethanisation	Digestate quality standard, available in French only.	Only in draft form at present writing, Draft Standard P 0413-500-6
	ACT RESPECTING TRANSITION ÉNERGÉTIQUE QUÉBEC		http://www.legisquebec.gouv.qc.ca/en/showdoc/cs/T-11.02
	BNQ Digestate Standard	Avail only in French, only for QC. Some specific feedstocks trigger need for dioxin and furan testing. Foreign matter using a surface area approach.	
NS	Environmental Regulations Handbook 2nd Edition	Regulates farm waste management.	http://www.nsfa-fane.ca/efp/wp-content/uploads/2018/08/env_regulations_handbk_NS.pdf
	Solid Waste-Resource Management Regulations under section 102 of the Environment Act		https://novascotia.ca/just/regulations/regs/envsolid.htm
	Renewable Electricity Regulations		https://novascotia.ca/just/regulations/regs/elecrenew.htm
PE	Environmental Protection Act Waste Resource Management Regulations		https://www.princeedwardisland.ca/en/legislation/environmental-protection-act/waste-resource-management-regulations
	Renewable Energy Act		https://www.princeedwardisland.ca/en/legislation/renewable-energy-act
	In addition to the above regulatory documents, the following Guidelines provide useful information pertaining to manure management on farm operations: "Guideline for Manure Management for Prince Edward Island"		

NB	Regulation 96-11 under the Clean Environment Act: Regional Solid Waste Commissions Regulation		http://extwprlegs1.fao.org/docs/pdf/nb47782.pdf
	Agricultural Land Protection and Development Act		https://www.ecolex.org/details/legislation/agricultural-land-protection-and-development-act-snb-1996-c-a-511-lex-faoc047749/
NL	Environmental Standards for Municipal Solid Waste Compost Facilities		https://www.mae.gov.nl.ca/env_protection/waste/composting_facility_april.pdf
	Farm Practices Protection Act		https://www.assembly.nl.ca/legislation/sr/statutes/f04-1.htm
ON	O. Reg 267/03: Nutrient Management Act of 2002	Regulates application and storage of nutrients, including compost, on agricultural lands. As more AD facilities are developed, use of digestate on agricultural land becomes a more viable option.	https://www.ontario.ca/laws/regulation/030267
	O. Reg 347: General - Waste Management under the Environmental Protection Act	Regulates waste management activities, including the receiving and processing of organic waste by compost facilities, as well as the application and use of compost.	https://www.ontario.ca/laws/regulation/900347
	O. Reg 359/09: Renewable Energy Approvals	Regulates facilities producing electricity from renewable sources.	https://www.ontario.ca/laws/regulation/090359
	Ontario Water Resources Act (OWRA)	Wastewater from AD facilities separated from end-use digestate streams must be managed and disposed of in accordance with regulations presented within the OWRA.	
	In addition to the above regulatory documents, the following MECP Guidelines		https://www.ontario.ca/page/d-1-land-use-and-compatibility

	provide useful information to assist in suitable site selection: - D-1 Land Use and Compatibility		
	- D-1-1 Land Use Compatibility: Procedure for Implementation		https://www.ontario.ca/page/d-1-1-land-use-compatibility-procedure-implementation
	- D-1-2 Land Use Compatibility: Specific Applications		https://www.ontario.ca/page/d-1-2-land-use-compatibility-specific-applications
	- D-1-3 Land Use Compatibility: Definitions		https://www.ontario.ca/page/d-1-3-land-use-compatibility-definitions
	Guideline to Applying for an Environmental Compliance Approval		https://www.ontario.ca/document/guide-applying-environmental-compliance-approval-0
	Technical Guide for Renewable Energy Approvals		https://www.ontario.ca/document/technical-guide-renewable-energy-approvals-0
YT	O.I.C. 2000/11 Solid Waste Regulations		http://www.gov.yk.ca/legislation/regs/oic2000_011.pdf
NT	Waste Reduction and Recovery Act		https://www.justice.gov.nt.ca/en/files/legislation/waste-reduction-recovery/waste-reduction-recovery.a.pdf

Note: The following website gives a rundown of nutrient management regulations in some Canadian provinces:
https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-permitting-and-compliance/hullcar/review-docs/631700-3_bc_agri_2017b_jurisdictional_scan_of_nutrient_management_regulations.pdf

Canadian Biogas Association

www.BiogasAssociation.ca