QUANTIFICATION PROTOCOL FOR ANAEROBIC TREATMENT OF WASTEWATER PROJECTS

MARCH 2009

Version 1.0

Alberta

ALBERTANS & CLIMATE CHANGE

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Any comments, questions, or suggestions regarding the content of this document may be directed to:

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1.0 PROJECT AND METHODOLOGY SCOPE AND DESCRIPTION

This quantification protocol is written for those familiar with wastewater treatment processes for industrial wastewater streams containing significant quantities of biodegradable organic matter and with the operation of anaerobic digesters and biogas utilization systems. Some familiarity with, or general understanding of the operation of these projects is expected.

The opportunity for generating carbon offsets with this protocol arises primarily from the capture and destruction of biogas, containing methane, that would have been emitted from wastewater treatment facilities where the baseline practice was the anaerobic treatment of wastewater and venting of produced methane to the atmosphere. There is also the opportunity for indirect greenhouse gas (GHG) emission reductions from the use of biogas produced by the wastewater treatment processes to displace electricity or thermal energy derived from fossil fuels or to displace natural gas in gas transmission systems. For those facilities that were already flaring biogas in the baseline, there is a small opportunity to generate carbon offsets based on the methane not combusted due to the inefficiency of the flare.

1.1 Protocol Scope and Description

This protocol is applicable to projects that involve the capture and destruction of methane produced from anaerobic wastewater treatment processes and take actions to prevent the venting of biogas to the atmosphere. These systems could be installed as retrofits or modifications to existing wastewater treatment operations or implemented at new Greenfield facilities as the best available control technology[1]. The feedstock to the anaerobic digestion system may be untreated industrial wastewater or sludge produced from other wastewater treatment processes at the project site

The most common baseline configuration would be the use of an uncovered deep anaerobic wastewater lagoon where biogas was vented to the atmosphere; however, other facilities may already operate more sophisticated anaerobic digester systems to treat raw wastewater effluents or sludges with high organic loadings but do not utilize the produced biogas. Additionally, for anaerobic waste water treatment projects implemented as part of the design of new Greenfield facilities, the baseline condition would be the flaring of all methane produced from the unit using an open flare with 96% efficiency.

This protocol is also applicable to projects that implement new equipment to utilize the produced biogas, where previously all biogas captured from the anaerobic wastewater treatment systems was flared without energy recovery. The baseline scenario in this case assumes the use of an open flare with 96% methane destruction efficiency.[2] Additionally,

[1] Note – only offsets from the displacement of fossil fuel-based energy are eligible from these projects, not methane avoidance.

[2] This assumption is consistent with the GE AES Methodology for Waste Water Treatment Methane Capture and Destruction Projects Version 1.1 – November 10, 2008

for projects where an aerobic system was previously in place, which was replaced with an anaerobic process that included systems to capture biogas for energy generation, the baseline scenario would only be the displacement of fossil fuels with energy output from the project biogas energy generation system.

This protocol is intended to be applied to anaerobic wastewater treatment systems used in the food processing industry, and as such may not be suitable for all other types of wastewater treatment systems. In addition, project proponents implementing other types of anaerobic digesters to produce biogas from agricultural residues, source separated organic materials or energy crops, should refer to the Alberta Offset System *Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials*. It should be noted that there is potential for overlap between this quantification protocol and the *Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials* as some centralized anaerobic digestion projects may treat a variety of organic materials including wastewater or sludges that originated from facilities that would have anaerobically treated the wastewater stream in the baseline such that methane would have been emitted to the atmosphere as defined under this protocol. In such instances the project proponent may refer to this protocol to account for the avoided emissions from wastewater treatment under SS B7 provided that they can meet the protocol applicability criteria specified in this document with appropriate records. Additionally, the project proponent would need to demonstrate what fraction of the COD contained in the wastewater would have been removed under anaerobic conditions (without biogas recovery) at the baseline wastewater treatment facility.

The decomposition of organic matter, contained in wastewater effluents as suspended or dissolved solids and or in more concentrated sludges, under clearly anaerobic (oxygen-free) conditions produces biogas consisting primarily of methane and carbon dioxide. Biogas composition will vary depending on the composition of wastewater treated, but typically consists of 50-80% methane and 20-50% carbon dioxide, with trace amounts of hydrogen sulphide and other volatile organic compounds. The degradable organic matter contained in wastewater effluents is usually measured in terms of chemical oxygen demand (COD) or biological oxygen demand (BOD). For consistency with the Intergovernmental Panel on Climate Change (IPCC) and Clean Development Mechanism Methodology ACM0014 approaches, this protocol uses COD.

Typically, the implementation of methane capture projects at anaerobic wastewater treatment facilities includes the establishment of several supporting units including biogas conditioning units, piping, blowers, flares and thermal/ electrical energy generation systems. This equipment would be installed in addition to other wastewater treatment equipment used to remove other contaminants present in the effluent and to ensure all wastewater discharged to a sanitary sewer system or surface water body meets applicable regional limits.

Wastewater is collected from different operations within the source facility and directed to a pre-treatment area for screening, grit removal, dissolved air flotation or other physical or chemical adjustments before it is treated in the anaerobic digester where anaerobic microbes consume the majority of organic matter and produce combustible biogas in the process. The wastewater then undergoes one or more aerobic treatment processes (bioreactors, clarifiers etc.) to remove the remaining organic solids to within acceptable limits. After the aerobic process the wastewater stream undergoes coagulation and flocculation to precipitate out inorganic compounds (e.g. phosphorous) and to settle out particles so that they can be physically separated using a filter or belt press. The filtered solids may be stored temporarily and then sent for disposal, composting or land application, while the effluent continues to a polishing step for any final chemical adjustments (e.g. pH) before continuing on to a storage lagoon or directly discharged from the site. The biogas produced in the anaerobic treatment unit is flared or conditioned to remove water vapour and other contaminants and then combusted to produce energy.

FIGURE 1.1 offers a process flow diagram for a typical project.

Protocol Approach:
To demonstrate that a project is covered by the scope of the protocol, the project developer must demonstrate that the wastewater effluent stream would have been managed differently such that methane would have been emitted to the atmosphere.

As evidence, the project developer must demonstrate that this baseline condition, illustrated in **FIGURE 1.2**, was either the previous practise or most likely practise based on conventional industry practices. Further, they must show that under the project activity the chemical oxygen demand of the wastewater effluent has been reduced by the anaerobic treatment process. This is accomplished by applying a mass balance on the chemical oxygen demand of the wastewater stream by measuring wastewater flow rates and COD concentrations at the inlets and outlets of the anaerobic treatment units. The quantification of offsets from the utilization of biogas produced from the anaerobic treatment process is accomplished by applying mass and energy balances around the project components that were installed to produce, capture and utilize the biogas. Project proponents would be responsible for metering of relevant energy inputs and outputs to the system.

For those projects that implement systems to utilize biogas produced from existing anaerobic wastewater treatment units, where energy recovery was previously not practiced, proponents must demonstrate that the project results in increased displacement of energy derived from fossil fuels either on or off-site.

For facilities that operated open flares in the baseline, the upgrade to a controlled combustion device, would also reduce methane emissions by improving the destruction efficiency. The baseline condition for these projects is defined as the methane emissions not destructed by the flare plus the combustion emissions from the fuel required to operate the flare as the baseline would not include the venting of methane to the atmosphere.

FIGURE 1.1: Process Flow Diagram for Project Condition

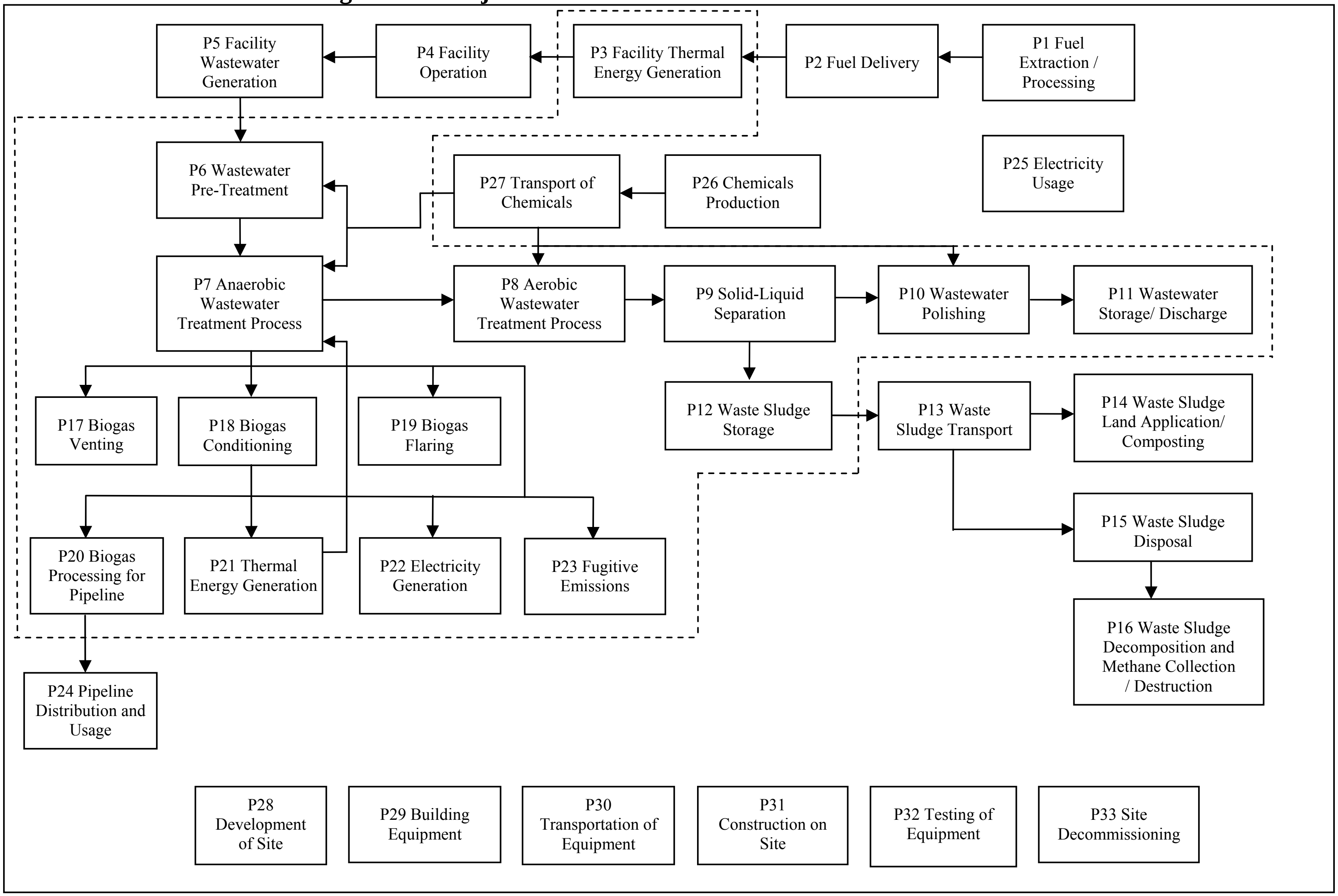
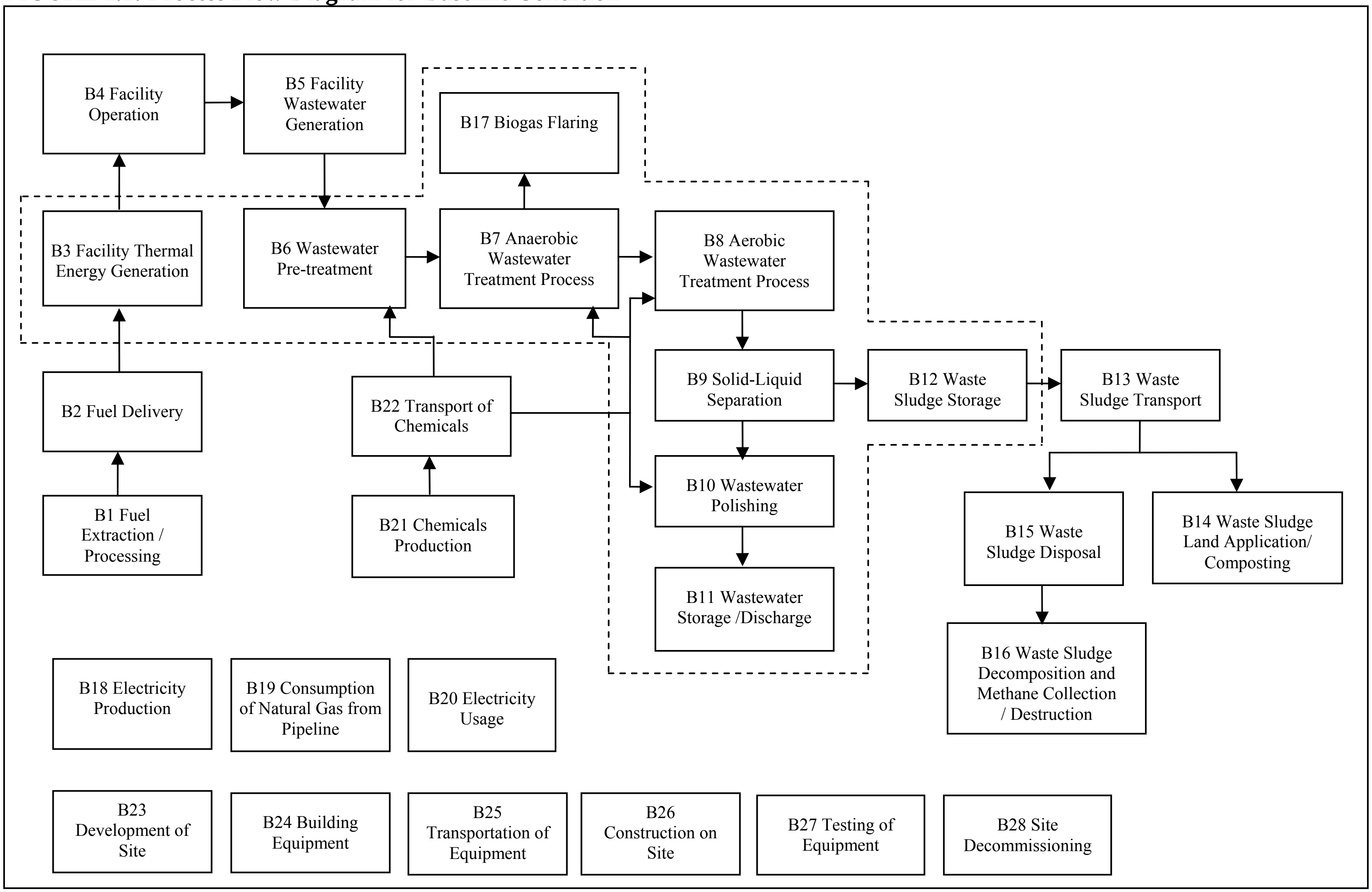


FIGURE 1.2: Process Flow Diagram for Baseline Condition



Protocol Applicability:

To demonstrate that a project meets the requirements under this protocol, the project developer must provide evidence that:

1. The project proponent must demonstrate that the baseline anaerobic wastewater treatment system (e.g. an uncovered deep lagoon or sludge pit) would have resulted in sufficiently anaerobic (oxygen-free) conditions to result in the formation of methane. For systems open to the atmosphere the project proponent should demonstrate that the baseline conditions were amenable to methane generation based on the depth of the treatment/storage unit, operational records showing a significant reduction in chemical oxygen demand in the unit, normal operating temperatures in the anaerobic treatment system and if applicable, the presence of a grease cap. For systems that are not enclosed or contained the average depth of the anaerobic system must be at least 1 metre deep;
2. For projects where methane production processes are enhanced through the addition of a heating source to create mesophilic or thermophilic conditions that were not previously present in the baseline anaerobic treatment unit, the anaerobic digestion facility must demonstrate reasonable diligence to manage the risk of fugitive emissions in keeping with the guidance provided in **APPENDIX B** as evidenced by an affirmation from the project developer and applicable records;
3. There must not be any applicable regulations that prescribe the project facility to install a biogas capture system to prevent the venting of methane emissions from wastewater treatment operations;
4. In project configurations where sedimentation in the anaerobic treatment unit results in a material reduction in chemical oxygen demand available for anaerobic digestion by microbes (and therefore an over estimate of the baseline methane generation potential of the wastewater), the project proponent must provide records of organic matter (sediments) removed from the anaerobic treatment unit. The project proponent should account for sedimentation COD losses if sediments have been collected and removed from the anaerobic treatment unit at a frequency of once every two years or more often;
5. For Greenfield wastewater treatment facilities implemented as part of the design of new processing plants, the baseline condition is the flaring of all methane produced from the unit using an open flare with 96% efficiency, and the carbon offsets eligible from this project are the displaced electricity or thermal energy derived from fossil fuels or displaced natural gas in gas transmission systems.
6. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and,

7. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System.

Protocol Flexibility

Flexibility in applying the quantification protocol is provided to project developers in four ways:

1. In cases where the project proponent measures BOD in the wastewater stream (and not the COD), the conversion factor of 2.4 kg of COD per 1 kg of BOD may be applied to convert from kg of BOD to kg of COD as per the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Further guidance is provided in **Appendix A** on the use of this factor;
2. For projects where the baseline condition was the flaring of biogas which has been replaced with a controlled combustion device (e.g.: due to the installation of equipment for energy recovery) the default flare destruction efficiency may be substituted with a site specific value based on manufacturer's specifications, flare combustion efficiency testing and flare operating records. Flare destruction efficiency may depend on the type of flare, the use of fuel gas, steam or air to assist in combustion, the net heating value of the combined gas stream (biogas plus supplemental fuel gas), flare gas exit velocity and cross-wind speed. Due to the uncertainty around assessing the destruction efficiencies of flares, if the project proponent wishes to substitute the default baseline flare efficiencies used in the protocol with a lower efficiency he/she must ensure that an independent third party validation of the flare destruction efficiency has been completed by a professional engineer in order to apply this flexibility mechanism.
3. For projects where historical wastewater temperatures were not measured prior to the implementation of the methane capture system, a heat transfer model may be developed to estimate the average monthly temperature of the wastewater in the anaerobic treatment unit in the baseline. Appendix A provides some limited guidance on some of the heat loss mechanisms that would impact the temperature of the wastewater in the baseline. The project developer must justify how the method used represents a reasonable approximation of the baseline temperature of the wastewater within the anaerobic treatment unit that is sufficiently conservative to avoid overestimation of the temperature, and therefore overestimation of the quantity of methane emitted to the atmosphere in the baseline under SS B7 Anaerobic Wastewater Treatment Process.
4. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must ensure accuracy; and be robust enough to provide uncertainty ranges in the factors; Appendix A provides additional guidance on when the use of site specific data under SS B7 Anaerobic Wastewater Treatment Process that may applicable in place of the IPCC values provided in the protocol.
5. Measurement and data management procedures may be modified by the project developer to account for the available equipment as long as the specified minimum

standards for data quantity, frequency and quality are met. Where these standards cannot be met, the project developer must justify why the method used represents a reasonable deviation to the protocol methodology provided.

The project proponent will have to justify their approach in detail to apply any of these flexibility mechanisms.

1.2 Glossary of New Terms

Anaerobic Digestion	The active and naturally occurring biological process where the organic matter, such as that contained in wastewater from certain industrial facilities (e.g. meat and vegetable processing, soft drink production beverage brewing and alcohol distillation) , is degraded under oxygen free conditions by methanogenic bacteria to yield biogas, consisting of primarily methane and carbon dioxide, and a nutrient rich effluent. Biogas may be collected for use in the generation of electricity, heat and / or power, or flared. The unit where anaerobic digestion occurs is generally referred to as an anaerobic digester or an anaerobic wastewater treatment unit. Common digesters include complete mix tank reactors, upflow anaerobic sludge blanket reactors or plug flow reactors.
Biological Oxygen Demand	The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water, such as that polluted by sewage. The BOD_5 test is a common analysis performed to determine the degree of water pollution from degradable organic compounds in wastewater. BOD_5 test measures the rate of oxygen uptake by micro-organisms in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark. In this protocol, the term BOD is used to represent BOD_5 following IPCC 2006 Guidance.
Chemical Oxygen Demand	The amount of oxygen required to chemically oxidize organic compounds in water. The chemical oxygen demand (COD) test is a common water quality test used to indirectly measure the total amount of organic compounds in a water sample using a strong oxidizing agent such as potassium dichromate. A

high COD value indicates a high concentration of organic matter in the water sample.

Functional Equivalence — The Project and the Baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as the mass of beef processed, m3 of wastewater generated per month) for comparison between the Project and Baseline activity.

Fugitive Emissions: — Intentional and unintentional releases of GHGs from joints, seals, packing, gaskets, etc. within anaerobic digestion systems, including all processing, piping and treatment equipment.

Land Application: — The beneficial use of stabilized sludge material from the effluent of an anaerobic digester or filter press, applied to cropland based upon crop needs and the composition of the agricultural material, as a source of soil amendment and/or nutrition.

Sludge Pit: — The pit or tank that receives untreated liquid sludge in which anaerobic bacteria decompose the liquid sludge, thereby decreasing its organic matter content, and emitting biogas. When the pit is dried out and sludge is stable, solids are removed for use.

2.0 QUANTIFICATION DEVELOPMENT AND JUSTIFICATION

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the relevant process flow diagrams, consulting with stakeholders (i.e. project proponents) and reviewing good practise guidance and other relevant greenhouse gas quantification protocols. This iterative process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1** and **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

FIGURE 2.1: Project Element Life Cycle Chart

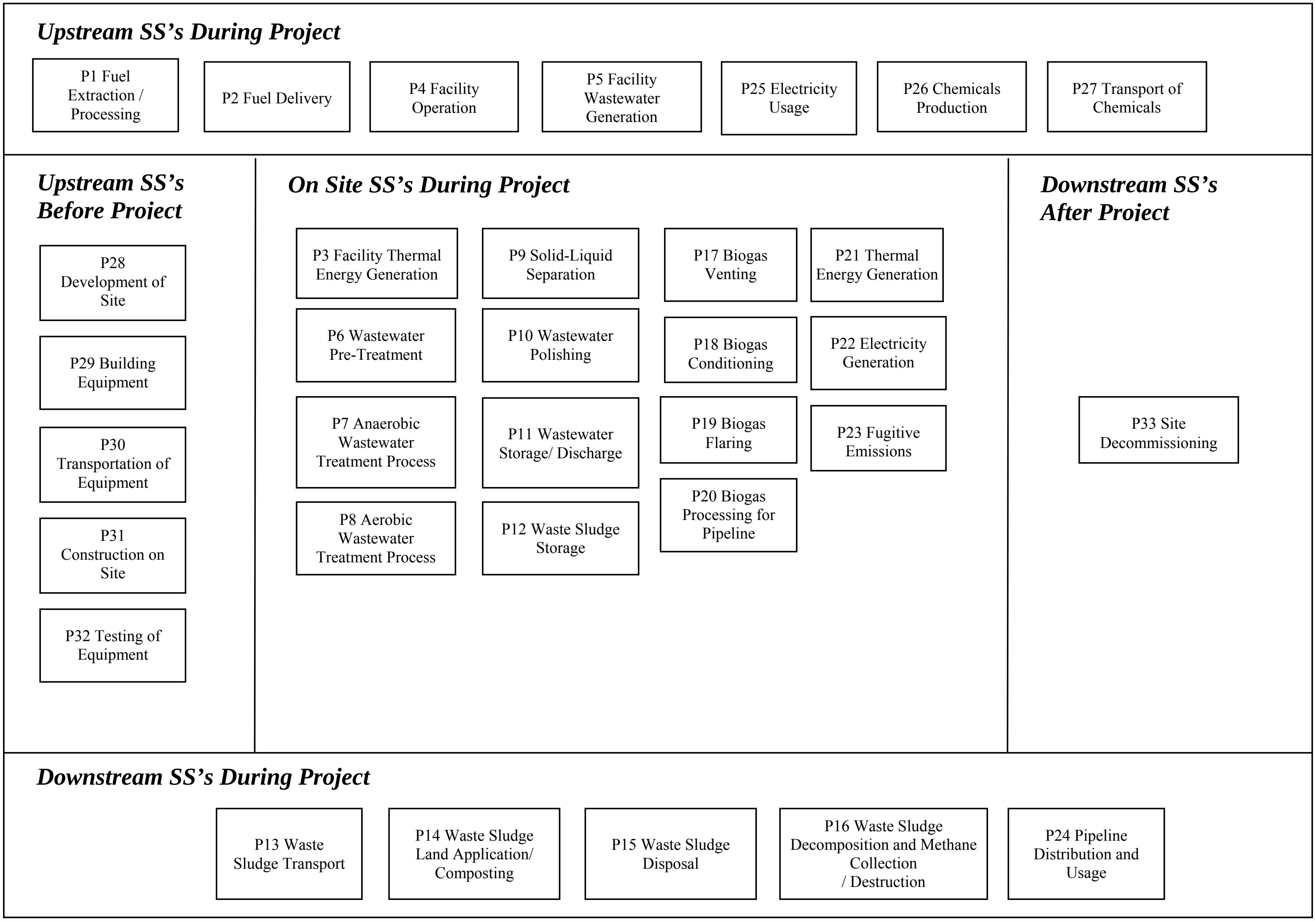


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Fuel Extraction / Processing	Each of the fuels used throughout the on-site component of the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P2 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
P4 Facility Operation	The facility that generates the wastewater would have a primary function or product and any number of processes that would require energy inputs and therefore consume fossil fuels as part of the process or unit operation or for material handling. Quantities for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P5 Facility Wastewater Generation	Wastewater is produced as a by-product of industrial operations in a number ways including from cleaning of process equipment and from the discharge of off-spec materials and by-products using water as a transport medium for the wastes. Greenhouse gas emissions may be associated with these industrial processes and the associated wastewater handling practices, which could include pumping, mixing, equalization and could be powered by fossil fuels either directly or indirectly through a centralized boiler or cogeneration unit. Quantities for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition. Typical facilities could include meat and vegetable processing facilities, distilleries, breweries and other industries that produce significant loadings of organic matter in wastewater streams.	Related
P25 Electricity Usage	Electricity may be required for operating the wastewater treatment facility (pumps, aeration units, mixers, blowers etc.), the anaerobic treatment unit, the biogas conditioning system and associated equipment. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid if the project activity includes the installation of an electricity generator. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
P26 Chemical Production	The production of chemicals from raw materials upstream of the project site may include several material and energy inputs such as natural gas and diesel. Quantities and types of chemicals used at the facility and their associated GHG intensity per unit would be contemplated to evaluate functional equivalence with the baseline condition.	Related

P27 Transport of Chemicals	Chemicals used at the project facility may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
Onsite SS's during Project Operation		
P3 Facility Thermal Energy Generation	The facility generating the wastewater may already operate a boiler or other equipment to generate thermal energy for the primary production processes, which are able to utilize the new source of biogas produced by the anaerobic wastewater treatment unit to supplement conventional fossil fuels. The quantity, composition and heating value of biogas produced and combusted for thermal energy generation should be tracked. Additionally if thermal energy (steam or hot water) is distributed to other users, then the quantity of thermal energy (GJ) should be tracked at the point nearest the user to account for any heat losses. If supplemental fossil fuels are consumed for start-up or to provide heat to maintain an appropriate temperature in the anaerobic digester system, the types and quantities of fuels should be tracked. Note that in some project configurations a new standalone cogeneration unit may be installed to use the biogas and export electricity and possibly heat from the site. In such scenarios the project proponent may exclude this SS (if the quantity of fossil fuels used to operate the facility is independent of the systems installed to utilize the biogas) and only include SS P21 Thermal Energy Generation.	Controlled
P6 Wastewater Pre-Treatment	Wastewater may be treated and/or processed prior to being input to the anaerobic treatment system. This could include physical processes such as screening, grit and solids removal, oil-water separation, dissolved air flotation for removal of fats and oils and other processes that adjust the chemical composition of the wastewater. This may involve the use of heavy equipment that operates using diesel or natural gas. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities for each of the energy inputs may all need to be tracked to evaluate functional equivalence with the baseline condition.	Controlled
P7 Anaerobic Wastewater Treatment Process	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the anaerobic treatment unit. This may include running any auxiliary equipment or monitoring systems and may include material handling. Thermal energy systems may be required to maintain the desired temperature for the anaerobic digester. This may include boilers or similar equipment, which may require several energy inputs such as natural gas or diesel. Quantities and types for each of the energy inputs would be tracked. The project proponent should ensure that this energy consumption is tracked in accordance with the thermal energy systems used for other primary processes (e.g. food processing), to ensure that the parasitic load is accounted for as well as the use of supplemental fossil fuels that is incremental to baseline activities.	Controlled

P8 Aerobic Wastewater Treatment Process	The anaerobic wastewater treatment unit may be followed by an aerobic process (bioreactor, aerobic digester, clarifiers etc.) or an alternating anaerobic-aerobic process to ensure sufficient removal of organic matter from the wastewater stream, beyond the capability of a standalone anaerobic unit. There may be multiple energy and chemical inputs to operate equipment for pumping, mixing, coagulation, flocculation and aeration. Additionally pockets wastewater may have anaerobic conditions either by design or due to poor mixing, creating some additional methane emissions. Quantities and types of fuels and the potential for anaerobic conditions should be tracked to evaluate functional equivalence with the baseline condition.	Controlled
P9 Solid-Liquid Separation	The aggregated particles that have coagulated and been concentrated are generally sent to a filter, press or centrifuge system for de-watering. The resulting solid product is then sent for disposal or land application and the wastewater is usually recycled back to the aerobic treatment process. There may be multiple energy and chemical inputs to operate the solid-liquid separator, pumps and associated equipment. Quantities and types of fuels should be tracked to evaluate functional equivalence with the baseline condition.	Controlled
P10 Wastewater Polishing	The wastewater may undergo some additional chemical adjustments in a polishing step to ensure that the wastewater meets applicable sewer or surface water discharge regulations. Additional chemicals and energy inputs may be required in this step, with associated energy inputs and GHG emissions. Functional equivalence would be evaluated relative to the baseline scenario.	Controlled
P11 Wastewater Storage/ Discharge	After the wastewater has undergone any remaining chemical adjustments in the polishing stage, it will either be stored indefinitely or discharged to the sewer system or another body of water. If any significant quantities of organic material were remaining in the wastewater stream (likely due to upset conditions), there could be some small amount of additional methane produced in the storage pond or downstream of the site. Functional equivalence would also be evaluated relative to the baseline scenario.	Controlled
P12 Waste Sludge Storage	Greenhouse gas emissions may also result if the solid material (sludge) from the solid-liquid separator (filter press) is stored on-site stored for extended periods of time. Further anaerobic decomposition may occur if the material is not fully stabilized resulting in some additional methane emissions. Functional equivalence with the baseline sludge handling practice would be evaluated to determine materiality. If a change in practice from the baseline resulted in incremental quantities of sludge being stored under anaerobic conditions for long periods of time in the project condition, the stability of the sludge material and methane generation potential should be evaluated to evaluate materiality of emissions.	Controlled
P17 Biogas Venting	Venting of the biogas may occur during upset conditions or during maintenance to the anaerobic treatment system or any elements downstream of the anaerobic unit. Additionally, venting may occur regularly as part of the methane capture system design to include pressure relief valves or passive vents for safety reasons to prevent excessive or unsafe gas build-ups. Emissions of methane under these circumstances would need to be considered. For non-routine venting the duration of the venting occasion, the methane production rate and the volume of biogas in the digester at the time of venting would all need to be tracked. For routine venting as part of the system design, the project proponent should refer to the manufacturer's collection efficiency in design documents or other industry common values for the type of methane capture and digester system in place.	Controlled

P18 Biogas Conditioning	Produced biogas will likely have a higher concentration of carbon dioxide and other impurities than may be acceptable to meet the required specifications for its use. Gas conditioning equipment such as separators, filters, knock-out drums, absorption units, adsorption beds, chillers, gas dryers, blowers, condensate pumps and other equipment may be required to treat the biogas and remove impurities in order meet the required specifications. This may require several energy inputs such as natural gas and diesel. Quantities and types of each energy input should be tracked.	
P19 Biogas Flaring	Flaring of the biogas may be required during upset conditions or during maintenance to any elements downstream of the anaerobic digester. Emissions of greenhouse gases would be contributed from the combustion of the biogas as well as from any pilot or make-up fuel used in flaring to ensure more complete combustion. Quantities of biogas being flared and the quantities of fossil fuels consumed for flaring would need to be tracked.	Controlled
P20 Biogas Processing for Pipeline	In addition to the biogas conditioning step additional energy inputs may be required to distribute the biogas to end users off-site via a gas distribution system. This may include supplemental energy inputs to compress the purified biogas for input into a gas distribution system such as natural gas. Quantities and types of fuels consumed to provide each energy input would be tracked.	Controlled
P21 Thermal Energy Generation	New Boilers or cogeneration systems may be implemented to produce thermal energy from the biogas, which may be used on-site (e.g. heat for the digester or anaerobic treatment unit) or distributed to other heat users. Supplemental fossil fuels may be required for start-up or to supplement system demands when biogas production volumes are low. Emissions of greenhouse gases are associated with the use of these supplemental fossil fuels. Quantities and types for each of the supplemental energy inputs would be tracked accounting for the parasitic load to operate the equipment. Note that this SS may overlap with the SS for P3 Facility Thermal Energy Generation as existing infrastructure may already be in place to utilize biogas and therefore sufficient metering and monitoring systems should be in place to track the quantity of energy supplied from biogas and the quantity of energy from fossil fuels as well as any incremental energy inputs used on-site to heat the anaerobic treatment unit or to distribute thermal energy to off-site users.	Controlled
P22 Electricity Generation	Electricity generation or cogeneration systems may be required to produce electricity for use at the project site or for distribution to the regional grid. The operation of this equipment may require several energy inputs such as natural gas or diesel to supplement the use of biogas. The important quantity to track would be the net electrical output of the system (net of any parasitic loads) and the quantities and types of any supplemental fuels used by the generation unit.	Controlled
P23 Fugitive Emissions	Greenhouse gas emissions may also result from fugitive emissions associated with the operation of the anaerobic digestion facility. These emissions would primarily be methane emissions associated with leaks through valves, connections and equipment seals as many of the facility components operate under pressure. The project proponent should conduct regular operational checks and maintenance activities to minimize the release of fugitive emissions. Functional equivalence would be evaluated based on whether the project system enhanced biogas production with supplemental heat. Refer to Appendix B for further guidance related to the management of fugitive emissions.	Related

Downstream SS's during Project Operation		
P13 Waste Sludge Transport	Sludge produced from wastewater treatment in a primary or secondary settler or other processes may need to be transported to a composting or other anaerobic digestion facility for additional material stabilization, or to a disposal site or to fields for land application. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled
P14 Waste Sludge Land Application/ Composting	The waste sludge may be further cured and stabilized using a composting process (e.g. passive or active windrowing) and then land applied or directly land applied. This process would require the use of heavy equipment and mechanical systems. This equipment would be fuelled by diesel, gas or natural gas, resulting in GHG emissions. Composting and land application may result in additional N_2O emissions and methane emissions from pockets of anaerobic conditions during composting or land application. Quantities for each of the energy inputs and evaluation of normal practices pre-post project would be contemplated to evaluate functional equivalence between the baseline and project conditions.	Related
P15 Waste Sludge Disposal	The wastewater treatment facility may generate significant amounts of waste sludge requiring disposal if the land applied is not practiced or allowed in the relevant region due to nutrient restrictions. Waste sludge may be disposed of at a disposal site, such as a landfill, by transferring the waste from the transportation container, spreading, burying, processing, otherwise handling the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gas or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs would be tracked.	Related
P16 Waste Sludge Decomposition and Methane Collection / Destruction	In the project condition some waste sludge may be sent to landfill in and may result in the production of methane due to anaerobic conditions at the landfill site. A methane collection and destruction system may be in place at the disposal site. The average percentage of methane collected and destructed for landfills in that jurisdiction should be accounted for in a reasonable manner otherwise specific disposal site characteristics and may need to be tracked as well as the characteristics of the specific methane collection and destruction system. The project proponent should track the wet weight of waste sludge sent to landfill and account for any occasions when sediments are removed from the anaerobic digester as the material may have some methane generation potential and be a source of GHG leakage.	Related
P24 Pipeline Distribution and Usage	Biogas may be input to the pipeline system and distributed to customers at another point on the distribution system. This gas will be then consumed by the consumer. The most reasonable fate would be combustion in a controlled manner as this relies on the highest emissions factors for the biogas. The total quantity and energy content of biogas input to the pipeline system would need to be tracked.	Related
Other		

P28 Development of Site	Additional development may be required for implementation of the anaerobic digester at the wastewater treatment facility. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
P29 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P30 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
P31 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
P32 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
P33 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

2.2 Baseline Scenario

2.2.1 Identification and Assessment of Possible Baseline Scenarios

An assessment of potential baseline scenarios was conducted based on the recommended methodology from best practice guidance in the Alberta Offset Credit Project Guidance Document and using CDM Methodology ACM0014. Potential baseline options were assessed based on their capacity to quantify the baseline methane emissions from anaerobic wastewater treatment in a practical manner using available data. Each baseline scenario also contemplated the selection of a static or dynamic approach. **TABLE 2.2**, below, provides a summary of the different baselines considered.

TABLE 2.2: **Assessment of Possible Baseline Scenarios**

1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
1.Historic Benchmark	Assessment of the baseline emissions from anaerobic wastewater treatment based on site-specific measurements of methane emissions over several years from the anaerobic treatment unit prior to the installation of a methane capture system.	Static	Reject. The measurement of methane emissions prior to the installation of a methane capture system is not generally practiced and therefore this data is not generally available.
2.Performance Standard	Assessment of the typical GHG emissions from anaerobic wastewater treatment facilities as a proxy to estimate the avoided GHG emissions from a specific site that implemented a methane capture project. This approach would likely require an industry-wide characterization of GHG emissions per unit of COD treated or per volume of wastewater treated.	Dynamic or Static	Reject. Typical industry GHG emissions data per unit of COD are not available in Canada. Each facility will also have different wastewater generation rates, inlet and outlet COD concentrations and technologies in place to meet end-of-pipe effluent limits. There is also a lack of projects to justify an accurate industry performance standard or benchmark. For example, in Alberta there are only two beef processing plants. Since the measurement of methane emissions from anaerobic wastewater treatment systems is not normally undertaken unless a capture system is already in place, it would not be feasible to establish normal industry GHG emissions.
3.Comparison-based	Assessment of the baseline GHG emissions from anaerobic wastewater treatment based on the performance of the project site as compared to a control group.	Dynamic	Reject. Individual facilities will vary greatly in terms of processing facility operations, wastewater generation rates, inlet and effluent COD concentrations, temperatures and wastewater treatment technologies employed. This approach would also create unnecessary monitoring and measurement burdens for the project developer.

1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
4. Projection - Based	Assessment of the baseline GHG emissions from anaerobic wastewater treatment using a model to predict the baseline emissions per unit of chemical oxygen demand removed from the wastewater under anaerobic conditions based on site specific temperatures and anaerobic treatment system depths.	Dynamic	Accept. This approach uses site specific measurements of COD removed in the anaerobic treatment unit (based on wastewater flow rates and COD concentrations) and average monthly temperatures to evaluate the baseline methane emissions according to a widely used model from CDM and IPCC best practice guidance. This method of predicting baseline methane emissions represents a conservative approach that accounts for site to site variations in temperature and depth, which may impact methane generation in the baseline.
5.Adjusted Baseline	Assessment of the baseline GHG emissions using site specific data and adjusting for existing methane capture activity levels or common industry practices. This approach could be used in conjunction with a performance standard if methane capture were the normal industry practice (e.g. due to regulations).	Static or Dynamic.	Reject. The variability in food processing operations is too high to generalize the industry wastewater treatment practices. A variety of wastewater treatment technologies are used in Canada, including both anaerobic and aerobic processes. The choice of system will depend on the type of wastewater, size of the facility, regional regulations, proximity to residential areas etc. Simple facilities may use open lagoons with long retention times operating at close to ambient temperatures, while others may use advanced high rate anaerobic reactors operating at elevated temperatures ideal for methane generation.

2.2.2 Selection of Baseline Scenario

The development of quantification approaches for methane capture from anaerobic wastewater treatment projects required the examination of a variety of baseline scenarios as described in **Section 2.2.1**. The main criteria used to evaluate each scenario included data availability, environmental integrity, accuracy, consistency with Alberta project configurations and ease of application (e.g. through monitoring requirements). These approaches included site-specific scenarios and more generalized scenarios that included regional average factors.

The selected baseline condition for this protocol is the projection based approach described in **TABLE 2.2**, above. Under this scenario, the baseline GHG emissions are quantified based on the anaerobic decomposition of an equivalent quantity of organic matter (expressed as COD) contained in the industrial wastewater effluent stream that is treated under clearly anaerobic (oxygen-free) conditions. The baseline methane emissions are calculated by applying a mass balance on the COD into and out of the anaerobic treatment system and accounting for the effects of temperature and oxygen exposure on the biological process consistent with the approach outlined in the Clean Development Mechanism Consolidated Methodology ACM0014 for Anaerobic Wastewater Treatment Projects. Further guidance is provided in Appendix A as to the parameters impacting the anaerobic digestion of organic matter in wastewater treatment systems and the use of site-specific data versus IPCC default values.

The GHG emissions from combustion of fossil fuels in the baseline that have been replaced with renewable energy output from the biogas utilization system would be accounted for using direct measurement of the biogas energy output in the project activity and displacement of the most likely or most conservative fossil fuel type.

The baseline scenario for projects that previously flared biogas without energy recovery in an open flare assumes a methane destruction efficiency of 96%, if operated in accordance with the flare specifications, while the methane destruction efficiency for an enclosed or controlled flare is assumed to be 98%. The default flare efficiencies used in this protocol are consistent with the GE AES Methodology for Wastewater Treatment Methane Capture and Destruction Projects Version 1.1. The majority of wastewater treatment plant operators would not have conducted combustion efficiency testing or monitoring of relevant flare operating parameters in the baseline prior to implementing a biogas energy utilization system and therefore the use of these factors represents a conservative but practical approach to estimating baseline methane emissions from flares. Additionally, for projects where an aerobic system was previously in place, which was replaced with an anaerobic process that included systems to capture biogas for energy generation, the baseline scenario would only be the displacement of fossil fuels with energy output from the project biogas energy generation system. Further, for wastewater treatment projects implemented as part of the design of new Greenfield wastewater treatment plants, the baseline condition is the flaring of all methane produced from the unit using an open flare with 96% efficiency.

This dynamic approach accounts for the market forces, weather and energy demand and operational parameters without adding multiple streams of material management. There are suitable models that can provide reasonable certainty.

The baseline condition is defined including the relevant SS's and processes as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in **Section 2.3**, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.3**

FIGURE 2.2: Baseline Element Life Cycle Chart

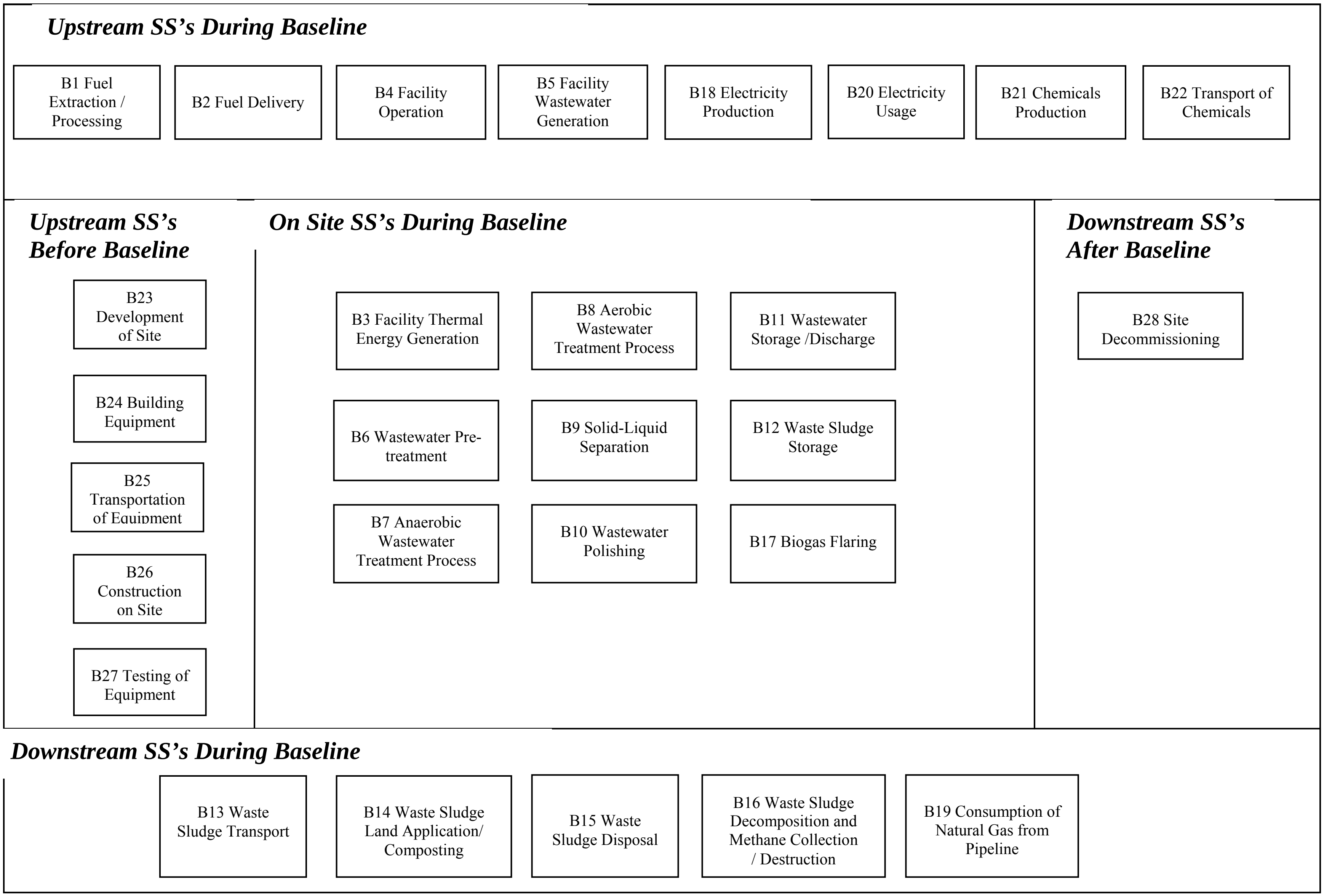


TABLE 2.3: Baseline SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Fuel Extraction / Processing	Each of the fuels used at the facility in the baseline will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are aggregated under this SS to account for GHG emissions associated with their extraction and processing at upstream oil and gas facilities. Volumes and types of fuels are the important characteristics to be tracked.	Related
B2 Fuel Delivery	Each of the fuels used at the facility in the baseline will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
B4 Facility Operation	The facility that generates the wastewater would have a primary function or product and any number of processes that would require energy inputs and therefore consume fossil fuels as part of process or unit operation and for material handling. Quantities for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
B5 Facility Wastewater Generation	Wastewater is produced as a by-product of industrial operations in a number ways including from cleaning of process equipment and from the discharge of off-spec materials and by-products using water as a transport medium for the wastes. Greenhouse gas emissions may be associated with these industrial processes and the associated wastewater handling practices, which could include heating, pumping, mixing, sterilization and equalization and could be powered by fossil fuels either directly or indirectly through a centralized boiler or cogeneration unit. Quantities for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition. Typical facilities could include meat and vegetable processing facilities, distilleries, breweries and other industries that produce significant loadings of organic matter in wastewater streams.	Related
B18 Electricity Production	Electricity will be produced at off-site grid connected generation facilities in the baseline to cover the electricity that is now being generated from the biogas output by the project anaerobic digestion facility. This electricity would have been produced at an emissions intensity as deemed appropriate by the Program Authority. The net quantity of electricity output by the facility in the project condition will need to be tracked in the project condition to quantify this SS.	Related
B20 Electricity Usage	Electricity may be required for operating a variety of equipment at the processing facility and at	

	the wastewater treatment facilities in the baseline. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity should be sufficient to track the use of electricity sourced from on and off-site electricity generation systems. For project configurations where electricity is generated from biogas produced from anaerobic digestion at the project condition, the net electricity output from the generator would displace an equivalent quantity of electricity on or off-site that would have been derived from fossil fuels and this would be accounted for under the SS B17 Electricity Production and not under this SS. Quantity and source of power used at the project site are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	
B21 Chemical Production	The production of chemicals from raw materials upstream of the project site may include several material and energy inputs such as natural gas and diesel. Quantities and types of chemicals used at the facility and their associated GHG intensity per unit would be contemplated to evaluate functional equivalence with the baseline condition.	Related
B22 Transport of Chemicals	Chemicals used at the project facility may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
Onsite SS's during Project Operation		
B3 Facility Thermal Energy Generation	The facility may have operated a boiler or other equipment to generate thermal energy for the primary production process by combusting fossil fuels. These fuels may be displaced by thermal energy produced from biogas captured in the project condition. The quantities and types of fuels combusted for thermal energy generation should be tracked in addition to the quantity of thermal energy produced from biogas in the project condition. Appropriate metering systems should be in place to account for any incremental parasitic heating requirements of the project activity such that they may be subtracted from the total quantity of thermal energy displacing the baseline fossil fuel. The project proponent should track the quantity, composition and energy content of biogas consumed on-site to supplement the thermal energy demands of the facility.	Controlled
B6 Wastewater Pre-Treatment	Wastewater may be treated and/or processed prior to being input to the anaerobic treatment system. This could include physical processes such as screening, grit and solids removal, oil-water separation, dissolved air flotation for removal of fats and oils and other processes that adjust the chemical composition of the wastewater. This may involve the use of heavy equipment that operates using diesel or natural gas. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities for each of the energy inputs may all need to be tracked to evaluate functional equivalence with the project condition.	Controlled
B7 Anaerobic Wastewater Treatment Process	Greenhouse gas emissions may occur that are associated with the operation of the baseline anaerobic treatment unit. The primary source of GHG emissions would be from the venting of	Controlled

	biogas to the atmosphere. The quantity of organic matter as chemical oxygen demand into and out of the anaerobic treatment unit should be tracked in the project condition to determine the quantity of COD removed by the anaerobic wastewater treatment unit in the baseline. This quantity of COD would have decayed to produce methane that would have been emitted to the atmosphere had a methane capture system not been installed. The quantity of methane emitted from the anaerobic treatment unit (e.g. and uncovered deep anaerobic lagoon) in the baseline is a function the mass of COD removed in the unit, the temperature of the wastewater, the maximum methane generation potential per unit of COD and the anaerobic conditions of the lagoon (referred to using a methane conversion factor). The project proponent should track the mass of COD in and out of the lagoon and the temperature of the wastewater at the entrance and exit of the anaerobic treatment unit.	
B8 Aerobic Wastewater Treatment Process	The anaerobic wastewater treatment unit may be followed by an aerobic process (bioreactor, aerobic digester, clarifier etc.) or an alternating anaerobic-aerobic process to ensure sufficient removal of organic matter from the wastewater stream, beyond the capability of a standalone anaerobic unit. There may be multiple energy and chemical inputs to operate equipment for pumping, mixing, coagulation, flocculation and aeration. Additionally pockets wastewater may have anaerobic conditions either by design or due to poor mixing, creating some additional methane emissions. Quantities and types of fuels and the potential for anaerobic conditions should be tracked to evaluate functional equivalence with the project condition.	Controlled
B9 Solid-Liquid Separation	The aggregated particles that have coagulated and been concentrated are generally sent to a filter, press or centrifuge system for de-watering. The resulting solid product is then sent for disposal or land application and the wastewater is usually recycled back to the aerobic treatment process. There may be multiple energy and chemical inputs to operate the solid-liquid separator, pumps and associated equipment. Quantities and types of fuels should be tracked to evaluate functional equivalence with the project condition.	Controlled
B10 Wastewater Polishing	The wastewater may undergo some additional chemical adjustments in a polishing step to ensure that the wastewater meets applicable sewer or surface water discharge regulations. Additional chemicals and energy inputs may be required in this step, with associated energy inputs and GHG emissions. Functional equivalence would be evaluated relative to the project scenario.	Controlled
B11 Wastewater Storage/ Discharge	After the wastewater has undergone any remaining chemical adjustments in the polishing stage, it will either be stored indefinitely or discharged to the sewer system or another body of water. If any significant quantities of organic material were remaining in the wastewater stream (likely due to upset conditions), there could be some small amount of additional methane produced in the storage pond or downstream of the site. Functional equivalence would also be evaluated relative to the baseline scenario.	Controlled
B12 Waste Sludge Storage	Greenhouse gas emissions may also result if the solid material (sludge) from the solid-liquid separator (filter press) is stored on-site stored for extended periods of time. Further anaerobic decomposition may occur if the material is not fully stabilized resulting in some additional	Controlled

	methane emissions. Functional equivalence with the sludge handling practice used in the project condition would be evaluated to determine materiality. If a change in practice from the baseline resulted in incremental quantities of sludge being stored under anaerobic conditions for long periods of time in the project condition, the stability of the sludge material and methane generation potential should be evaluated to evaluate materiality of emissions.	
B17 Biogas Flaring	In the baseline scenario a flare may have operated at the site to destroy some or all of the biogas produced from the anaerobic treatment unit. The project proponent would be responsible for tracking the volume of biogas flared, the type of flare unit (open or enclosed) and the flare destruction efficiency (e.g. from manufacturing specifications) as these items would impact the baseline methane emissions.	
Downstream SS's during Baseline Operation		
B13 Waste Sludge Transport	Sludge produced from wastewater treatment in a primary or secondary settler or other processes may need to be transported to a composting or other anaerobic digestion facility for additional material stabilization, or to a disposal site or to fields for land application. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled
B14 Waste Sludge Land Application/ Composting	The waste sludge may be further cured and stabilized using a composting process (e.g. passive or active windrowing) and then land applied or directly land applied. This process would require the use of heavy equipment and mechanical systems. This equipment would be fuelled by diesel, gas or natural gas, resulting in GHG emissions. Composting and land application may result in additional N_2O emissions and methane emissions from pockets of anaerobic conditions during composting or land application. Quantities for each of the energy inputs and evaluation of normal practices pre-post project would be contemplated to evaluate functional equivalence between the baseline and project conditions.	Related
B15 Waste Sludge Disposal	The wastewater treatment facility may generate significant amounts of waste sludge requiring disposal if the land applied is not practiced or allowed in the relevant region due to nutrient restrictions. Waste sludge may be disposed of at a disposal site, such as a landfill, by transferring the waste from the transportation container, spreading, burying, processing, otherwise handling the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gas or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs would be tracked.	Related

B16 Waste Sludge Decomposition and Methane Collection / Destruction	In the project condition some waste sludge may be sent to landfill in and may result in the production of methane due to anaerobic conditions at the landfill site. A methane collection and destruction system may be in place at the disposal site. The average percentage of methane collected and destructed for landfills in that jurisdiction should be accounted for in a reasonable manner otherwise specific disposal site characteristics and may need to be tracked as well as the characteristics of the specific methane collection and destruction system. The project proponent should track the wet weight of waste sludge sent to landfill and account for any occasions when sediments are removed from the anaerobic digester as the material may have some methane generation potential and be a source of GHG leakage.	Related
B19 Consumption of Natural Gas from Pipeline	Biogas may be input to the pipeline system and distributed to customers at another point on the distribution system in the project condition. This gas will be then consumed by the consumer and result in the displacement of natural gas that would normally have been consumed had the biogas not been input into the gas distribution system. The most reasonable fate would be combustion in a controlled manner as this relies on the highest emissions factors for the biogas. The total quantity and energy content of biogas input to the pipeline system would need to be tracked in the project condition to calculate the equivalent quantity of natural gas displaced in the baseline.	Related
Others		
B23 Development of Site	The site may need to be developed under the baseline condition. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas and offices, etc., as well as structures to enclose, support and house any equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
B24 Building Equipment	Equipment may need to be built either on-site or off-site. This can include the baseline components for the storage, handling and processing of the agricultural material. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B25 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

B26 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
B27 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test agricultural materials or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B28 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline conditions were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.4**, below. All other SS's listed previously are included.

TABLE 2.4: Comparison of SS's

1. Baseline Options	2. Baseline (C, R, A)	2. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
Upstream SS's				
P1 Fuel Extraction / Processing	N/A	Related	Include	N/A
B1 Fuel Extraction / Processing	Related	N/A	Include	
P2 Fuel Delivery	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them.
B2 Fuel Delivery	Related	N/A	Exclude	
P4 Facility Operation	N/A	Related	Exclude	Excluded as in the majority of project configurations the facility operations upstream of the wastewater treatment processes will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions.
B4 Facility Operation	Related	N/A	Exclude	
P5 Facility Wastewater Generation	N/A	Related	Exclude	Excluded as in the majority of project configurations the facility wastewater generation and collection systems upstream of the wastewater treatment processes will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B5 Facility Wastewater Generation	Related	N/A	Exclude	
B18 Electricity Production	Related	N/A	Include	N/A
P25 Electricity Usage	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under current greenhouse gas regulations.
B20 Electricity Usage	Related	N/A	Exclude	
P26 Chemical Production	N/A	Related	Exclude	Excluded as under the majority of configurations, chemical use in the project condition will be equivalent to the baseline scenario as the addition of a methane capture system would not be expected to materially impact chemical usage.
B21 Chemical Production	Related	N/A	Exclude	
P27 Transport of Chemicals	N/A	Related	Exclude	Excluded as under the majority of configurations, chemical use in the project condition will be equivalent to the baseline scenario as the addition of a methane capture system would not be expected to materially impact chemical usage.
B22 Transport of Chemicals	Related	N/A	Exclude	
Onsite SS's				
P3 Facility Thermal Energy Generation	N/A	Controlled	Include	N/A
B3 Facility Thermal Energy Generation	Controlled	N/A		
P6 Wastewater Pre-Treatment	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the facility wastewater pre-treatment systems upstream of the anaerobic treatment unit will not be
B6 Wastewater Pre-	Controlled	N/A		

Treatment				impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
P7 Anaerobic Wastewater Treatment Process	N/A	Controlled	Include	N/A
B7 Anaerobic Wastewater Treatment Process	Controlled	N/A		
P8 Aerobic Wastewater Treatment Process	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the aerobic wastewater treatment systems downstream of the anaerobic treatment unit will not be impacted by the project activity as the removal of COD in the anaerobic unit will remain consistent or potentially improve during the project activity and result in decreased treatment requirements downstream. Therefore the baseline and project conditions will be functionally equivalent.
B8 Aerobic Wastewater Treatment Process	Controlled	N/A		
P9 Solid-Liquid Separation	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the solid-liquid separation unit operation downstream of the anaerobic treatment unit will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B9 Solid-Liquid Separation	Controlled	N/A		
P10 Wastewater Polishing	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the polishing treatment downstream of the anaerobic treatment unit will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B10 Wastewater Polishing	Controlled	N/A		
P11 Wastewater Storage/ Discharge	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the wastewater storage and discharge systems downstream of the anaerobic treatment unit will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B11 Wastewater Storage/ Discharge	Controlled	N/A		
P12 Waste Sludge Storage	N/A	Controlled	Exclude	Excluded as in the majority of project configurations the sludge storage operations downstream of the anaerobic treatment unit will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B12 Waste Sludge Storage	Controlled	N/A		
P17 Biogas Venting	N/A	Controlled	Include	N/A
P18 Biogas Conditioning	N/A	Controlled	Include	N/A
P19 Biogas Flaring	N/A	Controlled	Include	N/A
B17 Biogas Flaring	Controlled	N/A		
P20 Biogas Processing for Pipeline	N/A	Controlled	Include	N/A
P21 Thermal Energy Generation	N/A	Controlled	Include	N/A

P22 Electricity Generation	N/A	Controlled	Include	N/A
P23 Fugitive Emissions	N/A	Related	Exclude	Excluded as projects that involve enhanced anaerobic digestion processes (e.g. incremental heating to provide mesophilic or thermophilic conditions in the anaerobic digester) applying this protocol must meet the requirements of with Sections 10.2 through 10.4 of the Canadian Standards Association (CSA) Code for Digester Gas and Landfill Gas Installations CAN/CGA-B105-M93 which specifies the relevant leakage and pressure testing requirements providing reasonable assurance that fugitive emissions are immaterial. Refer to Appendix B for further guidance.
Downstream SS's				
P13 Waste Sludge Transport	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in sludge disposal practices and therefore no change in fossil fuel consumption for sludge transportation, making the baseline and project scenarios functionally equivalent.
B13 Waste Sludge Transport	Related	N/A		
P14 Waste Sludge Land Application/ Composting	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in sludge land application or composting practices due to the project implementation of a methane capture system, making the baseline and project scenarios functionally equivalent.
B14 Waste Sludge Land Application/ Composting	Related	N/A		
P15 Waste Sludge Disposal	N/A	Related	Exclude	Excluded due to the relatively small quantity of GHG emissions from fossil fuel consumption to operate heavy equipment to handle the waste sludge at the disposal site (e.g. landfill).
B15 Waste Sludge Disposal	Related	N/A		
P16 Waste Sludge Decomposition and Methane Collection/ Destruction	N/A	Related	Include	Project proponents can exclude this SS from quantification if facility records demonstrate that no sludge or sediment is sent to landfill in the Project condition.
B16 Waste Sludge Decomposition and Methane Collection/ Destruction	Related	N/A	Exclude	Excluded for conservativeness as higher emissions in the baseline would result in larger emission reductions.
P24 Pipeline Distribution and Usage	N/A	Related	Include	N/A
B19 Consumption of Natural Gas from Pipeline	Related	N/A		
Other				
P28 Development of Site	N/A	Related	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
B23 Development of Site	Related	N/A	Exclude	Emissions from site development are not material for the baseline condition given the minimal site development typically required.
P29 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project

				life, and the minimal building equipment typically required.
B24 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
P30 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
B25 Transportation of Equipment	Related	N/A	Exclude	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
P31 Construction on Site	N/A	Related	Exclude	Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required.
B26 Construction on Site	Related	N/A	Exclude	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
P32 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
B27 Testing of Equipment	Related	N/A	Exclude	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.
P33 Site Decommissioning	N/A	Related	Exclude	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
B28 Site Decommissioning	Related	N/A	Exclude	Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required.

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.5,** below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Electricity Production}} + \text{Emissions}_{\text{Thermal Energy Generation}} + \text{Emissions}_{\text{Anaerobic Wastewater Treatment Process}} + \text{Emissions}_{\text{Biogas Flaring}} + \text{Emissions}_{\text{Consumption of Natural Gas from Pipeline}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Facility Thermal Energy Generation}} + \text{Emissions}_{\text{Anaerobic Wastewater Treatment Process}} + \text{Emissions}_{\text{Biogas Venting}} + \text{Emissions}_{\text{Biogas Conditioning}} + \text{Emissions}_{\text{Biogas Flaring}} + \text{Emissions}_{\text{Biogas Processing For Pipeline}} + \text{Emissions}_{\text{Thermal Energy Generation}} + \text{Emissions}_{\text{Electricity Generation}} + \text{Emissions}_{\text{Waste Sludge Decomposition and Methane Collection/ Destruction}} + \text{Emissions}_{\text{Pipeline Distribution}}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.

$\text{Emissions}_{\text{Fuel Extraction / Processing (SS B1)}}$
$\text{Emissions}_{\text{Electricity Production (SS B18)}}$
$\text{Emissions}_{\text{Thermal Energy Generation (SS B3)}}$
$\text{Emissions}_{\text{Anaerobic Wastewater Treatment Process (SS B7)}}$
$\text{Emissions}_{\text{Biogas Flaring (SS B17)}}$
$\text{Emissions}_{\text{Consumption of Natural Gas from Pipeline (SS B19)}}$

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.

$\text{Emissions}_{\text{Fuel Extraction / Processing (SS P1)}}$
$\text{Emissions}_{\text{Facility Thermal Energy Generation (SS P3)}}$
$\text{Emissions}_{\text{Anaerobic Wastewater Treatment Process (SS P7)}}$
$\text{Emissions}_{\text{Biogas Venting (SS P17)}}$
$\text{Emissions}_{\text{Biogas Conditioning (SS P18)}}$
$\text{Emissions}_{\text{Biogas Flaring (SS P19)}}$
$\text{Emissions}_{\text{Biogas Processing For Pipeline (SS P20)}}$
$\text{Emissions}_{\text{Thermal Energy Generation (SS P21)}}$
$\text{Emissions}_{\text{Electricity Generation (SS P22)}}$
$\text{Emissions}_{\text{Waste Sludge Decomposition and Methane Collection/Destruction (SS P16)}}$
$\text{Emissions}_{\text{Pipeline Distribution (SS P24)}}$

TABLE 2.5: Quantification Procedures

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P1 Fuel Extraction / Processing	Emissions $_{Fuel\ Extraction\ /\ Processing}$ = ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)					
	Volume of Fuel Consumed for P3, P7, P18, P19, P20, P21, P22, P24	L / m^3 / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P3 Facility Thermal Energy Generation P18 Biogas Conditioning P19 Biogas Flaring	Emissions $_{P3,\ P18,\ P19,\ P20,\ P21,\ P22,\ P24}$ = (Vol. Biogas $_{Combusted}$ * % CH_4 * ρ CH_4 * (1-DE)) ; (Vol. Biogas Combusted * % CH_4 * EF Biogas N_2O); ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$);					
	Emissions $_{P3,\ P18,\ P19,\ P20,\ P21,\ P22,\ P24}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as biogas and supplemental fossil fuel use on site is likely aggregated for these SS's.

P20 Biogas Processing for Pipeline P21 Thermal Energy Distribution P22 Electricity Generation P24 Pipeline Distribution and Usage	Volume of Biogas Combusted for P3, P18, P19, P20, P21, P22/ $\text{Vol. Biogas}_{\text{Combusted}}$	m^3	Measured	Direct metering of volume of biogas being combusted on and off-site.	Continuous metering.	Direct metering is standard practise. Frequency of metering is highest level possible.
	Methane Composition in Biogas / % CH_4	-	Measured	Direct measurement.	Monthly	Biogas composition should remain relatively stable during steady-state operation for wastewater treatment operations.
	Density of Methane / ρ CH_4	kg / m^3	Constant	0.7157 kg/m^3 at standard temperature and pressure.	Actual value	If this value is used all volumes should be adjusted accordingly to reflect standard temperature and pressure.
	Destruction Efficiency of Combustion Device / DE	%	Estimated	Default values are 96% destruction efficiency for open flares and 98% for all other enclosed combustion devices, which are conservative. For flares the Manufacturer's specifications may also be used provided that the flare is operating within the specified limits for gas heating value and flare exit tip velocity. If regulations are in place that require the facility to maintain a certain flare destruction efficiency of methane or non-methane organic compounds then that flare efficiency should be used.	Actual value	Default values taken from GE AES *Methodology for Waste Water Treatment Methane Capture and Destruction Projects Version 1.1 November 10, 2008*. The use of manufacturer's specifications for flare efficiency is consistent with the CCAR Livestock Reporting Protocol and specification of the gas heating value and exit gas velocity is consistent with US EPA CFR Part 60.18 New Source Performance Standards. CFR Part 60.18 specifies that steam or air assisted flares maintain a gas heating value of 11.2 MJ/ m^3 and that non-assisted flares maintain a net heating value of 7.45 MJ/m^3 or greater. Both types of flares should be designed for exit velocities less than 18.3 m/s.

	N_20 Emissions Factor for Biogas / EF Biogas $_{N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents. In the absence of biogas data, rely on emissions factors for Natural Gas. The generic Environment Canada emission factors (for industrial use of natural gas or electric utilities) may be adequate, but other factors specific to the type of combustion device (US-EPA AP-42 or CAPP) may be more appropriate.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. US EPA AP-42 values are commonly used by industry
	Volume of Each Type of Fuel Combusted for P3, P18, P19, P20, P21, P22, P24 / Vol Fuel $_i$	L / m^3 / other	Measured	Direct metering or reconciliation of volumes of supplemental fuels used for thermal energy generation, biogas conditioning, biogas flaring, biogas processing for input into the pipeline, electricity generation and pipeline distribution and usage. Where direct metering is not possible, reconciliation of the volumes of each fuel in storage (including volumes received) is reasonable.	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P7 Anaerobic Wastewater Treatment Process	This SS is accounted for under SS B7 Anaerobic Wastewater Treatment Process.					
P17 Biogas Venting	The equation below for Project Emissions from biogas venting includes a component for upset conditions such as when a tear or major leak occurs in a digester cover and a component to account for methane emissions due to digester collection efficiencies less than 100% efficient. $\text{Emissions}_{\text{Venting}} = [(\text{Max. Storage Vol.}_{\text{Vessel}} + \text{Flow Biogas}_{\text{Vessel}} * \text{Time}_{\text{Venting}}) * \%\ CH_4 * \rho\ CH_4 + (\text{Vol. Biogas} *((1\text{-CE})/\text{CE})* \%\ CH_4 * \rho\ CH_4)]$					
	Maximum volume of biogas stored in Vessel at Steady State / Max. Storage Vol. $_{\text{Vessel}}$	m^3	Estimated	From facility engineering specifications or engineering estimate based on dimensions. This may represent only the segment of the digester the leak occurred in if the digester is compartmentalized (eg covered lagoon)	Annual	Reference value will remain consistent unless system is re-engineered (i.e. change to maximum storage volume from change in cap).
	Flow Rate of Biogas at Steady State / Flow Biogas $_{\text{Vessel}}$	m^3 / hr	Measured	Average flow rate of biogas from the digester at steady state for the preceding period.	Weekly	Biogas flow rates are steady state for the previous week should provide a reasonable approximation of the biogas flow rate at time of venting.

	Time that vessel is venting / t	days	Estimated	Number of partial or complete days of venting either measured or estimated from site records of energy production, witness accounts, etc.	Daily	Number of days in a year when venting occurred is an absolute value.
	Methane Composition in Biogas / % CH_4	-	Measured	Direct measurement.	Monthly	Biogas composition should remain relatively stable during steady-state operation.
	Density of Methane / ρ CH_4	kg / m^3	Constant	0.7157 kg/m^3 at standard temperature and pressure.	Actual value	If this value is used all volumes should be adjusted accordingly to reflect standard temperature and pressure.
	Total Volume of Biogas Captured from Anaerobic Treatment System / Vol. Biogas	m3	Measured	Direct metering of volume of biogas being combusted.	Continuous metering.	Direct metering is standard practise. Frequency of metering is highest level possible.
	Collection Efficiency for Anaerobic Digester / CE	-	Estimated	Value of 95% collection efficiency for bank-to-bank covered lagoon systems and 98% for enclosed vessel systems (complete mix or fixed film digesters). Alternatively the project proponent may utilize engineering designs for the anaerobic digester and methane capture systems if available.	Annual	Values obtained from *US Environmental Protection Agency (EPA) Climate Leaders Draft Offset Protocol for Managing Manure with Biogas Recovery Systems* (October 2006) Table II.f. Digester Collection Efficiencies. Represents best practice guidance and a conservative approach to quantification. Venting emissions are not normally practical to measure, therefore estimation is reasonable.
P16 Waste Sludge Decomposition and	$Emissions_{Sludge\ Disposal} = (Mass_{Feedstock\ Landfill} * MCF * DOC * DOC_F * F * 16/12) * (1 - R) * (1 - OX)$					
	$Emissions_{Sludge\ Disposal}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.

Methane Collection/ Destruction	Mass of Sludge and Sediment Sent to Landfill / Mass Sludge Landfill	kg	Measured	Direct measurement of the incremental mass of waste sludge sent to a landfill facility in the project condition or reconciliation of disposal/haulage receipts. If sediments are removed from the anaerobic treatment system and sent to landfill, this mass should be accounted for under this SS.	Measurement of each load of waste prior to its being disposed of onsite or as it is received at the landfill facility.	Measuring the mass of each load prior to its being disposed of onsite or as it is received at the landfill facility represents the industry practise.
	Methane Correction Factor / MCF	-	Estimated	Calculated based on IPCC and Environment Canada guidelines, provided in Appendix D.	Annual	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Degradable Organic Carbon / DOC	-	Estimated	Calculated based on IPCC and Environment Canada guidelines, provided in Appendix D.	Annual	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Fraction of Degradable Organic Carbon Dissimilated / DOC_F	-	Estimated	Calculated based on IPCC and Environment Canada guidelines, provided in Appendix D.	Annual	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Fraction of CH_4 in Landfill Gas Produced At Disposal Site / F	-	Estimated	From IPCC guidelines.	Annual	Reference values adjusted periodically as part of internal IPCC review of its methodologies.

	Fraction of CH_4 Recovered at Landfill / R	-	Estimated	Based on an affirmation from the landfill operator or from landfill gas collection system engineering design efficiency if site-specific data is available to the project developer. If site specific data is not available or if biomass wastes disposed of in multiple landfills within a large area the project developer may use a regional average percentage of landfill methane collected in the region.	Annual	Percentage of methane collected and destroyed at the landfill sites where the materials were previously sent. In cases where biomass is sourced from a large area and diverted from multiple landfills the project developer may use a regional average based on landfill gas capture data from the National GHG Inventory or other relevant sources.
	Oxidation Factor / OX	-	Estimated	From IPCC guidelines.	Annual	Reference values adjusted periodically as part of internal IPCC review of its methodologies.
Baseline SS's						
B1 Fuel Extraction / Processing	$Emissions_{Fuel\ Extraction\ /\ Processing} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2})$; $\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4})$; $\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O})$					
	Volume of Fuel Consumed for B3 and B18	L / m^3 / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel / EF $Fuel_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B18 Electricity Production	Emissions $_{Electricity}$ = Electricity * EF $_{Elec}$					
	Emissions $_{Electricity}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated.
	Electricity Sent to Grid or Direct Connected Facilities in Project Condition/ Electricity	kWh	Measured	Direct metering of quantity of renewable electricity delivered to the regional grid or direct connected users net of parasitic loads attributable to the project activity. This quantity of electricity generated in the project condition displaces an equivalent quantity of electricity that would have been produced by other grid connected facilities had the project activity not been implemented.	Continuous metering	Continuous direct metering represents the industry practise and the highest level of detail.
	Emissions Factor for Electricity / EF $_{Elec}$	kg of CO2e per kWh	Estimated	From Alberta Environment reference documents.	Annual	Reference values adjusted as appropriate by Alberta Environment.
B3 Facility Thermal Energy Generation	Emissions $_{Thermal\ Heat}$ = $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)					
	Emissions $_{Thermal\ Heat}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Vol. Fuel $_i$ = Heat Load * % $_i$ / HHV fuel $_i$					

	Volume of Each Type of Fuel / Vol Fuel $_i$	L / m^3 / other	Measured	Calculated relative to metered quantity of thermal energy delivered to the end user and converted to an equivalent volume of fuel.	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Heat Load Produced under the Project Condition / Heat Load	GJ	Measured	Direct metering of quantity of thermal energy delivered to the end user or total GJ of biogas combusted in the project condition. If biogas is combusted with other fuels, the relative energy input in GJ of each fuel used should be tracked in the project condition and only the biogas component would be credited.	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Percentage of Each Type of Fuel Offset / % $_i$	%	Estimated	Based on recorded fossil fuel consumption in one or more years prior to the implementation of project.	Monthly	Represents most reasonable means of estimation.
	Higher Heating Value of Each Type of Fuel Being Offset by the Project / HHV fuel $_i$	GJ per L, m^3 or other unit	Estimated	Reference value.	N/A	Reference value. The use of the higher heating value is conservative and consistent with Environment Canada's National GHG Inventory.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B7 Anaerobic Wastewater Treatment Process	$Emissions_{Anaerobic\ Wastewater\ Treatment} = \sum(Flow_{IN} * COD_{IN} - Flow_{OUT} * COD_{OUT} - Q_{Sediment} * COD_{Sediment}) * MCF * Bo$					
	$Emissions_{Anaerobic\ Wastewater\ Treatment}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated.
	Flow Rate of Wastewater into the Anaerobic Treatment Unit in the Project Condition / $Flow_{IN}$	m^3 of wastewater	Measured	Direct measurement of volumetric flow rate of wastewater into the anaerobic treatment unit in the project condition.	Daily	Frequency of metering provides for reasonable diligence as wastewater volumes will be fairly consistent over the course of a year.
	Flow Rate of Wastewater exiting the Anaerobic Treatment Unit in the Project Condition / $Flow_{IN}$	m^3 of wastewater	Measured	Direct measurement of volumetric flow rates of wastewater exiting the anaerobic treatment unit in the project condition.	Daily	Frequency of metering provides for reasonable diligence as wastewater volumes will be fairly consistent over the course of a year.
	Concentration of Chemical Oxygen Demand in the Inlet Wastewater Stream Entering the Anaerobic Treatment Unit in the Project Condition / COD_{IN}	Kg COD/ m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of inlet wastewater to the anaerobic treatment unit in the project activity. Measurement may be performed on site by trained technicians or tested by an external third party laboratory.	Weekly	Frequency of metering provides for reasonable diligence.

	Concentration of Chemical Oxygen Demand in the Wastewater Stream Exiting the Anaerobic Treatment Unit in the Project Condition / COD_{OUT}	Kg COD/ m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of wastewater exiting the anaerobic treatment unit in the project activity. Measurement may be performed on site by trained technicians or tested by an external third party laboratory.	Weekly	Frequency of metering provides for reasonable diligence.
	Quantity of Sediments Removed from the Anaerobic Digester in the Project Condition/ $Q_{Sediment}$	m^3 of wastewater	Measured	Direct measurement or reconciliation from disposal or haulage fees.	Each time sediments are removed from the anaerobic digester	Frequency of metering represents the highest level of assurance.
	Concentration of Chemical Oxygen Demand in Sediments Removed from the Anaerobic Treatment Unit in the Project Condition / $COD_{Sediment}$	Kg COD/ m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of wastewater and sediments removed from the anaerobic treatment unit in the project activity (e.g. due to decreased volume in the anaerobic treatment unit because of sediment build up or due to upset conditions). Measurement may be performed on site by trained technicians or tested by an external third party laboratory.	Each time sediments are removed from the anaerobic digester	Frequency of metering represents the highest level of assurance.

	Methane Conversion Factor / MCF	-	Calculated	Calculated based on IPCC guidelines as per CDM Methodology ACM0014, further explanation provided in Appendix A.	Monthly	Values calculated based on *CDM Consolidated Methodology for Mitigation of Greenhouse Gas Emissions from Treatment of Industrial Wastewater* (ACM0014) and values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	$MCF = f_d * f_T * 0.89$					
	Depth Factor / f_d	-	Measured and Estimated.	Reconciliation of the dimensions of the anaerobic treatment unit from system designs or depth measurements under normal operating conditions. Depth of the lagoon or sludge pit is used to calculate the depth factor following CDM guidelines, provided in Appendix A.	Annual	Values calculated based on values published by CDM methodology ACM0014.
	Temperature Factor / f_T	-	Calculated	Calculated monthly following CDM methodology ACM0014 and the CCAR Livestock Project Reporting Protocol as outlined in Appendix A.	Monthly.	Values calculated based on methodologies published by the CDM and CCAR and values published by IPCC.
	Conservativeness Factor / 0.89	0.89	Estimated	Value from CDM methodology ACM0014.	-	The use of an extra conservative factor from CDM methodology ACM0014 is consistent with best practice guidance.

	$f_T = \exp[(15{,}175*(T_{Effluent} - 303.16)) / (1.987 * (303.16 * T_{Effluent}))]$ When $T_{Effluent} > 303$ K: $F_T = 1.0$ When $T_{Effluent} < 283$ K: $F_T = 0$					
	Temperature of the Wastewater Effluent from the Anaerobic Treatment Unit in the Baseline / $T_{Effluent}$	Degrees Kelvin	Measured	Reconciliation of monthly average temperatures of the wastewater at the effluent from the anaerobic treatment unit prior to the implementation of a methane capture system. Project proponents should provide sufficient data to account for seasonal variations in the wastewater temperature due to ambient temperatures. If historical temperature records are unavailable then a heat transfer model should be used to estimate the theoretical baseline temperature as outlined in Appendix A.	Monthly reconciliation	Frequency of reconciliation provides for reasonable diligence. Frequency of metering represents reasonable diligence since process wastewater temperatures are typically consistent.
	Maximum Methane Producing Capacity / Bo	kg CH_4 per kg COD	Estimated	Default value from IPCC guidelines and adjusted for uncertainty, provided in Appendix B.	Annual	IPCC default value. If wastewater does not contain materials akin to simple sugars, a different methane production capacity factor must be obtained from published literature and applied.
B17 Flaring of Biogas	$Emissions_{Biogas\ Flaring}$ = (Vol. $Biogas_{Combusted}$ * % CH_4 * ρ CH_4 * (1-DE)) ; (Vol. Biogas Combusted * % CH_4 * EF Biogas N_2O); ∑ (Vol. $Fuel_i$ * EF $Fuel_{i\ CO2}$) ; ∑ (Vol. $Fuel_i$ * EF $Fuel_{i\ CH4}$) ; ∑ (Vol. $Fuel_i$ * EF $Fuel_{i\ N2O}$);					
	$Emissions_{Biogas\ Flaring}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.

	Volume of Biogas Flared in the Baseline / Vol. Biogas	m^3	Measured	Direct metering of volume of biogas being combusted in the flare.	Continuous metering.	Direct metering is standard practise. Frequency of metering is highest level possible.
	Methane Composition in Biogas / % CH_4	-	Measured	Direct measurement.	Monthly	Biogas composition should remain relatively stable during steady-state operation for wastewater treatment operations.
	Density of Methane / ρ CH_4	kg / m^3	Constant	0.7157 kg/m^3 at standard temperature and pressure.	Actual value	If this value is used all volumes should be adjusted accordingly to reflect standard temperature and pressure.
	Destruction Efficiency of Combustion Device / DE	%	Estimated	Default values are 96% destruction efficiency for open flares and 98% for all other enclosed combustion devices. Manufacturer's specifications may also be appropriate where available. If regulations or permits require the facility to maintain a certain flare destruction efficiency of methane or non-methane organic compounds then that flare efficiency should be used.	Actual value	Default values taken from GE AES *Methodology for Waste Water Treatment Methane Capture and Destruction Projects Version 1.1 November 10, 2008*. The use of conservative default values in the baseline is appropriate as most wastewater treatment operators will not have access to the necessary measured data (e.g. combustion efficiency testing) to determine the site-specific flare efficiency. The use of regulated / permit flare destruction efficiencies in the baseline is conservative.

	N_20 Emissions Factor for Biogas / EF Biogas $_{N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents. In the absence of biogas data, rely on emissions factors for Natural Gas. The generic Environment Canada emission factors (for industrial use of natural gas or electric utilities) may be adequate, but other factors specific to the type of combustion device (US-EPA AP-42 or CAPP) may be more appropriate.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. US EPA AP-42 values are also commonly used by industry.
	Volume of Each Type of Supplemental Fuel Consumed to Operate the Flare / Vol Fuel $_i$	L / m^3 / other	Measured	Reconciliation of volume of supplemental fuel used for operation of the flare.	Monthly reconciliation.	Frequency of reconciliation provides for reasonable diligence. If baseline data is unavailable, it is reasonable to exclude the fuel use for flare operation as it is conservative to do so.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{N2O}$	kg N2O per L/ m^3/ other	Estimated	From Environment Canada reference documents. Provided in Appendix A.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B19 Consumption of	Emissions $_{Pipeline\ Gas}$ = ∑ (Vol. Natural Gas * EF Fuel $_{i\ CO2}$) ; ∑ (Vol. Natural Gas * EF Fuel $_{i\ CH4}$) ; ∑ (Vol. Natural Gas * EF Fuel $_{i\ N2O}$)					

Natural Gas from Pipeline	Emissions $_{Pipeline\ Gas}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Vol. Natural Gas = Heat $_{Biogas}$ / HHV $_{Gas}$					
	Equivalent Volume of Natural Gas Displaced by Biogas Produced in the Project Activity/ Vol. Natural Gas	L, m^3 or other	N/A	Calculated relative to the metered quantity of biogas input into the pipeline on an energy basis and converted to an equivalent volume of natural gas.	Monthly	Quantity being calculated.
	Total Heat Value of Upgraded Biogas Input into Natural Gas Pipeline in the Project Condition / Heat $_{Biogas}$	GJ	Measured	Direct metering of quantity and energy content of biogas input into the pipeline in the project condition.	Continuous metering.	Frequency of metering is highest level possible.
	Higher Heating Value of Natural Gas / HHV $_{Gas}$	GJ per m^3	Estimated	Reference value for pipeline quality natural gas.	N/A	Reference value. Use of the higher heating value is conservative and is consistent with Environment Canada's National GHG Inventory.
	CO_2 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per m^3	Estimated	From Environment Canada reference documents. Provided in Appendix A.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per m^3	Estimated	From Environment Canada reference documents. Provided in Appendix A.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{N2O}$	kg N2O per L/ m^3/ other	Estimated	From Environment Canada reference documents. Provided in Appendix A.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in TABLE 2.6**,** below.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practices should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.2 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a 'reality check';
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and
g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.6: **Contingent Data Collection Procedures**

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P3 Facility Thermal Energy Generation P18 Biogas Conditioning P19 Biogas Flaring P20 Biogas Processing for Pipeline P21 Thermal Energy Generation P22 Electricity Generation	Volume of Biogas Combusted for P3, P18, P19, P20, P21, P22/ Vol. Biogas $_{Combusted}$	m^3	Estimated	Reconciliation of total biogas produced, which would be the summation of biogas combusted for heat generation, electricity generation, input into a gas pipeline, for on-site supplemental energy needs and the remainder that is flared.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Methane Composition in Biogas / % CH_4	-	Estimated	Interpolation of previous and following values.	Annual	Biogas composition should remain relatively stable during steady-state operation for wastewater treatment operations.
	Volume of Each Type of Fuel Combusted for P3, P18, P19, P20, P21, P22/ Vol Fuel $_i$	L / m^3 / other	Estimated	Estimated fossil fuel consumption based on historical fossil fuel consumption per volume of biogas produced over the past 6 months for each SS. Fossil fuel consumption could result from supplemental fuels used for thermal energy generation, biogas conditioning, biogas flaring, biogas processing for input into the pipeline and electricity generation.	Monthly reconciliation.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

P17 Biogas Venting	Maximum volume of biogas stored in Vessel at Steady State / Max. Storage Vol. $_{Vessel}$	m^3	Estimated	From facility engineering specifications.	Annual	Reference value will remain consistent unless system is re-engineered (i.e. change to maximum storage volume from change in cap).
	Flow Rate of Biogas at Steady State / Flow Biogas $_{Vessel}$	m^3 / hr	Estimated	Average flow rate of biogas determined from previous week of operational data divided by the hours operated.	Weekly	Biogas flow rates at steady state for the previous week should provide a reasonable approximation of the biogas flow rate at time of venting.
	Time that vessel is venting / t	days	Estimated	Estimated from operator logs or equipment downtime records	Continuous	Number of days in a year when venting occurred is an absolute value.
	Total Volume of Biogas Captured from Anaerobic Treatment System / Vol. Biogas	m3	Estimated	Reconciliation of monthly total biogas production.	Reconciliation of Monthly Totals	Frequency of reconciliation provides for reasonable diligence.
	Methane Composition of Biogas / % CH_4	-	Estimated	Reconciliation of previous months or years gas analyses.	Annual	Biogas composition should remain relatively stable during steady-state operation. Distribution to the regional natural gas grid should result in predictable compositions due to pipeline quality specifications.
P16 Waste Sludge Decomposition and Methane Collection/ Destruction	Mass of Sludge and Sediment Sent to Landfill / Mass $_{Sludge\ Landfill}$	kg	Estimated	Reconciliation of disposal/haulage receipts each time waste sludge is sent to a landfill facility in the project condition.	Each time sludge is sent to landfill	Measurement of the mass of each load at the time of pick up or at entry to the landfill facility represents the industry practise.
P24 Pipeline Distribution and Usage	Volume of Biogas Piped from the Site / Vol Biogas $_{Pipeline}$	m^3	Estimated	Reconciliation of receipts for biogas input into the pipeline from pipeline operator.	Monthly	Frequency of reconciliation provides for reasonable diligence.

	Methane Composition of Biogas / % CH_4	-	Estimated	Reconciliation of previous months or years gas analyses.	Annual	Biogas composition should remain relatively stable during steady-state operation. Distribution to the regional natural gas grid should result in predictable compositions due to pipeline quality specifications.
	Volume of Each Type of Fuel used to Input Biogas into Pipeline System / Vol Fuel $_i$	L / m^3 / other	Estimated	Reconciliation of volumes of fossil fuels used for compression or other biogas processing operations from bills/ receipts. If biogas is used as a fuel then reconciliation of total biogas production versus quantity input into the pipeline may be necessary.	Reconciliation of monthly totals.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
Baseline SS's						
B18 Electricity Production	Electricity Sent to Grid or Direct Connected Facilities in Project Condition/ Electricity	kWh	Estimated	Reconciliation of quantity of renewable electricity delivered to the regional grid or direct connected users net of parasitic loads attributable to the project activity.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
B3 Facility Thermal Energy Generation	Heat Load Produced under the Project Condition / Heat Load	GJ	Estimated	Estimated from metered volume of biogas combusted, the % methane in biogas and the reference calorific value for pure methane.	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

B7 Anaerobic Wastewater Treatment Process	Flow Rate of Wastewater into the Anaerobic Treatment Unit in the Project Condition / $Flow_{IN}$	m^3 of wastewater	Estimated	Interpolation of previous and following flow rates. Reconciliation of operating logs may be necessary to confirm that wastewater was produced during the time period that data was missing.	Weekly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Flow Rate of Wastewater exiting the Anaerobic Treatment Unit in the Project Condition / $Flow_{IN}$	m^3 of wastewater	Estimated	Interpolation of previous and following flow rates. Reconciliation of operating logs may be necessary to confirm that wastewater was produced the time period that data was missing.	Weekly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Concentration of Chemical Oxygen Demand in the Inlet Wastewater Stream Entering the Anaerobic Treatment Unit in the Project Condition / COD_{IN}	Kg COD/ m^3 of wastewater	Estimated	Interpolation of previous and following COD concentrations in wastewater exiting the anaerobic treatment unit in the project activity.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Concentration of Chemical Oxygen Demand in the Wastewater Stream Exiting the Anaerobic Treatment Unit in the Project Condition / COD_{OUT}	Kg COD/ m^3 of wastewater	Estimated	Interpolation of previous and following COD concentrations in wastewater exiting the anaerobic treatment unit in the project activity.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

	Quantity of Sediments Removed from the Anaerobic Digester in the Project Condition/ $Q_{Sediment}$	m^3 of wastewater	Estimated	Estimated based on operator log books or other records of volume of sediments removed and daily records of inlet wastewater flow rates and volume of wastewater contained in the anaerobic treatment unit or other applicable operating data.	Each time sediments are removed from the anaerobic digester	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Concentration of Chemical Oxygen Demand in Sediments Removed from the Anaerobic Treatment Unit in the Project Condition / $COD_{Sediment}$	Kg COD/ m^3 of wastewater	Estimated	Reconciliation of chemical oxygen demand of inlet wastewater to the anaerobic treatment unit at the time that sediments were removed from the anaerobic treatment unit in the project activity.	Each time sediments are removed from the anaerobic digester	Represents a conservative approach to quantification since the inlet COD concentrations will be higher than the concentration of COD in partially degraded sediments removed from the lagoon.
B17 Biogas Flaring	Volume of Biogas Flared in the Baseline / Vol. Biogas	m^3	Estimated	Linear interpolation of previous and following values.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Methane Composition in Biogas / % CH_4	-	Estimated	Linear interpolation of previous and following values.	Monthly	Biogas composition should remain relatively stable during steady-state operation for wastewater treatment operations.
	Destruction Efficiency of Combustion Device / DE	%	Estimated	Manufacturer's specifications for flare destruction efficiency or industry best available destruction efficiencies for the specific type of flare used at the site.	Actual value	The use of manufacturer's design information is reasonable and conservative for the baseline.

	Volume of Each Type of Supplemental Fuel Consumed to Operate the Flare / Vol Fuel $_i$	L / m^3 / other	Estimated	Monthly reconciliation of fuel consumption. Otherwise the project proponent may assume this value to be zero for conservativeness in the baseline.	Monthly reconciliation.	Frequency of reconciliation provides for reasonable diligence.
B19 Consumption of Natural Gas from Pipeline	Total Heat Value of Upgraded Biogas Input into Natural Gas Pipeline in the Project Condition / Heat $_{Biogas}$	GJ	Estimated	Reconciliation of quantity and energy content of biogas input into the pipeline in the project condition based on payments/receipts from gas utility.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

APPENDIX A

Parameters Used in the Calculation of Baseline
Methane Emissions from Anaerobic Wastewater Treatment

Parameters Used in Determination of Baseline Methane Generation under SS B7.

This protocol utilizes best practice guidance from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the Clean Development Mechanism Methodology ACM0014 in the determination of baseline methane emissions from the anaerobic decomposition of organic matter contained in wastewater streams. Since it is not normally practical to measure methane generation from open anaerobic systems prior to the installation of a methane capture system, the best available quantification approach at this time is the use of the IPCC model that incorporates the impacts of temperature and depth of the anaerobic system on the methane production per unit of organic matter destructed in the system.

The quantification methods for the baseline GHG emissions from anaerobic wastewater treatment included in Table 2.5 of the protocol rely on the IPCC default values; however, the project proponent is encouraged to utilize site specific data wherever possible, provided that the data is of sufficient quality to ensure that the accuracy of the emission reduction calculation is not compromised.

The slightly modified IPCC approach is based on the mass balance of chemical oxygen demand into and out of the anaerobic treatment unit (e.g. deep lagoon) as shown in Equation 1, taken from Table 2.5.

1. CH_4 Emissions from Anaerobic Decomposition =
$\sum(\text{Flow}_{IN} * \text{COD}_{IN} - \text{Flow}_{OUT} * \text{COD}_{OUT} - Q_{Sediment} * \text{COD}_{Sediment}) * \text{MCF} * \text{Bo}$

The approach used in CDM Methodology ACM0014 represents the best estimate of baseline emissions from the anaerobic treatment unit by using site specific mass flow rates, temperature conditions, and depths combined with two additional factors for conservativeness which are incorporated into the MCF and Bo values to collectively reduce baseline emissions by 74.76%. The 74.76% overall conservativeness value was obtained by multiplying the 0.89 factor used in the calculation of the MCF (see below) times the ratio of 0.21/0.25 which represents the CDM recommended (conservative) value for Bo divided by the default IPCC value for Bo as discussed in the following sections. Therefore this approach represents an overly conservative method to estimate the baseline emissions to counter any uncertainties related to the use of the IPCC default MCF and B_0 values.

The following section discusses the relevant parameters and equations used in this protocol.

For each unit of chemical oxygen demand removed from the wastewater in the anaerobic treatment unit, a corresponding volume of methane can be produced under conditions favourable for methanogenic bacteria as discussed below.

Maximum Methane Generation Potential (Bo)
This factor expresses the maximum methane producing capacity per unit of COD. The IPCC 2006 default value is 0.25 kg CH_4 / kg COD. Taking into account the uncertainty of this estimate, CDM Methodology ACM0014 recommends using a value of 0.21 kg CH_4 / kg COD, which is also used in this protocol for conservativeness. If the wastewater contains materials not comparable to simple sugars, a project specific CH_4 generation potential should be measured or obtained from best available science for the specific type of organic materials contained in the wastewater.

The project proponent may substitute the use of the default IPCC B_0 value provided that an independent lab analysis is performed at least twice per year to test the methane generation potential per unit of COD contained in the wastewater. Each lab analysis conducted for the project proponent should include several samples such that the methane generation results can be averaged with any outlying data points excluded.

Additionally, if the project proponent measures Biological Oxygen Demand (BOD) rather than COD the following IPCC conversion factor can be utilized as shown below.

Conversion from BOD to COD
If BOD is measured at the project site it may be converted to an appropriate COD value by the following IPCC conversion factor as per Equation 2:

2. COD (kg COD / m^3) = 2.4 (kg COD/ kg BOD)* BOD (kg BOD / m^3)

This flexibility mechanism is included in the protocol since many wastewater treatment operators measure BOD_5 and not COD. For consistency with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, the term BOD in Equation 2 refers to the BOD_5, or the amount of oxygen consumed by aerobic bacteria over 5 days to decompose the biodegradable organic matter contained in a wastewater sample. The above factor was derived from the division of the methane generation potential of 0.60 kg CH_4/kg BOD_5 by the methane generation potential of 0.25kg CH_4/kg COD.

If the project proponent regularly conducts BOD_5 and COD wastewater analyses at both the influent and effluent to the anaerobic treatment unit, they may choose to substitute the default IPCC COD/BOD ratio provided in this protocol with their own site-specific COD/BOD ratio. To ensure data quality and minimize the impact of variability in wastewater compositions, the project proponent should complete COD and BOD analyses at the influent and effluent of the anaerobic treatment unit on a monthly basis. The use of measured site-specific BOD and COD values is encouraged to account for differences in wastewater compositions from the different wastewater producing facilities that may be able to apply this protocol.

As stated above, the theoretical maximum methane generation potential (B_0) of the wastewater does not take into account the actual site conditions that impact the maximum ability of the anaerobic bacteria to convert organic substrates into methane and therefore a methane conversion factor is used for this purpose as described below.

Methane Conversion Factor

The methane conversion factor represents the extent to which ideal anaerobic conditions are present in the wastewater treatment unit, which is primarily dependent on the depth (f_d) of the anaerobic treatment unit (e.g. lagoon) and the temperature (f_T) of the system. Methanogenic bacteria require oxygen free (anaerobic) conditions in order to survive and their rate of consumption of COD is dependent on temperature. Optimum temperatures for anaerobic digestion are generally from 35-40 °C or 55-60 °C for mesophilic and thermophilic systems, respectively. In most baseline scenarios the pre-existing anaerobic treatment unit would not operate at these temperatures and it is therefore necessary to correct for decreased methane generation due to lower temperatures.

As discussed in CDM Methodology ACM0014 the calculation of the methane conversion factor includes a depth factor, a temperature factor and an additional conservativeness factor of 0.89 to account for uncertainty with the approach used, as shown in Equation 3.

3. $MCF = f_d * f_T * 0.89$

In project conditions where an enclosed anaerobic treatment unit was already in place in the baseline scenario, but no methane capture was practiced, a default methane conversion factor of 90% may be used consistent with the US Environmental Protection Agency (EPA) Climate Leaders Draft Offset Protocol for Managing Manure with Biogas Recovery Systems (October 2006). Temperature and depth factors would not be necessary in this baseline scenario.

Depth Factor / f_d

The Depth Factor expresses the influence of the depth of the lagoon or sludge pit on methane generation based on the surface oxidation of chemical oxygen demand that occurs due to oxygen contact with the organic matter in the lagoon. According to CDM Methodology ACM0014 the following factors apply:

Depth (m)	Value (%)
> 5	70
1-5	50
< 1	0

The CDM depth factors are most relevant for outdoor lagoon type anaerobic treatment systems and therefore project proponents must evaluate their individual systems to assess the appropriateness of these factors. If the baseline scenario consisted of an enclosed anaerobic treatment system that was not exposed to ambient air, then the depth factor would not be applicable and a value of 1 can be used. Additionally, if a grease cap is present on the surface of the anaerobic treatment unit throughout the year then the above factors may not be appropriate as discussed below.

Anaerobic wastewater treatment lagoons used in the food processing industry typically consist of three layers, a scum layer or grease cap, a supernatant layer and a sludge layer. The scum or grease layer, which forms on the surface of the lagoon can become 40-60 mm thick and has a number of important functions. It insulates the pond, preventing heat loss, suppresses odours, and maintains anaerobic conditions in the supernatant by eliminating oxygen transfer between the air-water interface[3]. The presence of a grease cap barrier provides fully anaerobic conditions regardless of the depth of the lagoon and enhances the anaerobic digestion process. For projects where a consistently thick grease cap was present before the implementation of the methane capture system, the Depth Factor is assumed to be equal to 1 as no surface oxidation of the COD will occur (note the 0.89 conservativeness factor is still applicable as per Equation 3).

Monthly Temperature Factor / f_T

Consistent with CDM Methodology ACM0014 and the CCAR Livestock Project Reporting Protocol, this protocol utilizes the Van't Hoff Arrhenius Equation to account for the impact of temperature on methanogenic bacteria production of methane. This protocol does differ slightly from the above seed documents in that it requires the project proponent to use historic wastewater effluent temperatures (leaving the anaerobic treatment unit), if available, instead of ambient air temperatures at the project site. This approach was used in order to account for the fact that most anaerobic wastewater treatment units (e.g. lagoons) used in the food processing industry will operate at significantly higher temperatures than ambient temperatures (especially in the winter) due to the high temperature of the wastewater produced in the food processing operations. The equation below is used to calculate the temperature factor:

$$4.\ f_T = \exp\left[(15{,}175*(T_{Effluent} - 303.16)) / (1.987 * (303.16 * T_{Effluent}))\right]$$

Where:

f_T = Factor expressing the influence of the temperature on the methane generation in each month of the year

15,175 cal/mol = Activation energy constant.

$T_{Effluent}$ = Average historical monthly temperature of the effluent leaving the anaerobic treatment unit prior to implementation of the methane capture system (K).

303.16 K =Reference Temperature of 30 Degrees Celsius

1.987 = Ideal gas constant (1.987 cal / K mol)

If historical average monthly temperature data is unavailable, the project proponent must demonstrate how the temperature of the wastewater in the anaerobic treatment unit has historically been impacted by seasonal changes in ambient temperatures. This may be may be demonstrated through a more limited set of measurements of the wastewater

[3] Gray, N.F. Biology of Wastewater Treatment Second Edition, Imperial College Press, 2004. Section 6.3.1 Anaerobic Ponds and Lagoons.

effluent (prior to implementation of the methane capture system in place) during the coldest part of the year.

For anaerobic treatment units or sludge pits where the wastewater effluent is NOT at elevated temperatures as compared to ambient temperatures at the project site or if the retention time of the wastewater or sludge in the baseline was previously greater than one month, it may be assumed that the baseline wastewater temperature is equal to the ambient temperature at the project site (T_{Site}). This approach is consistent with the approach used in the CDM Methodology ACM0014.

Alternatively the project proponent must apply an appropriate heat transfer model to predict what the temperature would have been without the methane capture system based on ambient temperatures. A simple heat transfer model would be to assume that the heat exchanged between the atmosphere and the open anaerobic treatment unit would be equal to the enthalpy change between the influent wastewater stream and the effluent stream from the anaerobic treatment unit[4]. The primary heat exchanges between the anaerobic treatment unit and the surroundings would be heat losses due to convection, water evaporation, atmospheric radiation and conduction between the water and the walls of the anaerobic treatment unit, offset by energy gained from solar radiation.

An example of a simplified model of the impact of ambient temperatures on wastewater temperatures inside an aerated lagoon can be found in Wastewater Engineering: Treatment and Reuse, written by Metcalf and Eddy Inc. and published by McGraw Hill Professional in 2002.

5. Tw = (A*f*Ta +Q*Ti) / (A*f + Q)

Where,
Tw = calculated theoretical temperature of the wastewater in the anaerobic treatment unit (°C)
A = Surface area of the anaerobic treatment unit exposed to the atmosphere (m^2)
Q = flow rate of wastewater into the anaerobic treatment unit (m^3/day)
F = proportionality constant = 0.5 for
Ta = Average monthly atmospheric temperature (°C)
Ti = Temperature of the wastewater at the inlet to the anaerobic treatment unit (°C)

Project proponents that are unable to obtain historical temperature records will have to develop their own heat transfer model to estimate the theoretical temperature inside the anaerobic treatment unit in the baseline in a conservative manor. The third party verifier will use his/her professional discretion to assess the appropriateness of the model and the conservativeness of the approach in terms of how the baseline emissions are impacted by the estimation of temperature.

[4] Gillot, S. and Vanrolleghem P.A. "Equilibrium temperature in aerated basins- comparison of two prediction models." Water Research (2003) Volume 37, pages 3742-3748.

APPENDIX B

Relevant Emission Factors

All values interpreted from Volume 1 of the technical report: A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP).

Table B1: Emission Intensity of Fuel Extraction and Production (Diesel, Natural Gas, and Gasoline)

Diesel		
Production		
Emissions Factor (CO_2)	0.138	kg CO_2 per Litre
Emissions Factor (CH_4)	0.0109	kg CH_4 per Litre
Emissions Factor (N_2O)	0.000004	kg N_2O per Litre
Natural Gas		
Extraction		
Emissions Factor (CO_2)	0.043	kg CO_2 per m^3
Emissions Factor (CH_4)	0.0023	kg CH_4 per m^3
Emissions Factor (N_2O)	0.000004	kg N_2O per m^3
Processing		
Emissions Factor (CO_2)	0.090	kg CO_2 per m^3
Emissions Factor (CH_4)	0.0003	kg CH_4 per m^3
Emissions Factor (N_2O)	0.000003	kg N_2O per m^3
Gasoline		
Production		
Emissions Factor (CO_2)	0.138	kg CO_2 per Litre
Emissions Factor (CH_4)	0.0109	kg CH_4 per Litre
Emissions Factor (N_2O)	0.000004	kg N_2O per Litre

Table B2: Emission Intensity of Combustion (Diesel, Natural Gas and Gasoline)

Diesel		
Emissions Factor (CO_2)	2.730	kg CO_2 per Litre
Emissions Factor (CH_4)	0.000133	kg CH_4 per Litre
Emissions Factor (N_2O)	0.0004	kg N_2O per Litre
Natural Gas		
Electric Utilities		
Emissions Factor (CO_2)	1.891	kg CO_2 per m^3
Emissions Factor (CH_4)	0.00049	kg CH_4 per m^3
Emissions Factor (N_2O)	0.000049	kg N_2O per m^3
Gasoline		
Light Duty Gasoline Trucks		
Emissions Factor (CO_2)	2.360	kg CO_2 per Litre
Emissions Factor (CH_4)	0.00013	kg CH_4 per Litre
Emissions Factor (N_2O)	0.000025	kg N_2O per Litre

APPENDIX C

Fugitive Emissions Good Practise Guidance

Fugitive Emissions Good Practise Guidance

It is crucial to the integrity of the project emission reduction claim that fugitive emissions of methane from the anaerobic decomposition of the organic matter contained in the wastewater do not become a material source of emissions under the project condition. As such the following section provides a review of available guidance and provides recommendations for project proponents.

There are a number of standards that address fugitive emissions from similar systems including the Canadian Standards Association (CSA) Code for Digester Gas and Landfill Gas Installations (CAN/CGA-B105-M93) and the Safety Standards for Agricultural Biogas Installations from the German Federal Organization of Agricultural Cooperative Associations, Central Agency for Safety and Health Protection. These documents are both quite technical. As such, the following guidance has been developed to assist project developers in implementing maintenance and monitoring program that can ensure that fugitive emissions are immaterial.

General Recommendations

The following general recommendations are provided:

1. Trained, experience and certified personnel, as applicable, should be used to complete monitoring, testing, maintenance and construction/assembly work;
2. Seals that can be made permanent should made so;
3. Seals that are not permanent should remain accessible for testing and monitoring, as applicable; and,
4. Seals that are not accessible should be tested thoroughly upon installation (i.e. underground piping connections).

Step-Wise Approach

<u>Step #1: Inventory Joints, Seals and Equipment</u>

An inventory of all joints, seals and equipment should be compiled. This list may be drawn from as-built drawings or from a thorough review of the facility. Labelling of joints may also be considered.

<u>Step #2: Categorize Joints, Seals and Equipment</u>

Each joint, seal and piece of equipment should be categorized as permanently tight and technically tight based on the following definitions:

Permanently Tight

> Permanently technically tight facility and equipment parts are, e.g., welded equipment with removable components, whereby the necessary detachable connections have only to be operationally released very rarely, and the construction of which is designed in the same way as the following detachable pipe connections

(exception: metallically tightening connections). In addition, connecting pieces for the detachable attachment of pipes, armatures, or blind covers, whereby the necessary detachable connections have only to be operationally released very rarely, and the construction of which is designed in the same way as the following detachable pipe connections (exception: metallically tightening connections) can also be permanently technically tight.

Permanently technically tight pipe connections include non-detachable connections (i.e. welded) and detachable connections, which operationally are very rarely detached (i.e. professional flange connections).

Permanently technically tight connections for the connection of equipment, as far as they are rarely operationally detached, include pipe connections as mentioned above, and NPT-thread (National Pipe Paper Thread, cone type pipe thread) or other conical pipe threads, with sealing, as far as they are not exposed to changing thermal loads.

Beside pure design measures, technical measures combined with organizational measures can also lead to permanently technically tight equipment. This category includes, with appropriate monitoring and maintenance: dynamically loaded seals, e.g., for axle guides of pumps and thermally loaded seals of facility parts

Technically Tight

Equipment is technically tight if during a tightness test or tightness monitoring or control no leakage is detectable, e.g., by means of foam generating means or with leakage test or display instruments, whereby rare releases of gases and vapors cannot be excluded. This can include pumps whose technical tightness cannot be ensured permanently (e.g., with a simple sliding ring seal), and detachable connections which are rarely not detached.

Step #3: Establish Monitoring and Testing Procedures

Select appropriate testing and monitoring procedures for each of the joints, seals and equipment based on manufacturer's specifications, industry practice or applicable standards documents. Relevance, cost effectiveness, access and category should all be included in the analysis. Permanently tight joints, seals and equipment may require less extensive and frequent monitoring as compared to technically tight joints, seals and equipment.

Monitoring and testing frequency should also be established. Recommendations are annual monitoring and testing for permanently tight joints, seals and equipment, and quarterly (at a minimum) for technically tight joints, seals and equipment. In addition, all joints should be checked each time they are maintained, replaced or otherwise disturbed.
A sample data form is provided in the following pages.

Step #4: Track Compliance with Monitoring and Testing Procedures

Compliance with monitoring and testing procedures should be tracked. Maintenance activity records should correlate with the testing and monitoring procedures.
A sample tracking form is provided in the following pages.

Table C1: Sample Monitoring and Testing Procedures Form

Item Number	Joint, Seal of Equipment			Category		Monitoring/Testing Procedures (including frequency)
	Name	Location	Description	Permanently Tight	Technically Tight	

Table C2: Sample Monitoring and Testing Tracking Form

Item Number	Date of Monitoring or Testing Event	Activity Completed	Results	Remedial Action Required	Notes

APPENDIX D

Parameters for Use in Calculations Based
on Waste Disposal in Landfill by Landfill Type

Methane Generation Potential of Waste Materials

The following calculation methodologies were collected according to the information outlined in the "National Inventory Report – Greenhouse Gas Sources and Sinks in Canada, 1990-2004", Environment Canada, April 2006.

The methane generation potential of different waste materials disposed of in landfill depends on a number of factors including the composition of the waste and the type of landfill. The methane generation potential is calculated according to the equation below.

$$\mathbf{L_0 = MCF * DOC * DOC_F * F * 16/12 * 1000\ kg\ CH_4/t\ CH_4}$$

Where:

L_O	=	CH_4 generation potential (kg CH_4/ t waste)
MCF	=	CH_4 correction factor (fraction)
DOC	=	degradable organic carbon (t Carbon / t waste)
DOC_F	=	fraction DOC dissimilated
F	=	fraction CH_4 in landfill gas
16/12	=	stoichiometric factor

The methane correction factor is determined based on the physical characteristics of the landfill that the waste being disposed as shown in Table D.1, below. According to the IPCC Guidelines, the MCF for managed landfill sites has a value of 1.0. The method used to determine the degradable organic carbon is discussed in detail below. The Environment Canada default DOC_F value of 0.6 was used for all waste types except for wood wastes where a value of 0.5 was used representing the low end of the range of wastes high in lignin as used by Environment Canada. The fraction of CH_4 (F) emitted from a landfill ranges from 0.4 to 0.6 and was assumed to be 0.5.

TABLE D1: Landfill Type-Based Factors

	Mixed-Waste Landfills				
Parameter	**Managed**	**Unmanaged – Deep (>= 5m waste)**	**Unmanaged – Shallow (< 5m waste)**	**Uncategorized**	**Wood Waste Landfills**
Methane Correction Factor (MCF)	1.0	0.8	0.4	0.6	0.8[a]
Fraction of degradable organic carbon (DOC)	See below				0.3
Fraction of degradable organic carbon dissimilated (DOC_F)	0.77				0.5
Fraction of CH_4 in landfill gas (F)	0.5				

a - the default condition for a wood waste landfill is an unmanaged, deep landfill (Environment Canada, 2006). This parameter may be changed if the emissions are being calculated for an alternate type of wood waste landfill.

Calculation of DOC

Estimates of the degradable organic carbon (DOC) present in a waste stream can be calculated using the following equation based on the biodegradable portion of the waste:

DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)

Where:
A = fraction of MSW that is paper and textiles
B = fraction of MSW that is garden or park waste
C = fraction of MSW that is food waste
D = fraction of MSW that is wood or straw

The fractions A through D can be determined from a waste audit if mixed wastes are utilized in the project activity while source segregated waste streams can be classified according to the above descriptions. Note that the DOC value should only be calculated using the fractions of the waste that would have been destined for landfill in the baseline scenario and other materials used as feedstocks should not be considered when determining the values for the fractions A through D.

If site-specific waste characterization data is not available, default DOC values in the following table were calculated using average Lo values published by Environment Canada (2006) for mixed wastes disposed in landfills for each province. Note that the calculated DOC values are representative of mixed municipal wastes and assume a MCF of 1.0 and a DOC_F of 0.77, which may not be accurate for all project conditions (e.g. for disposal of biomass in an unmanaged shallow landfill with a MCF equal to 0.4 and the DOC_F equal to 0.5 would have yielded a different calculated DOC value).

TABLE D2: Estimates of DOC by Province

Province	Lo (value after 1990)	DOC (calculated)
British Columbia	108.8	0.21
Alberta	100.0	0.19
Saskatchewan	106.8	0.21
Manitoba	92.4	0.18
Ontario	90.3	0.18
Quebec	127.8	0.25
New Brunswick	117.0	0.23
Prince Edward Island	117.0	0.23
Nova Scotia	89.8	0.17
Newfoundland and Labrador	102.2	0.20
Northwest Territories and Nunavut	117.0	0.23
Yukon	117.0	0.23