

**QUANTIFICATION PROTOCOL FOR
AEROBIC LANDFILL BIOREACTOR PROJECTS:**

ABRIDGED

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Alberta Environment

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Disclaimer

The following document presents an abridged version of the Aerobic Landfill Bioreactor Project protocol prepared for Alberta Environment which has completed an initial round of technical review. This document has been prepared as a means of supporting a broader stakeholder consultation process. As such, this document should not be used as a quantification protocol.

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for the aerobic landfill bioreactor project developer. Some familiarity with or general understanding of, waste management practices including aerobic composting and the operation of a landfill is expected.

The opportunity for generating carbon offsets with this protocol arises from directly avoiding methane emissions from materials anaerobically decomposing in landfills. Specifically, this protocol covers landfills or landfill cell(s) which are at capacity / will not be accepting more waste materials, and are covered. Rather than the content of these landfills or landfill cell(s) decomposing anaerobically and producing methane, wells are drilled for the purposes of aerating the waste and recirculating leachate. Conditions are maintained to support aerobic decomposition of the waste. The resulting carbon dioxide emissions are considered as biogenic.

The project condition is that of an aerobic landfill bioreactor. This protocol can be applied to existing landfills or landfill cells that are retro-fitted to incorporate an aerobic landfill bioreactor, as well as to landfills or landfill cells that were originally designed and constructed to employ the use of aerobic landfill bioreactor technology.

Wells are drilled at various depths throughout the landfill or landfill cell(s). Some of these wells are used for pumping air into the waste material and recirculating leachate, while the rest are used as vents for the escaping gases. This provides the conditions to support aerobic decomposition and thus the production of carbon dioxide as the main product of decomposition. This carbon dioxide then follows a preferential escape pathway up and out of the venting wells. **FIGURE 1.1** offers an organization of the project SS's into life cycle categories for a typical project.

Typically, landfill gas (LFG) is passively emitted due to the anaerobic decomposition of the organic components within a landfill. This is considered as the baseline condition. This technology may be implemented at sites where there was previously a landfill collection and destruction system. This would indicate that the previously installed system was not meeting the operational objectives for the site. Further, this technology addresses the remaining methane potential at the site. Therefore, the baseline condition would revert to the passive emission of landfill gas generated under anaerobic conditions unless otherwise mandated by law. **FIGURE 1.2** offers an organization of the project SS's into life cycle categories for a typical baseline configuration.

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

FIGURE 1.1: Project Element Life Cycle Chart

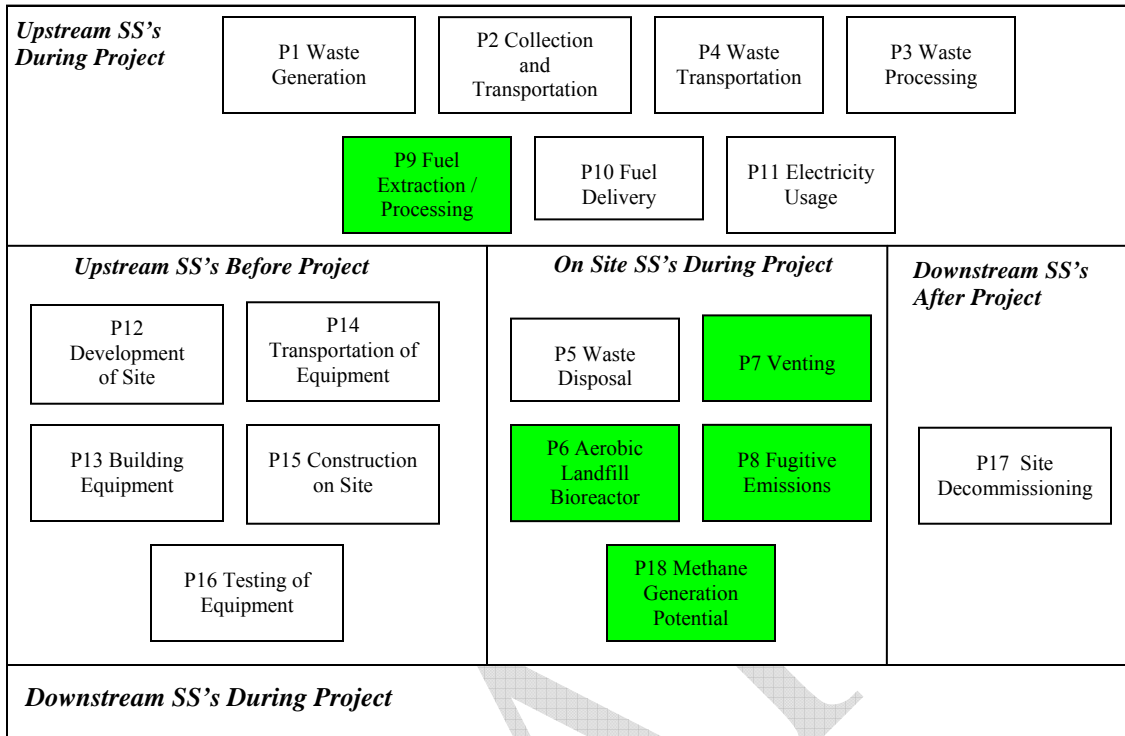
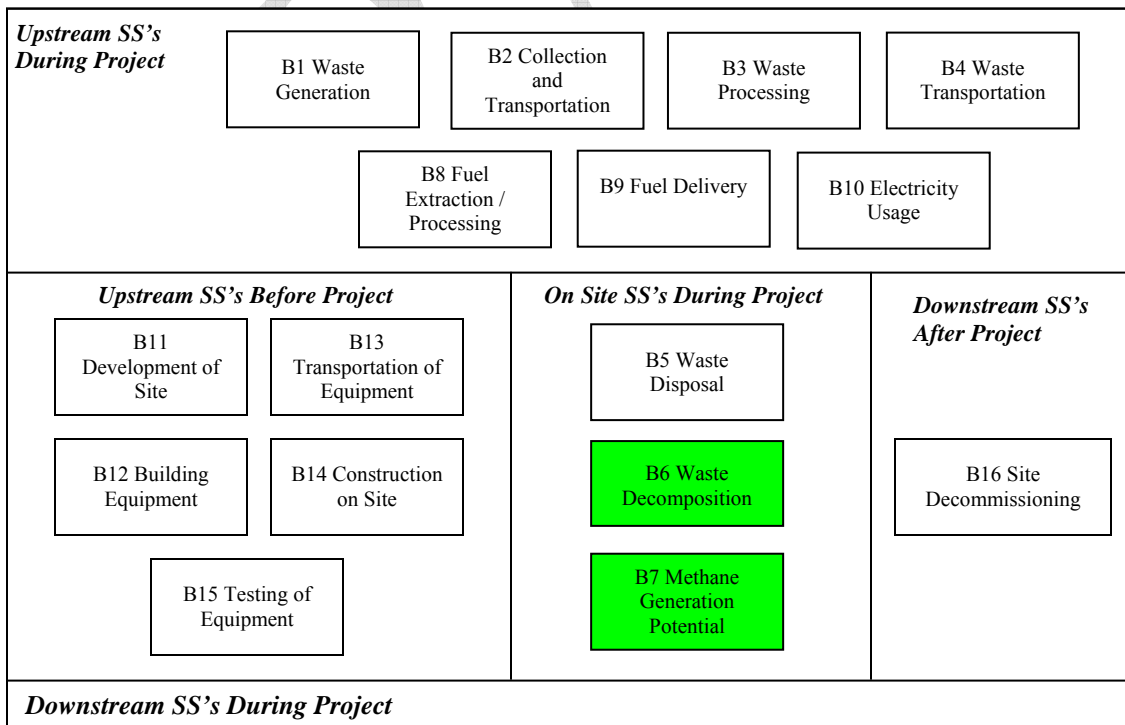


FIGURE 1.2: Baseline Element Life Cycle Chart



* Sources, sinks and reservoirs selected for measurement and monitoring under this protocol are highlighted.

1. The landfill facility is being operated under the conditions of its operating license;
2. The monitoring of the methane concentration and flow in the venting wells are maintained consistently and that gaps in automated or manual monitoring do not exceed 5 days;
3. During shut-downs of the aeration system, monitoring must be maintained on a minimum frequency of every 5 days, to account for any methane emissions that may occur should the bioreactor revert back to anaerobic conditions in the absence of air flow and that there are no material fugitive emissions of methane;
4. The landfill or landfill cell(s) are covered as per the operating requirements to manage passive landfill gas migration, and therefore minimal fugitive release of methane;
5. Fugitive emissions are measured 4 times per year using a flux chamber so as to calculate the flow rate and concentration of passive landfill emissions during project operation; and
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.

Flexibility in applying the quantification protocol is provided to project developers in one way:

1. During extended shut-down periods, alternative monitoring and/or modelling procedures may be implemented that must be shown to conservatively measure or estimate the methane emissions that may result for the during these periods should the bioreactor revert back to anaerobic conditions in the absence of air flow.

If applicable, the proponent must indicate and justify why flexibility provisions have been used.

2.0 Quantification of Identified Sources, Sinks and Reservoirs

Quantification of the reductions, removals and reversals for the sources, sinks and reservoirs selected for measurement and monitoring under this protocol will be completed using the methodologies outlined in **TABLE 2.1**, 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.

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Methane}}$$

$$\begin{aligned} \text{Emissions}_{\text{Project}} = & \text{Emissions}_{\text{Landfill Bioreactor Operation}} + \text{Emissions}_{\text{Venting}} \\ & + \text{Emissions}_{\text{Fugitive}} + \text{Emissions}_{\text{Fuel Extraction / Processing}} \\ & + \text{Emissions}_{\text{Methane Generation Potential}} \end{aligned}$$

Where:

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

$\text{Emissions}_{\text{Methane}}$ = emissions under SS B6 Waste Decomposition and SS B7 Methane Generation Potential

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

$\text{Emissions}_{\text{Aerobic Landfill Bioreactor Operation}}$ = emissions under SS P6 Aerobic Landfill Bioreactor Operation

$\text{Emissions}_{\text{Venting}}$ = emissions under SS P7 Venting

$\text{Emissions}_{\text{Fugitive}}$ = emissions under SS P8 Fugitive Emissions

$\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS P9 Fuel Extraction and Processing

$\text{Emissions}_{\text{Methane Generation Potential}}$ = emissions under SS P18 Methane Generation Potential

TABLE 1.1: Quantification Procedures

1. Project / Baseline SS	2. Parameter / Variable	3. Unit
Project SS's		
P6 Aerobic Landfill Bioreactor Operation	Emissions _{Aerobic Landfill Bioreactor Operation} = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{N}_2\text{O}})$	kg of CO ₂ ; CH ₄ ; N ₂ O
	Emissions _{Aerobic Landfill Bioreactor Operation}	kg of CO ₂ ; CH ₄ ; N ₂ O
	Volume of Each Type of Fuel / Vol. Fuel _i	L, m ³ or other
	CO ₂ Emissions Factor for Each Type of Fuel / EF Fuel _{iCO2}	Kg CO ₂ per L, m ³ or other
	CH ₄ Emissions Factor for Each Type of Fuel / EF Fuel _{iCH4}	kg CH ₄ per L, m ³ or other
	N ₂ O Emissions Factor for Each Type of Fuel / EF Fuel _{iN2O}	kg N ₂ O per L, m ³ or other
P7 Venting	Emissions _{Venting} = $[\text{CH}_4] * Q * t$	kg of CH ₄
	Emissions _{Venting}	kg of CH ₄
	Concentration of methane exiting the vents / [CH ₄]	kg / m ³
	Flow rate of air being blown into the system / Q	m ³ / day
	Time of system operation / t	days
P8 Fugitive Emissions	Emissions _{Fugitive} = $[\text{CH}_4] * Q * A * t$	kg of CH ₄
	Emissions _{Fugitive}	kg of CH ₄
	Concentration of methane escaping from the landfill / [CH ₄]	kg / m ²
	Flow rate of methane escaping from the landfill to the chamber / Q	m ³ / m ² / hr
	Surface area of the landfill / A	m ²
	Time in a Quarter/ t	hr
P9 Fuel Extraction and Processing	Emissions _{Fuel Extraction / Processing} = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{N}_2\text{O}})$	kg of CO ₂ e
	Emissions _{Fuel Extraction / Processing}	kg of CO ₂ e
	Volume of Each Type of Fuel Combusted for P6 / Vol. Fuel _i	L/ m ³ / other
	CO ₂ Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel _{iCO2}	kg CO ₂ per L/ m ³ / other
	CH ₄ Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel _{iCH4}	kg CH ₄ per L/ m ³ / other
	N ₂ O Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel _{iN2O}	kg N ₂ O per L/ m ³ / other
P18 Methane Generation Potential	Emissions _{Methane Generation Potential} = $L_0 * m$	kg of CH ₄
	Emissions _{Methane Generation Potential}	kg of CH ₄
	The potential for methane generation of the landfill remaining at the end of the project period / L ₀	kg of CH ₄ / tonne of waste
	Mass of the landfill at the start of the project / m	tonnes of waste
Baseline SS's		
B6 Waste Decomposition and Methane Collection / Destruction and B7 Methane Generation Potential	Emissions _{Methane} = $L_0 * m$	kg of CH ₄
	Emissions _{Methane}	kg of CH ₄
	The potential for methane generation of the landfill at the start of the project period / L ₀	kg of CH ₄ / tonne of waste
	Mass of the landfill at the start of the project / m	tonnes of waste

APPENDIX A: Glossary of New Terms

Aerobic Landfill Bioreactor:	A landfill cell that is specifically engineered to enhance the aerobic decomposition of wastes through careful manipulation of site conditions
Anaerobic Decomposition:	The decomposition of organic matter in the absence of oxygen.
Landfill:	A landfill is a site at which materials are stored where they can undergo anaerobic decomposition. This may include the materials being buried, piled, mixed with other waste materials, or otherwise. Landfills, classified as either controlled or uncontrolled, are included in this definition. The designation of controlled or uncontrolled refers to the level of permitting and technical controls in place at the disposal site. Uncontrolled landfills may exist where although there is no expressly stated goal to leave the materials in place, there is a track record of material residing in that place for extended periods (greater than 10 years) and there are no plans or regulatory requirements for the material to be transferred to another disposal site.
Landfill Gas:	Gas resulting from the decomposition of wastes placed in a landfill typically comprised primarily of methane, carbon dioxide and other trace compounds.
Landfill Gas System:	Installation of infrastructure that in operating causes a decrease in GHG emissions through the collection and destruction of the methane component of LFG.
Project Period:	The period of time in between methane generation potential measurements - also known as the reporting period.