Carbon Offset Emission Factors Handbook

Version 2.0

November 2019

Title:	**Carbon Offset Emission Factors Handbook**
Number:	**2.0**
Program Name:	**Alberta Emission Offset System**
Effective Date:	**November 18, 2019**
This document was updated on:	**November 2019**
ISBN No.:	**ISBN 978-1-4601-4606-4**

Summary of Revisions

Version	Date	Summary of Revisions
2.0	November 2019	• Updated to current Alberta Environment and Parks template and changes made to reflect current electricity grid factor and line loss of transmission and distribution of electricity. • Updated emission factors in Tables 5 and 6 (Combustion of natural gas and refined petroleum products) based on the 2019 National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada. • Updated Table 9: Model Parameters for Quantification of Avoided landfill and Stockpile Methane Emission to remove methane emissions from wood waste stockpiles.
1.0	March 2016	• Original Publication.

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Related Publications

- Technology, Innovation and Emissions Reduction Regulation
- *Emissions Management and Climate Resilience Act*
- *Environmental Protection and Enhancement Act*
- Specified Gas Reporting Regulation
- Standard for Greenhouse Gas Emission Offset Project Developers
- Technical Guidance for Offset Protocol Development and Revision
- Technical Guidance for the Assessment of Additionality
- Standard for Greenhouse Gas Validation, Verification, and Audit

Introduction

The Carbon Offset Emission Factors Handbook contains a listing of common emission factors used in the Alberta emission offset system as well as common quantification methodologies.

Common emission factors, provided in Section 1, are intended as inputs to formulae provided in approved quantification protocols.

Common quantification methods, provided in Section 2, are commonly used formulae for quantification of emission offsets in Alberta. This section includes both quantification methods and factors required for emission offset quantification.

Emission factors and quantification methodologies are subject to periodic updates. Emission offset project developers must use the most current version of the Handbook when initiating an emission offset project. If the Handbook is updated during the offset crediting period or extension period of an emission offset project, the offset project developer should refer to the Standard for Greenhouse Gas Emission Offset Project Developers for guidance.

1.0 Common Emission Factors

1.1 Global Warming Potential

The Global Warming Potentials (GWPs) of specified gases are published in the Standard for Completing Greenhouse Gas Compliance and Forecasting Reports.

1.2 Electricity Grid Use and Displacement Factors

Factors in Table 1 and 2 apply to emission offset projects that displace grid electricity with renewable electricity, reduce grid electricity usage, or result in additional electricity usage from the Alberta electricity grid. These factors will be reviewed every two years. The factors published in Table 1 and 2 are effective for use from January 1, 2020 to December 31, 2022.

Table 1: Electricity Grid Displacement and Grid Usage Factors

Factor	t CO_2e/MWh	Description
Electricity grid displacement factor		
Electricity grid displacement with renewable generation	0.53	Applicable to projects displacing grid–electricity with renewable generation.
Electricity grid displacement factor with line loss applied		
Increased on-site grid electricity use (includes line loss)	0.57	Applicable for use in projects that increase electricity usage in the project condition.
Reduction in grid electricity usage (includes line loss)	0.57	Applicable to energy efficiency projects resulting in decreased grid electricity usage in the project condition.
Distributed renewable displacement at point of use (includes line loss)	0.57	Applicable to projects displacing grid electricity with distributed renewable electricity generation at point of use.

2018 Electricity Grid Displacement Discussion Paper, calculation methodology is based on 2007 EDC Associates, Calculation of the Grid Emission Intensity Factor for Alberta.

Table 2: Total Transmission and Distribution Line Loss

Line loss Factor	MWh line loss/MWh consumed	Description

Total line loss for transmission and distribution	1.072	Weighted average line loss for transmission and distribution in Alberta is 6.68% (calculated as 1/(1-line loss)). Line loss is incorporated into the factors in Table 1 when reducing grid electricity usage or when renewable generation is at point of use.

2018 Electricity Grid Displacement Discussion Paper, calculation methodology is based on 2007 EDC Associates, Calculation of the Grid Emission Intensity Factor for Alberta; 2017 AESO Market Statistics Data: Market Surveillance Administrator (MSA)

1.3 Fuel Extraction and Production Related Emissions

Below are emission factors associated with the extraction and production of fuels. Values are sourced from a Canadian Association of Petroleum Producers (CAPP) report on upstream oil and gas emissions.

Table 3: Emission Intensity of Fuel Extraction and Production

Source	Emission Factors		
	kg CO_2/L	kg CH_4/L	kg N_2O/L
Diesel Production	0.138	0.0109	0.000004
Gasoline Production	0.138	0.0109	0.000004
	kg CO_2/m^3	kg CH_4/m^3	kg N_2O/m^3
Natural Gas Extraction	0.043	0.0023	0.000004
Natural Gas Processing	0.090	0.0003	0.000003

2004. A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry, Volume 1. Clearstone Engineering Ltd. Prepared on behalf of Canadian Association of Petroleum Producers.

Table 4: Emission Factors for Gasoline and Diesel Production

Source	Approximate Proportionate Amount in Year of Emission Factor Generation ($10^3 m^3$/yr)	Emission Factors ($t/10^3\ m^3$)		
		CO_2	CH_4	N_2O
Light / Medium Crude Oil Production	55,588	86.3	4.41	0.0038
Heavy Crude Oil Cold Production	30,924	75	25.1	0.0033
Heavy Crude Oil Thermal Production	10,589	594.2	3.75	0.009

2004. A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry, Volume 1. Clearstone Engineering Ltd. Prepared on behalf of Canadian Association of Petroleum Producers.

1.4 Fuel Combustion Related Emissions

Table 5: Emission Factors for Combustion of Natural Gas and Natural Gas Liquids

Source	Emission Factors		
	CO_2 (g/m^3)	CH_4(g/m^3)	N_2O(g/m^3)
Natural Gas			
Electric Utilities	1928	0.49	0.049
Industrial	1928	0.037	0.033
Oil and Gas Sector Producer Consumption (non-marketable product)	2392	6.4	0.06
Pipelines	1928	1.9	0.05
Cement	1928	0.037	0.034
Manufacturing Industries	1928	0.037	0.033
Residential, Construction, Commercial/Institutional, Agriculture	1928	0.037	0.035
Propane	**g/L**	**g/L**	**g/L**
Residential	1515	0.027	0.108
All Other Uses	1515	0.024	0.108
Ethane	986	0.024	0.108
Butane	1747	0.024	0.108

2019 National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada. The Canadian Government's Submission to the UN Framework Convention on Climate Change. Part 2.

Table 6: Emission Factors for Combustion of Refined Petroleum Products

Source	Emission Factors		
	CO_2 (g/L)	CH_4(g/L)	N_2O(g/L)
Light Fuel Oil			
Electric Utilities	2753	0.18	0.031
Industrial	2753	0.006	0.031
Producer Consumption	2670	0.006	0.031
Residential	2753	0.026	0.006
Forestry, Construction, Public Administration and Commercial/Institutional	2753	0.026	0.031
Heavy Fuel Oil			
Electric Utilities	3156	0.034	0.064
Industrial	3156	0.12	0.064
Producer Consumption	3190	0.12	0.064
Residential, Forestry, Construction, Public Administration, and Commercial/Institutional	3156	0.057	0.064
Kerosene			
Electric Utilities	2560	0.006	0.031
Industrial	2560	0.006	0.031
Producer Consumption	2560	0.006	0.031
Residential	2560	0.026	0.006
Forestry, Construction, Public Administration and Commercial/ Institutional	2560	0.026	0.031
Diesel- Refineries and others	2681	0.133	0.4
Diesel - Upgraders	2681	0.151	1.10
Motor Gasoline	2307	0.100	0.02

2019 National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada. The Canadian Government's Submission to the UN Framework Convention on Climate Change. Part 2.

2.0 Common Quantification Methods

2.1 Quantification of Avoided Landfill Methane Emissions

The methodology for quantifying greenhouse gas emissions reductions from the diversion of organic materials from a Municipal Solid Waste (MSW) landfill, wood waste landfill is provided below. Emission reductions are achieved by reducing methane emissions associated with anaerobic decomposition. In Alberta, landfills are classified as outlined in the Waste Control Regulation. If a Class II landfill meets the definition of a MSW landfill or a wood waste landfill, waste diversion from it is eligible under this methodology. Waste diverted from Class III landfills is not eligible under this methodology because they are for the disposal of inert waste. Waste diverted from a wood waste stockpile is not eligible under this methodology because is not an eligible baseline in any approved Alberta quantification protocols.

Table 7: Landfill Definitions Applicable to Avoided Landfill Methane Emissions Quantification in Alberta

Definitions	
Municipal Solid Waste (MSW) Landfill	A Municipal Solid Waste (MSW) landfill includes residential, Industrial, commercial and institutional (ICI) and construction and demolition (C&D) wastes in various amounts.
Wood Waste Landfill	A wood waste landfill is an industrial on-site landfill for the disposal of wood waste.
Eligible Waste	Organic waste that is expected to decompose and generate methane in a landfill or stockpile under anaerobic conditions.
Class II Landfill	As defined in the Alberta Waste Control Regulation: a landfill for the disposal of waste not including hazardous waste.
Class III Landfill	As defined in the Alberta Waste Control Regulation: A landfill for the disposal of inert waste.
Inert Waste	Solid waste that, when disposed of in a landfill or re-used, is not reasonably expected to undergo physical, chemical or biological changes to such an extent as to produce substances that may cause an adverse effect, and includes, but is not limited to, demolition debris, concrete, asphalt, glass, ceramic materials, scrap metal and dry timber or wood that has not been chemically treated.

Projects related to landfills whose designation is unclear should contact ACCO for further guidance.

Table 8: Quantification of Avoided Landfill Methane Emission

First Order Decay (FOD) Methane Quantification Model	
Methane (CH_4) Quantification Model: Waste Diversion	The principle formula for the first order decay (FOD) Scholl-Canyon Model to be used for estimating avoided methane emissions as a result of waste diversion is: $\mathbf{Q} = \sum_{x=1}^{40}\left[\mathbf{k} * \mathbf{W_C} * \mathbf{L_o} * e^{-k(x-1)} * (\mathbf{1} - \mathbf{R})\right] * (\mathbf{1} - \mathbf{OX})$ Where: Q = amount of methane emitted in the years x = 1 to 40 by the waste W_C (tonne CH_4/yr) under the assumed baseline waste disposal practice k = methane generation rate (1/yr) W_C = amount of eligible waste diverted from disposal in the current year C (wet weight, t) L_o = methane generation potential (tonne CH_4/ tonne waste) R = methane captured and destroyed (fraction) OX = oxidation of methane in cover material (fraction)

First Order Decay (FOD) Methane Quantification Model	
	x = iterative FOD emissions in year 1 to 40 from a given mass of waste W_C For the purpose of Alberta waste diversion protocols, the FOD model is used to calculate emissions forward over a period of 40 years (x =1 to 40), beginning in the year in which the waste is initially diverted. These emissions are applied to the total baseline emissions for the project in the year of waste diversion.
Methane Generation Potential (L_o)	$\mathbf{L_o = MCF * DOC * DOC_f * F * 16/12}$ Where: L_o = methane generation potential (tonne CH_4/ tonne waste) MCF = methane correction factor (fraction) in the year of decomposition DOC = fraction of degradable organic carbon in the waste (tonne Carbon/tonne waste, by wet weight) in the year of decomposition DOC_f = fraction of DOC that decomposes (weight fraction) F= fraction by volume of methane in landfill gas 16/12 = stoichiometric factor to convert weight of carbon to weight of methane (molecular weight ratio CH_4/C)

Table 9: Model Parameters for Quantification of Avoided Landfill Methane Emissions

Parameter	MSW Landfill				Wood Waste Landfill
Methane Correction Factor (MCF)	Managed (anaerobic)[a]	Unmanaged – Deep[c] (≥5 metres waste)	Unmanaged – Shallow[d] (<5 metres waste)	Uncategorized[e]	
	1.0 (0.5 semi-aerobic)[b]	0.8	0.4	0.6	0.8 (deep landfill >5m) 0.4 (shallow landfill <5m)
	a. **Anaerobic managed solid waste disposal sites (SWDS)**: These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste. b. **Semi-aerobic managed SWDS**: These must have controlled placement of waste and will include all of the following structures for introducing air to waste layer: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv)gas ventilation system. c. **Unmanaged deep and/or high water table SWDS:** All SWDS not meeting the criteria of managed SWDS and which have depths of greater or equal to 5 metres and/or high water table at or near ground level. Latter situation corresponds to filling inland water, such as pond, river or wetland by waste. d. **Unmanaged shallow SWDS:** All SWDS not meeting the criteria of managed SWDS and which have depths of less than 5 metres. e. **Uncategorized SWDS:** Only if projects cannot categorize their SWDS into the above four categories can this category be used.				
Fraction of CH_4 in Landfill Gas (F)	0.5				0.5

<table>
<tr><th>Parameter</th><th>MSW Landfill</th><th>Wood Waste Landfill</th></tr>
<tr><td>Default
Fraction of Degradable Organic Carbon (DOC)</td><td>If detailed information on the landfill waste composition is not available or applicable, default DOC should be used. If information on how the landfill is managed is not available to determine MCF, then use default Lo. Use DOC_f = 0.6 if comprehensive wood waste diversion program in place and DOC_f = 0.5 if no wood waste diversion program in place.

Default values for Alberta:

<table><tr><th>DOC content in % of wet weight</th><th>DOC</th><th>L_o [f]
(DOC_f = 0.5)</th><th>L_o [f]
(DOC_f = 0.6)</th></tr><tr><td>from 1990-present</td><td>0.17</td><td>56.67</td><td>67.95</td></tr></table>
f -Lo in kg CH4/tonne waste. Must divide by 1000 kg CH4 to convert to tonne CH4/tonne waste.</td><td><table><tr><td>L_o [f,g]</td><td>80</td></tr></table>
g - for a shallow landfill

L_o =40</td></tr>
<tr><td>Fraction of Degradable Organic Carbon (DOC)</td><td>If the landfill specific waste stream is well understood[h], individual DOC for the measured proportion of each waste stream in the landfill can be used to calculate a landfill-specific DOC using the formula provided below, or ideally based on measurement of the actual DOC content of each waste type in the landfill's waste stream. This landfill-specific mixed waste DOC value must be used in conjunction with the mixed waste landfill default DOC_f of 0.5 to 0.6.

DOC = (0.4*A) + (0.2*B) + (0.15*C) + (0.43*D)

DOC content in % of wet weight

<table><tr><th>Fraction of waste</th><th>A</th><th>B</th><th>C</th><th>D</th></tr><tr><td>Waste Type</td><td>Paper</td><td>Garden and Yard</td><td>Food</td><td>Wood</td></tr><tr><td>DOC[iii]</td><td>0.4</td><td>0.2</td><td>0.15</td><td>0.43</td></tr></table></td><td>N/A</td></tr>
</table>

Parameter	MSW Landfill	Wood Waste Landfill
	h -The sampling program for the waste composition monitoring should be based on industry accepted techniques. Sorting and documentation of the waste composition should be undertaken according to the Alberta Environment Provincial Waste Characterization Framework[iv].	
Default Fraction of Degradable Organic Carbon Dissimilated (DOC_f)	DOC_f = 0.6 if comprehensive wood waste diversion program in place DOC_f = 0.5 otherwise	N/A
Waste Type-Specific DOC and DOC_f	Currently not available. The landfill/stockpile default Lo must be used when diverting a specific waste type (i.e. waste type-specific DOC cannot be used).	
Oxidation Factor (OX)	See table below. For the case of different site types at different landfill areas, an average methane oxidation rate can be calculated by:	

Type of Site	CH_4 Oxidation Rates (OX, %)	Developed Area (m^2)
Default	10	-
Managed, unmanaged and uncategorized landfill (not covered with aerated material)	0	A
Managed covered with CH_4 oxidizing material e.g. topsoil/compost	10	B

Parameter	MSW Landfill	Wood Waste Landfill
	$$\mathbf{OX_{average}} = \frac{[(\mathbf{0\%} * \mathbf{A}) + (\mathbf{10\%} * \mathbf{B})]}{(\mathbf{A} + \mathbf{B})}$$ The use of an oxidation value other than 10 per cent should be clearly documented, referenced and supported by data relevant to the geographical context.	
Methane Collection and Destruction (1-R)	The fraction of methane collected and destroyed at the landfill (taking collection and Destruction efficiencies into account). Projects diverting waste from landfills must provide clear documentation of landfill gas collection and destruction at all areas at the source landfills, i.e., the average LFG_{CE} at the source landfills (it cannot be assumed that R=0 because waste is being diverted from active cells).	

R = LFG Collection Efficiency (LFG_{CE})*Methane Destruction Efficiency (LFG_{DE})

Default Values for LFG Collection Efficiencies (LFG_{CE})[v,vi]:

Type of Cover System	LFG Collection Efficiency		Developed Area
	Range (%)	**Default (%)**	**m^2**
Operating Cell	-	35.0	A
Temporary Covered Cell	65-68	66.5	B
Final Clay Covered Cell	85-92	88.5	C
Composite Liner System	90-97	93.5	D
LFG Mitigation Control System	Site Specific	Site Specific	E

For the case of various cover systems applied to different landfill areas, an average LFG_{CE} can be calculated by:

$$\mathbf{LFG_{CEaverage}} = \frac{[(\mathbf{35\%} * \mathbf{A}) + (\mathbf{66.5\%} * \mathbf{B}) + (\mathbf{88.5\%} * \mathbf{C}) + (\mathbf{93.5\%} * \mathbf{D})]}{(\mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D})}$$

Parameter	MSW Landfill	Wood Waste Landfill

Default Values for Methane Destruction Efficiency (LFG_{DE})[vii]:

Type of LFG Device	Methane Destruction Efficiency	
	Range (%)	Average (%)
Boiler/Steam Turbines	67-99+	99.8
Gas Turbines	97-99+	98.2
Flares	38-99+	99.7
IC Engines	25-99+	86.1
Passive Venting	n/a	0

Alternative methane controls at landfills must be appropriately taken into account (i.e., bioreactor technology, enhanced oxidation practices).

Default k-value

The recommended equation as per Alberta's Technical Guidance for Quantification of Specified Gas Emissions from Landfills[viii] is to be used to calculate k-values until on-going research permits further assessment of these values.

Wood Waste Landfill: 0.02

k= 0.00003 * PCPN + 0.01

Where:

PCPN = Annual average precipitation at the nearest weather station for the most recently available Environment Canada 30-year climate normal period (mm/yr).

In the case where additional liquids are introduced into the landfill (e.g. at a bioreactor landfill), the amount of additional liquids should be converted and added to the amount of precipitation at the site. For these cases the formula for k would be:

Parameter	MSW Landfill	Wood Waste Landfill
	$k = 0.00003 * (PCPN+AL) + 0.01$ Where: AL = Amount of additional liquid into the landfill cell (mm/yr.)	
Landfill-Specific k-value	Landfill-specific k-value calculation for those landfills in a position to do should follow the MSW Landfill k-value calculation[ix].	

[i]2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
[ii]2009. Methodological Tool. Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site. EB 41 Annex 10 Version 04. United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM).
[iii]2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5 Waste. Intergovernmental Panel on Climate Change (IPCC).
[iv]2005. Provincial waste characterization framework: A Joint Project of Alberta Environment, Government of Canada, Action Plan 2000 on Climate Change (Enhanced Recycling Program) and the Recycling Council of Alberta, Final Report. Alberta Environment.
[v]2003. French Calculation Guidelines for Estimating Atmospheric Emissions of CH4, CO2, SOX and NOX released by Non-Hazardous Waste Landfills (English Version). French Environmental Agency. ADEME.
[vi]2007. Current MSW Industry Position and State-of-the-Practice on LFG Collection, Methane Oxidation, and Carbon Sequestration in Landfills. Prepared for Solid Waste Industry for Climate Solutions (SWICS). Prepared by SCS Engineers.
[vii]1998. USEPA AP-42 Compilation of Emission Factors, November 1998, Attachment A. U.S. Environmental Protection Agency.
[viii]2008. Technical Guidance for the Quantification of Specified Gas Emissions from Landfills (Version 1.2). Alberta Environment

[ix]October 2014. MSW Landfill k-value Calculation Best Management Practice. Alberta Environment

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