Guardyan

Greenhouse Gas Avoidance Methodology

Version 4.0
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The conclusions drawn in this Thesis are the result of an extensive exploration and analysis of the research questions and objectives outlined. These conclusions reflect the findings and insights obtained from the research conducted and the methodologies applied. It is essential to recognize that conclusions presented herein are subject to the limitations of the study, potential biases, and the specific scope of research. Further studies and advancements in the field may lead to refined or altered understandings of the topics covered.

Throughout this Thesis, various intellectual property concepts, theories, and practices have been discussed. It is important to recognize that intellectual property rights play a pivotal role in incentivizing innovation, creativity, and the advancement of knowledge. The discussions presented here do not constitute legal advice or a comprehensive analysis of intellectual property law, but rather provide an academic exploration of the subject matter. Readers seeking legal guidance or advice on specific intellectual property matters should consult qualified legal professionals.

Table of Contents

EXECUTIVE SUMMARY

The purpose of the Greenhouse Gas (GHG) Avoidance Methodology is to generate carbon credits by guarding the carbon fossil deposits that would otherwise be produced through an approved drilling program, a Steam Assisted Gravity Drainage (SAGD) facility's construction and operations, refining of the crude product, and combustion or other use of the final oil inventory. This approach is unlike typical emission reduction projects (e.g., carbon capture and storage which cannot capture 100% of emissions) in that it is preventative rather than reactive, eliminating 100% of potential GHG emissions and ensuring that these fossil fuels remain in-situ, in perpetuity.

The methodology accounts for the emissions of the drilling program, construction activities, the operational facility, and the emissions that occur at the point of combustion which are avoided by eliminating the possible usage of the synthetic crude oil end-product.

The parameters of this methodology have been carefully chosen to establish additionality by demonstrating that the mineral rights lease owner has obtained all the necessary means to produce the reserves and distribute the synthetic crude oil product but has made the choice to halt project development to enter the carbon markets without any guarantee that it will be the most profitable decision.

The success of the GHG Avoidance Methodology aligns with and propels the United Nations goal of mitigating the risks associated with climate change. As it pertains to this project, this methodology will decrease the production of fossil fuels and generate an alternative monetary value to in-situ oil reserves. Incentivizing oil and gas developers to generate profit from carbon credits rather than petroleum products will increase the global motivation to shift from the use of petroleum products to renewable alternatives.

1. METHODOLOGY BACKGROUND

Guardyan Conservation Corp. (Guardyan) has developed this methodology for generating carbon credits via GHG avoidance to guard fossil carbon deposits (in this case bitumen) that would otherwise be extracted by an energy demanding SAGD facility. The extraction would be followed by an emissions-intensive refining process resulting in a variety of petroleum products, the majority of which release GHG emissions through combustion (e.g., diesel, jet fuel, gasoline).

The GHG Avoidance Methodology allows mineral rights lease holders to associate a value (through carbon credits) to the reserves as they exist, in the ground. This methodology is an accumulation of established avoidance mechanisms that avoid CO2e emissions in perpetuity and the successful application of its framework will incentivize additional oil and gas producers to consider the carbon credit value of their reserves according to the GHG Avoidance Methodology in addition to the market price of oil.

There is one globally recognized emissions measurement standard utilized by industry's most relevant and scrutinized registries. This standard, ISO 14064 Greenhouse Gases – Part 2: Specification with Guidance at the Project Level for Quantification, Monitoring and Reporting of Greenhouse Gas Emission Reductions or Removal Enhancements (ISO 14064-2:2019) was used to develop the GHG Avoidance Methodology.

This GHG Avoidance Methodology, while complying with the same additionality, permanence, leakage, and calculation standards as globally recognized Voluntary and Compliant Registries, will stand independent of existing registry frameworks and approvals. Millions of tons of CO2e are actively emitted instead of avoided or removed because the queue of projects to be certified by the current registries is greater than can be facilitated without a global governing body to drive accountability. Behind the climate crisis is an urgency to act and this methodology enables a call to action while maintaining the essential integrity and transparency of the carbon markets.

2. METHODOLOGY

2.1 METHODOLOGY JUSTIFICATION

The ideological basis of this methodology is to determine the GHG emission reductions resulting from the decision to not develop and produce a bitumen reserve and instead protect the land and geological formations as they exist today. The projects that meet the requirements for this methodology will be eligible for carbon credits ascribed from emissions avoided for Scopes 1, 2 and 3 that would have otherwise been available for production through industrial resource extraction, refining and use. Scope 1 and 2 emissions are calculated using emission estimates from a baseline designed facility and account for the difference between the designed and constructed facility and no facility. For Scope 3, emissions are determined based on the more conservative of two approaches: the carbon content of the facility product or the emissions associated with the end-products. In this context, conservative means the approach which results in fewer emissions and, therefore, less credit generation. This consideration further legitimizes the methodology's approach and success application to additionality; a requirement of ISO 14064-2:2019.

2.2 METHODOLOGY CONDITIONS

The methodology requires conditions for projects to qualify thereby ensuring that the carbon credits issued for applicable projects are truly providing additionality, permanence and impacting overall global emissions. These conditions include the following:

1) Documented geological formations that demonstrate viable oil and gas reserves with potential for extraction through industry standard means of production.
2) Documented mineral rights to the lease for access and extraction of the oil and gas reserves within the geological formation are required for the duration of the credit issuance period.
3) Demonstration of legal safeguards committing vote-casting shareholders not to reverse development decision for a minimum of 50 years in addition to safeguards disabling counterparts from reversing the development decision. The only means in which this decision may be reversed is a scenario where the entirety of Scopes 1, 2 and 3 emissions from the extraction, refining and use of the reserves can be achieved with an emissions factor of zero.
4) Approval from the appropriate regulatory body to produce the reserves belonging to the mineral rights lease.
5) Demonstrated financial feasibility of development of the full lifecycle of reserves' economic lifespan, including initial development and future planned expansions.

The above are presented as prudent and conservative criteria to ensure that the project avoided is feasible and practical to prevent misuse. Misuse is defined as the generation of carbon credits by closing-in or halting the production of an uneconomic, unregulated, or infeasible asset or project.

2.3 METHODOLOGY BOUNDARY

ISO 14064-2:2019 defines a project GHG boundary as the relevant sources, sinks and reservoirs (SSRs) related to a project. The SSRs relevant to this methodology and applicable projects are limited to the following:

- Emission sources of the designated facility (alternative scenario), and
- Emissions associated to the release of the oil and gas reserve contained within the geological formations identified by the project.

Based on the identified GHG SSRs of projects, the associated Scope 1, 2 and 3 emissions of the designed facility, refineries, and end-products are included within the project GHG boundary. Within these Scopes, this methodology will consider and calculate the emissions avoided for the following GHGs:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)

2.4 ADDITIONALITY

In compliance with ISO 14064-2:2019, this methodology is required to demonstrate that applicable projects result in emission reductions compared to what would have happened in the absence of the project. For a project to be additional, the possibility to sell carbon credits must play a decisive “make or break” role in the decision to implement it.[1] Additionality occurs in the case where GHGs would not have been reduced in the absence of a market for monetizing carbon credits.

For a project to be applicable to this methodology through the requirement of additionality, projects must demonstrate that in the absence of the carbon markets, the project would have pursued the development of an operational SAGD facility for the purposes of extracting the oil and gas reserve identified within the reservoir, accessible through the granted mineral rights lease agreements. This allows for a quantifiable differentiation from the scenario absent of the possibility of credit generation. Once this is established, the project proponent has the opportunity to make the decisive decision to stop facility development in order to pursue carbon credits because of their availability through the carbon markets. The fulfilment of this circular requirement demonstrates the true requirement of the market for monetizing carbon credits and therefore the true additionality of projects utilizing this methodology in providing impactful emission reductions.

2.5 ADDITIONALITY SAFEGUARD

Under no circumstances can this methodology be used for the development of projects that lack production potential or that prove to be uneconomical. This is to ensure that no projects can begin the development of carbon credits that do not provide additionality for carbon emission reductions. It is anticipated that in many cases the profit generated by producing the reserve will be higher than that generated by carbon credits, meaning the application of this methodology is not necessarily the most economic option.

2.6 LEAKAGE

Carbon leakage, in the context of the GHG Avoidance Methodology, is a concept related to Scope 3 emissions quantification. Although the direct effect on the global supply and demand of petroleum products with the implementation of one project will be minimal, the implementation of multiple projects could substantially reduce the availability of fossil fuels and therefore propel the energy transition to renewable resources. The demand for energy will continue with the implementation of this methodology but, what this methodology does, is decrease the long-term availability of the non-renewable resource and diminishes the available domestic resource pool for future extraction.

[1] “Additionality.” Carbon Offset Guide. Stockholm Environment Institute and Greenhouse Gas Management Institute, September 9, 2022. https://www.offsetguide.org/high-quality-offsets/additionality/.

2.7 PERMANENCE

Permanence in the case of emission avoidance is qualified by the ability to demonstrate the actuality of the outcome. Within the framework of this methodology, the avoided emissions are contained within underground carbon fossil fuel deposits and are therefore not exposed to risk of reversal by natural disaster, inadvertent human disruption, or technology application error.

In order to monitor the success of permanence of the avoided emissions, the methodology stipulates (Section 2.2: Methodology Conditions) that the mineral rights lease owner must provide legally binding contracts between the majority vote-casting shareholders stating the reserves will not be produced for a minimum of 50 years or until the reserves and resulting facility, refining and end-product use can be achieved with a proven emissions factor of zero.

3. PROJECT ACTIVITIES

In an industry that is often criticised for its environmental impacts, the GHG Avoidance Methodology will provide an opportunity to accelerate the energy transition by diminishing availability of oil and gas resources. This differentiates the methodology from typical emission reduction projects (e.g. carbon capture and storage) as it is preventative rather than reactive.

The methodology will apply only to projects meeting the prescribed criteria in Section 2.2: Methodology Conditions. The methodology can be used to evaluate the theoretical impacts of a designed facility, sized according to the reserves available and estimate a baseline for the emissions it would generate. The potential carbon credits are represented by the difference between the baseline (designed facility, its production and end-product) and having no facility, production, or end-product.

4. QUANTIFICATION OF EMISSION REDUCTIONS

4.1 BASELINE DESIGN

ISO 14064-2:2019 states that project baselines may be determined based on the setting of alternative scenarios according to the requirements of the intended user. The baseline for a project in compliance with this methodology would be developed by designing a facility intended to extract and process heavy oil using SAGD technology. These facilities typically include natural gas-powered steam generation, compression, sweetening equipment, and other sources of GHG emissions. The facility design must represent a modern, efficient SAGD facility and include industry standard practices to prevent overestimating the emissions being avoided. The design requirements include:

1) Minimum issued for regulatory (IFR) level design, including plot plans, process flow diagram, material balance and high-level equipment selection stamped by an engineer in good standing with the applicable area’s engineering association.
   a) Facility design must be in accordance with CSA, American Society of Mechanical

Engineers (ASME) or any other relevant design standards that impact the equipment selection or operational estimates listed below.

2) Evaluation of electricity cogeneration on the steam generators and waste heat recovery throughout the facility.
3) Reasonable estimate of grid power import, considering cogeneration capabilities.
4) Sizing and selection of natural gas driven equipment with minimum front-end engineering and design (FEED) study accuracy based on:
    a) Defensible capital expenditure for full project implementation using estimates for design, engineering, procurement, and construction.
    b) Reasonable extraction of heavy oil (bitumen) based on reservoir capacity and conditions.
5) Installation of instrument air and vapour recovery (i.e. zero routine venting).
6) Any additional industry best practices or regional regulatory requirements for a design of this level.

4.2 BASELINE EMISSIONS CALCULATIONS

Emissions associated to the alternative scenario (baseline) are calculated and quantified using both detailed methodologies derived from ISO 14064:2019 and the TIER Alberta Greenhouse Gas Quantification Methodologies Version 2 (AQM). TIER is a stringent and prescriptive greenhouse gas program with a track record of maintaining equivalency to the Canadian Federal mandate to drastically reduce emissions. To ensure the emissions calculations are not overestimated, the AQM and other publicly available, industry-specific guidance documents will be evaluated annually to update this methodology appropriately.

As this facility will not be constructed, it should be noted that it cannot comply with the full scope of TIER which includes site visits and annual emissions reporting. Thus, this methodology only adopts AQM components relevant to emissions quantification. The following sections of the methodology include excerpts from the TIER AQM where specifically referenced. Where the TIER AQM is not referenced, detailed quantification methodology is provided.

Based on the facility design, engineering estimates for the project construction and operational activities must be made by an appropriate professional. These estimates must be reasonable and include:

1) Drilling and completions program required to supply the operational facility including:
    a. Drilling and facility construction timeline and required resources (conservative estimate of equipment required).
    b. Fuel gas usage for equipment required.
2) Facility fuel gas usage based on design and operational data such as:
    a. Equipment selection, manufacturer data or engineered estimates, estimates for the equipment used and downtime due to maintenance, equipment load factors and other relevant considerations at the discretion of the stamping engineer or other appropriate professional.
3) Flaring activities assuming robust preventative maintenance plan and appropriate measures to

eliminate routine flaring and minimize upset flaring.

4) Fugitive emissions assuming regionally compliant fugitive emissions management program and appropriate repair response.
5) On-site transportation gasoline and diesel use for operations and maintenance.
6) Other relevant operational volumetrics based on the facility design.
7) If detailed operational parameter estimates cannot be made, assumptions which result in lower emissions must be used.
8) Small amounts of stationary combustion of diesel and propane for backup power should be considered negligible.

The input data and calculations used within the GHG Avoidance Methodology are summarized in Table 1.

GREENHOUSE GAS	INPUT DATA REQUIRED	METHODOLOGY ADOPTED	EQUATION USED	RECOMMENDED EMISSION FACTORS SOURCE*
FACILITY CONSTRUCTION				
CO_2	Engineered estimates for construction equipment and timeline (to extrapolate estimates fuel use)	AQM Method 5-1	AQM Equation 1-1a	AQM Table 1-1 (Diesel and/or Gasoline in Alberta)
CH_4 N_2O		AQM Method 5-3	AQM Equation 1-5a	AQM Table 5-1 (Light and Heavy Duty Vehicles - Advanced control)
DRILLING AND COMPLETIONS				
CO_2	Engineered estimates for drilling and completions program (duration and number of rigs) to extrapolate natural gas use	AQM Method 1-2	AQM Equation 1-2	N/A - Constants are prescribed in equation 1-2
CH_4 N_2O		AQM Method 1-6	AQM Equation 1-5a	AQM Table 1-2 (Sector Based Emission Factors - Producer Consumption)
FACILITY OPERATIONS - SCOPE 1 - STATIONARY COMBUSTION OF NATURAL GAS				
CO_2	Engineered estimate of fuel use volume, representative fuel gas lab analysis or process model prediction, weighted average carbon content calculation as per AQM Equation C.1-1a	AQM Method 1-3	AQM Equation 1-3a	N/A - Uses weighted average carbon content for area/project specific gas
CH_4 N_2O	Engineered estimate of fuel use volume	AQM Method 1-6	AQM Equation 1-5a	AQM Table 1-2 (Sector Based Emission Factors - Producer Consumption)
FACILITY OPERATIONS - SCOPE 1 - FLARING				
CO_2	Engineered estimates for flared volumes due to facility upsets and preventative maintenance	AQM Method 2-1	AQM Equation 2-1a	AQM Table 2-2 (Medium Rich Gas @ 99.5% Efficiency)
CH_4				AQM Table 2-3 (Medium Rich Gas @ 99.5% Efficiency)
N_2O		AQM Method 2-4	AQM Equation 2-7a	AQM Table 2-4 (Hydrocarbon gas)
FACILITY OPERATIONS - SCOPE 2				
CO_2 CH_4 N_2O	Engineered estimate for power import including cogeneration considerations and AESO EGDF for reporting year	Combined because AESO reports in CO_2 equivalence - Basic emission factor methodology adopted and shown in methodology report	Emission factor equation shown in methodology report	Provided annually by AESO
FACILITY OPERATIONS - LIMITED SCOPE 3 (OPTION ONE) - PRODUCT REFINING				
CO_2 CH_4 N_2O	Refinery facilities GHGRP data and AER oil inlet volumes for most recent reporting year. Annual crude product volumes from facility engineered process model	Combined because GHGRP provides total tCO_2 data - Basic emission factor methodology adopted and shown in methodology report	Emission factor equation shown in methodology report	Data provided annually by GHGRP and AER
FACILITY OPERATIONS - LIMITED SCOPE 3 (OPTION ONE) - PRODUCT END USE FOR PRODUCTS INCLUDED WITHIN AQM				
CO_2	CCEI volumetric breakdown of products associated with raw product (3 year average). Projected facility production volume.	AQM Method 5-1	AQM Equation 1-1a	AQM Table 1-1 (Diesel and gasoline use in Alberta)
CH_4 N_2O		AQM Methods 1-6 and 5-3	AQM Equations 1-5a	AQM Tables 1-4, 1-5 and 5-1 (Appropriate EF for product)
FACILITY OPERATIONS - LIMITED SCOPE 3 (OPTION ONE) - PRODUCT END USE FOR PRODUCTS NOT INCLUDED WITHIN AQM				
CO_2	CCEI volumetric breakdown of products associated with raw product (3 year average). Projected facility production volume.	US EIA emissions factors applied	Emission factor equation shown in methodology report	Published US EIA emission factors
CH_4 N_2O	N/A - CH_4 and N_2O not included in US EIA emissions factors tables			
FACILITY OPERATIONS - LIMITED SCOPE 3 (OPTION TWO) - CARBON CONTENT METHOD				
CO_2	Engineered estimates for facility product volumes and compositions	AQM Appendix C	AQM Equation 1-3d	N/A
CH_4 N_2O	N/A - CH_4 and N_2O not included in carbon content calculations			

*Emission factors are recommended based on guidance documentation currently deemed relevant. Alternate emission factors may be adopted based on on-going evaluation of project and publicly available documentation.

Table 1: Detailed quantification methodology summary.

4.3 GLOBAL WARMING POTENTIAL

In all GHG quantification calculations adopted within this document, the following International Panel on Climate Change (IPCC) global warming potentials will be adopted: [2]

$$1\text{t } CH_4 = 25\text{t } CO_2$$
$$1\text{t } N_2O = 298\text{t } CO_2$$

The global warming potential implemented will be evaluated each year as IPCC and Environment and Climate Change Canada release updated documentation.

4.4 FACILITY CONSTRUCTION, DRILLING, AND COMPLETIONS: SCOPE 1 EMISSIONS

Emissions associated with the construction of the facility will be quantified using the engineered estimates for the equipment required and construction timeline. This will inform the educated prediction of diesel and/or gasoline required for the construction of the facility.

4.4.1 CARBON DIOXIDE FROM FACILITY CONSTRUCTION

Chapter 5 of the AQM prescribes the methodology to quantify emissions from on-site transportation in Alberta. Method 5-1 from the AQM will be used to quantify CO_2 from facility construction in conjunction with Equation 1-1a and the emission factors from Table 1-1.[3]

$$CO_{2,\rho} = \nu_{fuel,\rho} \times EF_{vol}$$

Where:

$CO_{2,\rho}$	= CO_2 mass emissions for the gaseous fuel combusted during the construction period, ρ (tonnes CO_2).
$\nu_{fuel,\rho}$	= Volume of fuel in kl at standard conditions combusted during the construction period, ρ.
EF_{vol}	= Volumetric emission factor from AQM *Table 1-1* in tonnes per kl.

[2] "2.10.2 Direct Global Warming Potentials," 2.10.2 Direct Global Warming Potentials - AR4 WGI Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing (Intergovernmental Panel on Climate Change), accessed November 28, 2022, https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

[3] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

Table 2: Default Emission Factor by Fuel Type (AQM Table 1-1)

Default Emission Factor by Fuel Type	CO_2
	Tonne/kl
Diesel in Alberta	2.610
Gasoline in Alberta	2.174

4.4.2 METHANE AND NITROUS OXIDE FROM FACILITY CONSTRUCTION

Method 5-3 of the AQM will be used to quantify CH_4 and N_2O, along with Equation 1-5a and Table 5-1.[4]

$$CH_{4,\rho} \text{ or } N_2O_\rho = Fuel_\rho \times EF_{vol}$$

Where:

$CH_{4,\rho}$ or N_2O_ρ = CH_4 or N_2O mass emissions for specific fuel type during the construction period, ρ in tonnes.

$Fuel_\rho$ = The quantity of fuel combusted in cubic meters during the construction period, ρ, in standard conditions.

EF_{vol} = Fuel specific default CH_4 or N_2O emission factor from Table 5-1 in tonnes per volume unit (kL).

Table 3: Emission Factors Based on Fuel and Mobile Equipment Type (AQM Table 5-1)

Emission Factors Based on Fuel and Mobile Equipment Type	CH_4	N_2O
	Tonne/kl	Tonne/kl
Light-Duty Diesel Vehicles (Advanced Control) *	5.1E-05	2.2E-04
Heavy-Duty Diesel Vehicles (Advanced Control) *	1.1E-04	2.2E-04
Light Duty Gasoline Vehicles (Tier 2)	1.4E-04	2.2E-05
Heavy Duty Gasoline Vehicles (Non-Catalytic Controlled)	2.9E-04	4.7E-05

*Note: advanced control emission factors are assumed as they are the most conservative.

4.4.3 CARBON DIOXIDE FROM DRILLING AND COMPLETIONS

The drilling and completions program will be used to inform the number of drilling rigs required and predicted number of days of each drill. The volume of natural gas required to execute the drilling and

[4] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

completions program will be estimated based on the above. Natural gas is the assumed fuel source because it is conservative and industry standard is transitioning away from diesel driven drilling rigs.

Chapter 1 of the AQM outlines the methodology for stationary fuel combustion. Method 1-2 and Equation 1-2 will be used to quantify the CO_2 emissions associated with the combustion of natural gas associated with drilling and completions.[5]

$$CO_{2,\rho} = \nu_{fuel,\rho} \times \left(60.554 \times HHV_p - 404.15\right) \times 10^{-6}$$

Where:

$CO_{2,\rho}$	= CO_2 mass emissions for the gaseous fuel combusted during the drilling and completions period, ρ (tonnes CO_2).
$\nu_{fuel,\rho}$	= Volume of fuel (m^3) at standard conditions combusted during the drilling and completions period, ρ.
HHV_p	= High heat value of natural gas in MJ/m^3 as provided by representative gas analysis or an engineered model.
$(60.554 \times HHV_p - 404.15)$	= Empirical equation adapted for Environment and Climate Change Canada (ECCC) representing the relationship between CO^2 and volume of natural gas determined through HHV using a discrete sets of data collected by ECCC.
10^{-6}	= Mass conversion factor (t/g)

4.4.4 METHANE AND NITROUS OXIDE FROM DRILLING AND COMPLETIONS

Methane and nitrous oxide emissions due to stationary combustion by the drilling rigs are calculated using the AQM Method 1-6, Sector-based Default of the Oil and Gas Sector and Producer Consumption Emission Factors in Table 1-2 and Equation 1-5a.[6]

$$CH_{4,\rho} \text{ or } N_2O_\rho = Fuel_\rho \times (EF_{vol} \text{ or } EF_{ene})$$

Where:

$CH_{4,\rho}$ or N_2O_ρ	= CH_4 or N_2O mass emissions for the specific fuel type during the drilling and completions period, ρ in tonnes.

[5] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.
[6] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

$Fuel_\rho$	= The quantity of fuel estimated in cubic meters during the drilling and completions period, ρ, in standard conditions.
EF_{vol}	= Fuel specific default CH_4 or N_2O emission factor from Table 1-2 in tonnes per volume unit (m^3).
EF_{ene}	= Sector specific default CH_4 or N_2O emission factor from Table 1-2 in tonnes per energy unit (GJ).

Table 4: Sector Based Default Emission Factors for Natural Gas (AQM Table 1-2)

Sector Based Default Emission Factors for Natural Gas	CH_4 Emission Factor		N_2O Emission Factor	
	Tonne/m^3	Tonne/GJ	Tonne/m^3	Tonne/GJ
Oil and Gas Sector and Producer Consumption (Non-Marketable)	6.4E-06	1.4E-04	6.0E-08	1.3E-06

*Note: energy-based emission factors should be used if fuel HHV data is available.

4.5 FACILITY OPERATIONS: SCOPE 1 EMISSIONS

The designed facility will be utilized to quantify GHG emissions for an appropriate operational facility level classification. If data for the prescribed facility classification is unavailable, methods for lower-level classifications within the current version of the AQM guidance document may be used.

The quantified Scope 1 emissions sources will include stationary fuel combustion, fugitive emissions, flaring, and any other relevant emissions within the prescribed methodology framework. An evaluation of publicly available GHG reporting data and facility licensed design data will be made to ensure that the Scope 1 emissions profile of the designed facility is reasonable as compared to existing SAGD facilities.

4.5.1 STATIONARY FUEL COMBUSTION

4.5.1.1 WEIGHTED AVERAGE CARBON CONTENT

A representative fuel gas analysis can be used to calculate a fuel specific emission factor based on the composition of the natural gas. If a representative gas analysis is not available, a composition may be provided by an engineered process model. Equation C.1-1a of the AQM is used to convert the mole fraction to kilogram of carbon per cubic metre of fuel for stationary combustion emissions calculations.[7]

$$CC_i = \sum_{j=1}^{c} \left(MF_j \times NC_j \right) \times \frac{12.01}{MVC}$$

Where:

CC_i = Carbon content of the fuel gas i (kg of C/m^3).

MF_j = Normalized mole fraction of component, j.

NC_j = Number of carbon atoms in component j.

c = Number of components.

MVC = 23.645 m^3/kmol (standard molar volume conversion).

12.01 = Molecular weight of carbon (kg/kmol).

4.5.1.2 CARBON DIOXIDE FROM STATIONARY FUEL COMBUSTION

The methodology prescribed for the calculation of CO_2 emissions from stationary fuel gas combustion is Method 1-3 of the AQM: CO_2 Emissions from Variable Fuels Based on the Measured Fuel Carbon Content. Equation 1-3a of the AQM is used to calculate CO_2 mass emissions for gaseous fuels.[8]

$$CO_{2,\rho} = \nu_{fuel(gas),\rho} \times CC_{gas,\rho} \times 3.664 \times 0.001$$

Where:

$CO_{2,\rho}$ = CO_2 mass emissions for the gaseous fuel projected for the operational period, ρ (tonnes CO_2).

$\nu_{fuel(gas),\rho}$ = Volume of fuel (m^3) at standard conditions projected for the operational period, ρ.

$CC_{gas,\rho}$ = Weighted average carbon content of the gaseous fuel calculated in above section 4.5.1.1 ρ (kg of C/m^3).

3.664 = Ratio of molecular weights, CO_2 to carbon.

[7] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

[8] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

0.001 = Mass conversion factor (t/kg).

4.5.1.3 METHANE AND NITROUS OXIDE FROM STATIONARY FUEL COMBUSTION

Methane and nitrous oxide emissions due to stationary fuel combustion are calculated using Method 1-6 of the AQM: Sector-based Default Oil and Gas Sector and Producer Consumption Emission Factors in Table 1-2 and Equation 1-5a.[9]

$$CH_{4,\rho} \text{ or } N_2O_\rho = Fuel_\rho \times (EF_{vol} \text{ or } EF_{ene})$$

Where:

$CH_{4,\rho}$ or N_2O_ρ = CH_4 or N_2O mass emissions for fuel gas during the operational period, ρ in tonnes.

$Fuel_\rho$ = The quantity of fuel estimated in cubic meters during the operational period, ρ, in standard conditions.

EF_{vol} = Sector specific default CH_4 or N_2O emission factor from Table 1-2 in tonnes per volume unit (m^3).

EF_{ene} = Sector specific default CH_4 or N_2O emission factor from Table 1-2 in tonnes per energy unit (GJ).

Table 5: Sector Based Default Emission Factors for Natural Gas (AQM Table 1-2)

Sector Based Default Emission Factors for Natural Gas	CH_4 Emission Factor		N_2O Emission Factor	
	Tonne/m^3	Tonne/GJ	Tonne/m^3	Tonne/GJ
Oil and Gas Sector and Producer Consumption (Non-Marketable)	6.4E-06	1.4E-04	6.0E-08	1.3E-06

4.5.2 FLARING

4.5.2.1 CARBON DIOXIDE AND METHANE FROM FLARING

Method 2-1 and Equation 2-1a of the AQM is adopted for this facility because it is assumed that the design of a modern SAGD facility would not include routine flaring. The methodology utilizes default CO_2 and CH_4 emission factors included in Tables 2-2/2-3 and Equation 2-1a:[10]

[9] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.
[10] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

$$GHG = \sum_{F=1}^{N} V_{FL,F} \times EF_{vol,F} \times 10^{-6}$$

Where:

GHG	= CO_2 or CH_4 mass emissions from flaring (tonnes) for the operational period.
F	= Flare gas stream.
N	= Number of flare gas streams.
$V_{FL,F}$	= Volume to flare in m^3 at standard conditions.
$EF_{vol,F}$	= Default CO_2 of CH_4 emission factor from Tables 2-2 and 2-3 of the AQM.

Table 6: Default Emission Factors for Different Flare Gas Types (AQM Table 2-2 and 2-3)

Default Emission Factors for Different Flare Gas Types	CO_2 Emission Factor		CH_4 Emission Factor	
	g/m^3	g/MJ	g/m^3	g/MJ
Medium Rich Gas @ 99.5% Efficiency	2.1E+03	5.0E+01	1.2E+01	2.5E-01

*Note: volumetric factors may be adopted as the process gas heat value will not likely be known. The emission factor for medium rich gas is currently recommended. This may be updated based on project evaluation.

4.5.2.2 NITROUS OXIDE FROM FLARING

Method 2-4 of the AQM is used to calculate N_2O emissions as a result of non-routine flaring. A default emissions factor from Table 2-4 and Equation 2-7a are used based on the metered flare volumes included in the previous section 4.5.2.1.[11]

$$N_2O = \sum_{F=1}^{N} V_{FL,F} \times EF_{vol,F} \times 10^{-6}$$

Where:

N_2O	= N_2O mass emissions from a flare source for the operational period.
F	= Flare gas stream.

[11] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

N = Number of flare gas streams.

$V_{FL,F}$ = Volume of flare gas stream, F, in m^3 at standard conditions.

$EF_{vol,F}$ = Default N_2O emission factor selected from Table 2-4 of the AQM.

Table 7: Default Emission Factors for Different Flare Gas Types (AQM Table 2-4)

Default Emission Factors for Different Flare Gas Types	(N_2O) Emission Factor	
	g/m^3	g/MJ
Hydrocarbon gas (sales gas, lean to rich gas)	3.3E-02	8.7E-04

4.6 FACILITY OPERATIONS: SCOPE 2 EMISSIONS

Scope 2 emissions will be quantified using defensible operational estimates and Alberta grid average emission factors. The Alberta Electric System Operator (AESO) has announced a framework to achieve a net-zero grid by 2035. The average annual grid displacement factor (EGDF) year over year will be assumed for quantifying Scope 2 emissions to account for changes to the energy sources of the grid, as outlined in Section 6: Monitoring of this document.

The AESO EGDF is given in the units of tCO_2e per MWh electricity import.[12] This emission factor will be used in conjunction with the engineered electricity demand projection to calculate an annual Scope 2 emissions profile.

$$CO_2e = Power_\rho \times EF_{AESO}$$

Where:

CO_2e = CO_2e mass emissions for electricity import during the operational period, ρ (tonnes CO_2e).

$Power_\rho$ = The estimated quantity of power required per period, ρ, in MWh.

EF_{AESO} = The AESO EGDF in tCO_2/MWh power consumption for operational year.

4.7 FACILITY SCOPE 3 EMISSIONS

The use of the end-product will form the basis of Scope 3 emissions quantified within this framework. This

[12] "AESO Net-Zero Report" (AESO), accessed January 3, 2023, https://www.aeso.ca/market/net-zero-emissions-pathways/.

will be accomplished by the more conservative of two methods where conservative is the method that produces fewer carbon credits.

1) Assessment of raw product refining and CO_2e emissions of the end use products.
2) Assessment of the CO_2 potential of the molecules of bitumen production using the carbon content method.

4.7.1 FACILITY SCOPE 3 EMISSIONS – OPTION ONE

4.7.1.1 EMISSIONS DUE TO REFINING RAW PRODUCT

Scope 3 emissions quantified within this framework will include the use of the refined products. Refineries in Canada are required to report their GHG emissions annually through the federal Greenhouse Gas Reporting Program (GHGRP). This data is publicly available up to the previous year and represents the refineries' Scope 1 emissions. These are quantified and reported using strict ECCC methodology and guidelines. Additionally, the Alberta Energy Regulator (AER) provides the reported annual raw product processing volumes of the five refineries located in Alberta to the public. These two data points are used to generate a refinery industry average emission factor as a function of crude product inlet.

$$\mathrm{EF_{Refine}} = \sum_{F=1}^{N} \frac{\mathrm{CO_2}e_{Reported}}{\mathrm{Raw\ Product_{Inlet}}}$$

Where:

$\mathrm{EF_{Refine}}$	= The annual average emission factor for the refining process in tCO_2e/e^3m^3.
F	= Refinery.
N	= Number of refineries.
$\mathrm{CO_2}e_{Reported}$	= The annual reported GHG emissions as per the GHGRP in tCO_2e.
$\mathrm{Raw\ Product_{Inlet}}$	= The refinery annual inlet volume provided by the AER in e^3m^3.

The emission factor calculated through the equation above can then be applied to the projected facility's annual production to account for emissions associated with refining.

$$\mathrm{CO_2e}_{\rho} = \mathrm{Production_{Vol,\rho}} \times \mathrm{EF_{Refine}}$$

Where:

$\mathrm{CO_2e}_{\rho}$	= $\mathrm{CO_2}$e mass emissions for time period ρ (tonnes).

$Production_{Vol,\rho}$ = The estimated quantity of raw product production from the facility per period ρ in e^3m^3.

EF_{Refine} = The annual average emission factor for the refining process in tCO_2e per e^3m^3.

4.7.1.2 EMISSIONS DUE TO END USE OF REFINED PRODUCTS

The Government of Canada provides annual refined petroleum product volumetric data broken down by disposition.[13] This includes end use products that are ultimately combusted such as motor gasoline, aviation gasoline, jet fuel, kerosene, and distillate fuel oil. These are provided as the percent of petroleum products produced from one barrel of bitumen input. The average of the most recent three years of data from the Canadian Center for Energy Information (CCEI) is used to quantify the breakdown of products associated with the annual volume of bitumen production forecasted for this facility. Products that do not result in combustion during the end use such as lubricants and waxes will be excluded.

$$Product_{Vol,\rho} = \sum_{F=1}^{N} \%\ Breakdown, \mu \times Production_{Vol}$$

Where:

$Product_{Vol,\rho}$ = End use product volume in m^3 over period, ρ.

F = Individual product.

N = Number of products.

% Breakdown, μ = Percent breakdown of individual products from CCEI over most recent three-year period of available data, μ.

4.7.1.2.1 CARBON DIOXIDE FROM END USE OF REFINED PRODUCTS

The generic CO_2 emissions factors provided in the AQM are applied to the volumes of usable products that are included within Table 1-1. This will follow Section 5: On-site transportation of the AQM with Method 5-1 Equation 1-1a.[14]

$$CO_{2,\rho} = \nu_{fuel,\rho} \times EF_{vol}$$

[13] Government of Canada, Statistics Canada, “Petroleum Products by Supply and Disposition, Monthly,” Petroleum products by supply and disposition, monthly (Government of Canada, Statistics Canada, January 9, 2023), https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=2510008101.

[14] “Alberta Greenhouse Gas Quantification Methodologies Version 2.2,” Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

Where:

$CO_{2,\rho}$ = CO_2 mass emissions for the gaseous fuel combusted during the operational period, ρ (tonnes CO2).

$\nu_{fuel,\rho}$ = Volume of fuel in kl at standard conditions combusted during the operational period, ρ.

EF_{vol} = Volumetric emission factor from AQM table 1-1 in tonnes per kl.

Table 8: Default Emission Factor by Fuel Type (AQM Table 1-1)

Default Emission Factor by Fuel Type	CO_2
	Tonne/kl
Diesel in Alberta	2.610
Gasoline in Alberta	2.174

Not all projected products are included within the AQM CO_2 emission factors tables. The United States Energy Information Administration (EIA) provides a full list of CO_2 emission factors which includes kerosene, residual heating oil, petroleum coke and jet fuel and is used in cases where the emissions factors are not listed within the AQM. [15]

$$CO_{2,\rho} = \nu_{fuel,\rho} \times EF_{vol}$$

Where:

$CO_{2,\rho}$ = CO_2 mass emissions for the gaseous fuel combusted during the operational period, ρ (tonnes CO_2).

$\nu_{fuel(gas),\rho}$ = Volume of fuel in kl at standard conditions combusted during the operational period, ρ.

EF_{vol} = Volumetric emission factor from US EIA publication in tonnes per kl.

Table 9: Default Emission Factor by Fuel Type (US EIA)

Default Emission Factor by Fuel Type	CO_2
	Tonne/kl
Jet Fuel	2.576
Kerosene	2.610
Residual Heating Oil	2.969

[15] "U.S. Energy Information Administration - EIA - Carbon Dioxide Emission Coefficients" (U.S. Energy Information Administration), accessed January 4, 2023, https://www.eia.gov/environment/emissions/co2_vol_mass.php.

Petroleum Coke	3.936

Projected products associated with refineries in Canada may vary over time. Appropriate methodologies and emissions factors will be evaluated annually and updated accordingly.

4.7.1.2.2 METHANE AND NITROUS OXIDE FROM END USE OF REFINED PRODUCTS

CH_4 and N_2O emissions can be quantified for fuels that would be used in stationary combustion activities and are listed in Tables 1-4 or 1-5 of the AQM using Method 1-6 and Equation 1-5a.[16] CH_4 and N_2O emissions associated with the combustion of products in mobile sources such as light duty vehicles are quantified using AQM Method 5-3 and Equation 1-5a with emission factors from Table 5-1.[17]

$$\mathrm{CH}_{4,\rho} \text{ or } \mathrm{N_2O}_{\rho} = \mathrm{Fuel}_{\rho} \times (\mathrm{EF}_{\mathrm{vol}} \text{ or } \mathrm{EF}_{\mathrm{ene}})$$

Where:

$\mathrm{CH}_{4,\rho}$ or $\mathrm{N_2O}_{\rho}$ = CH_4 or N_2O mass emissions for fuel gas during the operational period, ρ (tonnes).

Fuel_{ρ} = The quantity of fuel estimated in m^3 during the operational period, ρ, in standard conditions.

$\mathrm{EF}_{\mathrm{vol}}$ = Sector specific default CH_4 or N_2O emission factor from Table 1-4, 1-5 or 5-1 in tonnes per volume unit (m^3).

$\mathrm{EF}_{\mathrm{ene}}$ = Sector specific default CH_4 or N_2O emission factor from Table 1-4, 1-5 or 5-1 in tonnes per energy unit (GJ).

Table 10: Default CH_4 and N_2O Emission Factors for Liquid and Solid Fuels (AQM Table 1-4 and 1-5)

Stationary Combustion	CH_4	N_2O
	Tonne/kl	Tonne/kl
Kerosene (Producer Consumption)	6.0E-06	3.1E-05
Pretroleum Coke (Refinery and Others)	1.2E-04	2.8E-05

[16] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.
[17] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

Table 11: Emission Factors Based on Fuel and Mobile Equipment Type *(AQM Table 5-1)*

Mobile Combustion	CH_4	N_2O
	Tonne/kl	Tonne/kl
Light-Duty Diesel Vehicles (Advanced Control)	5.1E-05	2.2E-04
Heavy-Duty Diesel Vehicles (Advanced Control)	1.1E-04	2.2E-04
Light Duty Gasoline Vehicles (Tier 2)	1.4E-04	2.2E-05
Heavy Duty Gasoline Vehicles (Non Catalytic Controlled)	2.9E-04	4.7E-05

4.7.2 FACILITY SCOPE 3 EMISSIONS – OPTION TWO

Process engineering will be utilized to determine the composition of the facility products. The composition breakdown will show the projected hydrocarbon makeup of each primary facility product. Product specific CO_2 emission factors will be calculated using the carbon contents as described in Method 1-3 and Equation 1-3d of the AQM.[18] This emission factor will be applied to the annual volume of crude bitumen product projected by the engineered model.

$$CO_{2,\rho} = m_{fuel\ (sol),\rho} \times CC_{sol,\rho} \times 3.664$$

Where:

$CO_{2,\rho}$ = CO_2 mass emissions for the solid fuel during the operational period, ρ (tonnes).

$m_{fuel\ (sol),\rho}$ = Mass of solid fuel projected for the operational period, ρ (tonnes).

$CC_{sol,\rho}$ = Weighted average carbon content of the fuel during the reporting period p, calculated in accordance with Chapter 17 and Appendix C of the AQM. CCp is in units of tonnes of carbon per tonnes of solid fuel (tonnes C/tonnes).

3.664 = Ratio of molecular weights, CO_2 to carbon.

[18] "Alberta Greenhouse Gas Quantification Methodologies Version 2.2," Alberta Greenhouse Gas Quantification Methodologies Version 2.2 § (2021), https://open.alberta.ca/publications/alberta-greenhouse-gas-quantification-methodologies.

4.8 PROJECT EMISSIONS

The emissions avoided by the project scenario are calculated by applying a 'tonnes of CO_2e per barrel of oil produced' multiplier to the guarded carbon deposit. There are a range of widely available and scientifically accepted multipliers to represent the tonnes of CO_2e emitted per barrel of oil produced. This methodology sources three of these multipliers and utilizes the most conservative of the three, where conservative is the multiplier that produces the fewest carbon credits.

The three verified multipliers are from the Carnegie Endowment for International Peace, United States Environmental Protection Agency, and the calculations set forth in this GHG Avoidance methodology. These three sources of data were chosen strategically to incorporate the knowledge and represent the perspectives of varying levels of global, federal and provincial organizations to demonstrate a balanced understanding of the value of emissions avoided per barrel of oil guarded.

Once all three multipliers are compared and the most conservative is selected, the CO_2e emissions avoided by protecting the guarded carbon deposit are determined by multiplying the original bitumen in place by the established multiplier.

5. CREDIT ISSUANCE AND VALIDATION

Carbon credits will be issued at the onset of the project by calculating the avoided emissions (per Section 4.8: Project Emissions) and equating each tonne of CO_2e to one carbon credit. The number of credits issued will be continuously updated to incorporate necessary changes from the Project Monitoring (reference Section 6: Monitoring) and advancements in the understanding of avoided emissions associated with guarded carbon deposits.

The project's carbon credits will be validated at the time of sale through an Emissions Reduction Purchasing Agreement (ERPA). Once a sale is executed, the number of available carbon credits will be decreased from the issuance total. The total issued credits will fluctuate with yearly evaluations and the total validated credits will fluctuate with the total sales and draw down the total issued credits.

Of the credits issued, a portion of the credits must be set aside and will not be eligible for validation (sale) as they will be assigned to a contingency fund. The number of credits prescribed to contingency will be 15% of the total issued and will only be released upon validation of the remaining 85% of issued credits. The contingency mechanism ensures the project is reflective of market growth in terms of available knowledge and expertise on the impacts of avoidance projects. Thus, if there are any shifts in the value of the multiplier, the project can accommodate increases, as well as decreases, to the multiplier.

6. MONITORING

The project is monitored annually by:

1) Reviewing the facility's baseline design to assess applicability of regulatory requirement updates and technological optimizations. Regulatory requirement updates will be implemented within the regulator's prescribed timeline. Technological optimizations will be implemented based on economic feasibility and industry adoption. Specifically, the requirement is that the facility must implement any operating optimizations to lower emissions in line with the requirements and initiatives set out by

industry, with a facility of the same vintage as the year of the Project's activation date (when credits began issuance).

2) Ensuring the Project does not make any attempts to reverse the decision to guard the carbon fossil fuel deposits. This is accomplished by reviewing a legally binding declaration that ensures the reserve and its above ground land will remain as is for the duration of the 50-year commitment or until technology and innovations allow for the reservoir and resulting synthetic crude oil product to be produced with zero emissions.
3) Review of satellite imaging of the lease boundary, demonstrating the continued lack of development of the oil reserves.
4) Review of mineral rights to the lease for access and extraction of the oil and gas reserves within the GHG boundary.
5) Review of financial feasibility of continued operations and future planned expansions for potential incorporation to update the baseline design.

The methodology and emission factors cited in this document are based on the current GHG guidance documents, regulations and understanding of the engineered project. These factors will be continuously evaluated to better ensure appropriate methodologies are applied, including (but not limited to):

1) Updates to the TIER AQM and/or evaluation of the methodologies and emission factors adopted from within the AQM.
2) IPCC global warming potential.
3) Federally published end use product breakdowns.
4) Provincially reported refinery volumetric data.

7. CONCLUSION

The GHG Avoidance Methodology developed by Guardyan Conservation Corp. has the potential to revolutionize the way oil and gas producers view their reserves. Instead of simply viewing their reserves in terms of the market price of petroleum products, producers will now be able to associate a value to their reserves in the form of carbon credits.

This GHG Avoidance Methodology will incentivize producers to consider the carbon credit value of their reserves in conjunction with the market price of oil, thus driving a shift from the use of petroleum products to renewable alternatives. The methodology is compliant with ISO 14064:2019 and has been designed with strict parameters to ensure additionality, permanence, leakage, and accurate calculations of emissions avoided. Ultimately, the GHG Avoidance Methodology has the potential to directly contribute to the global goal of mitigating the risks associated with climate change.