



Report Partner Document

STATE OF SCIENCE ON EMISSION RATE THRESHOLDS FOR UPSTREAM PETROLEUM
INDUSTRY LEAKS CORRESPONDING TO A RANGE OF PPM CONCENTRATION BASED
THRESHOLDS

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This partner document has been created to provide a non-technical summary of information presented in State of Science on Emission Rate Thresholds for Upstream Petroleum Industry Leaks Corresponding to a Range of ppm Concentration Based Thresholds (2024) referred to in this document as “The Report”, prepared by Equilibrium Environmental Inc. for and with funding by Petroleum Technology Alliance Canada (PTAC) and the Clean Resource Innovation Network (CRIN). Additional background information is provided in this partner document to supplement the readers understanding of progress presented in The Report.

Introduction

The Report presents the findings of a study conducted by Equilibrium Environmental Inc. The primary objective of the study is to review current science, regulatory guidelines, and detection technologies, and to provide recommendations for improving methane emissions detection, reporting, and management in alignment with federal and provincial requirements.

Background Information

Methane (CH₄) is a colourless, odourless, flammable greenhouse gas (GHG) that is significantly more potent than carbon dioxide (CO₂) in trapping atmospheric heat. While methane has a shorter atmospheric life than CO₂, its high global warming potential (GWP) makes it a critical target for emissions reduction.

In Canada, approximately 13% of national GHG emissions are methane, and about 40% of those methane emissions originate from the oil and gas sector. Reducing these emissions is therefore a key component of both federal and provincial climate policies. Two relevant, but distinct regulatory frameworks are relevant: Leak Detection and Repair (LDAR) Programs and GHG Reporting.

The purpose of LDAR is to identify and mitigate equipment leaks in oil and gas operations to limit fugitive methane emissions. LDAR compliance thresholds are generally expressed in concentration units of parts per million by volume (ppmv). Federally, Environment and Climate Change Canada (ECCC) sets a 500 ppmv threshold for methane leaks, with repairs required within 30 days unless operational constraints apply. Instruments used in detection must comply with Method 21 from the US Environmental Protection Agency (EPA) or be approved optical gas imaging (OGI) technology with sufficient sensitivity. Provincial regulations such as the Alberta Energy Regulator (AER) Directive 060 may have additional or slightly different requirements but often have equivalency agreements with federal rules. LDAR ensures timely repair of leaks that exceed concentration thresholds, thereby preventing prolonged methane release.

The purpose of GHG Reporting is to provide an accurate accounting total of GHG emissions from a facility for regulatory oversight, climate policy tracking, and carbon pricing and taxation. GHG reporting is done on a mass basis in units of tonnes of CO₂ equivalent (CO₂e) per year, requiring methane emissions to be expressed as a mass flow rate. Under the federal GHG Reporting Program (GHGRP), facilities emitting 10,000 tonnes CO₂e or more per year must report annually. Mass emissions may be measured directly or estimated using emissions factors, mass balance calculations, or regression correlations from concentration data. GHG Reporting data feeds into national emissions inventories, informs climate policy, and determines carbon pricing obligations.

LDAR is a compliance and maintenance tool, designed to detect and fix leaks promptly, using ppmv concentration measurements as a trigger for repairs. GHG Reporting is an accounting and policy tool, quantifying total emissions over time on a mass basis to meet national reporting standards and financial obligations under carbon pricing frameworks. The challenge, and the key focus of The Report, is that LDAR measurements cannot be directly used for GHG Reporting without applying correlation equations or

conversion factors. These correlations can carry significant uncertainty, especially when based on generic emissions factors not tailored to specific facilities, components, or operational conditions.

Project Summary

METHANE DETECTION TECHNOLOGY

The Report evaluates a broad range of methane detection technologies, each with distinct capabilities, limitations, and applications in the field.

Calorimetric sensors are portable, point-source devices that detect methane through catalytic oxidation, where methane reacts with a heated catalyst such as platinum or palladium, releasing heat that is converted into a measurable signal. They are low-cost and simple to operate, but their accuracy decreases at low methane concentrations, making them better suited for high concentration leaks.

Flame ionization detectors (FIDs) measure hydrocarbons by burning the sample in a hydrogen flame, producing ions that generate an electrical current proportional to the hydrocarbon content. They are highly sensitive and accurate, with detection limits down to sub-ppm levels, but require a hydrogen supply and have fallen somewhat out of favour due to logistical challenges in the field.

Photoionization detectors (PIDs) use ultraviolet light to ionize compounds, producing a measurable electrical signal based on ion flow between charged plates. While excellent for detecting many volatile organic compounds (VOCs), most PIDs cannot detect methane without specialized lamps, limiting their direct applicability to methane monitoring in standard configurations.

Infrared (IR) sensors detect methane by measuring its absorption of IR light at specific wavelengths. These devices come in both portable and fixed configurations, offering rapid, non-contact detection, but may also respond to other hydrocarbons like ethane and propane, potentially leading to cross-sensitivity issues.

Laser spectroscopy, including Tunable Diode Laser Absorption Spectroscopy (TDLAS) and Dual Frequency Comb Spectroscopy (DCS) use laser light tuned to methane's absorption lines to measure gas concentrations with high precision, even over long distances. These technologies enable continuous monitoring and mass emission rate calculations, though they can be more expensive and require stable mounting locations for best accuracy.

High Flow Sampler (HFS) devices physically capture and enclose a leaking gas stream, then measure both the methane concentration and the volumetric flow rate to calculate a direct mass emission rate. They provide highly accurate results for a wide range of leak sizes, though their portability can be limited and maximum reliable flow rates are constrained by device specifications.

Optical Gas Imaging (OGI) cameras visualize methane plumes in real time by detecting IR light absorbed by the gas, producing a live image of leaks on a screen. Detection sensitivity is influenced by environmental factors such as temperature contrast, wind, and distance to the leak, making operator expertise critical for reliable use.

Quantitative OGI (QOGI) integrates OGI cameras with proprietary software to quantify the size of methane plumes and estimate mass emission rates in units like grams per hour. While offering rapid, visual quantification, the accuracy depends on factors like camera calibration, environmental conditions, and correct setup, and results can vary between equipment manufacturers.

Light Detection and Ranging (LiDAR) systems emit laser pulses and measure the reflected signal to detect methane concentrations from the air or space, often using differential absorption techniques to distinguish methane from background air. These systems excel in large-scale, remote monitoring, but detection accuracy can be affected by wind, surface reflectance, and atmospheric conditions.

ANALYSIS AND TECHNOLOGY DISCUSSION

The Report highlights a central challenge for the oil and gas sector: while LDAR programs rely on concentration-based measurement to trigger repairs, GHG Reporting requires mass-based emissions data. Converting between these units is not straightforward and traditional conversion equations can introduce significant uncertainty.

Regression analyses comparing concentration to mass emission rate reveal that long-standing equations often significantly underestimate methane emissions when compared with more recent, component-specific models. This discrepancy arises from differences in the datasets used to develop the equations, the types of equipment studies, and whether the correlations were methane-specific or based on broader VOC categories. For example, Equilibrium Environmental's 2022 analysis for valve leaks produced results nearly two orders of magnitude higher than EPA estimates for the same concentration values.

Direct measurement technologies like HFS, QOGI, and advanced laser spectroscopy offer a way to bypass this conversion challenge by measuring both concentration and flow directly in the field. Field trials and controlled experiments have shown these methods can achieve much higher accuracy. For instance, HFS devices are highly precise within their operational range, routinely achieved $\pm 5\%$ accuracy for small leaks. However, HFS devices cannot reliably measure larger, high-flow leaks. QOGI systems, while less precise in percentage terms, can detect and quantify a much broader range of emission rates and do so more quickly over large areas. Each technology has operational trade-offs, such as flow rate limits for HFS or environmental sensitivity for OGI and QOGI.

Third-party validation studies provide important context for technology selection. In the Concawe European field studies, OGI and Method 21 showed broad agreement for larger leaks, but QOGI quantification produced results much closer to actual controlled release rates than concentration-to-mass conversions. The Alberta Methane Field Challenge demonstrated that aerial and drone-mounted sensors can quickly identify high-emitting sites, though pinpointing and quantifying individual leaks still required ground-based follow ups. The METEC evaluation of DCS further underscored the potential of continuous, site-wide monitoring systems capable of detecting leaks as small as 0.0031 kilograms per hour from over a kilometer away.

The Report indicates that the most accurate and defensible emissions data come from direct measurement approaches, particularly when coupled with technology combinations that provide both rapid site coverage and detailed leak quantification. The choice of technology should be guided by regulatory requirements, site characteristics, and operational priorities, with an emphasis on reducing uncertainty in reported emissions.

Conclusion

The Report underscores that direct mass emission measurement should be prioritized wherever feasible to improve accuracy in both LDAR compliance and GHG Reporting. Reliance on historical emission factor-based methods introduces significant uncertainty, potentially underestimating actual emissions and affecting both environmental outcomes and financial obligations under carbon pricing. Facility- or process-specific regression models developed from simultaneous concentration and mass flow measurements are recommended to increase precision. Industry collaboration and data sharing could accelerate methodology refinement, reduce costs, and improve methane management across the sector.