DRIVING EFFICIENCY AND EMISSIONS REDUCTIONS THROUGH CONTINUOUS MONITORING: A COST-EFFECTIVE APPROACH TO LDAR COMPLIANCE

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Abstract

As global pressure mounts to reduce methane emissions, the energy industry faces increasingly stringent regulations to detect and repair leaks. In March 2024, the EPA finalized rules, including New Source Performance Standards (NSPS) OOOOb and Emissions Guidelines, mandating facilities to implement robust Leak Detection and Repair (LDAR) programs. These programs can leverage either traditional Optical Gas Imaging (OGI) surveys or advanced Alternative Test Methods (ATMs), such as continuous, real-time monitoring technologies.

This paper highlights the transformative impact of continuous monitoring on emissions detection, quantification, and operational cost efficiency. The monitoring system comprises three integrated components: (i) a network of metal oxide semiconductor sensors to measure methane concentrations and environmental parameters; (ii) a cloud-based platform using physics-based Gaussian Plume Modeling to locate and quantify leaks; and (iii) a web-based dashboard that aggregates emissions data and generates actionable alerts for remedial action.

We compare continuous monitoring to periodic OGI surveys, showcasing its ability to reduce compliance costs and expedite leak repairs at facilities in Texas and Colorado. Beyond LDAR compliance, continuous monitoring has proven effective at detecting operational inefficiencies, such as underperforming flares and burners – issues often missed by traditional methods. Real-world deployments achieved a 60% reduction in emissions within three months and an 80% annual reduction by adhering to NSPS OOOOb thresholds. By generating a continuous emissions dataset, the technology also mitigates compliance risks by time-bounding Super Emitter events. These emissions reductions have significantly lowered the frequency of OGI inspections, delivering substantial multi-year cost savings.

Through case studies in the Permian basin, we explore strategies for deploying continuous monitoring across diverse facility designs. Participants will gain insights into best practices for visualizing emissions plumes, conducting investigative analyses, and remotely diagnosing leaks to minimize unnecessary field visits.

Continuous monitoring is not just a compliance tool; it is a strategic advantage for reducing emissions, safeguarding operational integrity, and controlling costs. This technology empowers field operators to take ownership of emissions management, ensuring regulatory alignment while mitigating external scrutiny.

1 Introduction

Methane emissions have become a critical focus within the oil and gas industry, particularly in the Permian Basin, which accounts for a significant portion of U.S. hydrocarbon production. The rising importance of emission intensity as a key performance metric—driven by investor expectations, regulatory pressures, and environmental commitments—has led to a shift toward advanced Leak Detection and Repair (LDAR) strategies.

Traditional LDAR methods rely on periodic inspections using Optical Gas Imaging (OGI) or handheld gas analyzers, which can miss intermittent emissions or fail to capture real-time fluctuations. In contrast, continuous methane monitoring offers a proactive approach, allowing operators to detect, localize, and quantify emissions in real time, facilitating immediate corrective actions. This paper explores the regulatory landscape, technological advancements, and case studies demonstrating the effectiveness of continuous monitoring in the Permian Basin.

2 The Case for Continuous Methane Monitoring

Methane emissions from oil and gas operations result from a variety of sources, including venting, equipment malfunctions, and operational activities. The Permian Basin, spanning West Texas and southeastern New Mexico, presents unique challenges due to its high production volumes and dispersed infrastructure.

Unlike traditional LDAR programs, which conduct inspections every few months, continuous monitoring provides real-time data, enabling early leak detection, reduced methane loss, and improved compliance with stringent regulations.

Key benefits of continuous monitoring include:

- **Early Detection & Prevention:** Identifies leaks before they escalate into major emission events.
- **Regulatory Compliance:** Aligns with evolving federal and state methane regulations.
- **Operational Efficiency:** Reduces downtime and maintenance costs through proactive response.
- **Cost-Effectiveness:** Optimizes LDAR-related operational expenditures by focusing resources on actual emissions events.

3 Regulatory Landscape

3.1 Federal Regulations

The U.S. Environmental Protection Agency (EPA) has established stringent methane emissions regulations under the New Source Performance Standards (NSPS) OOOOb and Emissions Guidelines (EG) OOOOc. These regulations impact oil and gas facilities based on their construction date, as well as any modifications or reconstructions, requiring frequent LDAR inspections. Operators must choose between conventional monitoring programs, periodic screening, or continuous monitoring to comply with the best system of emission reduction (BSER) requirements.

Under these frameworks, continuous monitoring provides real-time emissions data, enabling operators to respond promptly to leaks, avoid regulatory penalties, and optimize compliance costs.

3.2 State Regulations

State-level regulations vary widely, reflecting diverse approaches to emissions management:

3.2.1 New Mexico

New Mexico’s Ozone Precursor Rule Part 50 introduces flexibility by allowing operators to implement Alternative Equipment Leak Monitoring Plans (AELMP) as a substitute for OGI, supporting early adoption of continuous monitoring. The New Mexico Natural Gas Waste Reduction Rule allows operator to use

Advanced Leak Detection and Repair Monitoring (ALARM) technology to earn credits that offset a portion of an operator's total annual volume of lost gas.

3.2.2 Colorado

Colorado's Regulation 7 emphasizes robust emission tracking. Part B Section VI: Oil and Natural Gas Pre-Production, Early-Production, and Production Operations, requires continuous monitoring data in minutes from ten days before spud through six months after initial production, ensuring early detection and mitigation of emissions. Monthly bump testing is mandated to verify and maintain system calibration accuracy. Part B Section VIII: Greenhouse Gas Intensity Program for Oil and Natural Gas Upstream Segment, requires the collection of quantified emissions data to support a measurement-informed emissions inventory, enhancing transparency for the public. Regulation 7 has a required LDAR program for well production facilities and natural gas compressor stations throughout the lifespan of these facilities using an Approved Instrument Monitoring Method (AIMM). AQCC Regulation 7 defines AIMM as an infrared (IR) camera, EPA Method 21, or other instrument-based monitoring method or program approved in accordance with the requirements of Regulation 7, Part B, Section I.L.8 ("Alternative AIMM").

3.2.3 California

California's Senate Bill 1137 requires oil and gas operators to develop leak detection and response plans to be implemented in the future. These plans include installing continuous monitoring systems for methane and hydrogen sulfide within designated Health Protection Zones, prioritizing public health and safety.

While regulatory approaches vary, stringent requirements in states such as California and Colorado have influenced capital reallocation, impacting domestic clean hydrocarbon production and industry investment strategies. However, advancements in emissions monitoring technology present opportunities for operators to enhance efficiency, reduce environmental impact, and achieve compliance with evolving standards. Companies that proactively adopt innovative solutions can navigate regulatory complexities effectively and position themselves for long-term success in a dynamic industry landscape.

3.3 Global Regulations

When exporting product considerations must be made for regulations governing the customer's jurisdiction.

3.3.1 OGMP

The Oil and Gas Methane Partnership (OGMP) is a voluntary initiative established by the United Nations Environment Program (UNEP) and the Climate and Clean Air Coalition (CCAC) to support methane emissions reduction in the oil and gas sector. The program provides a standardized reporting framework to help companies measure, report, and mitigate methane emissions while demonstrating progress toward reduction targets. OGMP operates through a five-level system, ranging from generic emission factors (Level 3) to site-level quantification (Level 5), enabling companies to adopt more precise emissions measurement methods. Participation in OGMP enhances operational safety, strengthens credibility in sustainability efforts, and helps stakeholders distinguish industry leaders in methane management.

3.3.2 EU Methane Regulation

The EU Methane Regulation (EU/2024/1787), which took effect on August 4, 2024, is a key component of the EU Methane Strategy, introducing stricter measurement, reporting, and verification (MRV) requirements, mandatory Leak Detection and Repair (LDAR), and a ban on venting and flaring. The regulation also enforces methane transparency for imports, requiring exporters to disclose their emissions measurement and reduction practices per specific timeframes in the future. This is driving changes in import contract language, compelling LNG exporters to engage suppliers to meet compliance obligations. To achieve equivalence with EU standards, companies can pursue one of three pathways: country-level regulatory alignment, company specific MRV compliance, or OGMP 2.0 certification with third-party verification. Companies should assess existing contracts, monitor emerging regulatory language, and determine if their emissions quantification aligns with evolving EU requirements.

These evolving regulatory frameworks are pushing operators to adopt continuous methane monitoring to meet compliance and sustainability goals efficiently.

4 Continuous Monitoring for Enhanced LDAR

Traditional LDAR programs rely on scheduled inspections, which can miss emissions events occurring between surveys. Continuous monitoring bridges this gap by detecting and quantifying methane emissions in real-time. Modern continuous methane monitoring systems utilize sensor networks and advanced analytics to detect and quantify emissions.

4.1 How Continuous Monitoring Works

Continuous methane monitoring systems typically operate using a three-tiered approach:

- **Sensor Networks:** In our paper, we discuss metal oxide semiconductor (MOS) sensors, which are an economical and reliable method to measure methane concentrations and environmental conditions.
- **Cloud-Based Analytics**: Sensor data is processed using data models (e.g., physics-based Gaussian plume models) to quantify and localize emission sources.
- **Web-Based Dashboard**: Operators receive alerts, track emission trends, and log repairs, ensuring regulatory compliance.

This real-time approach enhances compliance and operational decision-making, particularly in high-production areas like the Permian Basin.

4.2 Deploying a Continuous Monitoring System

Deploying a continuous monitoring system requires a customized approach that considers the unique characteristics of each site. Several factors must be assessed during the planning phase:

- The size and layout of the facility
- The location of potential emission sources such as tanks, compressors, and flares
- Local wind patterns that may influence detection accuracy
- Potential obstructions and interference from routine operations
- Budget considerations to ensure cost-effective coverage

By carefully planning deployment, continuous monitoring can be optimized to deliver maximum effectiveness in detecting and managing emissions.

Implementation data demonstrates the significant impact of continuous monitoring systems. Operators in the Permian Basin have achieved notable reductions in methane emissions at well sites. On average, operators achieve a 50% reduction in methane emissions at upstream facilities within the first three months of deployment. One Permian Basin operator recorded a 70% decrease in methane emissions across 75 locations over a six-month period.

After installation, comprehensive support ensures optimal system performance. Technical support teams typically maintain high system uptime (98% or better). Remote diagnostics identify anomalous data across the monitoring fleet, while field technicians positioned across major U.S. basins provide on-site support when needed. Customer success teams facilitate communication of monitoring results to key stakeholders, including field personnel, air quality teams, and executive leadership. This collaborative approach ensures alignment with operational and regulatory objectives throughout the system's lifecycle.

4.3 Leak Detection and Repair Supported by Continuous Monitoring

The workflow below outlines the continuous monitoring and operator actions to manage leak detection supported by a continuous monitoring system.

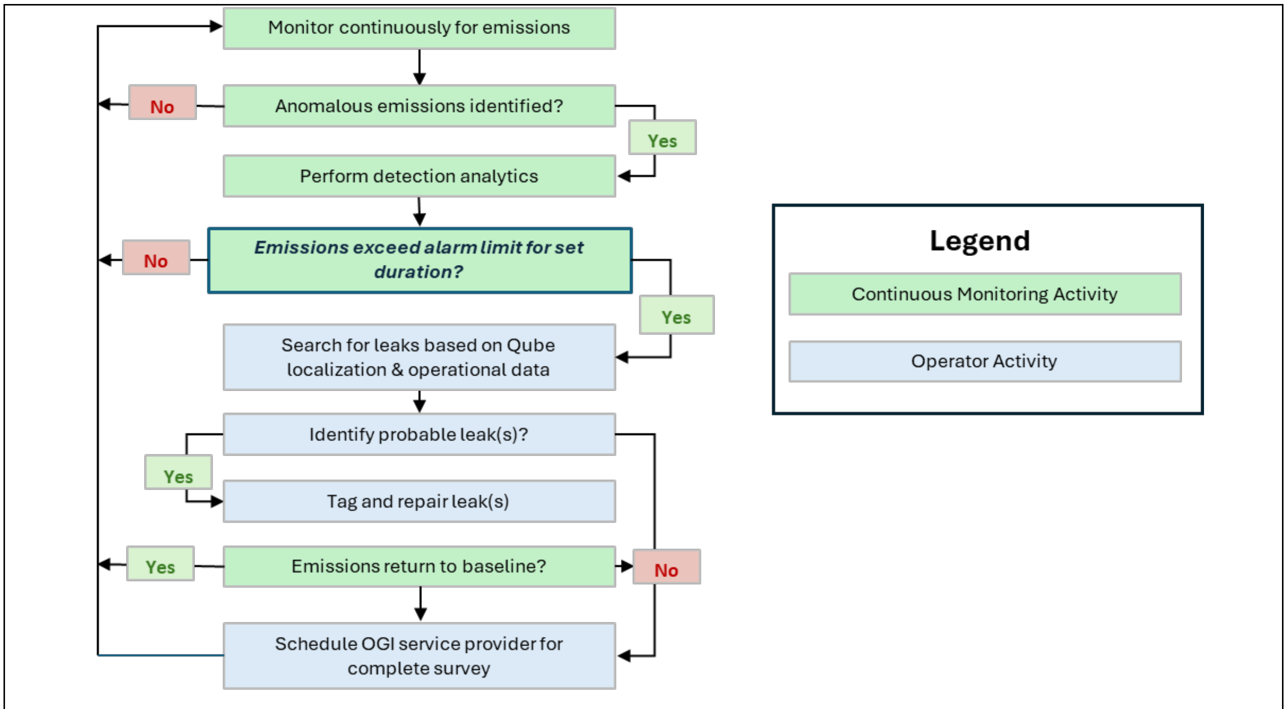

Figure 1 – Continuous monitoring-supported LDAR workflow.

5 Case Studies

The case studies presented in this paper all come from operated sites in the Permian Basin, Midland, TX area.

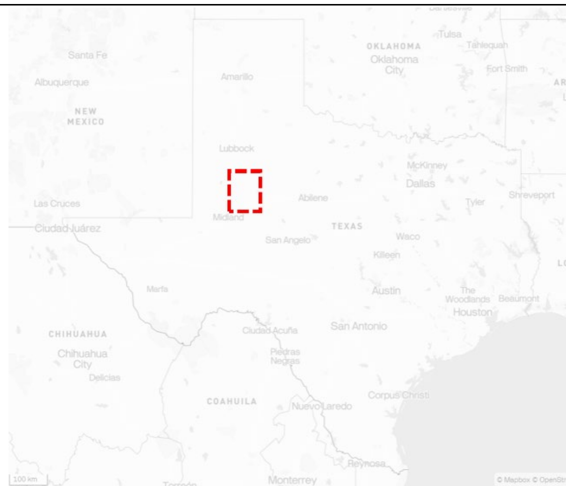

Figure 2 - Map area of case studies in Midland, Texas region.

Case Study #1: Tracking Emissions to Tank Maintenance

Site Information: Well pad with multiple production tanks

Challenge

The operator deployed four continuous monitoring devices at their Permian well site. On January 28, 2025, elevated methane emissions triggered multiple alarms. The emissions persisted, prompting an operational response.

Detection

Continuous monitoring devices localized the emissions to the production tanks. Historical data showed emissions spiked in short bursts. This pattern suggested emissions due to operational activity rather than equipment failure.

Investigation

Operators inspected the tanks and found that an “end-of-line” vent had been opened and resealed. The correlation between emissions and tank maintenance reinforced that these were routine operational releases, not leaks.

Resolution

The emissions event was logged in the continuous monitoring dashboard for regulatory and maintenance tracking. Continuous monitoring proved its value by distinguishing maintenance activities from actual leaks, eliminating the need for further action.

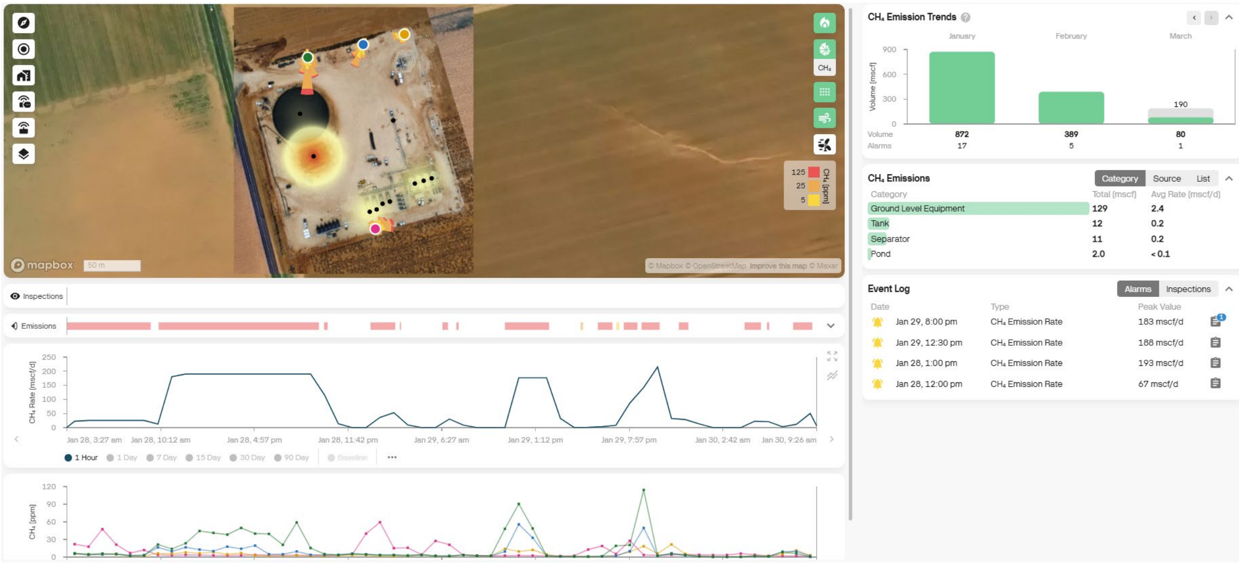

Figure 3 - Case Study 1 – The dashboard localized operational emissions to production tanks and correlated the emissions with maintenance work.

Case Study #2: Leak Detection & Repair at the VRU

Site Information: Central Facility with Vapor Recovery Units (VRUs).

Challenge

On February 11, 2025, the operator detected a persistent methane emission event at a Permian facility with VRUs.

Detection

Continuous monitoring devices identified persistent emissions exceeding baseline levels. The emissions were localized to the VRU, prompting further investigation.

Investigation

Operators reviewed equipment logs and determined the VRU was experiencing operational issues. They noted that maintenance teams had drained the suction scrubber several times to remove condensate, potentially causing emissions spikes.

Resolution

The VRU was repaired and brought back online after maintenance. Operators linked troubleshooting activities to emissions spikes in the dashboard, providing a clear historical record.

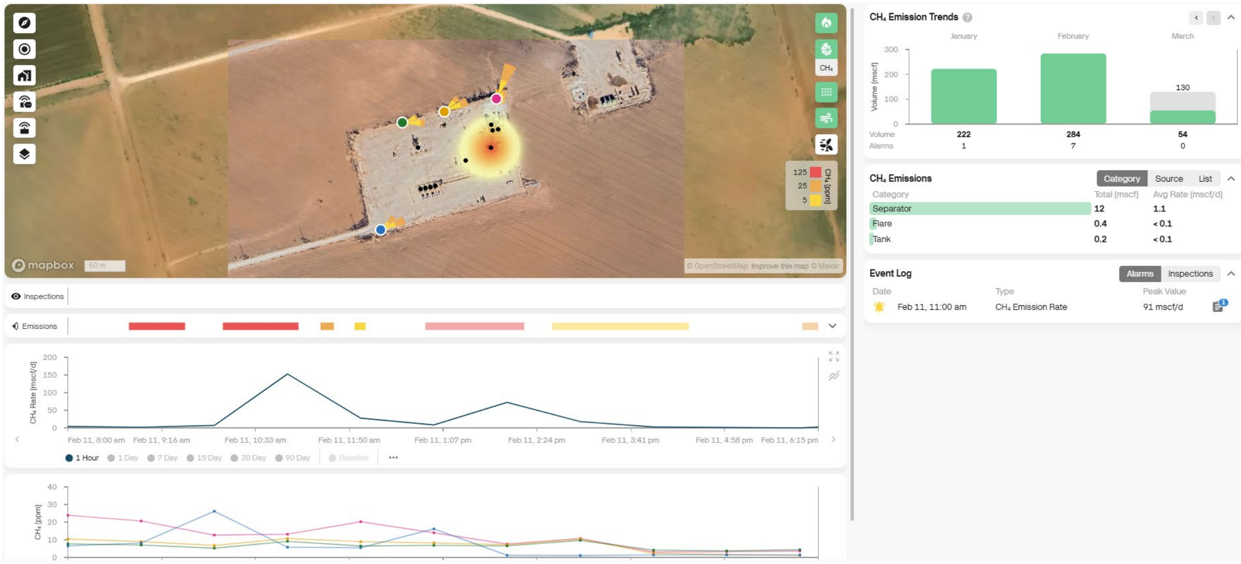

Figure 4 - Case Study 2 – Dashboard view of the emissions release and verification of repairs at the VRU.

Case Study #3: VRU Maintenance Work Initiated by Continuous Monitoring

Site Information: Facility with VRUs and multiple emissions sources

Challenge

On January 24, 2025, continuous monitoring devices detected excess CH_4 emissions originating from the south heater area.

Detection

The emissions persisted, and analysis pointed towards VRU operations. Operators confirmed the VRU was turned off, diverting tank vapors to the tank vapor flare.

Investigation

Operators identified oxygen issues within the system. Specifically, the VRU shutdown caused vapors to bypass normal recovery. Additional issues were discovered with the flame arrestor on the tank vapor flare.

Resolution

The field personnel cleaned the flame arrestor and the VRU was returned to operations. Continuous monitoring devices confirmed emissions returned to baseline levels, verifying the repairs were successful.

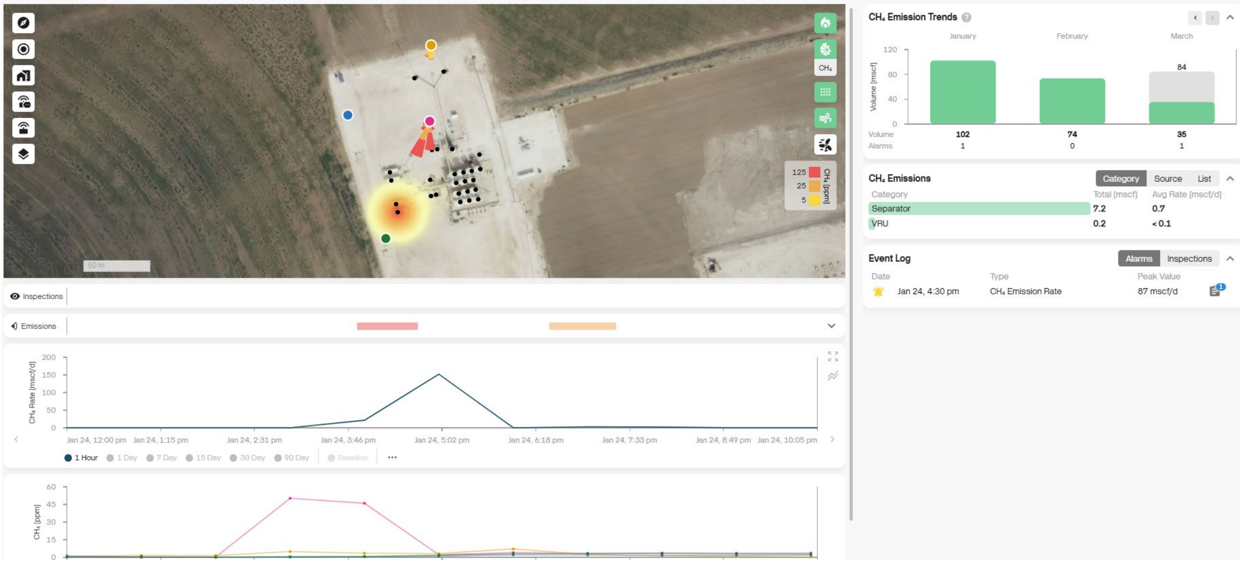

Figure 5 - Case Study 3 – The dashboard displays emissions localized to the VRU and confirms that optimization efforts resulted in reduced emissions.

Case Study #4: Unlit Flare Pilot Detected by Continuous Monitoring

Site Information: Facility with flare system

Challenge

On April 11, 2024, continuous monitoring devices detected elevated methane emissions near the flare stack.

Detection

The emissions were localized to the flare, indicating possible combustion failure. In addition, the data pattern suggested a flare outage rather than a routine event.

Investigation

Operators inspected the flare and found the pilot light had gone out.

Resolution

The pilot was relit, and emissions immediately dropped back to baseline levels. Operators confirmed the flare's stability using the continuous monitoring dashboard.

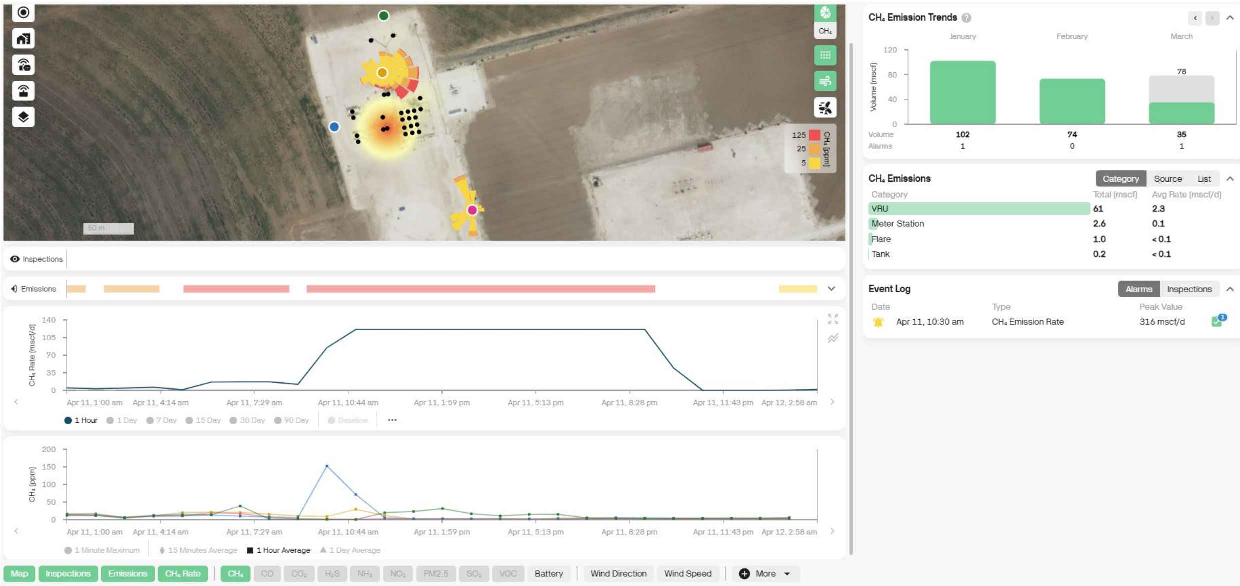

Figure 6 - Case Study 4 – The dashboard localized persistent emissions to the flare stack, leading to the discovery that the pilot had gone out.

Case Study #5: Operational Improvements to avoid Third Party Super Emitters

Site Information: Large-scale oil and gas operation

Challenge

In October 2024, a flare outage resulted in uncombusted methane emissions, triggering alarms in the continuous monitoring system. However, before corrective action was fully implemented, a third-party aerial emissions survey detected the leak and published the data on Carbon Mapper's public platform three weeks later.

Detection

Continuous monitoring identified elevated emissions at the tanks and flare, prompting an internal alert. With this information, operators confirmed high pressures at the tanks, indicating issues with VRUs.

Investigation

Initial troubleshooting led to rerouting gas to a low-pressure flare, but emissions persisted. Days later, a detailed site inspection revealed that an end-of-line vent was releasing gas from the tanks.

Resolution

Operators adjusted valve weights and stabilized the tank system, bringing emissions back to baseline. While the leak was eventually mitigated, the delay in response meant the event was recorded and publicly reported by Carbon Mapper, reinforcing the need for faster action in the future.

Future Adaptation: This event demonstrated the growing role of third-party emissions monitoring and the need for proactive response strategies. Moving forward, the operator utilizes real-time alarms to take immediate action—before leaks can be externally detected and reported.

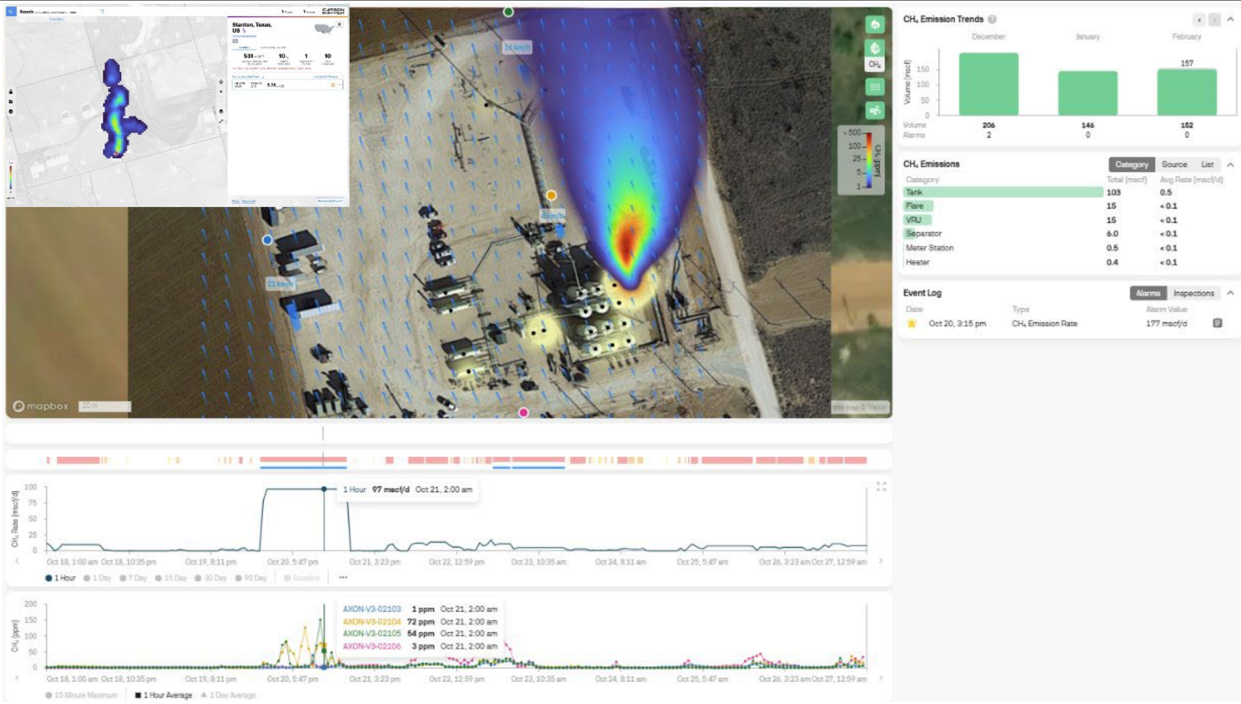

Figure 7 - Case Study 5 – Continuous monitoring detected the emission event prior to detection and publication by Carbon Mapper (upper left panel).

Case Study #6: Continuous Monitoring Detects H_2S Gas Treatment Hatch Left Open

Site Information: Facility with H_2S gas treatment tanks

Challenge

On June 24, 2024, continuous monitoring detected persistent emissions near the H_2S gas treatment system.

Detection

The continuous monitoring dashboard localized the emissions to the treatment tank area.

Investigation

Operators discovered the top hatch of the spent tank was left open, allowing emissions to escape.

Resolution

The hatch was closed and secured, and emissions immediately returned to baseline levels. Operators recorded the incident in the continuous monitoring dashboard for future reference.

Figure 8 - Case Study 6: Continuous monitoring detection of H_2S leads open top hatch of a spent tank.

6 Conclusion

The case studies presented in this paper highlight the effectiveness of continuous methane monitoring in reducing emissions, ensuring regulatory compliance, and improving operational efficiency. By providing real-time leak detection and rapid response capabilities, continuous monitoring has enabled operators to achieve up to 70% reductions in methane emissions within six months, significantly lowering environmental impact and regulatory risk.

A key advantage of continuous monitoring is its ability to distinguish between routine maintenance activities and actual leaks, preventing unnecessary shutdowns while ensuring swift corrective actions for genuine issues. This was evident in cases where emissions events were linked to flare pilot failures, VRU malfunctions, and tank maintenance. The ability to detect and address these events immediately minimizes downtime and prevents regulatory violations.

With stringent EPA and state-level regulations now mandating more frequent and precise emissions tracking, continuous monitoring provides a critical compliance advantage. Unlike traditional LDAR programs that rely on periodic inspections, continuous systems generate a comprehensive emissions dataset, allowing operators to demonstrate compliance, optimize maintenance schedules, and reduce enforcement risks.

Additionally, as third-party satellite and aerial methane detection programs increase public scrutiny, continuous monitoring offers a proactive solution. By ensuring that emissions are addressed internally before being externally reported, operators are better equipped to navigate evolving regulations, enhance efficiency, and strengthen their social license to operate. Continuous methane monitoring empowers operators with real-time repair alarms, cost savings, and improved regulatory alignment thus positioning their organizations for long-term success.