QUBE

Description of Technology report (non-CBI)

EPA Alternative Test Method Application

Periodic Screening

Submission date
2025-01-10

Focus
This document is the part of Qube's application package for regulatory approval as a periodic screening alternative test method as per Title 40 CFR part 60 NSPS OOOO Rules Section §60.5398b(b) and §60.5398b(d).

The document focus is to provide a complete description of Qube's continuous emissions monitoring system technology.

Team

Alex MacGregor, CEO
Eric Wen, COO
Greg Taylor, CTO
Tej Grewal, VP of Innovation
Andrew Walsh, VP Customer Success
Everett Robinson, Director of Data Science
Matt Blair, VP of Operations
Dr. Carol Brereton, Sr. Data Scientist
Brad Roger, Director of Product
Jon Bain, Sr. Product Manager
Waseem Alkhayer, Hardware Development Manager

Table of contents

1. Document Overview

This document is referred to as the "Description of Technology" document, one of three documents (not including supporting information) associated with the Qube Technologies (Qube) periodic screening alternative test method application package. This document aims to describe how Qube's technology works from first principles through solution.

The organizational structure of this document is as follows:

- Section 2: How each component of Qube's solution works independently
- Section 3: How each component works together as a complete solution to go from field measurements to site emission rates
- Section 4: How the solution performs in the field including 3rd party data validating Qube's aggregate detection threshold
- Section 5: How the solution is supported in the field including field calibration, health checks, and downtime tracking

Figure 1 provides a graphical view of the document structure with how each section relates to the requirements outlined in 40 CFR §60.5398b(d). Reference to this figure throughout the document will act as a guide for the reviewer (i.e., the topic will be highlighted in a solid color).

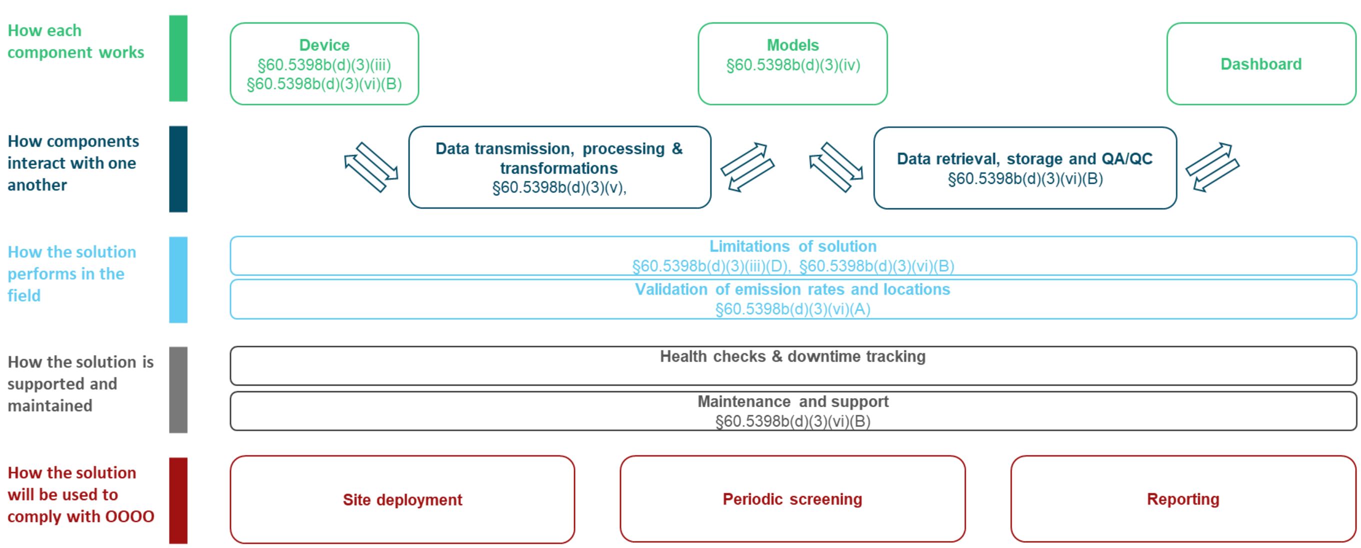


Figure 1 - Organizational structure of Qube's Description of Technology document

2. How each component works

Qube's emissions monitoring system is a network of fixed devices on a site designed to detect, locate, and quantify methane emissions in real time. The technology consists of three components (Figure 2): (i) an Industrial Internet of Things (IIoT) device houses various sensors that measure gas concentration and environmental data and transmits it to the cloud, (ii) a cloud-based platform that records and analyzes data received by the IIoT device and uses physics-based models to convert device data into leak locations and quantities and (iii) a web-based dashboard that aggregates critical insights such as emission rates and alarms generated by the analytics platform and identifies the remedial actions that need to take place by operators.

For the purposes of this Methane Alternative Test Method, the methane emission rates will be provided to operators in kg/hr to be aligned with EPA minimum detection level requirements. The data flow and algorithms behind emission rate estimation will be further described in this application in section 2.2.1.

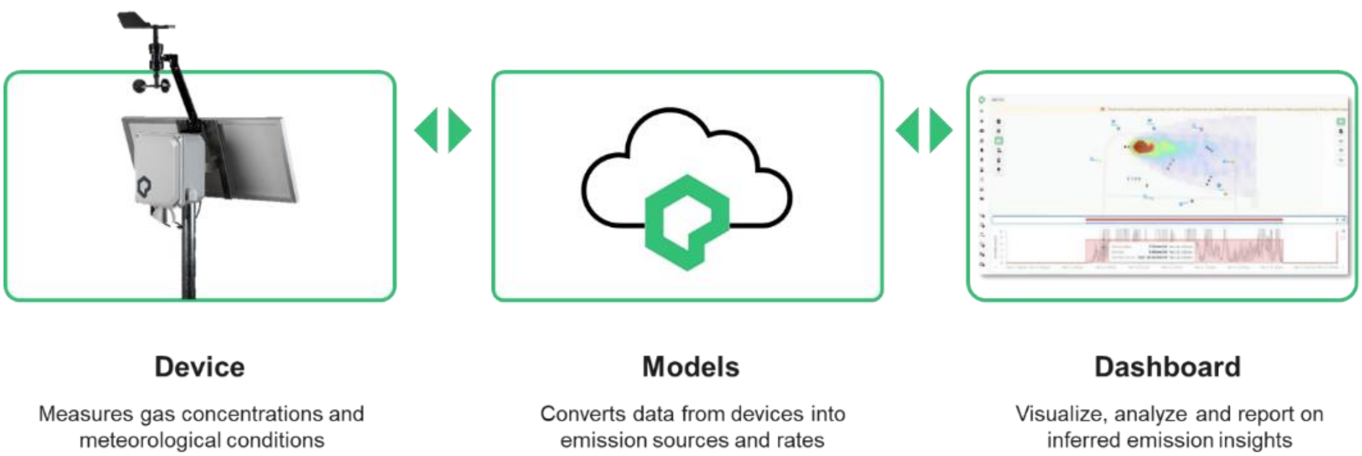
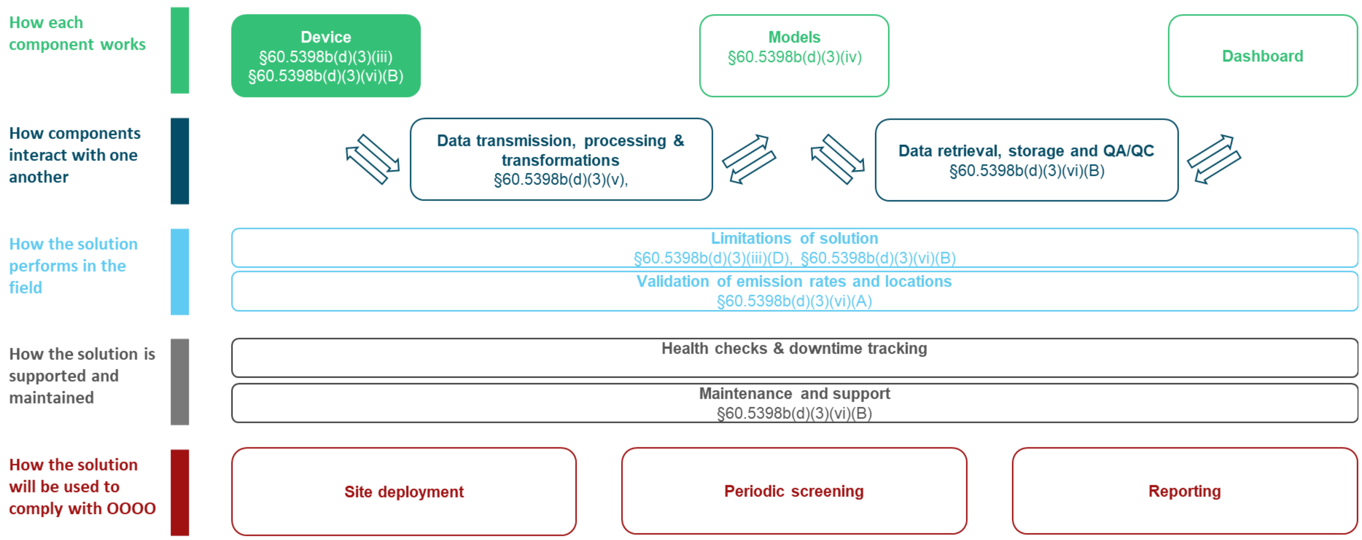


Figure 2 - Qube's three-part solution

The following subsection will provide technical details on how each component works from first principles.

2.1. Device



The first part of Qube's solution is the IIoT device that houses the sensors which are deployed around a facility. The following section details the physical instrumentation of the device, how the methane sensor works from first principles, how Qube calibrates each sensor individually to compensate for a wide range of operating conditions (e.g., temperature and relative humidity), and how the calibration is verified and maintained in the field over extended periods of time.

2.1.1. Description of physical instrumentation

The primary physical instrumentation of Qube's monitoring system is the Qube IIoT device, illustrated in Figure 3. On the left, an external view of the device is presented, while the right side provides a breakdown of its internal components.

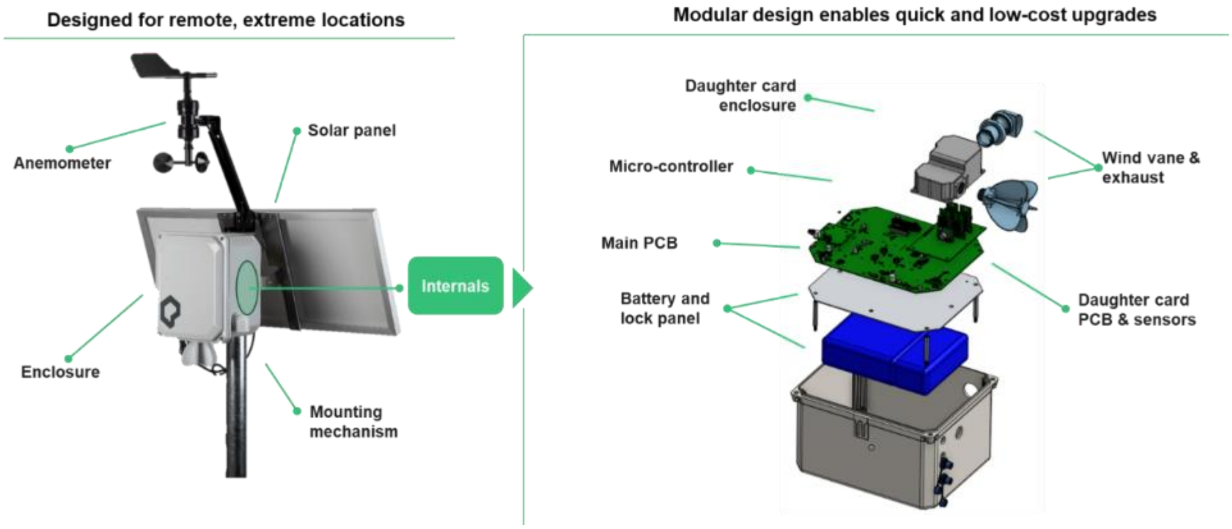


Figure 3 – Qube's Industrial Internet of Things (IIoT) device and its individual components

Further description of the key components of the Qube IIoT device is provided below:

2.1.1.1. Enclosure

The enclosure is a Polycase ZQ-100806. It has been designed for outdoor operations with waterproofing and UV-resistant coating making it capable of withstanding significant exposure to the elements (e.g., extreme temperatures, wind, sun, etc.). The enclosure has an Ingress Protection level of 57 (IP57) which protects the internal components from airborne solid materials (e.g., dust and sand) and liquids (e.g., rain). The enclosure also has a flame rating of UL94 5VA making it ideal for use in oil and gas operations.

2.1.1.2. Micro-controller and communications module

The Qube IIoT device uses a micro-controller, which allows the device to collect and process large amounts of data. The micro-controller processor also intelligently increases the communication frequency to once every 2-3 seconds when methane is detected above the baseline so that the quantification models can run in near real-time with high-frequency data. Communication frequency drops to a minimum of once every hour when methane is not present to conserve battery life.

Embedded on the microcontroller is a modem that is designed to transmit data through the cellular and wireless internet networks. The modem is compatible with LTE Cat M1 and 2G/3G bands enabling Qube to deploy the same device in various regions around the world.

2.1.1.3. Power source (solar panel and battery)

The Qube device includes its own independent power source supported by a 30W solar panel and is designed to operate in remote, off-grid locations. Devices are powered by a rechargeable battery with a 10+ year lifespan. The rechargeable pack can provide power for approximately 179 hours or 7.5 days without sunlight.

2.1.1.4. Environmental sensors

Qube's IIoT devices include environmental sensors, which are all commercially available and currently used in industrial applications. Device-level environmental data is essential for inverse plume modeling required to convert concentration data into volumetric flow rates. Qube's IIoT device includes the following environmental sensors:

- Temperature sensor to measure and record temperature
- Barometer to measure and record barometric pressure
- Humidity sensor to measure and record humidity
- Anemometer and wind direction sensor to measure and record wind speed and direction
- GPS to measure the positioning of the device

2.1.1.5. [Content reserved for CBI]

2.1.2. [Content reserved for CBI]

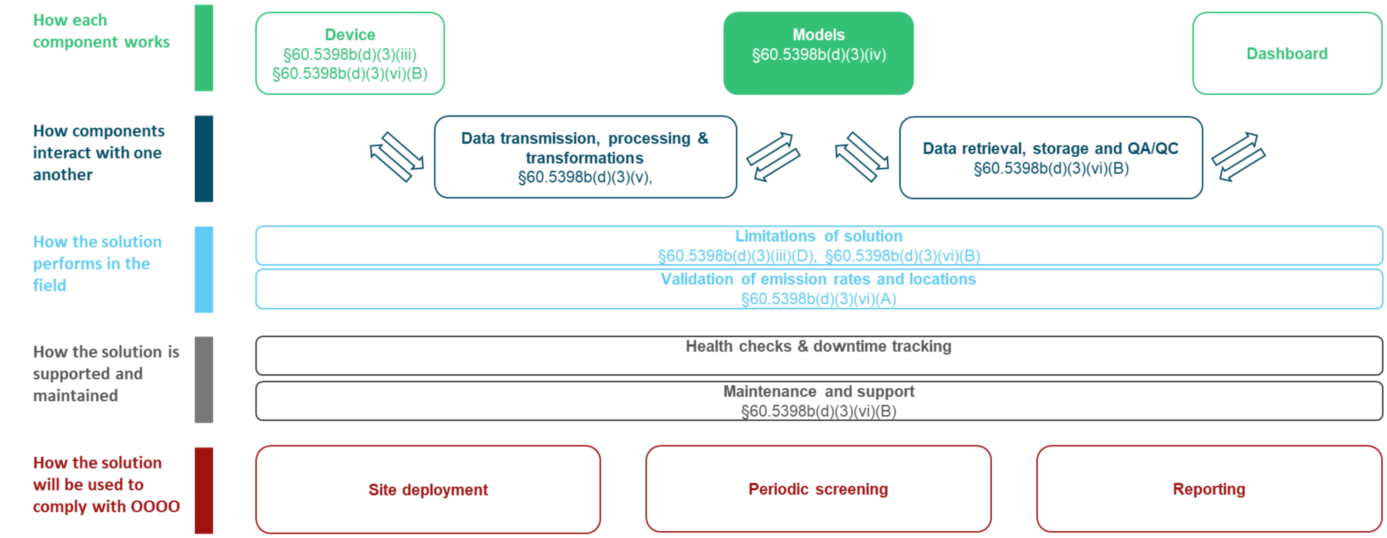
2.1.3. [Content reserved for CBI]

2.1.4. [Content reserved for CBI]

2.1.5. [Content reserved for CBI]

2.1.6. [Content reserved for CBI]

2.2. Models



The second part of Qube's solution is the cloud-based analytics platform that records and analyzes data received by the IIoT devices and converts this data into mass emission rates using models. The following section details how Qube quantification and localization models work from first principles, the method in which the models convert methane measurements to mass emission rates, how offsite emissions are dealt with, and how plume spread is estimated.

2.2.1. Conversion from methane measurement to mass emission rate overview

The Qube platform continuously monitors gas concentration and environmental data at each device, collecting measurements every 8 seconds. The environmental data obtained includes temperature, barometric pressure, humidity, wind speed and direction, as well as sensor location. Each Qube device is equipped with an anemometer to provide a comprehensive understanding of how the wind field evolves across the landscape of a facility. By utilizing the wind speed and direction measurements from each device, Qube estimates the trajectory of transported gas and identifies the potential source(s) of emissions. Additionally, these measurements, along with the recorded pressure and temperature, are employed in inversion modelling to support the estimation of emission rates. The data is continuously streamed to the cloud-based platform, where it undergoes real-time analysis and processing. Results are produced every minute based on measurements gathered over the previous 10 minutes. Figure 4 provides a visual workflow of those data processing steps.

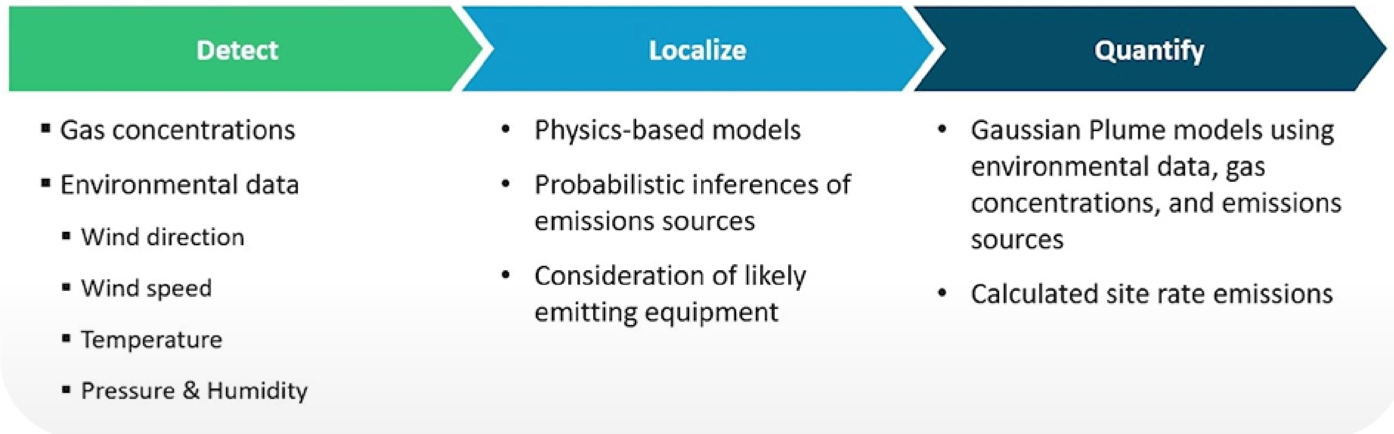


Figure 4. Workflow of how Qube converts measurements into mass emission rates by source

A brief description of each step and a more in-depth discussion of the scientific theory is covered in the following subsections. The Qube algorithm is fully automated and requires no manual intervention to generate estimates. Qube's platform also contains separate models and processes for identifying devices producing bad data and excluding these devices from participating in the above algorithm once identified (see section **Error! Reference source not found.** for more details on data processing).

2.2.2. [Content reserved for CBI]

2.2.3. [Content reserved for CBI]

2.2.4. [Content reserved for CBI]

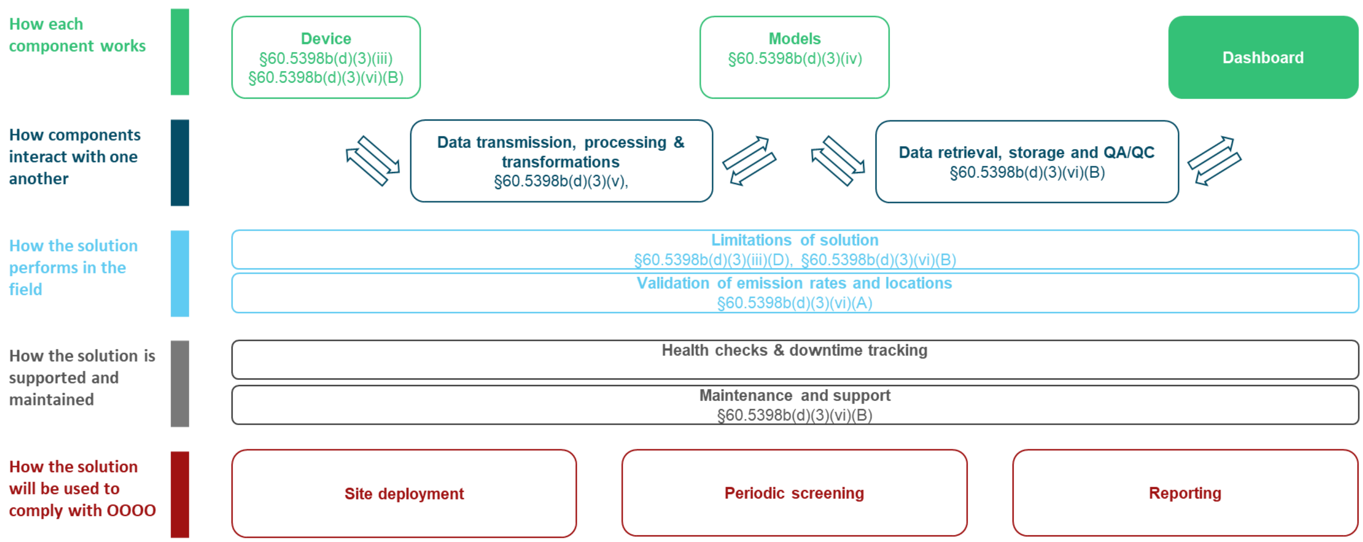
2.2.5. Model updates and tuning

Qube's monitoring system leverages data science techniques when evaluating new and existing models against ground truth emissions data sources. These include hyper-parameter optimization through grid search, stochastic gradient descent, and Bayesian optimization. It can be individually targeted at specific sub-components of the overall model or applied holistically against the entire model simultaneously. Experiments are tracked using common machine learning and data science software suited to this purpose, and model artifacts are registered and version controlled. The Qube monitoring system does not employ uninterpretable machine learning algorithms which obscure the physical processes (fugitive emission plume dispersion considering emission rate, wind speed, and other relevant parameters) being modeled. In this way, Qube's monitoring system does not integrate any "black box machine learning algorithms," so all model inputs and outputs can be traced back to real-world processes.

As part of the update process, new versions are back tested against previous versions to determine the change in model results on controlled release datasets before deployment. This is in line with the EPA's notification process required for changes greater than 5%.

Once the system is deployed, operators access emissions data through the dashboard, which provides detailed information about potential sources and rates (see section 2.3). The platform user has access to both the emission event and raw minute-level rate estimates, and all collected data is meticulously recorded within the dashboard, ensuring a comprehensive and transparent tracking system.

2.3. Dashboard



The Qube monitoring system provides data streams to the end user via the proprietary Qube dashboard, which includes a web-based dashboard and REST API. The Qube dashboard was designed with the oil and gas industry's needs in mind and is the result of multiple iterations of incorporating operators' needs during pilot deployments. The following figures demonstrate the various data streams available and the multiple methods for the user to access them.

2.3.1. Overview dashboard

Figure 5 shows the overview dashboard, which serves as the command center for the emissions management system. It provides immediate information about all monitored sites. The main features include:

- An **overview map** with sites in scope and relative emission volumes per site
- A **date picker** to select the time period being evaluated
- A **plot with monthly emission trends**, including alert counts and emissions volume at all sites

- **Sites and equipment list** to rank sites and equipment by emission volume, alert count and average daily emission rate

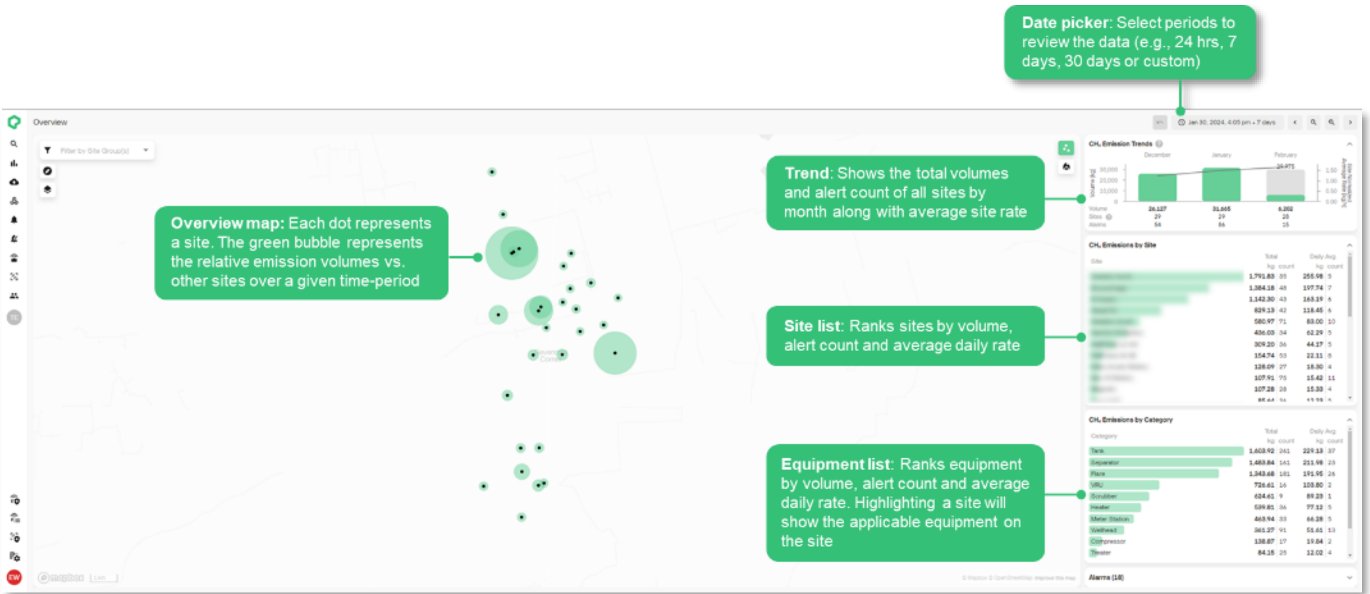


Figure 5 - Overview dashboard

2.3.2. Site dashboard

Figure 6 shows the site dashboard. It offers a site-level view, delivering precise emissions data at the equipment level. Similar to the overview dashboard, the site dashboard includes:

- A **map view** with the site layout showing potential emission sources alongside Qube Device locations with various data visualization tools such as:
  - A **heatmap** of emission volumes and their source locations during the selected time period
  - Device-level "**concentration roses**", with concentration spikes during the selected time period, represented on a wind rose to show the direction of the plume source, allowing the user to triangulate the source of the gas visually
  - **Wind field** visualization of the wind direction across the entire facility
  - **Plume simulation** of specific emissions which shows a visual representation of the modeled methane plumes, similar to what is seen in flyover imagery
- A **date picker** to select the time period being evaluated
- A **plot with monthly emission trends**, including alert counts and emissions volume
- **Equipment list and equipment category** to rank equipment and equipment types by emission volume and average daily emission rate

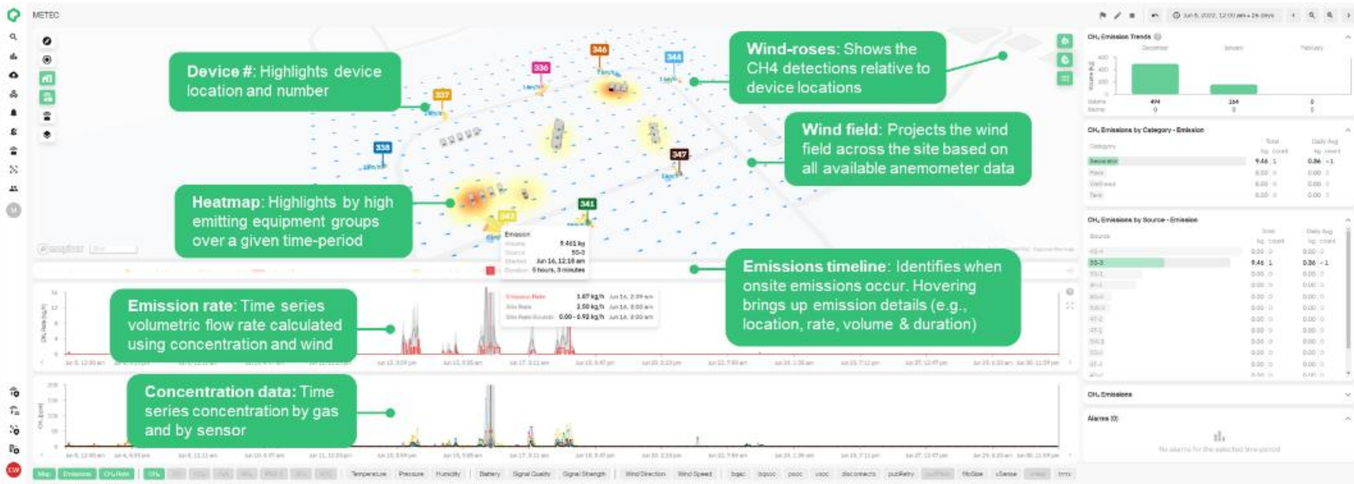


Figure 6 - Site dashboard

Figure 24 shows the plume simulation tool, which helps users understand the model results and visualize how the device data streams are converted into emission rates.

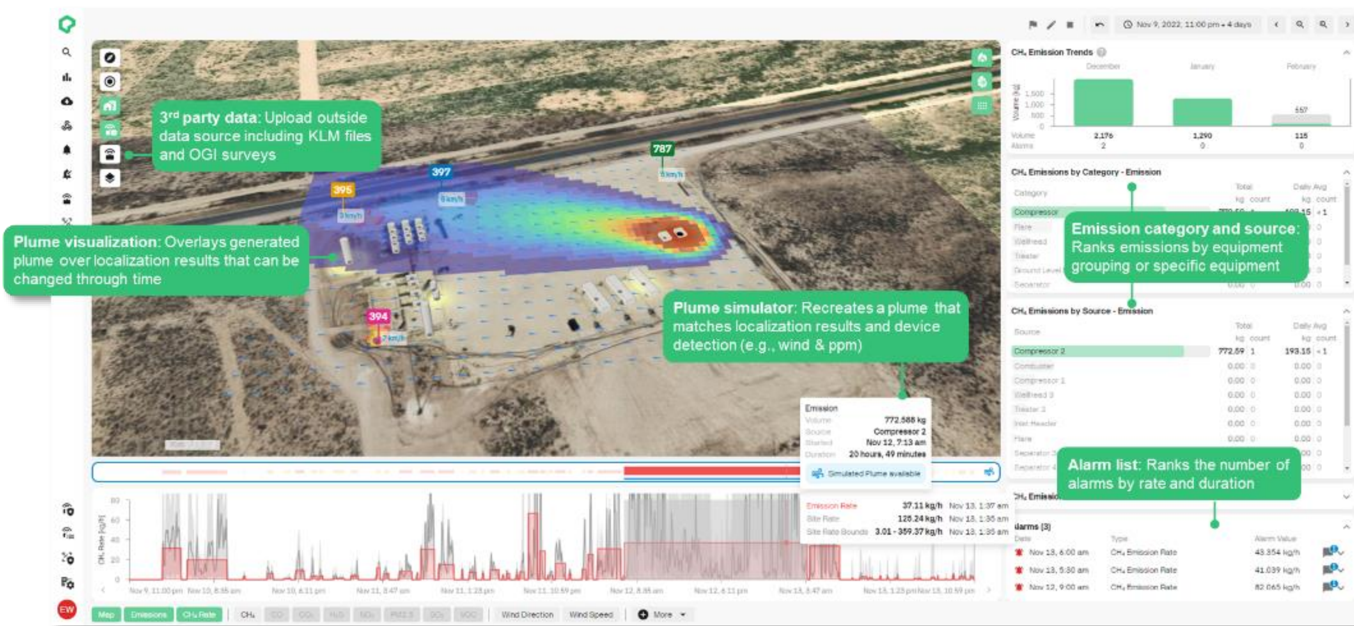


Figure 7 - Plume simulation is available via the site dashboard

2.3.3. Emission trends dashboard

The emission trends dashboard (Figure 25) shows emission volumes over time and allows operators to split volumes by site and source type to find trends within their complex emission data.

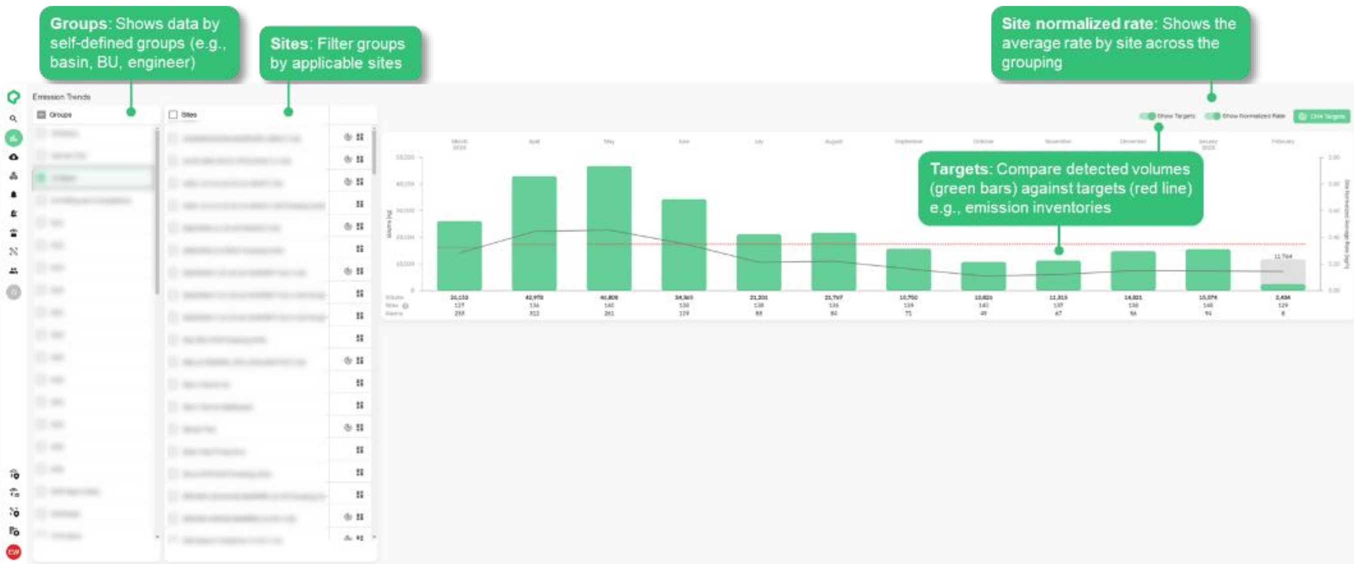


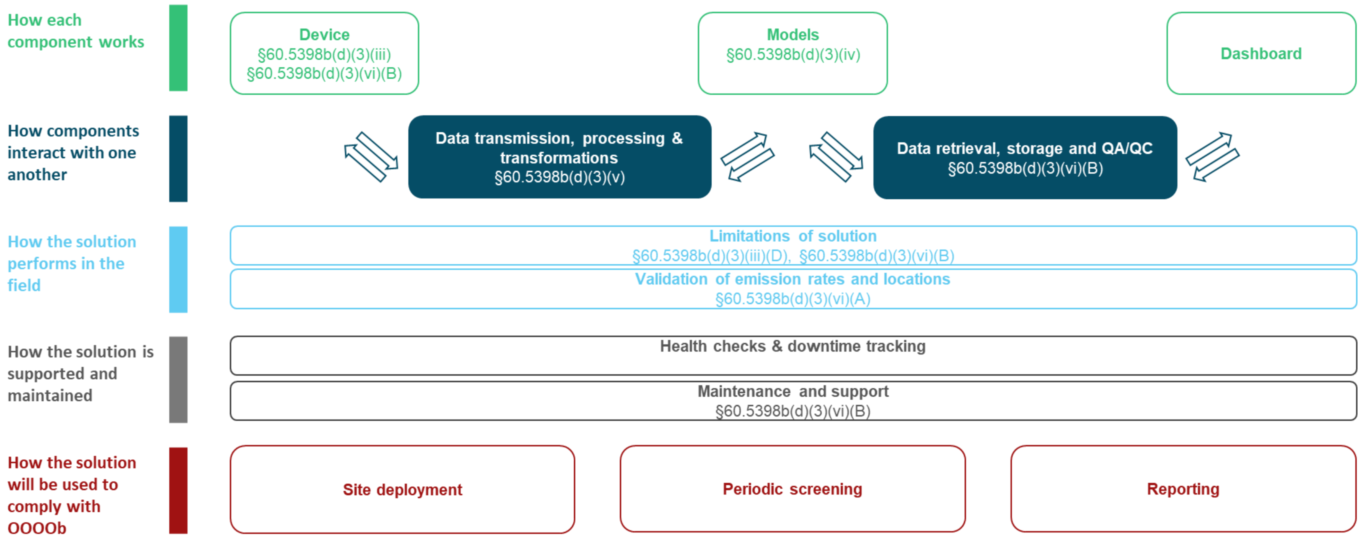
Figure 8 - Emission trends dashboard

2.3.4. [Content reserved for CBI]

2.3.5. [Content reserved for CBI]

2.3.6. [Content reserved for CBI]

3. How components interact with one another



Qube monitoring system provides real-time emission data from IIoT devices deployed in the field to dashboards located around the world through cellular networks and public cloud services.

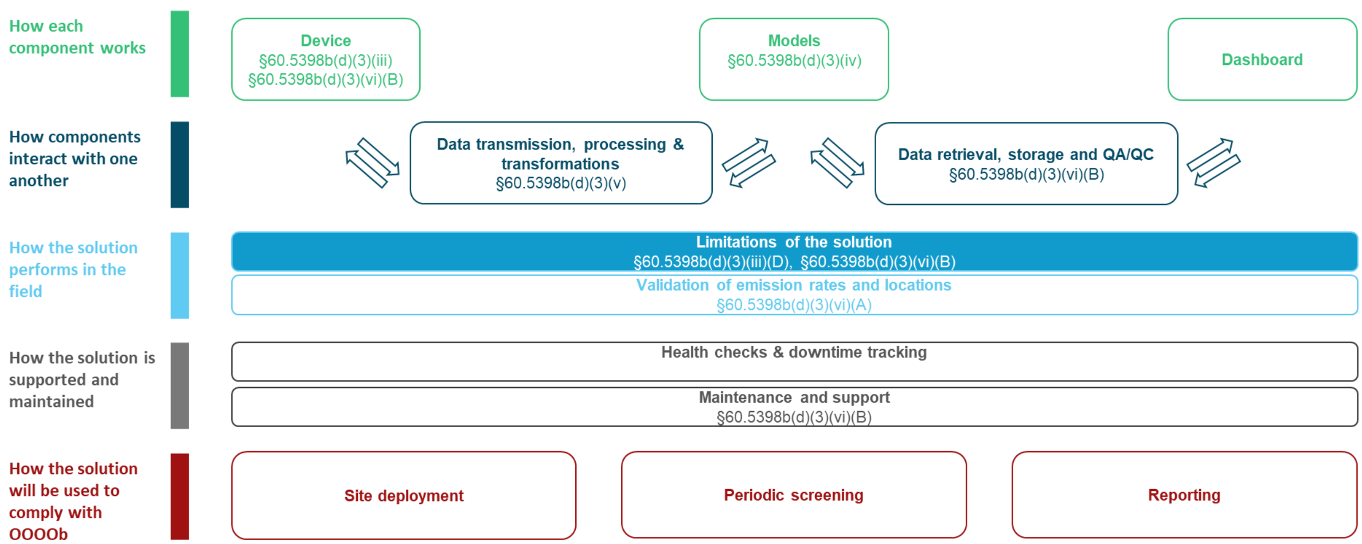
3.1. [Content reserved for CBI]

3.2. [Content reserved for CBI]

4. How the solution performs in the field

This section delves into the operational intricacies of Qube's solution in the field including an overview of the limitations of the solution as well as validation of the solution's performance through 3rd party testing, regulatory applications, and operator deployments.

4.1. Limitations of the solution



While Qube's monitoring system can play a pivotal role in real-time emissions tracking and regulatory compliance, it is not without limitations. The following is a summary of the known limitations of Qube's solution:

4.1.1. [Content reserved for CBI]

4.1.2. Offsite and confounding emissions

Qube's sensors may detect methane emissions from non-target oil and gas facilities or unrelated sources, such as livestock or wetlands. Distinguishing confounding sources and offsite emissions is challenging for all continuous monitoring systems and is an area of continuous research on artificial intelligence/machine learning (AI/ML) models and improving data filtering to reduce occurrences. Qube's models include an evaluation to determine if the emission is coming from offsite sources and allow elevated concentrations from upwind offsite sources to be considered when baselining model inputs by evaluating wind patterns. Placing additional devices upwind or between confounding sources can be used to improve disambiguation of offsite emissions and source localization.

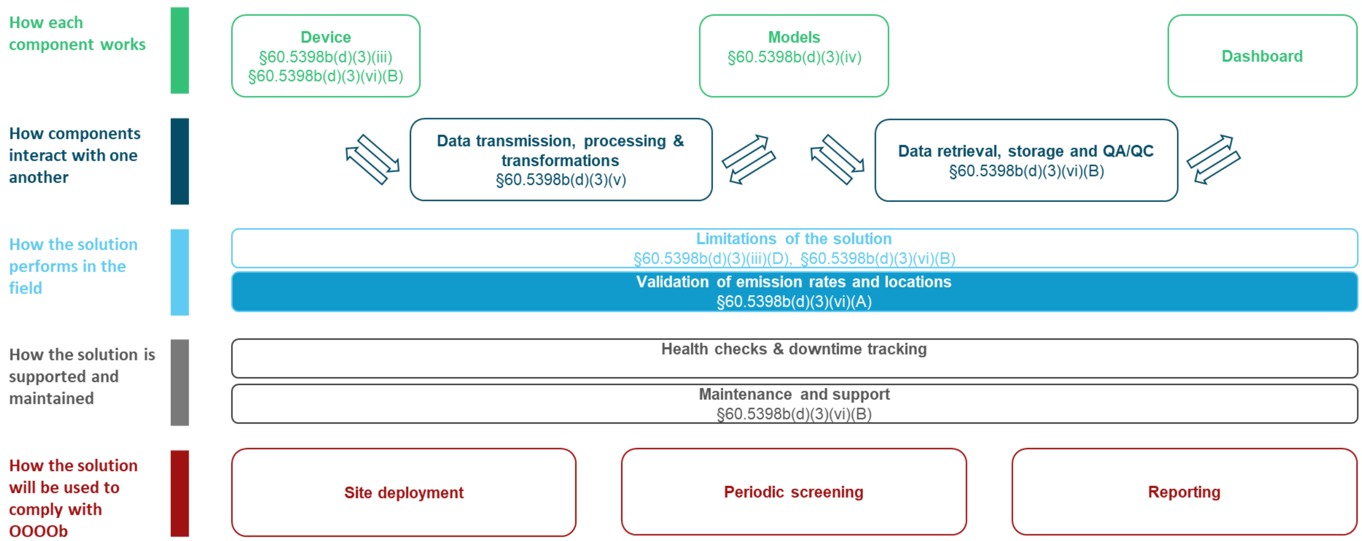
4.1.3. [Content reserved for CBI]

4.1.4. [Content reserved for CBI]

4.1.5. [Content reserved for CBI]

4.2. Validation of emission rates and locations

Ensuring the reliability and accuracy of Qube's monitoring solution requires rigorous validation of its performance. This section will provide a summary of the solution's performance specifications, third-party testing, regulatory applications, and extensive field deployments.



4.2.1. Solution specifications

Table 1 summarizes the detailed system specifications including operational ranges (concentration, temperature, and relative humidity), minimum detection limit, data measurement, and transmission frequencies, among other things. A few notes regarding specific sensor generation requirements are included at the bottom of the table. A copy of the specifications[1] that are shared with customers can be found in the supporting documentation package.

[17] Qube Technologies, "Qube Solution Specifications," Calgary, 2024.

Metric	Range/Value
Concentration measurement range	0 – 1,000ppm
Concentration measurement accuracy	± 1%
Concentration measurement precision	± 1 ppm
Detection temperature range[1]	-40 to 70 °C
Detection relative humidity range[2]	10 – 100%
Minimum detection limit[3]	0.1 kg/hr
90% Probability of detection[3]	1.5 kg/hr
Measurement frequency[4]	3-5 seconds
Transmission frequency[4]	1-20 minutes
Quantification frequency	1 minute
Connectivity	LTE Cat M1: bands: 2, 4, 5, 12, 13
Solar panel	30-45W
Battery[5]	Lithium titanate with 8 days of reserve

Table 1 - Qube system overall performance specifications

[1] Temperature detection range varies depending on whether high-temperature or Gen 3 methane sensors are deployed. Gen 3 temperature range is -40 to +50°C. The high-temperature sensor range is -10 to 70°C.
[2] The relative humidity range varies depending on whether high-temperature or Gen 3 methane sensors are deployed. Gen 3 RH range is 10-90% RH. The high-temperature sensor RH range is 10-100%.
[3] The minimum detection limit was verified through blinded 3rd party testing at METEC and through single-blinded testing performed in collaboration with Highwood. Copies of reports are provided in supplementary information package.
[4] Measurement and transmission frequencies vary depending on compression at the device level (e.g. if there is no detection, the transmission frequency lowers).
[5] Battery can discharge at -40°C, but solar recharge is limited at <-20°C, so a reserve of 8 days at 100% is included.

4.2.2. Third-party testing

Qube has continuously worked with industry and academia to understand and improve Qube's performance. In the past few years, Qube has been tested in blind controlled release test studies conducted by third parties and participated in multiple field trials. Blind controlled release test studies were performed to benchmark Qube's performance in a controlled environment, while field trials were conducted to evaluate performance under real operational conditions.

Controlled release testing results suggest that Qube's system can reliably detect rates of 1.5 kg/hr from distances of 75 to 100 meters. (i.e., 90% detection probability or greater).

Two of these blind controlled release test studies are described in the following section. The first was completed by the consulting firm Highwood Emissions Management (Highwood), and the second was conducted as part of the Methane Emissions Technology Evaluation Center (METEC) Advancing Development of Emissions Detection (ADED) Program at Colorado State University. The supporting documents attached to this application include the complete report from both studies[2,3].

4.2.2.1. Highwood testing

Qube Technologies has a Controlled Release Testing Facility (CRTF) located in Bighorn No. 8 (Alberta, Canada), a district located between Calgary and Banff National Park. In 2022, Qube's continuous monitoring system performance was evaluated by Highwood Emissions Management (Highwood) in a single-blinded study performed at the CRTF. For the study, fifteen Qube devices were installed at 50m, 75m, and 100m "steps" away from the release source, with five devices deployed at each distance. Empirical CRTF wind data was used to establish a prevailing wind direction and guide the placement of Qube devices on the downwind side of the CRTF. Emission source and Qube devices were set up approximately 2m above ground level.

All releases were performed using one of three controlled Mass Flow Controllers (MFCs) at a single release point. Controlled releases were performed from February 24 to May 10, 2022, with a total of 29 days of active measurement. Qube Technologies set up the devices, while Highwood designed the methane release schedule, controlled release rates, and initiated the releases remotely. Qube devices autonomously pushed data to the cloud and issued hourly detection reports to Highwood via email.

Testing protocols were developed to guarantee that release occurrence, timing, emission rate, and environmental conditions were only known by Highwood and not by Qube Technologies staff. Highwood remotely activated all controlled releases. Highwood also compiled testing results by processing automated alert data (received via an email system) and ancillary data (wind speed and direction data pulled from the Qube cloud-based platform).

The probability of detection was calculated as a function of emission rate, distance from source to sensor, wind speed, and wind direction. Emission rates ranged from 0.10 kg/h up to 1.38 kg/h, and each release consisted of

---

[18] Colorado State University Methane Emissions Technology Evaluation Center (METEC)., "Continous Monitoring Final Report: Solution A," Fort Collins, 2022.
[19] Highwood Emissions Management, "Qube Technologies Continuous Monitoring Probability of Detection: Results from independent single-blind controlled release testing," August 2022. [Online]. Available: https://highwoodemissions.com/wp-content/uploads/2022/09/2022-08-25_Qube-Probability-of-Detection-White-Paper.pdf.

40 minutes of steady-state methane discharge fixed at the release rate being tested, followed by 20 minutes of “non-release” to ensure the air was clear for the following release. Wind speeds ranged from 1 to 19 m/s, and ambient temperature ranged from -14 to 13°C. A detection at any point within the release window was considered a true positive.

Data collected was used to build a probability of detection estimate. The logistic regression model took the following factors into consideration: release rate, distance, wind speed, and wind index (represented as a wind favorability index value. “Ideal” conditions would see wind index values near 1.0). Results show that under average wind conditions (wind index of 0.4 and wind speed of 6 m/s), the probability of detection of a 1.0 kg/hr release rate for the Qube Solution is approximately 37% at 100m, 58% at 75m, and 78% at 50m for a 40-minute release window. At 75m, the Qube Solution has a 90% probability of detecting a 1.5 kg/hr emission (Figure 9).

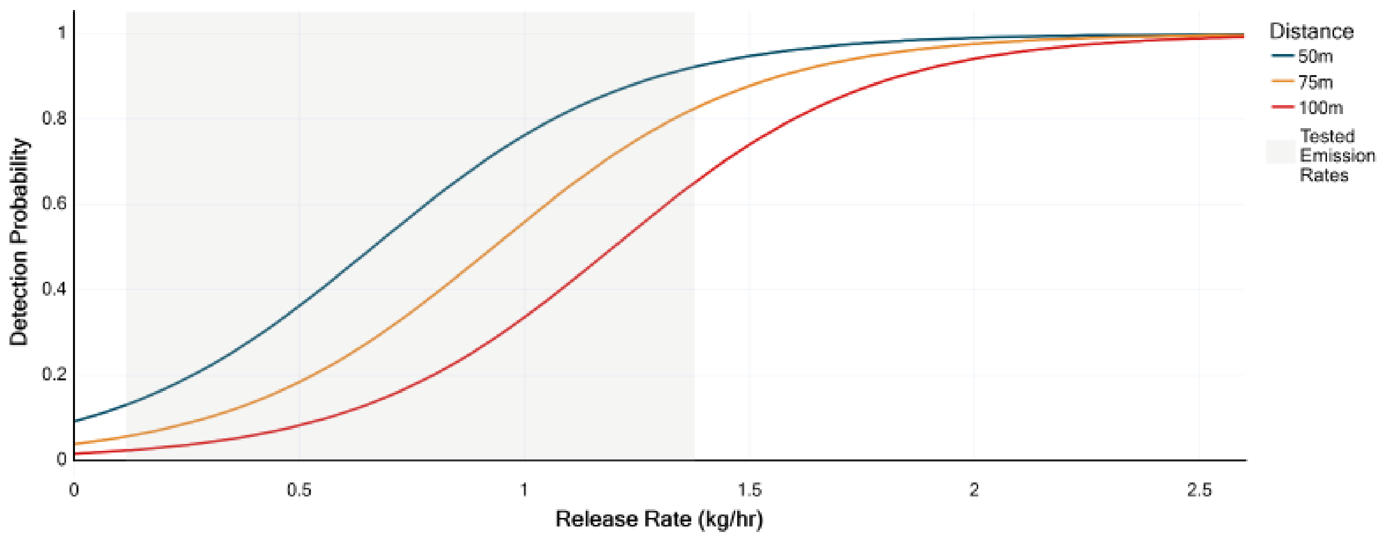


Figure 9 - Probability of detection at variable distance based on emission rate assuming favorable wind conditions

From a time perspective, the Highwood tests showed that the average time between when an emission starts and when the Qube system reports the emission to be between 14 and 19 minutes. The range is a function of the release rate and the distance between sensors and the release point (Table 2).

Release Rate (kg/h)	50m time to detect (minutes)	75m time to detect (minutes)	100m time to detect (minutes)
1.38	10	12	15
1	18	20	20
0.5	13	24	28

0.2	22	22	22
0.1	35	23	32
Average	**14**	**16**	**19**

Table 2 - Highwood controlled release testing time to detect

It should be noted that the times show above are between release and reporting. Relative wind variability and direction directly relate to the observability for any particular set of source and sensor positions, as plume measurements require the plume to pass over the sensor to be observed and directly affect time to detect.

4.2.2.2. [Content reserved for CBI]

4.2.3. Regulatory applications

Qube currently has five Alternative Fugitive Emissions Management Programs (Alt-FEMP) which have been approved by the Alberta Energy Regulator (AER) with Enhance Energy, Kiwetinohk, Tidewater, Tourmaline, and Ember Resources. The purpose of the Alt-FEMP is to allow operators to use alternative technologies which are capable of equivalent emissions reductions compared to prescribed annual or tri-annual leak detection and repair surveys.

The subsequent section describes our Alt-FEMP with Enhance Energy[4]. A detailed performance report can be found on the AER's Website and in the supporting documents[5] which describes the results of the Alt-FEMP project. This program has been active since 2021 and its status was changed from a pilot to a full-scale program in 2023. In 2021, a pilot project was established to test the effectiveness of an Alt-FEMP approved by the AER. The pilot project was conducted in a 140 km (north-south) by 100 km (east-west) quadrant positioned around Red Deer, Alberta. The region is typical of Alberta oil and natural gas production and has a mixture of older conventional and newer unconventional light oil and natural gas wells. The density of the wells in this region is very high, and the topography and land cover are relatively simple, consisting mostly of low-relief farmland. See Figure 10 for a map of the Alt-FEMP area.

---

[20] Benko et. al. (2023). Continuous Methane Monitoring: Equivalency Evaluation of Regulator-Approved Alternative Leak Detection and Repair Program in Alberta, Canada. SPE Annual Technical Conference and Exhibition. SPE-209973-MS
[21] Highwood Emissions Management, "Alt-FEMP Performance Report: Enhance Energy and Qube Technologies Single-Operator Pilot," March 2023. [Online]. Available: https://static.aer.ca/prd/documents/about-us/femp-enhance-alt-report.pdf.

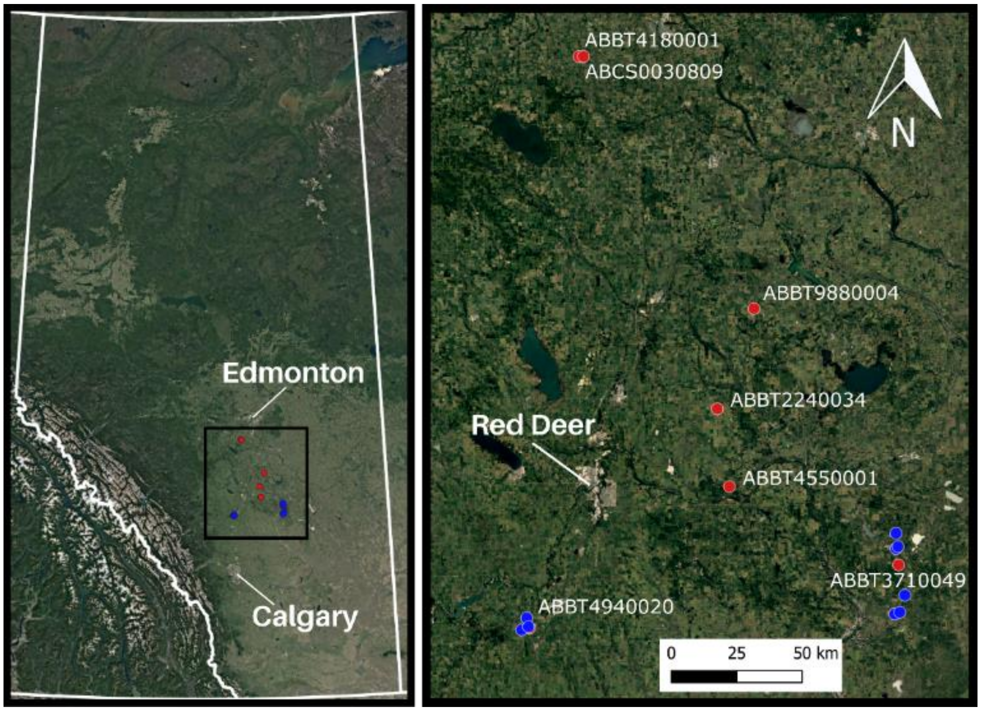


Figure 10 - Map of Alt-FEMP program area for Enhance Energy

A total of 16 facilities were included in the pilot project, with the primary facility types being conventional multi-well oil batteries and compressor stations. These facilities were selected for two reasons: (1) they represented the program area described above, and (2) they represented a range of facility types and sizes. In addition, the facilities had existing historical LDAR data, which would allow for a lookback to be performed to compare program efficacy to a traditional LDAR program using an OGI camera.

A total of 52 Qube IIoT devices were installed at the 16 facilities and started continuously monitoring for emissions in September 2021. A tracking tool was developed to document emission detections from the sensors, follow-up inspections as directed by the work practice outlined in LDAR-Sim and the Alt-FEMP application, and any repairs that were conducted. Figure 11 shows the work practice process modelled in LDAR-Sim and followed during the field pilot.

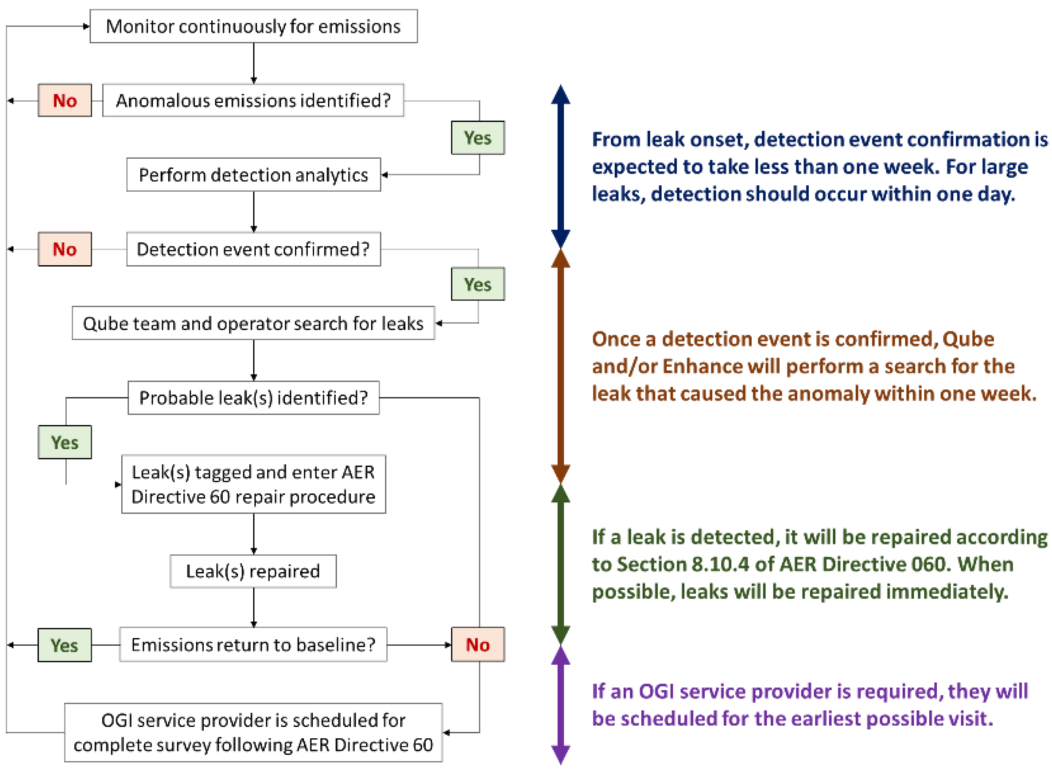


Figure 11 - CM work practice flow adopted during Alt-FEMP Pilot

During the pilot, Qube's continuous monitoring system recorded 213 detection events, with 36 classified as potential fugitive emissions. This real-time identification allowed for immediate responses, unlike traditional methods which rely on periodic surveys and can miss leaks for months. Follow-up inspections were conducted on 21 occasions, identifying 7 fugitive emission sources, primarily due to malfunctioning thief hatches and valves. Figure 12 shows an example of a thief hatch leak that was detected and subsequently remediated using data from the Qube system.

Figure 12 - Site rate and methane concentration detecting an open thief hatch during Enhance's Alt-FEMP with Qube's CM system

The program demonstrated the system's capability to rapidly detect emissions, with the average time between detection and follow-up inspections being 27 days. All seven repairs were completed within the stipulated timeframe, typically within 14 days.

At the end of the pilot project, simulations were conducted using an emissions modeling tool called LDAR-Sim based on the actual data collected during the pilot to estimate the emissions reductions associated with the Alt-FEMP, the prescribed regulatory program, and a baseline scenario with no LDAR program.

Figure 13 below presents the results of the LDAR-Sim model and compares three scenarios, (1) average daily emissions for the Enhance Qube-based Alt-FEMP (P_Enhance_AltFEMP), (2) average daily emissions for the prescribed regulatory OGI inspections (P_Regulatory_OGI), and (3) a baseline scenario with no LDAR program (P_none). Due to the quick detection and remediation times, the continuous monitoring program demonstrated reductions of ~89%, surpassing the ~30% reduction potential achieved by the regulatory program.

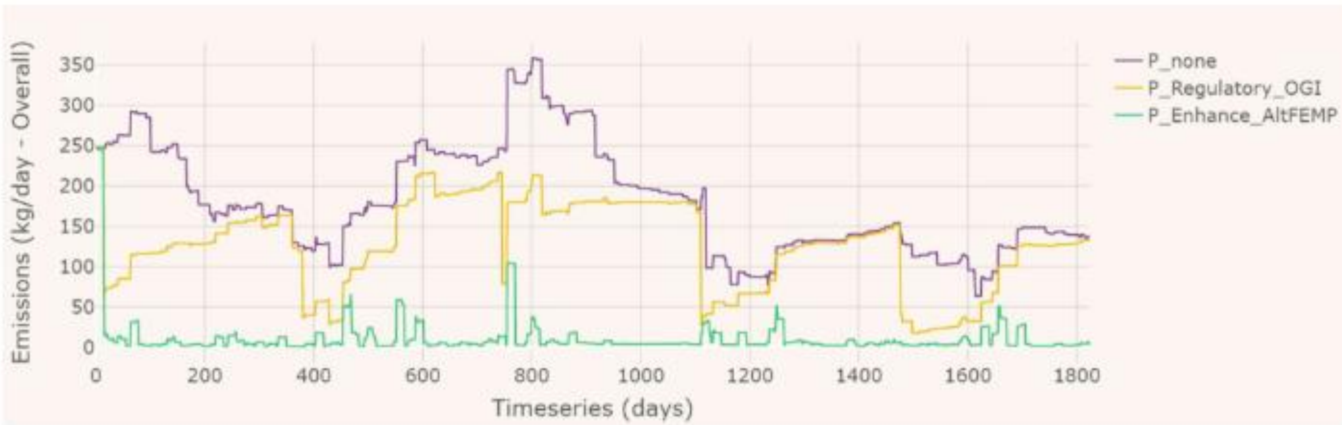


Figure 7. Timeseries of average emissions per day considering the 16 sites in scope. Comparison of programs based on the Enhance Qube-based Alt-FEMP (P_Enhance_AltFEMP), FEMP routine OGI inspections defined by Directive 060 (P_Regulatory_OGI) and annual emissions in the absence of an LDAR program (P_none). The cyclicity of the P_Regulatory_OGI time series is indicative of the dominant annual survey requirements of the modeled programs with the Alt-FEMP (P_Enhance_AltFEMP) showing a lack of cyclicity due to the continuous monitoring nature of the program.

Figure 13 - LDAR-Sim comparison of different LDAR programs for Enhance Energy including none, regulatory OGI and CM Alt-FEMP

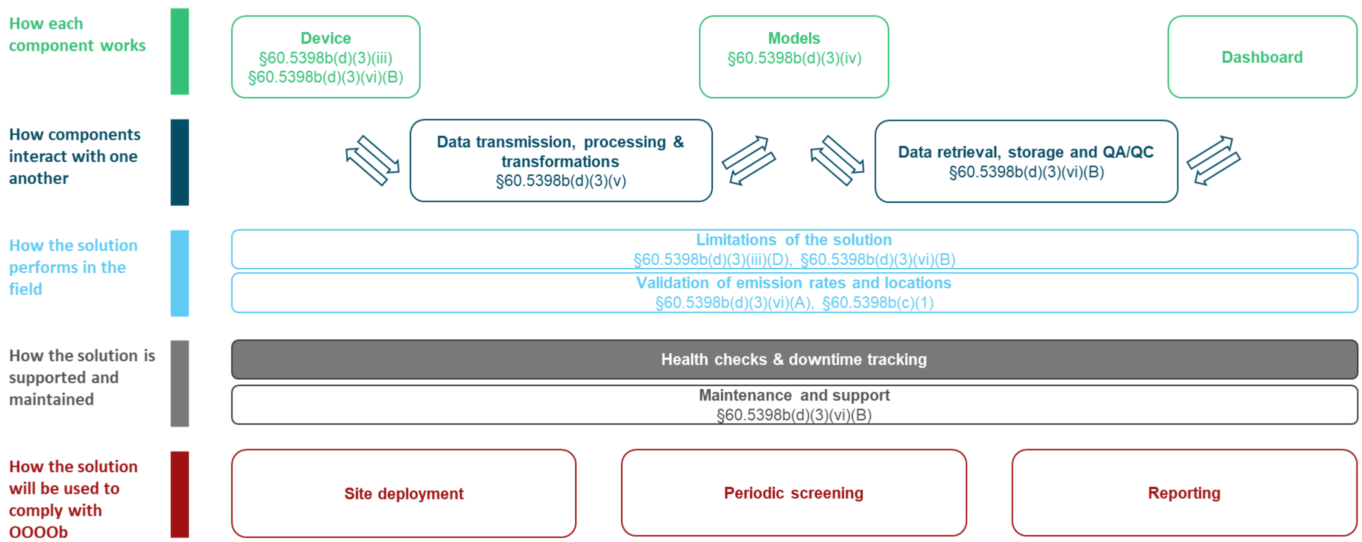
Moreover, the pilot highlighted the operational benefits of advanced technology in emissions monitoring. The Qube dashboard's real-time data visualization improved the efficiency of follow-up inspections and informed enhancements to Qube's platform. This continuous data collection and technological development are crucial for optimizing emissions management programs, leading to more precise emissions tracking and reporting, ultimately contributing to better environmental outcomes. Based on the success of the pilot program, the Alberta Energy Regulator issued a full-scale approval for this program in 2023.

4.2.4. [Content reserved for CBI]

5. How the solution is supported in the field

5.1. Health checks and downtime tracking

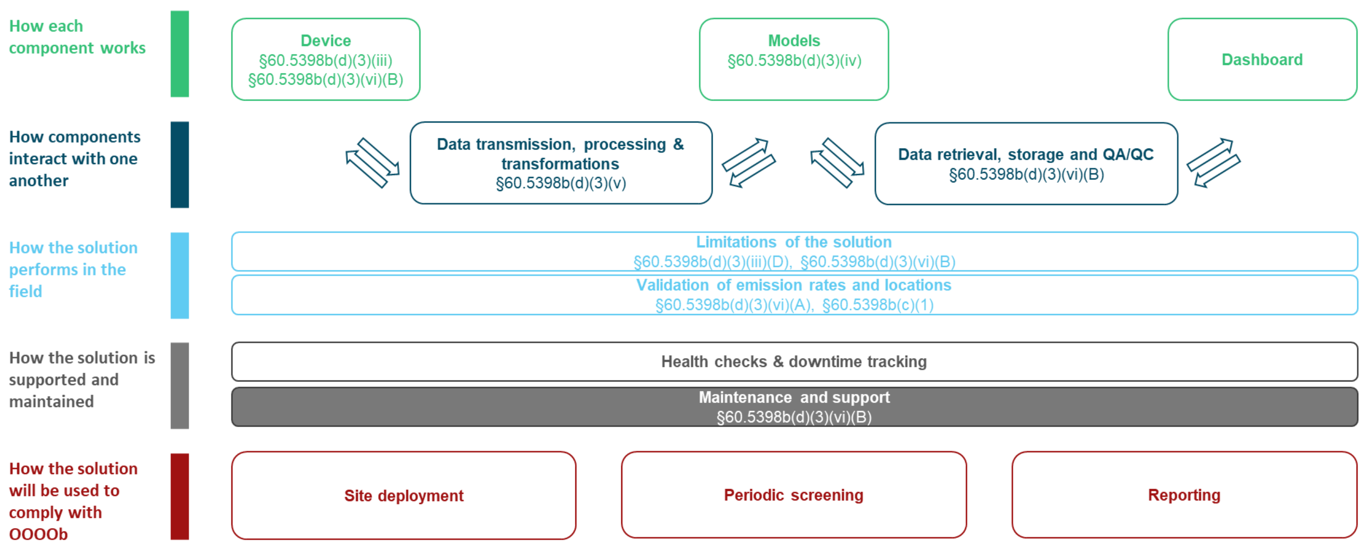
The following section details how Qube measures and tracks device downtime in line with EPA OOOOb regulations. Also included in this section is an overview of the device health checks that Qube's support team performs to ensure devices are operating optimally in the field.



5.1.1. [Reserved for CBI]

5.1.2. [Reserved for CBI]

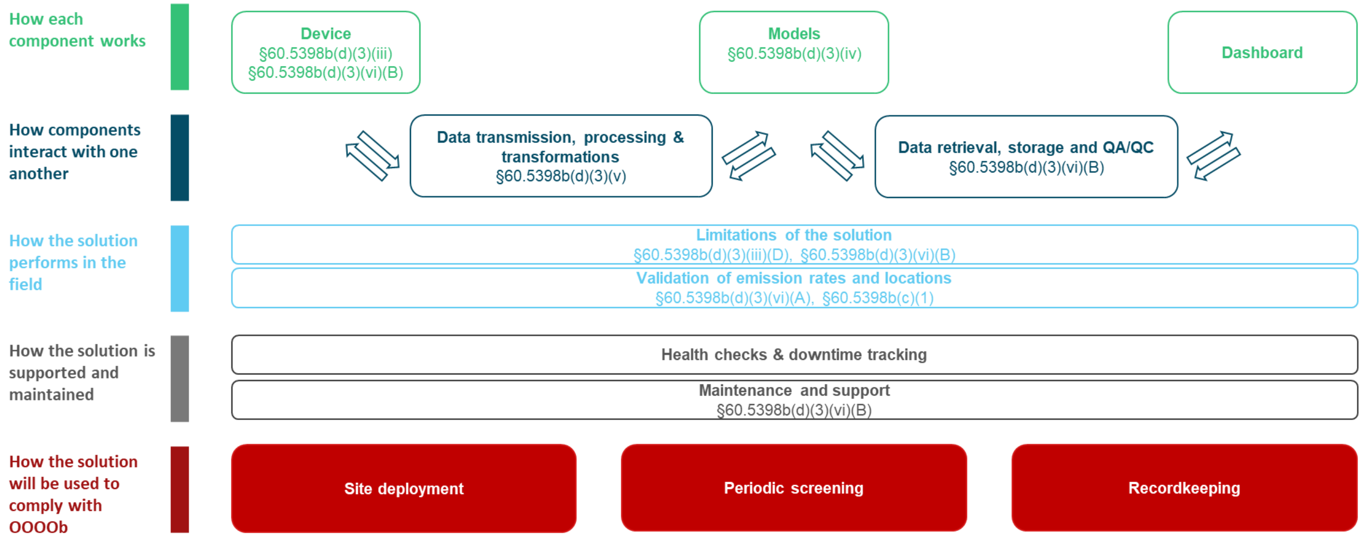
5.2. Maintenance and support



5.2.1. [Content reserved for CBI]

5.2.2. [Content reserved for CBI]

6. How the solution will be used to comply with OOOOb



Qube's periodic screening workflow can be represented by three processes: the site deployment, the periodic screening (which includes data collection, data processing, data reporting), and the recordkeeping.

6.1. [Content reserved for CBI]

6.2. [Content reserved for CBI]

6.3. [Content reserved for CBI]

7. References

[1] S. N. Riddick, D. L. Mauzerall, M. Celia, G. Allen, J. Pitt, M. Kang and J. C. Riddick, "The calibration and deployment of a low-cost methane sensors," *Atmospheric Environment,* vol. 230, p. 117440, 2020.

[2] W. Eugster, J. Laundre, J. Eugster and G. W. Kling, "Long-term reliability of the Figaro TGS 2600 solid-state methane sensor under low-Arctic conditions at Toolik Lake, Alaska," *Atmospheric Measurement Techniques,* vol. 13, no. 5, p. 15, 2020.

[3] M. Yadav, M. Kumar, S. Chaudhary, K. Yadav and A. Sharma, "A Review on Chemiresistive Hybrid Zinc Oxide and Nanocomposites for Gas Sensing," *Industrial & Engineering Chemistry Research,* vol. 62, no. 29, pp. 11259-11278, 2023.

[4] Figaro USA Inc., "TGS 2611-C00 - for the detection of Methane," Figaro Sensors, Rollling Meadows, 2022.

[5] Qube Technologies, "Innovating Methane Detection: The Role of Qube Technologies' Controlled Release Test Facility," in *SPE Methane Emissions Management for a Sustainable Future Workshop*, Banff, 2024.

[6] ABB Measurement & Analytics, "Data Sheet GLA132-GGA Greenhouse gas analyzer – Ultraportable," Quebec, 2021.

[7] A. Dumitru, "System and Method to Auto Calibrate and Auto Baseline a Pollutant Gas Detector". Canada Patent PCT/CA2024/050275, 6 March 2024.

[8] J. A. Pudykiewicz, "Application of adjoint tracer transport equations for evaluating source parameters," *Atmospheric Environment,* vol. 32, no. 17, pp. 3039-3050, 1998.

[9] C. A. Brereton, I. M. Joynes, L. J. Campbell and M. R. Johnson, "Fugitive emission source characterization using a gradient-based optimization scheme and scalar transport adjoint," *Atmospheric Environment,* vol. 181, pp. 106-116, 2018.

[10] F. Pasquill, "Atmospheric Dispersion Parameters In Gaussian Plume Modeling, Part 2 Possible Requirements For Change In The Turner Workbook Values," U.S. EPA, Research Triangle Park, North Carolina, 1976.

[11] D. T. Allen, A. P. Pacsi, D. W. Sullivan, D. Zavala-Araiza, M. Harrison, K. Keen, M. P. Fraser, A. D. Hill, R. F. Sawyer and J. H. Seinfeld, "Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers," *Environmental Science & Technology,* vol. 49, no. 1, pp. 633-640, 2015.

[12] A. R. Brandt, G. A. Heath and D. Cooley, "Methane Leaks from Natural Gas Systems Follow Extreme Distributions," *Environmental Science & Technology,* vol. 50, no. 22, pp. 12512-12520, 2016.

[13] W. J. Veigele and J. H. Head, "Derivation of the Gaussian Plume Model," *Journal of the Air Pollution Control Association,* vol. 28, no. 11, pp. 1139-1140, 1978.

[14] V. Isakov, T. Sax, A. Venkatram, D. Pankratz, J. Heumann and D. Fitz, "Near-field dispersion modeling for regulatory applications," *Journal of the Air & Waste Management Association,* vol. 54, no. 4, pp. 473-82, 2004.

[15] Qube Technologies, "System and Organization Controls (SOC) 2 Type 1 Report for Qube," Laika Compliance, Arlington, 2023.

[16] Qube Technologies, "Validation of Qube Ambient CH4 Concentration Readings," Calgary, 2022.

[17] Qube Technologies, "Qube Solution Specifications," Calgary, 2024.

[18] Colorado State University Methane Emissions Technology Evaluation Center (METEC)., "Continous Monitoring Final Report: Solution A," Fort Collins, 2022.

[19] Highwood Emissions Management, "Qube Technologies Continuous Monitoring Probability of Detection: Results from independent single-blind controlled release testing," August 2022. [Online]. Available: https://highwoodemissions.com/wp-content/uploads/2022/09/2022-08-25_Qube-Probability-of-Detection-White-Paper.pdf.

[20] T. Benko, A. MacGregor, E. Wen, T. Fox and B. Moorhouse, "Continuous Methane Measurement: Equivalency Evaluation of Regulator-Approved Alternative Leak Detection and Repair Program in Alberta, Canada," *SPE Production & Operations,* vol. 38, no. 3, pp. 383-390, 2023.

[21] Highwood Emissions Management, "Alt-FEMP Performance Report: Enhance Energy and Qube Technologies Single-Operator Pilot," March 2023. [Online]. Available: https://static.aer.ca/prd/documents/about-us/femp-enhance-alt-report.pdf.

[22] Qube Technologies, "Qube Installation Guide (v3.1)," Calgary, 2024.

[23] Qube Technologies, "Qube Dashboard Training Manual (v1.0)," Calgary, 2024.

[24] Qube Technologies, "Qube Preventative Maintenance Manual (v1.1)," Calgary, 2023.