



Final Outcomes Report

Public Version

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Methane Imaging Solution for Continuous Leak Detection and Quantification for Tank Emissions and Facility Monitoring

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Public Abstract (non-confidential)

“Methane Imaging Solution for Continuous Leak Detection and Quantification for Tank Emissions and Facility Monitoring”

The project included the year-round operation of a continuous methane monitoring camera at eight oil and gas sites and deployment at 80 sites for shorter periods. The deployments demonstrated the ability of the Kuva camera to operate reliably under all weather conditions, to automatically detect and alert on methane emission events, to quantify emissions and the feasibility of using a relocatable camera solution to determine if emissions from uncontrolled tanks are within limits. Unexpected emissions from equipment malfunctions were detected and the ability to reliably pinpoint emissions to its source based on images enabled efficient root-cause analysis and repair.

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1 Executive Summary

The Kuva methane monitoring camera is a continuous monitoring solution for fast detection and quantification of methane emissions at oil and gas sites. At the start of this project the solution (consisting of camera, tower and cloud) was at a prototype stage, ready for field demonstration (TRL 7). Throughout the course of the project the solution was continually improved and successfully advanced to full commercial stage (TRL 10).

The main objective of the project was the demonstration of reliable, continuous operation, automatic leak detection and quantification in year-round installations as well as in relocatable installations at sites with uncontrolled tanks. Additional objectives were to establish leak rate quantification accuracy and to demonstrate the use of the solution under the AltFEMP regulatory program.

Kuva conducted controlled release and metered tests at three different types of sites across all seasons, tested the camera for weeks at a time at 80 upstream gas sites and installed 8 cameras long-term (more than one year) at multiple upstream and midstream sites.

The project met its goals for quantification accuracy, exceeded goals for detection sensitivity and met the goal for an Alt-FEMP trial. The solution successfully demonstrated continuous, automatic leak detection but fell short on the numerical goals for camera uptime during the project. Changes made to the camera hardware led to an improved, second-generation camera that has since met the uptime goal in subsequent deployments.

The project proved to be an excellent opportunity for learning and iterative improvement of the overall solution and it inspired numerous design refinements and changes. For example, the tower used initially to install cameras was expensive and impractical for fast installation. This inspired the development of a fast-install tower, which has earned very positive feedback from operators and installers alike. The cloud solution and user interface were improved in part based on feedback from operators. Camera failures of early versions led to design changes and related reliability improvements. Camera remote and self-diagnostics were significantly improved. Kuva's suitability for the Canadian climate was confirmed through this project with operations throughout all seasons, ranging from snow and extreme cold (below -40° Celsius) to smoke from wildfires in the summer.

The project achieved what is believed to be a world's first regulator-approved equivalency of continuous methane monitoring cameras through the Alberta Energy Regulator's Alternative Fugitive Emissions Management Program approval ("AltFEMP") pertaining to Directive 60's methane monitoring requirements, supporting emissions reduction action, innovation and operational excellence for the industry.

The overarching goal of this project was to support advancing Kuva's low-cost continuous methane monitoring camera, cloud solution and accessories from TRL 7 to TRL 10. This was successfully achieved with the solution achieving first commercial sales in July 2021 and broad commercial availability in 2023.

Another key insight from the project was a confirmation of the prevalence of intermittent emissions from malfunctions, especially from tanks and flares. These tend to get missed by conventional OGI inspections and are therefore unaddressed. Moreover, establishing the root cause of intermittent tank emissions, especially at sites with VRUs, can be very time-consuming and expensive. Discussions with operators during the project led to a deeper understanding of cost-benefit of the solution. While replacing the cost

of frequent OGI inspections provides a tangible benefit, an even larger benefit is the significant cost reduction in identifying, analysing and establishing root-cause of intermittent emissions events by eliminating the need for frequent site visits and reducing the need for complex engineering analysis, especially at sites with VRUs. As the number of sites that will require VRUs is expected to increase significantly under strengthened methane regulations, the commercial incentive to adopt Kuva solutions is expected to grow.

Very significant environmental benefits for Alberta are expected for the coming years as a result of the commercialization of the technology. While the solution is a measurement solution and therefore an enabling technology, fast detection of emissions is essential to achieve quick repair and therefore emissions reductions.

2 Project Description

2.1 Overview on technology to be demonstrated

The image-based methane detection technology on which this project is based has been developed from 2017 to 2020 with support from an ERA grant (O160169) as well as with NRC-IRAP support. At the start of this project, it had been demonstrated in a laboratory setting and in brief field deployments.

While the camera technology is based on infrared detection of methane emissions, the underlying physical principle is fundamentally different from conventional thermal imaging cameras. Thermal infrared cameras (such as the FLIR GfX320 and FLIR GF77a) measure thermal infrared emissions from scene background as well as from gas plumes. Significant thermal emissions from a scene background and from gas itself can only be observed in the IR spectral range of $3\mu\text{m}$ wavelength and higher. While these technologies are proven, they are expensive, require sophisticated cooling and they have been hard to automate as machine vision algorithms frequently create false positive detections. Moreover, their quantification accuracy is low as the underlying detection mechanism is based on measuring temperature differences instead of measuring the amount of gas present.

The Kuva solution detects and measures the presence of hydrocarbon gases directly by means of differential absorption spectroscopy of reflected or directly transmitted IR light. The underlying physical principle is well known and open path detectors using this detection principle are widely available and used in the oil and gas industry for gas safety applications. Instead of using a dedicated illuminator as a light source like an open path detector, the Kuva solution uses ambient solar illumination in conjunction with sophisticated image processing algorithms.

Key benefits of this approach are:

- Use of widely available and comparatively low-cost infrared semiconductors enabling much lower system cost
- No complex cooling required, resulting in lower cost, ruggedness and much longer lifetime
- Ability to directly measure the amount of gas present for every pixel (no extrapolation from temperature differences)
- Better suited for automation by machine vision due to a lower prevalence of false positive alarms as temperature signals do not confuse the detection algorithms
- the camera does not confuse water vapor or CO₂ with hydrocarbons

The Kuva camera and cloud solution provide six core functions:

- 1) automatically detect methane and VOCs
- 2) present detected gas as a colour overlay on an image of the environment
- 3) automatically generate alarms
- 4) quantify and report emission rates
- 5) visually pinpoint the location of a leak and allow an operator to assess and plan repairs accordingly, and
- 6) validate the repair based on lack of emissions.

The Kuva GCI360 Camera scans each region-of-interest repeatedly to detect and measure emissions from a distance, while pinpointing emissions to their source. Emissions images are processed on the camera in real-time and uploaded over an ethernet connection or via LTE cell modem. A close-up view of the Kuva camera is shown in the image to the right.



2.2 Background of the Project

Kuva Canada Inc. teamed up with industry partners Whitecap Resources and Cenovus Energy, along with the CMC Research Institute, to demonstrate Kuva's low-cost, automatic methane imaging solution for continuous detection and quantification of tank and other emissions at natural gas wells and for facility monitoring at gas plants.

Tank emissions are one of the main contributors to upstream methane emissions in Alberta; they can fluctuate widely and are often mis-characterized when evaluated using engineering calculations based on oil to gas ratio and site specific configuration. This project intended to demonstrate: (1) a relocatable camera site assessment solution especially for quantifying tank related emissions; and (2) permanently installed cameras at well pads and gas plants to quickly detect equipment malfunctions, to demonstrate regulatory compliance and for replacement of manual leak detection. The project included a comprehensive measurement study of 80 upstream sites in a variety of production regions and tank construction styles to further the understanding of well site emission characteristics. Permanent camera installation at eight upstream sites as well as gas plants and tank farms were planned for more than one year each.

Leak mitigation was conducted at two sites because of emissions detected by the Kuva Camera. The project demonstrated Kuva's solution within the "detect - quantify - mitigate" lifecycle and allowed Alberta operators to first understand the emissions problem, and cost-effectively mitigate the emissions, and then validate the emission reductions. An industry-wide strategy focused on accurately quantifying tank vents and then mitigating the largest emitters for a 45% overall reduction may both be a low-cost way to achieve Canada's methane reduction goals as well as to position Alberta as a leader and innovator with visual, quantified evidence of its clean natural gas industry.

2.3 Project Objectives

The project had three main objectives:

- A. Establish and improve leak rate quantification accuracy under all environmental conditions.
- B. Demonstrate reliable, continuous operation, automatic leak detection and quantification at well sites with relocatable and installed solutions.
- C. Demonstrate reliable, continuous facility leak detection as an Alt-FEMP pilot project with AER.

The most important objective for commercialization was to demonstrate reliable, continuous operation and automatic leak detection as this is the core of the product offering. Until 2024 quantification has only been requested by customers in rare cases, however it is an emerging functionality with view on potential future methane intensity certification of oil and gas production.

The work plan for these three primary objectives is outlined in the table below.

Table 2-1 Project Objectives

	Objective	Tasks
A	Establish and improve leak rate quantification accuracy under all environmental conditions	<ol style="list-style-type: none"> 1. Conduct a comprehensive test release program with one camera at CaMI throughout the project to gather controlled release data for algorithm validation under all environmental conditions and various representative gas mixtures and flow rates. See below for test release program test parameter. 2. Improve accuracy of leak rate quantification algorithms based on results
B	Demonstrate reliable, continuous operation, automatic leak detection and quantification at well sites with relocatable and installed solutions	<ol style="list-style-type: none"> 1. Monitor approximately 104 well sites with 11 relocatable systems for a period of approximately two weeks each in order to study emissions profiles for a wide range of tank types and production geologies in Alberta. Phase I to assess 24 sites. Phase II to assess approximately 80 sites. 2. Install cameras for a period of one year at eight upstream sites. 3. Determine and implement tank vent mitigation at four well sites.
C	Demonstrate reliable, continuous facility leak detection, with one as an Alt-FEMP pilot project with AER	<ol style="list-style-type: none"> 1. Installation of a total of eight cameras in multiple locations (for example two gas plants and one tank farm) for a one year period. 2. Integrate the automatic detection and repair validation into industry partner workflow. 3. Application as an Alt-FEMP pilot project with AER. 4. Continuous hardware and software improvements based on operator feedback and algorithm updates.

2.4 Performance Metrics

The performance metrics as determined at the project outset are listed in the table below.

Table 2-3 Success Metrics

Success Metric	Commercialization target	Project Target	Achievements Pre-Project
Quantification for small steady leaks; wind speed 1-5 km/h	+30 %	+30 %	N/A
Quantification for large steady leaks; wind speed 1-5 km/h	+20 %	+20 %	N/A
Quantification for transient leaks; wind speed 1-5 km/h	+25 %	+25 %	N/A
Demonstrate reliable, continuous operation of camera, mast, power supply and communications solution under all weather conditions	Continuous camera and cloud uptime operation @ 99%	Continuous camera and cloud uptime operation @ 99%	4 days of continuous operation
Demonstrate suitability to replace LDAR in an Alt-FEMP pilot project.	Accepted by AER	Accepted by AER	No applications submitted to AER.

Additional valuable metrics that were considered after the project commencement are below.

Table 2-4 Additional Success Metrics

Success Metric	Commercialization target	Project Target	Achievements Pre-Project
90% Probability of detection at 20m distance	5kg/h per m/s wind	10kg/h per m/s wind	N/A

2.5 Changes Throughout Project

The acquisition of Project partner NAL Resources by Whitecap Resources closed January 4, 2021. This did not materially affect the project and Whitecap continued to serve as a valuable site host partner.

Multisensor Scientific Inc and subsidiary Multisensor Canada Inc. as the project proponent was known at the beginning of the project, changed their names to Multisensor Scientific inc. dba Kuva Systems Inc. and Kuva Canada Inc. soon after the start of the project.

2.6 Technology Risks

The original technology risks as per the project proposal are tabulated below. While these risks did prove valid, the mitigation strategies were appropriate. Internal Processes were added and refined as needed, and included additional significant quality and reliability testing and validation that was conducted throughout the course of the project.

Table 2-5 Evaluation of Risks

Key Risks	Prob	Imp.	Risk	Risk Mitigation and Response Strategy
Camera hardware is delayed	Low	Mid	M	Camera has been under development since 2016 and passed Draeger's intensive technical due diligence. Draeger has offered access to its global gas detection experts for technical or manufacturing assistance. Extensive validation and testing prior to installation will ensure performance.
Software is delayed	Mid	Mid	M	Iterative software development process; bugs can be fixed immediately. Skilled and experienced soft team. Over-the-air update capability for cameras. Extensive validation and testing plans will ensure performance.

Other risks that were not identified at the outset were regarding:

- whether the market requirements would change throughout the course of the project.

At the outset of the project, the market was expected to require a 24/7 (night-time) compatible device, which posed a risk because the active illumination mode had further development needs that needed to be addressed. What transpired, through testing and evaluation, was an acceptance by potential clients that daytime only monitoring is adequate as it is a significant improvement on the current manual OGI and that customers preferred a lower-priced daytime only camera over a potential higher priced solution that would have included nighttime monitoring.

3 Project Work Scope

3.1 Methodology

The project was broken down into objectives with various components to each objective, some of which evolved over the course of the project. As mentioned in the Project Objectives section, the objectives were:

- Objective A: Establish and improve leak rate quantification accuracy under all environmental conditions
- Objective B: Demonstrate reliable, continuous operation, automatic leak detection and quantification at well sites with relocatable and installed solutions
- Objective C: Demonstrate reliable, continuous facility leak detection, with one as an Alt-FEMP pilot project with AER

The components of each objective are described below.

3.1.1 Objective A

Objective A was to “Establish and improve leak rate quantification accuracy under all environmental conditions” by completing the following tasks:

1. Conduct a comprehensive test release program with one camera at CaMI throughout the project to gather controlled release data for algorithm validation under all environmental conditions and various representative gas mixtures and flow rates.
2. Improve accuracy of leak rate quantification algorithms based on results leading to a commercial software release in September 2022

The test release program was done using single blind releases from various locations at the test facility and under various rates, durations, and compositions. The ground truth data was compared with the detection results and true positive and false negative detections were assigned to each test release. A double blind test was performed near the end of the project where release data was compared to detection performance in order to determine a Probability of Detection curve.

In addition to controlled testing at CaMI, partway through the project, Kuva was invited to install cameras at the Emissions Test Centre (ETC), as part of the Natural Gas Innovation Fund (NGIF), which consists of several facilities. Kuva installed a total of 3 cameras at 2 locations. Those locations were:

- An operating Gas Plant in the Edson region
- An inactive well site in the Saddle Hills region

These sites were metered for emissions and so served as additional test sites with valuable ground truth data that helped validate our quantification algorithms.

There were also a number of sites that were part of the relocatable deployments where ground truth data was also collected, and are captured under Objective B using other relocatable systems. These deployments were part of PTAC and NGIF projects that ran in conjunction with this project, and leveraged other technologies simultaneously.

3.1.2 Objective B

Objective B was to “Demonstrate reliable, continuous operation, automatic leak detection and quantification at well sites with relocatable and installed solutions”. Accomplishing this objective was completed over various phases and projects, which included:

- Phase 1: Initial site screening of 24 sites operated by our project partners Cenovus Energy and Whitecap Resources
- Phase 2: Broad deployment of systems for temporary installation at 56 sites (originally 80), which included:
 - o PTAC tank vent study
 - o NGIF Round 6 Project which had 36 sites in Alberta and BC
 - o NGIF Emissions Test Centre (ETC) deployment of 3 systems
- Long-term deployment of 8 systems for a period of more than one year each

Deploying in phases allowed for multiple cycles of iteration of both hardware and software. Reliable, continuous operation was measured by uptime and troubleshooting visits to site.

3.1.3 Objective C

Objective C was to “Demonstrate reliable, continuous facility leak detection, with one as an Alt-FEMP pilot project with AER”. This was accomplished by determining suitable potential sites with partner Whitecap Resources (NAL Resources at the time), gathering sufficient supporting data from controlled testing, and having Whitecap apply to the Alberta Energy Regulator for the Pilot Alt-FEMP program.

3.2 *Technology development, installation and commissioning description*

The project included the production, delivery, and deployment of 28 systems, which consisted of:

- Kuva GCI360 camera
- Relocatable tower
- Relocatable solar power supply

One of the requirements for the system was that installation could be completed by two people, in less than a half day, could be done virtually anywhere and would result in a system that could operate continuously for months without the need for intervention. All of these requirements were ultimately achieved through proper design, test and validation of each of the three major components, and their integration as a complete system.

Because the system was designed to be relocatable, the development and installation process was able to be refined and improved incrementally and many different methods of installation were trialed. For instance, the Kuva Camera was initially installed on a relocatable tower that was purchased from a vendor and required no crane or other equipment to install. This resulted in an effective, yet manually intensive process that led to the development of the Kuva Tower.

3.2.1 Hardware

As per objective B, more than 50 sites were monitored for a period of 2 weeks or more. Each deployment went through this installation, commissioning and decommissioning process and was refined throughout. Initially the project used towers that were 9m tall with solar power supplies that were mounted to the towers. See the image below for an example of the initial designs.



Figure 3-1 Original Kuva Camera with Off the Shelf 9m tower

After many installations, it was determined that improvements to the tower could be made because the original was too short, and too laborious to install. This led to the design of the Kuva tower and solar skid, which was nearly 4m taller and able to be installed using precast ballast blocks instead of manually installed cinder blocks to weigh the camera down. Below is an image of the complete system as of the end of the project.



Figure 3-2 Kuva Camera on Kuva Tower with Solar Skid

3.2.2 Software

Along with the hardware, there are multiple layers of software:

- Camera software
- Cloud database and APIs
- User interface
- Algorithms

3.2.2.1 Camera Software

The software that controls the camera movement and data collection, IoT connection and algorithms run in specialized containers that can be remotely updated. One improvement of note throughout the project was the collection speed per image and the site coverage. Initially only a single Point of Interest (POI) was able to be configured on the camera at a time and it would take approximately a minute to collect. By the conclusion of the project, six POIs were configurable and the time to collect an image collection was reduced by approximately 65%.

3.2.2.2 Cloud Software and APIs

Application Programming Interfaces (APIs) that manage the communication between various systems (device to cloud to user interface, for example) were developed to integrate all of the various components within the system. This also lays the foundation for allowing Kuva to provide customers with direct access from their own data management and operational systems to Kuva data.

3.2.2.3 User Interfaces

The Kuva Portal allows users to see, manage, configure and control the devices associated with their account and easily access any emissions events. Once a camera gets installed and plugged in, it connects to the cloud via the cell modem and immediately becomes accessible to a user with access to it on the Kuva Portal. In order to commission a camera after install, a panorama image can be collected at the click of a button and all the camera settings can be set. These which include:

- Latitude and Longitude (in order to display the location of the system on the customers dashboard)
- Site name
- Scan schedule (start scanning at sunrise, and end at sunset)
- Time zone
- Points of interest

See below for screenshots of the dashboard used to commission the deployments:

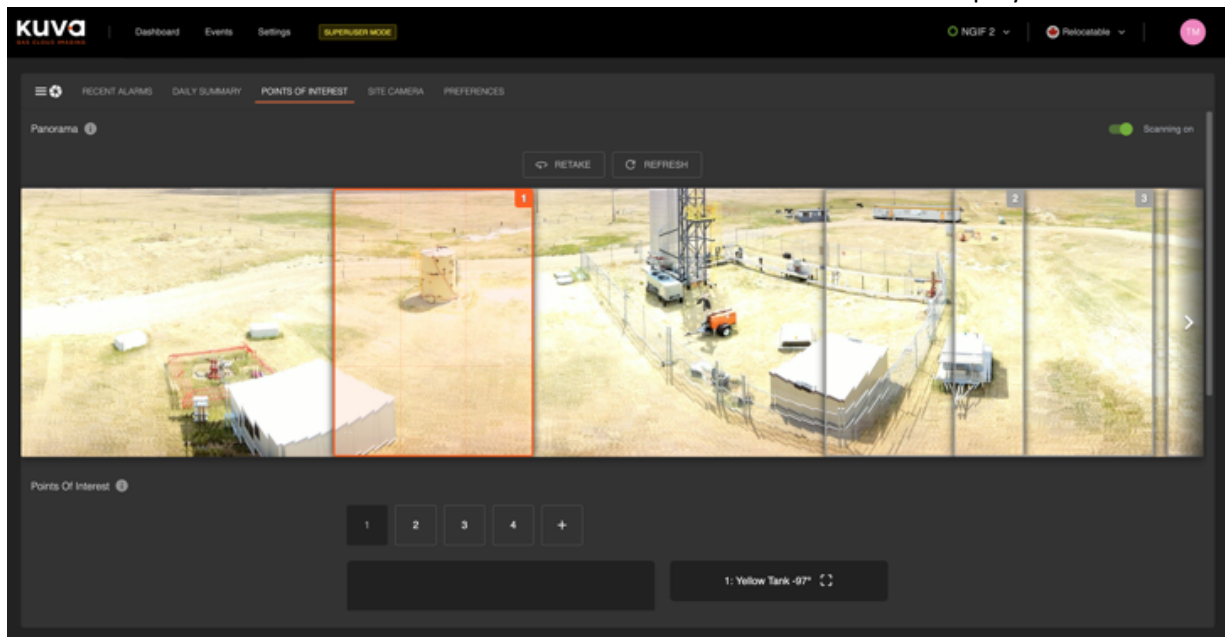


Figure 3-3 User Interface: Setting Points of Interest

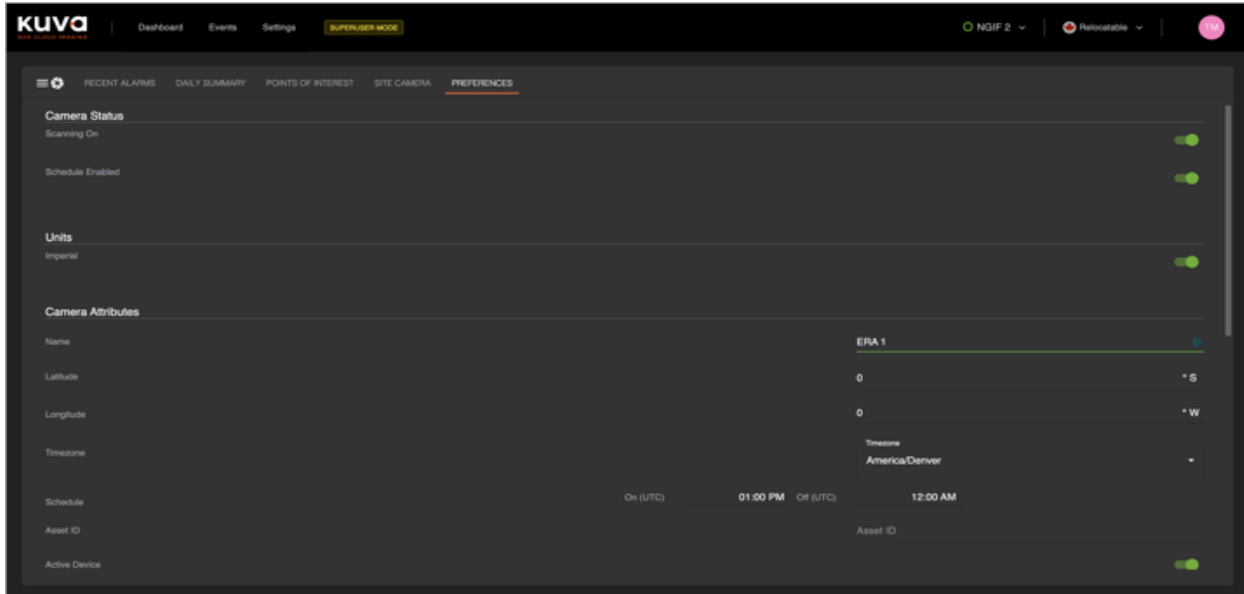


Figure 3-4 User Interface: Setting Camera Preferences

Once configured, the camera can be left to scan repeatedly and continuously for emissions. All visible images are immediately accessible on the dashboard.

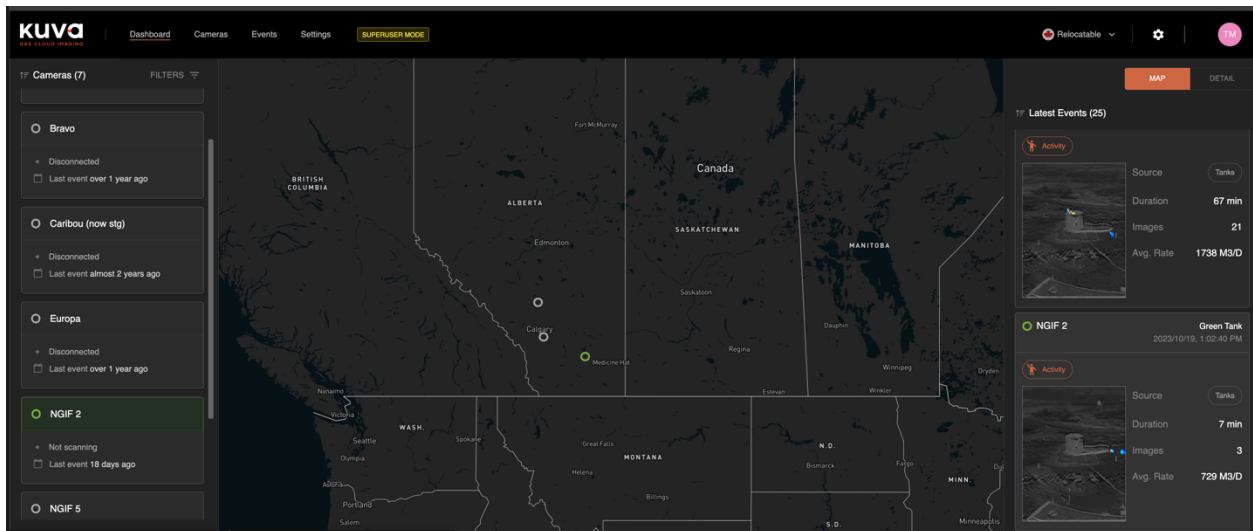


Figure 3-5 User Interface: Kuva Dashboard

3.3 Overall Project achievements relative to stated objective and performance metrics

The project achieved most of its stated metrics at the end of the project (objectives A and C) or shortly thereafter (Objective B). The most important achievement was long-term reliable operation. During the project the goal of 99% uptime was missed, however it was achieved subsequently based on further improvements to camera and cloud solution. A key missed objective was the characterization of quantification under all environmental conditions. This turned out to be a much more complex problem and it was not reflected in the metrics, which only reflect benign conditions and short distances. Table 3-1 below shows an outline of the project achievements.

Table 3-1 Success Metrics Evaluated

Success Metric	Objective	Project Target	Project Achievement
Quantification for small steady leaks; wind speed 1-5 km/h	A	+30 %	1.5 to 27%
Quantification for large steady leaks; wind speed 1-5 km/h	A	+20 %	26%
Quantification for transient leaks; wind speed 1-5 km/h	A	+25 %	17%
Demonstrate reliable, continuous operation of camera, mast, power supply and communications solution under all weather conditions	B	Continuous camera and cloud uptime operation @ 99%	Continuous camera and cloud uptime operation @ 90% of sites
Demonstrate suitability to replace LDAR in an Alt-FEMP pilot project.	C	Accepted by AER	Accepted by AER
90% Probability of detection at 20m distance	A	10kg/h per m/s windspeed	3kg/h per m/s windspeed

3.4 Results

Under Objective A a series of controlled release blind-tests was conducted that demonstrated a 90% probability of detection of 99.7 m³/day per m/s wind. These tests as well as uncontrolled, metered tests at the ETC gas plant and the ETC well pad were used to develop, refine and validate emissions quantification algorithms (see Table 3-1 above for results).

Under Objective B Kuva cameras were deployed for relatively short periods of on average 5 weeks at 80 upstream sites across Alberta. Kuva deployed 8 systems for one year or more at facilities in Central Alberta and Grande Prairie. The field experience resulted in ongoing iterative improvements to the camera, the cloud solution as well as the tower system which improved uptime as well as speed and ease of deployment.

Under Objective C Kuva and Project Partner Whitecap Resources applied and got approved under an AltFEMP program and Kuva installed and operated 3 cameras at a Gas Plant for more than 2 years. The operation group at the plant successfully integrated Kuva notifications into their workflow which enabled them to follow up on any detected emissions.

3.4.2 Objective A

The two main metrics for the Objectives were to determine the probability of detection under a given scenario and to evaluate the accuracy of the quantification measurements. This was done at three venues under different conditions. Two scenarios were controlled release testing at non-operating sites, and the

third was at an operating site with typical background emissions and randomly occurring fugitive emissions, as often is the case at normal operating facilities.

3.4.2.1 Controlled Testing at CMC Field Research Station in Brooks, Ab

Over 30 days of controlled release tests were completed at the Brooks facility with the goal to cover as many environmental conditions as possible. Testing was conducted using natural gas and propane as the released product and was performed over all seasons, spanning more than a two year period. While initial tests were used to help refine algorithms, the final tests were used to evaluate the system. The final test was conducted in a double-blind format where the release location, duration, start time and flow rates were unknown over a two month period.

This final test plan consisted of 8 days of releases with varying flow rates and environmental conditions. Kuva compiled accurate wind data to create a Probability of Detection Curve based on the varying environmental conditions. As of the completion of the project in May 2023, the Kuva camera was able to achieve a 90% probability of detection of 99.7 m3/day (3kg/h) per m/s wind and a 50% probability of detection at 73.5 m3/day (2.2kg/h) per m/s wind.

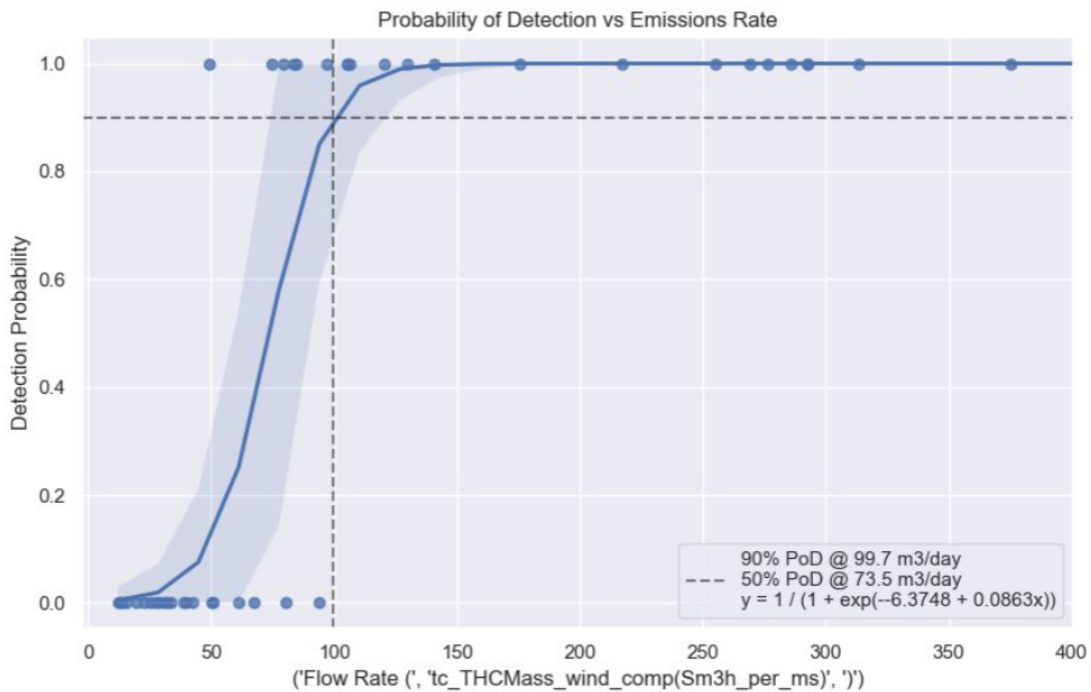


Figure 3-7 Probability of Detection Curve (May 2023)

Through multiple cycles of quantification algorithm development, Kuva was able to significantly improve its quantification accuracy. During the various test programs completed in 2023, some events were quantified. An example of a test release that was quantified during this trial occurred on April 4th, 2023. The release rate for this test was 1,300m3/d and it was estimated as 1,633m3/d by Kuva, which is a difference of 26% (see Figures 3-8 and 3-9 below).

Flow Meter vs Kuva Quant

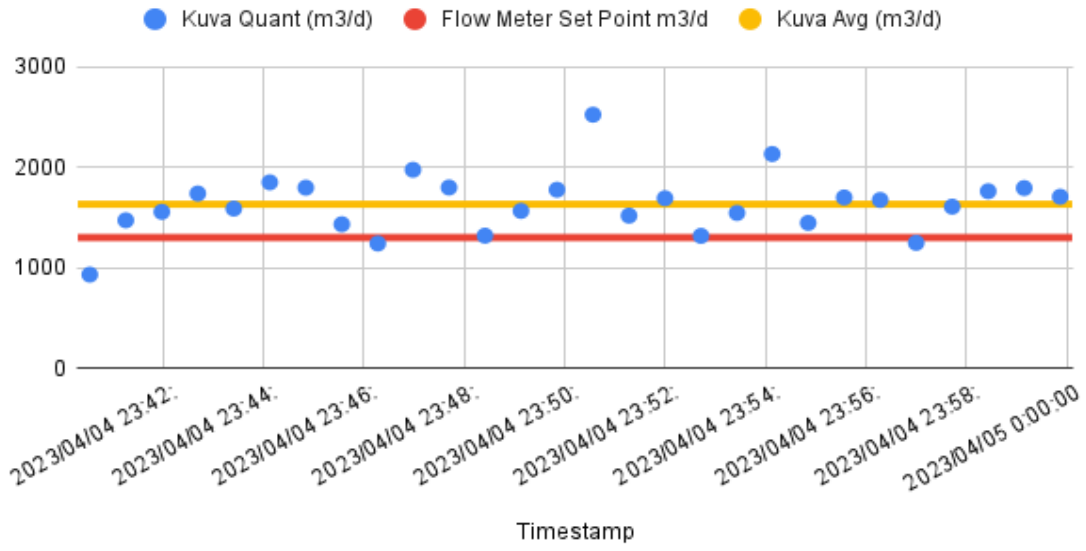


Figure 3-8 Controlled Release Testing: Comparison of Quantification

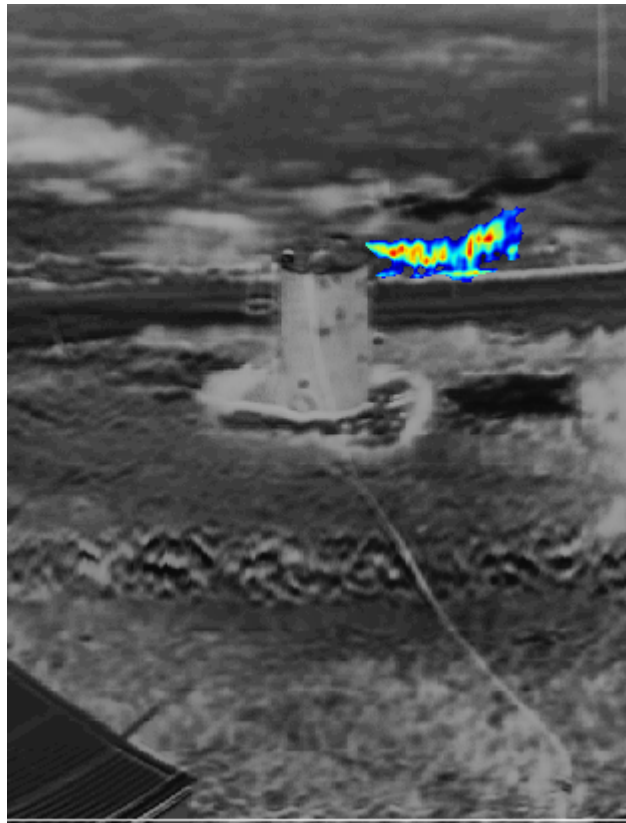


Figure 3-9 Controlled Release Testing: Image from April 4, 2024 Test

3.4.2.2 Uncontrolled Metered Testing at ETC East Edson Gas Plant

Two Kuva cameras were installed at the Emissions Test Centre (ETC) Gas Plant near Edson, AB. The cameras were installed at opposite ends of a catwalk on a tank battery. Emissions from each tank were metered for a portion of the installation. See photograph of one of the cameras and a schematic of the layout below with the green dots as the Kuva cameras.

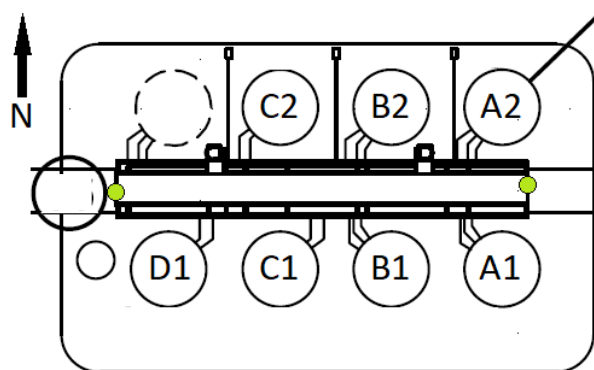


Table 3-2 below the plot shows the integrated rates (i.e. the emitted volumes) as metered and as estimated by Kuva Quantification over the entire 10-hour period.

Table 3-2 Summary of Tank Release Volumes - Kuva vs. Flow Meter (June 1, 2022) at ETC Gas Plant

Tank Type	Kuva Q (m ³)	Flow Meter (m ³)
Produced Water	235.2	289.8
Slop	8.2	3.5
Condensate	0.06	0.3
Total	243.4	293.6

The total volume estimated by Kuva (243m³) was 17% less than the metered value (294m³) over the same 10-hour timespan.

Figure 3-12 below shows an example detection image that was used to quantify emissions from June 1st and was taken at 17:22 MDT from the west camera. In this image tanks C2, B2, A2 (near to far) are shown to the left of the catwalk. While two distinct plumes can be seen in the image, the emissions at the time were emitting from four of the tanks as confirmed by the flow meters.

One other valuable piece of situational context that is captured by the camera is that a tanker truck is visible in the RGB and was at the tank farm's load station at the time of this large, planned release. This visual capability to correlate emissions with any human activity, trucking or maintenance occurring at the site is a key benefit of camera-based continuous monitoring to allow site operators to discern whether an emissions event requires action or is from the normal course of operations.

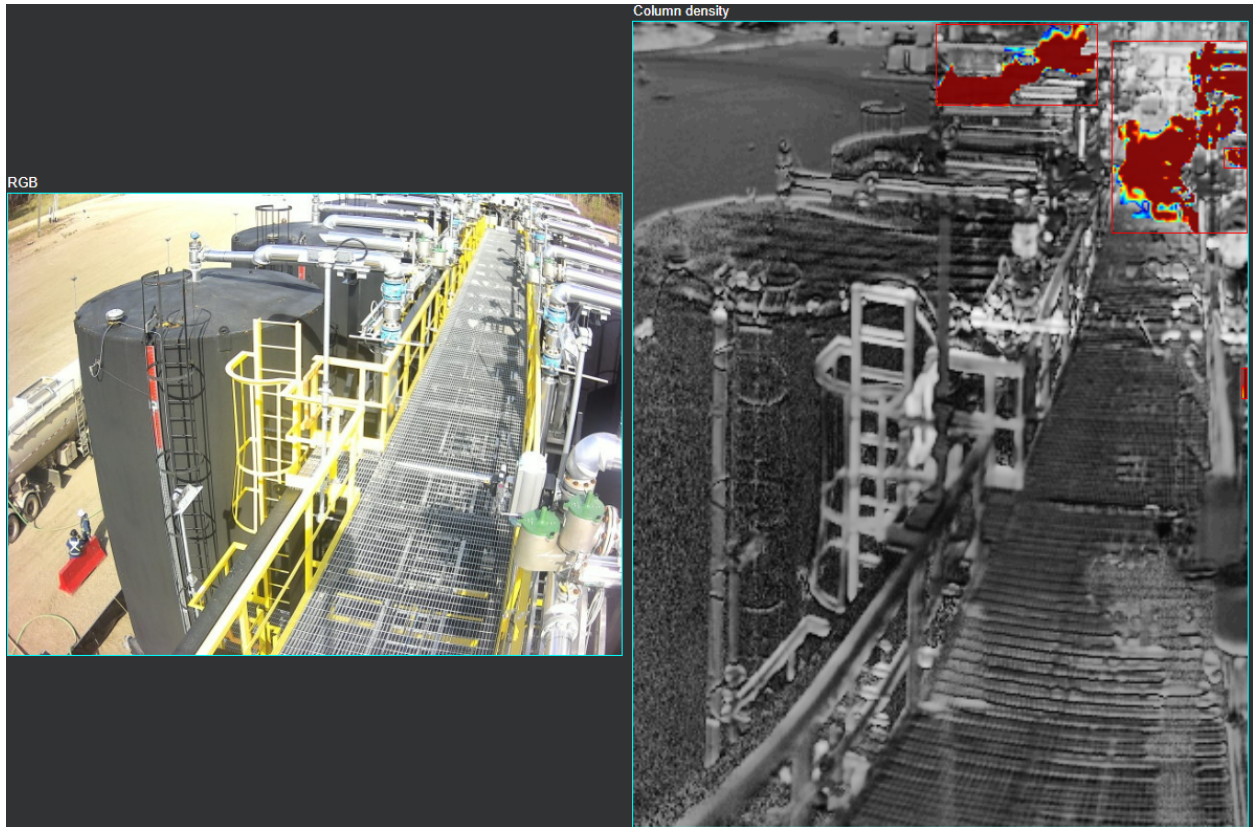


Figure 3-12 Emissions Associated with Tank Unloading and Overlapping of Emission Plumes at ETC Gas Plant

3.4.2.3 Controlled Testing at ETC Saddle Hills Controlled Vent Site

At the Emissions Test Centre (ETC) Saddle Hills Controlled Vent Site, the test setup was highly controlled, ensuring precise measurements of emission events using a flow meter, and single source releases. This contrasts with the East Edson Gas Plant, where operational occurrences led to emissions being released from multiple sources simultaneously, with some being measured and others not.

On December 1st, 2022, ambient conditions at the snow-covered site were good and resulted in a significant number of detections. The test releases were performed from the tank. The controlled flow rates were released at 150 m³/day and then increased to 250 m³/day. In Figure 3-14 below an image from December 1, 2022, at 10:30 (MST) shows a detection during the 150m³/day flow rate period.

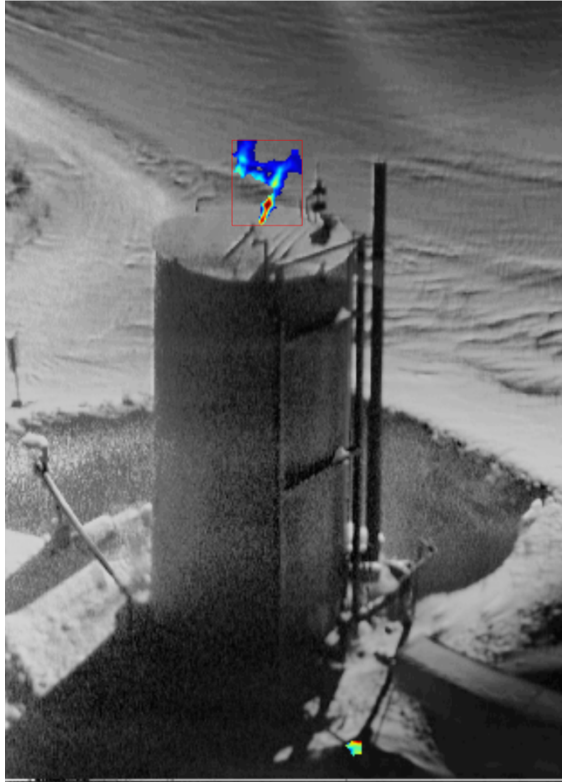


Figure 3-14 Image from ETC Well Site During 150m³/d Metered Release (Dec 1,2022)

Kuva's quantification algorithm processed all images that were collected over a 2.5 hour period. Below the Kuva Quantification data and the Flow Meter data are plotted vs time. Kuva results are shown as "x" marks and the measured FM data is circles. The averages of both measurements are shown as solid lines. Averages were calculated for each of the 2 flow rates; during the 150 m³/day flow Kuva's average quantification was 174 m³/day and during the 250 m³/day flow period Kuva's average quantification was 226 m³/day. The 150 m³/day test was quantified with a 16% error while the 250 m³/day was quantified with an error of 10%.

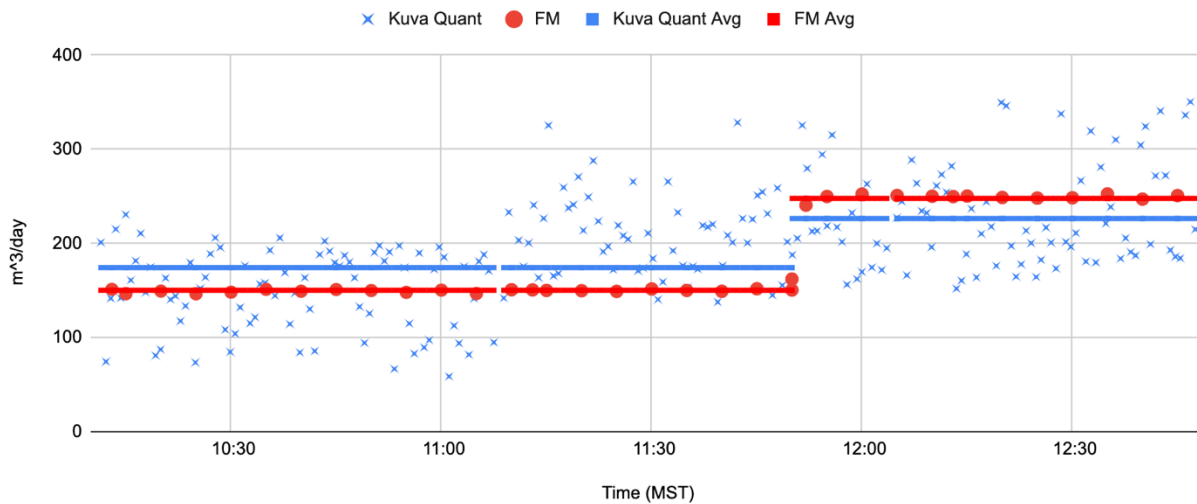


Figure 3-15 ETC Well Site - Kuva Quantification under Constant Release Rates (Dec 1, 2022)

3.4.2.4 Evaluation of Results

The primary results for Objective A were regarding quantification accuracy and detection sensitivity. These results were generally very positive. The Kuva camera was able to achieve a 90% probability of detection of 99.7 m³/day (3kg/h) per m/s wind and a 50% probability of detection at 73.5 m³/day (2.2kg/h) per m/s wind. This result was significantly better than the initial target of 10kg/h per m/s wind speed and is considered a very positive result from the project.

Testing throughout all seasons in the Canadian climate, including snow cover and extreme cold (lowest recorded was -41° Celsius on a February day) as well as wildfires in the summer, further validated Kuva's operational and detection capabilities in Canadian environmental conditions. Kuva's visual detection capability was further observed to provide efficiencies to an operator's workflow to discern whether an emissions event requires action or is from the normal course of operations by correlating emissions with any human activity, trucking or maintenance. Longer days in the summer provided longer detection hours for operators and less hours, although still capable, in the winter. Although not a typically offered benefit, Kuva's visible image camera was even used by an operator to remotely monitor wildfire activity close to its facility in summer.

The quantification accuracy was tested in various locations, at test facilities with no background emissions and at active upstream sites. While the quantification estimates of individual frames could vary by more than 300%, the accuracy of complete events had very good results of between 1.5% to 28% error. The opportunity to evaluate emissions at both active and test sites was very helpful to understand the sources of emissions, the variability or intermittency of real-world emissions and how difficult it is to replicate real-world scenarios in test facilities.

The success metrics as defined at the outset of the project for quantification accuracy were classified in three different ways:

- Low flow
- High flow
- Transient flow

The low flow case can be considered the ETC Saddle Hills well site with test releases measuring from 50 to 250m³/d. These results varied from as low as 1.5% error for the event that was 80m³/d, up to 27% for

the event that was 50m³/d. The success metric for this quantification of this type of flow was less than 30%, which these results satisfy.

The high flow case can be considered the CaMI results as portrayed above with a flow rate of 1300m³/d and an estimated flow rate of 1633m³/d, which results in an error of 26%. The success metric for quantification of this type of flow was 25%, which is of negligible difference to the measured performance.

The transient flow case can be considered from the ETC Gas Plant, which had emissions fluctuating throughout the day and the emissions volumes as estimated by Kuva were 17% less than measured values. The success metric for quantification of this type of flow was less than 20%, which these results satisfy.

It is accepted that this is only a small sample size of results and more thorough testing is required. It should also be noted that the detections that were quantified were the emissions detected and that many emissions went undetected.

3.4.3 Objective B

The three components of Objective B were:

- 1) Short term screening of approximately 80 wellsites with 11 relocatable systems for a period of approximately two weeks each to study emissions profiles for a wide range of tank types and production geologies in Alberta.
 - a) Phase I assessed 24 sites.
 - b) Phase II assessed 56 additional sites
- 2) Long term Installations period of one year at eight upstream sites.
- 3) Determine and implement tank vent mitigation at two well sites.

3.4.3.1 ERA short term screening

The first screening phase of short-term testing was completed at sites owned and operated by project partners. Twenty-four sites were evaluated for multiple weeks each. This initial screening phase allowed Kuva to identify 8 sites with reasonable potential for mitigation.

In Phase 2 of the short-term installations, the majority of sites that Kuva deployed to were in association with other projects. There were seven sites that were not also part of any project outside of ERA. The table below outlines the summary of the short-term deployments throughout the project.

Table 3-3 Deployment Duration by Project

Short-term Deployments	Sites	Camera Weeks
Phase 1	24	84
Phase 2	56	353
Total	80	437

One of the objectives of phase 2 was to expand the geographical extent of these short-term deployments. This was accomplished with sites ranging throughout western Alberta from Cochrane, to north of Grande Prairie, and East of Edmonton in the Mannville region. Several deployments were even in Northeastern British Columbia, between Fort Saint John and Fort Nelson. This provided both excellent environmental test conditions (the most northern deployments occurred over the winter solstice for extreme condition

testing of limitations) and a variety of basins and production geologies. See below for a breakdown of the number of sites surveyed per region.

Table 3-4 Deployments by Region

Short-term Deployment Region	Sites
Central Alberta	44
Grande Prairie	15
Edson	7
Mannville	7
Northeast British Columbia	7

3.4.3.2 PTAC (September 2021-September 2022)

Kuva was deployed to sixteen different sites from three different companies for a total of 163 weeks in association with the PTAC project (this “PTAC project” was coordinated to support joint site testing alongside other technologies). A portion of these sites had alternative emission monitoring methods employed for some of the deployment duration of the Kuva Camera. The variety of measurement methods that were deployed helped form a complete picture of what was going on at the wellhead. Each technology provided a slightly different value to the overall evaluation of the site emissions.

The gas and liquid sampling and analysis that was performed on a handful of the sites, was useful in developing a better understanding of the chemical and physical properties of emissions from upstream sites and how these differences were observed with the Kuva Camera. The data gathered during these deployments from other technologies has been and will continue to be helpful in developing and comparing the Kuva quantification methodologies under a range of circumstances that cannot be easily replicated in a controlled environment.

The project also served as a valuable demonstration in contrasting the benefits (and disadvantages) of Kuva’s continuous image-based monitoring compared to the other technologies deployed in the project. The Kuva solution allowed for the detection of unexpected emissions, such as temporarily unlit flares and simultaneous emissions from vents and thief hatches, that would have gone undetected otherwise.

The graph in the image below is an excerpt from the turbine meter data and each of the images above them show the gas detection images as provided by Kuva. The SWIR images are grayscale, and the detected gas is overlaid in colour, with red pixels indicating higher column density (ppm-m) and blue pixels indicating lower column density. The magnitude of the detections in the images clearly corresponds to the relative flow rate as measured by the turbine meter.

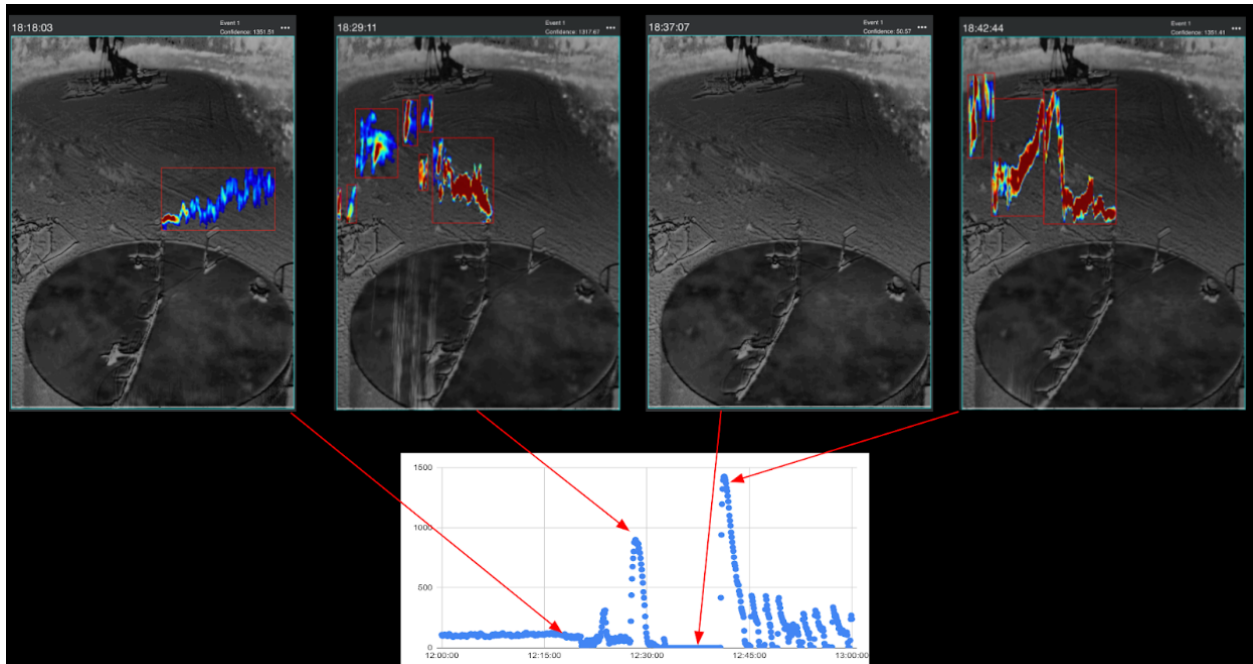


Figure 3-17 Comparison of Emissions from Uncontrolled Tank with Metering

During one of the deployments, the Kuva camera detected a flare outage using the flare's shadow (Image below). This was one of the earliest detections of such an event by Kuva and an exciting development of additional Kuva use cases for a significant market need. This technique has been used to detect emissions from elevated sources, mainly flares, in multiple installations across North America and continues to be a defining competitive advantage provided by the Kuva camera, helping operators mitigate previously unidentified emissions.



Figure 3-18 Flare Detection at Upstream Site

3.4.3.3 NGIF (September 2022 – April 2023)

The NGIF project involved Kuva being deployed to 33 sites from 6 different companies over the span of 177 camera weeks. During this time Kuva monitored different types of equipment including tanks, compressors and flares. Below are graphs that show what equipment was monitored and where most of the detections were found.

NGIF Monitoring Summary

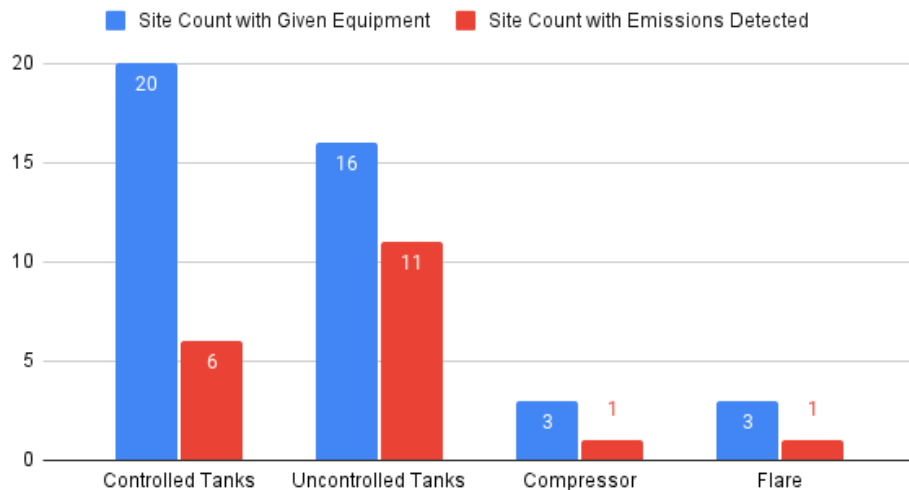


Figure 3-19 Site and Emissions Count by Equipment

Starting with “Controlled Tanks”, they were found to have recurring issues around thief hatches. One issue pertaining to thief hatches involved them prematurely “popping” at a tank pressure that was less than expected. Along with the faulty pressure settings, a common failure point was the seal the thief hatch sits on. These seals were found to deteriorate over time and resulted in unexpected emissions.

“Uncontrolled Tanks” are open venting tanks and are expected and permitted to vent, to an extent. Some of these tanks had emissions due to how much heat was applied to the contents of the tank. One producer that heated their tanks throughout the year had water vapor constantly emitting from them. Kuva was able to share that there were hydrocarbons in the vapors leaving the tank which was later confirmed by further testing done by the client. This resulted in some operational changes reducing the amount of hydrocarbons escaping with the water vapor.

Kuva had a small sample size for monitoring compressor buildings and found emissions at one of three sites where Kuva was deployed. Detecting fugitive emissions outside of compressor buildings is a difficult task due to the variety of potential release points that often surround the buildings.

Flare outages, although uncommon, can easily go undetected. The rate of emissions that are able to escape from an unlit flare stack typically significantly exceeds most venting tanks. Kuva is able to effectively monitor flares and quickly notify operators of outages, resulting in fewer emissions and a fast response time from operators. During the NGIF project, Kuva was positioned to monitor 3 sites with flare stacks and successfully found fugitive emissions from one which would have gone otherwise unnoticed.

Kuva applied the quantification process to a full day of detection results from each site. The graph below shows a summarization of the average daily emission rates found at the sites where Kuva was installed.

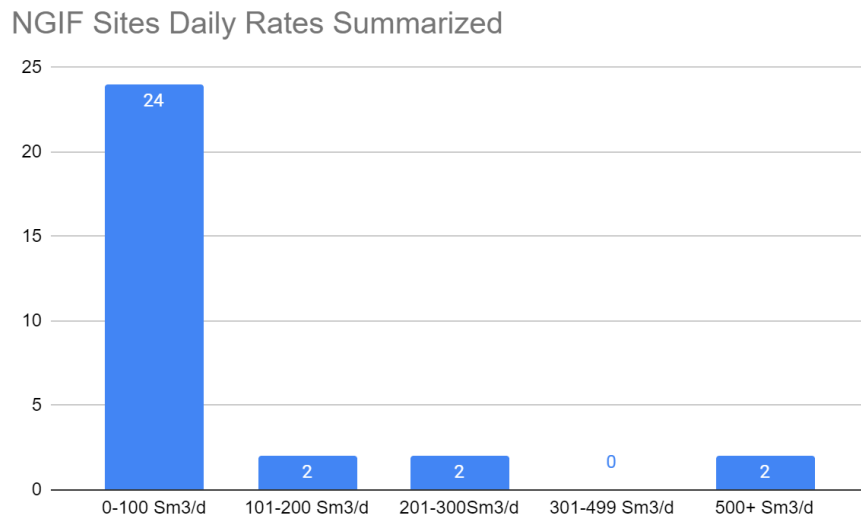


Figure 3-20 Average Daily Site Emissions

Kuva was able to show a daily average rate from each site. Although some fugitive events had high instantaneous rates, the total daily was in fact relatively small with only two sites averaging more than 500 Sm³/d of emissions.

The image below depicts a tank, which is from a site at an extreme Northern latitude of this installation (57° North latitude), which is the most northern latitude that a detection was made during this project.

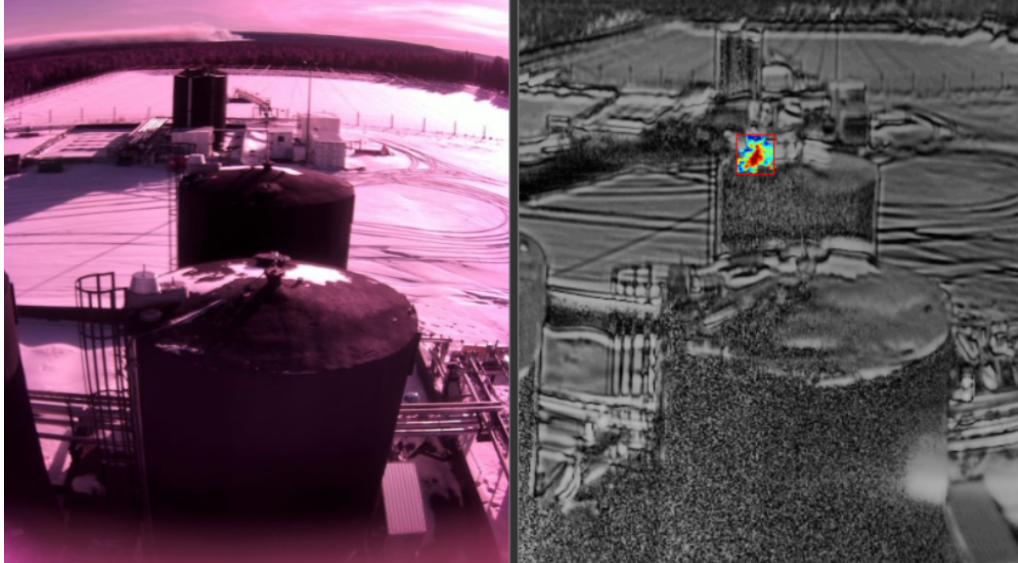


Figure 3-21 Detection in Northern Site with Low Light Conditions After Algorithm Improvement

3.4.3.4 ERA Long term deployments

Kuva deployed 8 systems for one year or more at facilities in Central Alberta and Grande Prairie. After several months of monitoring and discussions with the operators, there were two sites that Kuva provided data that helped determine the source of emissions and the operators were subsequently able to mitigate the emissions. One site was a set of controlled tanks at a facility in the Sundre area. It was discovered that there were multiple leaking locations from the thief hatches and on the piping that connects the tanks together and to the VRU. It was estimated that this repair mitigated approximately 100m³/d of methane since the repair was made. Below is an image that was captured prior to the repairs.



Figure 3-22 Emissions from Controlled Tanks Before Repair

The second site that was mitigated was from a natural gas blanketed amine storage tank at a gas plant. The pressure control device in the tank was not functioning properly and resulted in over pressurisation of the tank causing the pressure relief valve to open. The pressure regulator was repaired with some maintenance, which stopped the emissions. There were no project expenses associated with these repairs. Below is an image that was captured prior to the repairs as well as a plot that shows the number of Kuvu detected emissions events leading up to and after the repairs were completed. These emissions were not able to be quantified directly because wind speed was unavailable; however, a rough estimate of the rate of these emissions prior to repair, based on plumes of similar size, is approximately 300m³/d.

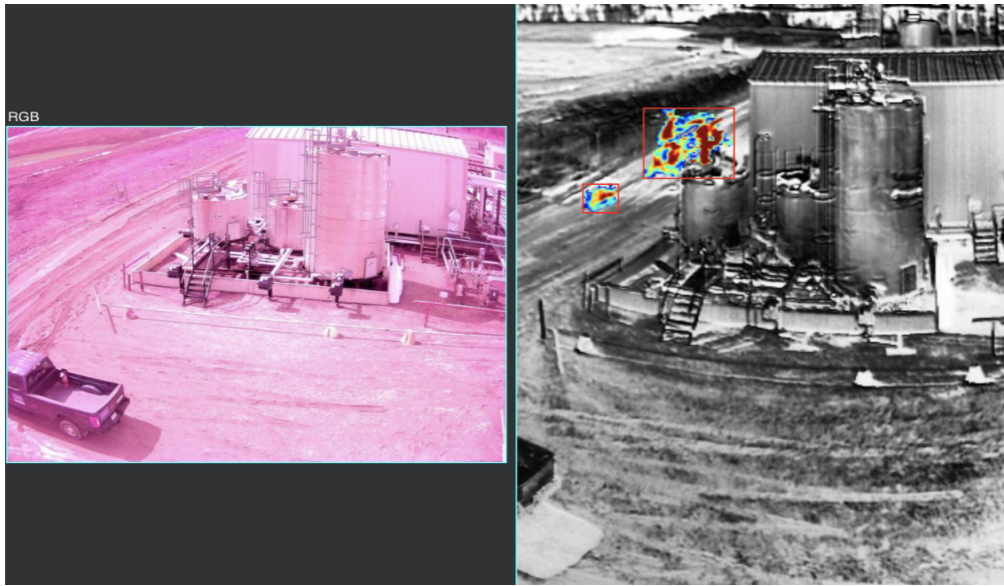


Figure 3-23 Emission from Amine Storage Tank Before Repair

Alarms Created vs Month on Tanks (2022)

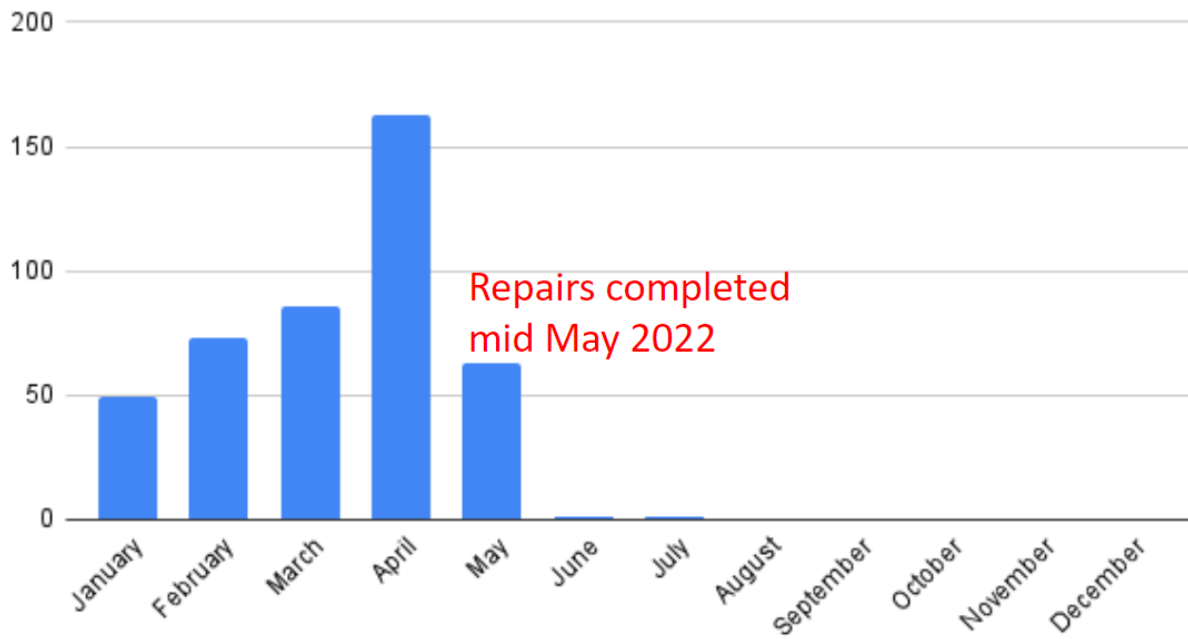


Figure 3-24 Emissions Event Detected by Month in Context of Repair

While it was difficult to evaluate the exact runtime of each camera, the quality and reliability of each device initially varied. Based on insights from failures a significantly improved, second generation camera hardware design was developed and released for production in late 2022. This 2nd generation design has proven very successful and has operated reliably to the point where any remaining problems are typically caused by camera external circumstances such as power supply and cell data connectivity.

3.4.3.5 Evaluation of Results

The scale of deployments of Objective B was very substantial and to our knowledge represented one of the largest campaigns for continuous monitoring using a visual, image-based technology in the world to date. Some of the learnings from the campaign are:

- Emissions at upstream sites can be intermittent and very high in volume at times but relatively low in terms of total volumes.
- Controlled tanks with Vapor Recovery Units can have significant emissions if not maintained and operated appropriately. The Kuva camera is ideal in detecting abnormal behavior, enabling root cause analysis and demonstrating subsequent successful repair.
- Emissions from uncontrolled tanks can be mitigated through operational changes
- Unlit flares can be detected by the Kuva camera by monitoring the shadow of the unburnt gas

The project target of automated emissions detection during stationary and relocatable operation was fully demonstrated under all weather conditions and all seasons, subject to a weather dependent, variable detection limit. The target of emissions quantification during stationary and relocatable operation was also achieved. However, additional work is required to automate the quantification solution, to evaluate accuracy under less than ideal conditions and to extrapolate detections to a full year.

Based on hardware and software improvements as well as improved installation practices Kuva has subsequently achieved 99% operational uptime at commercial installations outside of this project.

3.4.4 Objective C

The primary tasks in Objective C were the:

1. Installation of a total of eight cameras in multiple locations for long term installations
2. Integrate the automatic detection and repair validation into industry partner workflow.
3. Application as an Alt-FEMP pilot project with AER.
4. Continuous hardware and software improvements based on feedback from operators and algorithm updates.

3.4.4.1 Alt FEMP with Whitecap Resources

Kuva was involved in an Alt-FEMP pilot program from 2022 to 2023 with Whitecap at a gas plant. Kuva installed 3 cameras that allowed Kuva to monitor tanks, compressors, pigging station and surrounding equipment. The position of the cameras are seen in the image below.

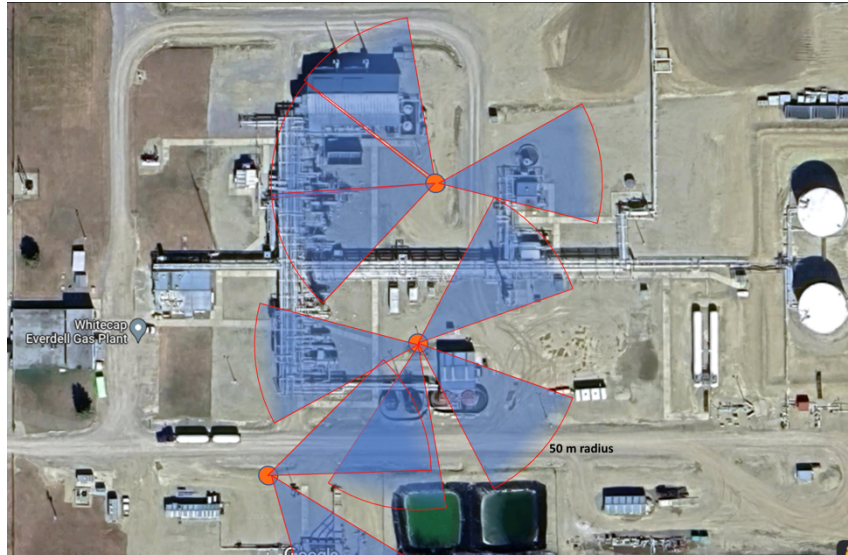


Figure 3-25 Site Layout with Kuva Cameras for Alt-FEMP Pilot Program

The operation group at the gas plant had integrated Kuva email notifications into their workflow in order to follow up on any detected emissions. This workflow, as agreed in the Alt-FEMP proposal, was that a notification alert would be sent by email to the operators of the plant when an emissions event would exceed 15 minutes in duration. The operations team would then follow the links in the email to the event in the Kuva dashboard, which would provide the context of the emission event for the operator to determine any necessary action.

3.4.4.2 Other Installations

There were five installations at facilities outside of the Alt-FEMP project, three of which were discussed in Objective A and were at the NGIF ETC sites in Edson and Saddle Hills, while the other two were rail loading terminal in Bruderheim, AB. The ETC sites, as discussed, were excellent testing grounds with a good variety of emissions and opportunity to develop quantification algorithms. The rail loading terminal sites had very little in the way of detected emissions, which was beneficial as the site is near a sensitive residential area.

3.4.4.3 Evaluation of Results

The long term deployments as part of this objective, were a success in several ways:

- An Alt-FEMP program can successfully be obtained and administered by using the Kuva Camera and associated workflows (believed to be a world's first regulatory approval of camera-based continuous monitoring);
- It demonstrated that the verification of the absence of meaningful emissions, like at the rail loading terminal, is a valuable piece of information and peace of mind for adjacent residential occupants.
- Quantification and detection algorithms benefitted from the ETC deployments and the ground truth information that was provided.
- Failures in the hardware design provided insights in weak points that were addressed in the 2nd generation camera hardware design.

The camera performance has significantly improved since the initial installations, reducing the number of required cameras for the gas plant. The effective site coverage provided by the upgraded software and 2nd generation camera have increased by about 400%. The improved detection sensitivity allows for greater range from the camera for the detection of a given emission size and the increased number of POIs allows for coverage of 270 degrees. A further improvement to full 360 degrees is to be released in 2024.

With these improvements and greater understanding of the operational benefits of the Kuva camera, as well as increased regulatory requirement for survey frequency, as the upcoming regulations are expected to contain, customers who opt for a visual detection technology, the Kuva camera may provide the most economically competitive and operationally insightful solution for complex upstream sites, especially with controlled tanks.

4 Commercialization

At the start of the project in September of 2020, Kuva only had a prototype camera that was based on the low-cost SWIR based methane detection method that had been developed and demonstrated in a previous ERA project and subsequently refined. After starting to conduct field trials as part of the ERA project, Kuva secured its first commercial / customer paid demonstration project in July 2021. In 2022 additional demonstration projects were won, the software solution was very significantly enhanced in functionality and stability, detection sensitivity was significantly improved and the camera underwent a redesign process for reliability. The ability to learn from the field deployments under this grant as well as the ability to quickly make and test improvements at these sites (rather than at paying customers with higher expectations) were instrumental in maturing the overall solution. Being able to point to larger scale deployments in Alberta under this grant provided confidence for commercial customers to pay for additional deployments. The ability to reference the AltFEMP regulatory approval also was helpful when Kuva applied in Colorado for regulatory approval.

At the end of this project (May 2023) the daytime version of the camera with a focus on detection and alarming was fully commercial (TRL 10), while the development of the nighttime version was stopped based on current feedback from customers and prospects. Moreover, a Kuva quick-install tower was designed in-house and commercialised at the same time.

While customer requirements were initially focused on efficient detection and reliable operation, they have now branched out into use for regulatory compliance as well as annualized, site emissions inventories based on direct measurements.

As a result, further development is ongoing in the following areas:

- The quantification algorithm is currently in beta trials with the real-time implementation and full automation pending.

Based on feedback from commercial customers the following further improvements are planned:

- Expansion of the event-based quantification discussed so far into a solution to establish the emissions intensity of an entire upstream or midstream site for an full year
- Improvements in the cloud solution for more comprehensive alert categorisation as well as integration of camera detected alarms into customers workflow management systems

On the regulatory side a key milestone was the AltFEMP approval in Alberta during this project. Kuva has since been approved in Colorado, including replacing monthly OGI inspections and is applying for

equivalency under the recently issued US EPA methane inspection rules. Kuva expects to also apply for equivalency under Alberta methane regulations once finalized.

5 Lessons Learned

There were a large number of lessons learned throughout this project. Key lessons are the following:

Legal processes for site-access and data sharing are very lengthy

- Oil and gas producers and operators are conservative with their legal approach to data sharing. They can be very sensitive to emissions data, understandably so, which can lead to negotiation times that extend well into the hundreds of days. The lesson learned here is to have a law firm that is knowledgeable in this industry and to provide as much time as possible up front to allow for the negotiations to occur.

Early stage hardware and software requires iterative improvements to become fully commercial

- In the initial deployments, there were times that the cameras would become unreachable or non-functioning for many reasons. This led to the development of significant additional data logging features, software changes as well as a redesign of camera hardware and to a stable commercial solution as of 2023.

Efficient installation requires a custom quick-install tower of 12m height

- Production tanks at upstream sites are often more than 9m tall, especially with the pilings on many of the tanks in the northern regions that elevate the base of the tank above the ground by another meter. This resulted in a complete redesign of the towers used by Kuva and the need to design a system in-house. This has resulted in a lighter, superior product that can monitor most upstream production tanks.

Continuous monitoring leads to a better understanding of tank emissions and their root causes

- While uncontrolled tanks are known to emit and permitted to vent a certain amount in Alberta, controlled tanks can also emit significant amounts during times of malfunctions. Continuous monitoring allows for the fast detection, efficient root-cause analysis and subsequent repair of malfunctions.

The core value of the camera is detection and pinpointing of emissions without false alarms as well as much simplified root-cause analysis - there is currently no commercial need for night-time detection

- At the outset of the project, it was frequently discussed whether not being able to monitor at night was going to be a problem. The initial reaction from potential customers was that a daytime only camera would be of limited value, especially when compared with continuous point sensors. However, the experience from the project and from commercial deployments over the past three years has shown that the value of a continuous camera is in detecting emissions without false alarms, the ability to pinpoint emissions to a specific location with images, the ability to enable cost-effective root-cause analysis of emissions (often remotely, without need for visiting a site). As upstream sites and most midstream sites do not have site-personnel onsite 24 hours a day and are often remote, a detection during the day has proven sufficient to accomplish these goals. While a nighttime detection capability would be nice, operators signaled they would not be willing to pay more for it as the value of efficient detection, pinpointing and root-cause analysis can already be accomplished with the daytime only solution.

The target market for Kuva cameras are complex upstream and midstream sites, not simple upstream sites

- A key learning over the past three years has been to clarify the target market for a continuous Kuva camera. Alberta has about 100,000 simple upstream sites, often single wellheads with little related equipment. These sites can be well covered with continuous monitoring by low cost point sensors as the ability to pinpoint emissions to a source is not relevant due to the limited quantity of equipment present. Therefore, these sites do not constitute a target market for Kuva cameras. On the other hand, according to the AER, Alberta also has about 27,000 oil facilities or other sites with a larger number of tanks as well as about 18,000 gas plants or other such complex midstream sites. These sites typically have a larger number of tall equipment structures, they have a large number of points that can cause emissions, emissions from tanks and flares can be unexpected and relatively large and pinpointing emissions to their source can often be challenging. While a side-by-side comparison with point sensors was not a direct part of the project, the Kuva camera was the only solution to find significant unexpected emissions from tanks at the ETC test site - despite the site being heavily instrumented with point sensors and being inspected with OGI. Side-by-side comparisons with point sensors by multiple oil and gas companies that were conducted outside the ERA project confirmed this result. The Kuva camera frequently detected tank and flare emissions that were missed by point sensors, due to the elevation of the source, the presence of large number of equipment that creates complex eddy currents not anticipated in dispersion models, elevated levels of background methane concentration from compressor methane slip and due to the need of point sensors to have fairly high alarm limits in order to avoid a flood of false positive alarms.

The total-cost-of-ownership of continuous monitoring was identified and developed as the relevant metric when evaluating multiple continuous monitoring approaches from an operator perspective for market adoption and scaling

- Discussion with operators about continuous monitoring of methane emissions will usually include the cost of a solution. While the Kuva camera is by far the lowest cost camera-based solution for methane detection in the market, it is still more expensive than point sensor-based approaches in most scenarios. In 2021 and 2022 this led to operators preferring point sensors for commercial deployments at dozens and sometimes of a hundred of complex sites in the US. However, subsequent evaluation has shown that this approach proved to be costly and often resulted in small or no emission reductions. The reason is that complex sites tend to have a larger number of emission events, especially from tanks, compressors and flares. For the point sensor deployments this resulted in dozens or hundreds of alarm events per site per year. These alarms create costly follow-up site-visits, often including a manual, labour-intensive OGI screening. Field operators often could not pinpoint the source of the detected emissions - either because they were hard to observe from the ground, they were a false alarm or the emission had ended by the time the inspection was conducted. Even if intermittent emissions (often from tanks) were detected, it proved to be costly to conduct a full root cause analysis. A Kuva camera on the other hand pinpoints emissions to their source, does not produce false alarms and allows operators to view and analyze intermittency of emissions remotely. This proved to be especially valuable for sites with Vapor Recovery Units which often suffer from intermittent emissions. Kuva, together with one US operator, developed a total-cost-of-ownership model, that demonstrated the value of the Kuva solution at a complex site had a significantly lower total cost of ownership than point sensors when taking the cost of avoided OGI inspections / alarm response, no false alarms as well as the much simplified cost of root-cause analysis into account. Kuva has since focused its

communication with operators on the total-cost-of-ownership as opposed to the purchase cost of continuous monitoring. It is noted that the calculation depends very significantly on the amount of equipment present at a site and that for simple sites point sensors are more cost effective.

6 Environmental Benefits

Methane Emissions Reduction Impact

Methane emissions in the oil and gas industry can be broadly categorized in three groups:

- Small, randomly occurring leaks from fatigue and wear and tear such as from loose flanges
- Designed-in emissions such as permitted tank venting and compressor methane slip
- Emissions from unexpected and abnormal behavior such as malfunctions of vapor recovery units and flares

The recent comprehensive emissions inventory study has shown that the contribution of each of these areas is roughly a third to overall methane emissions in Alberta¹. The first category is best addressed with conventional OGI inspections as the leaks tend to be too small to be detected by other technologies like planes, point sensors or cameras. The second category typically requires regulations if reductions are desired. As was demonstrated under this project the Kuva camera can be used to validate if an existing regulatory emissions limit for tank venting is adhered to. The key use case for continuous monitoring with Kuva cameras is the third source of emissions. As was demonstrated in this project emissions from malfunctions are being created at random times and are often intermittent. For this class of emissions the Kuva solution directly enables emissions reductions through faster detection and by reducing the cost, time and complexity of root-cause-analysis.

Emissions reductions during the project

During the project, thousands of individual emissions events were detected, many of which were at uncontrolled tanks and others were at sites where the Kuva solution was relocated before repairs may have been made and results are therefore unknown to Kuva. Two emission events were detected by Kuva where we can directly tie the detection to subsequent repairs by operators. The reduction was approximately 400m³/d of methane emissions. The overall reduction depends on assumptions on when an operator would have detected the emission in the absence of continuous monitoring, typically an annual OGI inspection.

Emissions reductions in Alberta

In order to estimate the expected reduction in GHG emissions in Alberta on a commercial scale deployment, we present the use cases and the regulatory framework that may allow for this type of commercial environment. The two use cases for the Kuva camera to be deployed are:

1. Permanent installation at complex upstream and midstream facilities to monitor for abnormal process-related emissions as well as maintenance or equipment failures.
2. Temporary installation at upstream production sites in order to measure tank and site level emissions.

For use case 1, continuous monitoring at upstream facilities is likely to become widespread in the coming years for Leak Detection and Repair (LDAR) as well as Measurement, Monitoring, Reporting and

¹ See: <https://www.nature.com/articles/s43247-023-01081-0>

Verification (MMRV). There are several motivations for operators to pursue this. For complex sites with intermittent emissions problems a camera significantly reduces the cost and effort for root-cause analysis of emission events and the total cost-of-ownership of a camera is lower than for point sensor installations (see also discussion in chapter 5). Beyond using continuous monitoring as a tool for fast detection and efficient repair, continuous monitoring will in the coming years permit operators to become certified as a low methane intensity producer and to gain a premium for the sale of their product via accreditation by organizations such as MiQ or OGMP 2.0. The rate of adoption of this type of monitoring may occur especially in conjunction with possible strengthening of regulatory requirements. Under such a scenario the total addressable market (TAM) for image-based continuous monitoring for these purposes will likely be approximately 45,000 complex sites (there are 27,000 oil facilities and 18,000 gas facilities in the province as of 2023, according to the AER). Adoption by industry will likely be driven by a number of factors. Kuva aims to be the market leader for image-based monitoring and to own at least a one third share of the TAM. If one third of the overall TAM adopts continuous monitoring by 2030, that would be 15,000 sites, of which Kuva expects to have a presence at 5,000. According to a recent study from Conrad et al. (2023), the average crude oil multi-well proration battery in Alberta has been found to emit 5.79kg methane/h. Kuva would expect to be able to provide a reduction potential of 90% of that, of approximately 5.2kg methane/h per site. Therefore, if Kuva were to be installed at 5,000 sites, the reduction potential across all sites would be 227,760 t methane/year. By 2050, continuous monitoring at all 45,000 facilities is expected to occur and provided Kuva maintains the same market share, the total reduction potential would be 683,280 t methane/y at 15,000 sites.

For use case 2, this will be driven if strengthened regulations were to shift permitted emissions from a site from the previous 500m³/d to 42m³/d for new sites, to potentially 0m³/d in the future. While there is currently considerable vagueness in the definition of these measurements (whether they are instantaneous or average over a long period of time), the only way to understand these types of emissions is to measure them continuously and Kuva is the most affordable technology that can do this for sites with multiple possible emission sources. While there are >300,000 active well sites in the province today, it is estimated that there may be on average one production tank for every three wells and if a quarter of those are designed to vent, that leaves 25,000 such candidate sites. From the studies that were conducted in this project, there were approximately 20% of sites that had emissions greater than 100m³/d. If a fleet of 10 Kuva cameras was doubled every year starting in 2025, and each camera were deployed for 2 weeks, it could be estimated that the total number of temporary tank installations could follow the schedule below:

Table 6-1 Emission Reduction Potential in Alberta for Commercial Relocatable Solution

Year	Average Camera Count	Sites per year	Cumulative sites	Potential Excess Emissions (million m ³ /year)	Potential t CO ₂ e/year reduction
2025	10	260	260	1.9	36,050
2026	20	520	780	3.8	72,100

2027	40	1,040	1,820	7.6	144,200
2028	80	2,080	3,900	15.2	288,400
2029	160	4,160	8,060	30.4	576,800
2030	320	8,320	16,380	60.7	1,153,600

If the assumptions above were to be true, the total number of sites to be visited by 2030 is estimated to be 16,380. If 20% of sites had >100m³/d of excess emissions this would result in detection (and possible mitigation) of more than 60.7 million m³/year of emissions of 1.1 million t CO₂e in 2030. With the right incentives and regulation enacted and enforced by regulators and government, we consider this an attainable number. Furthermore, under the assumption that each site could be monitored for an estimated fee of \$2,000, this would cost approximately \$33M in 2030, for an estimated permanent reduction potential of emissions of 1,153,600 tCO₂e.

While these emissions reductions would likely persist, if pending ECCC proposed regulations outlawing tank venting were enacted there is not expected to be any permissible venting for new sites beyond 2030 and as such, the additional emission reduction potential for years beyond 2030 is likely minimal. However, the emissions reductions until such point would still be very significant.

Other Environmental Impacts

While the Kuva camera does detect methane, it also detects other hydrocarbon gases. Hydrocarbons C₃+ are considered Volatile Organic Compounds (VOCs) and are often found in the same emissions as methane emissions. While it is difficult to measure the quantity of VOCs that were detected by the Kuva camera in this project, it is expected to be significant, considering the composition from tank emissions can contain as much as 90% VOCs and most emissions detected by the Kuva camera came from tanks. VOCs are undesirable because they are precursors to photochemical smog and known carcinogens. Enabling the measurement and avoidance of VOC emissions is another significant potential application for the Kuva camera.

7 Economic and Social Impacts

ERA's investment in this project leveraged significant positive economic and social impacts for Alberta.

Kuva Canada established its physical local presence in Alberta during the course of this project through its office in downtown Calgary (Work Nicer) and warehousing in Crossfield and Grande Prairie, AB, which was a significant growth step from its temporary lab and desk space at Southern Alberta Institute of Technology (SAIT) at the project's commencement.

The project caused significant foreign direct investment from the US to Alberta with Kuva USA's investment to its Calgary-based 100% subsidiary Kuva Canada, increasing jobs, innovation capacity and knowledge development. At the start of the project Kuva Canada had 3 full time employees. At the end of the project, Kuva Canada provided jobs (primarily for highly qualified personnel) for 25 employees in

Canada, 19 of which were in Alberta and 15 directly attributed to this project. Of these, 3 STEM (science, technology, engineering and math) jobs were women which helped improve gender equity balance within Kuva. All of these jobs are permanent and Kuva Canada's employment has subsequently grown to 32 employees (March 2024).

Innovation capacity was significantly increased in Alberta during the course of this project. As a hardware-enabled digital clean tech company serving the local oil and gas community, Kuva Canada contributed to Alberta's economic diversification and the growth of its local digital and clean tech sectors. By partnering with CMC Research Institute (CaMI) and the NGIF Emissions Testing Centre, this project utilized local innovation ecosystem resources and directly engaged with local oil and gas companies and their personnel during testing, operations and product feedback sessions. Through the project's duration, highly skilled personnel were trained in complex matters including cutting edge emissions detection, quantification and algorithm development. This knowledge was transferred from internal Kuva product developers to external testing partners (testing centers and Kuva users including oil and gas customers) which in turn helped them better understand their emissions at a variety of test locations and configurations across Alberta. Alberta's expertise in methane management, an attractive and exportable commodity, was further developed and enhanced with this project which will only grow in importance for the province and affected industries as emissions scrutiny deepens.

One of the long-term results of the project is that the Kuva Software-as-a-Service cloud solution as well as the false alarm screening is maintained and operated in Canada and exported internationally. Every Kuva camera requires connection and subscription to the Kuva Canada SaaS solution to function.

Additional benefits for the Alberta oil and gas industry from deploying continuous monitoring cameras may include increased employee safety as the need for optical gas inspections and related site visits and drive times will be minimized by continuous cameras.

Moreover, Kuva leveraged participation in this ERA-funded project with other subsequent innovation ecosystem organizations and resources for both simultaneous and follow-on projects, including non-dilutive capital from Natural Gas Innovation Fund's Industry Grants (Round 6) and Clean Resource Innovation Network. Kuva acknowledges that ERA's brand and reputation were helpful in securing these additional funding and support mechanisms for Kuva's continued technology development, testing and commercialization beyond this ERA-supported project.

8 Overall Conclusions

Kuva considers this project a great success as it allowed the company to advance the camera solution from TRL 7 (demonstrated in a commercial setting) to TRL 10 (routinely deployed commercially). All performance targets laid out at the start of the project were met either by the end of the project (quantification accuracy, AltFEMP) or shortly thereafter (camera and cloud uptime).

Key conclusions are listed below:

Testing under real world field conditions in all seasons allowed for iterative improvement of hardware and software reliability and subsequent commercialisation

- The initial stages of the project allowed for Kuva to prove out the technical viability of the continuous monitoring detection technology and iterate the product to deliver and establish a reliable, valuable solution and installation experience for the customer. The testing at real world sites is imperative to understanding actual performance and value to a customer. To our

knowledge this has been the largest scale (in terms of number of sites) deployment of continuous monitoring methane detection camera technologies to date anywhere in the world.

Experience with deployment at a large number of sites led to series of installation related improvements

- During the project the operational procedures and use of accessories were refined and improved. Examples include choice of solar power solution and installation, methods for installation as well as learnings and insights that led to the development and commercialisation of a quick-install 12m tower.

Controlled release testing allowed for development and characterisation of quantification algorithms

- Kuva conducted multiple rounds of controlled release and metered testing projects together with and through NGIF, PTAC and with CMC as a project partner. This allowed validation of quantification to be completed under multiple different operational scenarios. The quantification accuracy through all tests, on a per event basis, was found to range between 1.5 to 28% for both controlled and uncontrolled but metered releases. Further work is needed to fully automate the quantification algorithm as part of a real-time workflow and to expand it from event-based quantification into a whole-site methane intensity metric.

Detection sensitivity exceeded targets

- The 90% probability of detection was determined to be approximately 100m³/d (3kg/h) per m/s wind speed, which surpassed the targets for the project. The performance was validated in peer-reviewed blind testing at the METEC facility in Colorado with excellent results. Additional significant improvements to detection sensitivity were achieved after the end of the project.

Operational configuration and target market were clarified and value proposition fully developed

- During the project the suitable operational configuration was clarified (daylight only operation as opposed to day and night operation with additional reflectors). Interaction with operators clarified the target market - complex upstream and midstream sites. Discussions with operators during the project and outside of it led to the development of a total-cost-of-ownership model that validates the commercially advantageous position of the camera solution for complex sites.

World's first regulatory equivalency recognition for camera-based continuous methane monitoring

- An Alt-FEMP program can successfully be obtained and administered by using the Kuva Camera and associated workflows (believed to be a world's first regulatory approval of camera-based continuous monitoring).

9 Communications Plan

Kuva's target audience are upstream and midstream oil and gas operators as well as regulators across North America. During the project Kuva regularly engaged with oil and gas operating partners Cenovus Energy and Whitecap Resources as well as the NGIF and PTAC project site hosts for the relocatable testing for regular product feedback and sharing of learnings. Moreover, Kuva participated in numerous conferences and webinars across North America to participate in knowledge-sharing and to market its solution. We estimate that in 2022 and 2023 we participated in approximately 20 events per year. In Alberta, Kuva presented at the PTAC Net Zero Conference in October 2022 (Calgary), the PTAC Methane Emissions Leadership Summit in April 2023 (Banff), and CRIN Project Café for Digital Oil and Gas Technology Competition in May 2023 (Calgary).

Kuva secured what is believed to be the world's first equivalency approval by a regulator for camera-based continuous methane monitoring which was announced publicly as a press release. <https://www.kuvasystems.com/press-release/kuva-cameras-deemed-equivalent-to-traditional-ogi-inspections> Kuva worked with Alberta Energy Regulator personnel as well as the site host Whitecap to arrange this regulatory approval.

Kuva submitted a written report to PTAC / AUPERF as part of the project "Methods for Estimating Emissions from Tanks" that summarized findings for sharing amongst PTAC members, and eventually, the general public. Similarly, Kuva submitted comments supporting testing at the NGIF ETC facility which had some overlap with this Project and a sample of the results were presented in this report.

Of critical value for Kuva's independent technology performance validation was Kuva's participation (simultaneous to this Project) of the testing of several continuous monitoring technologies at METEC at Colorado State University over a five month period in 2021 under a peer-reviewed test protocol for continuous monitoring, Advancing Development of Emissions Detection (ADED). These METEC test results were released in a scientific paper (see <https://doi.org/10.26434/chemrxiv-2022-4hc7q-v3>), which has become a key source for the evaluation of the performance of continuous methane monitoring technologies that regulators and industry alike look to across North America and globally. Kuva is listed as

solution “J” in the article. Kuva achieved an excellent result with a combination of a 90% probability of detection at 3.5 kg/h in combination with no false positive detections. This is the best result for any camera and the only technology without false positive alarms.

Future anticipated knowledge sharing activities includes ongoing participation at trade shows and webinars as well as participation in and contribution to PTAC’s relevant events. Kuva is also considering submitting a Society of Petroleum Engineers (SPE) technical paper with study results for consideration for SPE events globally and inclusion in industry acclaimed and peer reviewed SPE’s Journal of Petroleum Technology.

Outlook

Customer requirements for methane measurement have evolved beyond detection, root cause analysis and repair to also include the calculation of methane intensity data (i.e. amount of methane lost as a function of oil and gas produced) at an asset level. Notably, Japan as a major customer for Alberta LNG is starting to request asset level emissions data from all of its suppliers and it is urging suppliers to report under the OGMP 2.0 reporting framework. The default method for collecting this data is currently the combination of emissions data collected from aircraft surveys with data from OGI inspections and high flow samplers. This approach has methodological shortcomings with regards to accounting for the size and duration of emissions from abnormal behavior. The Kuva solution is well suited to gather and provide high quality, source resolved (bottom-up) emissions data, however work is required for a full characterization of emissions quantification accuracy as well as implementation of a statistical model for calculating annualized emissions inventories.

Discussion with the oil and gas industry indicate that a solution that can enable rapid detection and repair of abnormal emission events, provides high quality data for methane emissions reporting under OGMP and can be used for compliance with current and future regulations is required for commercial scaling. Kuva plans to continue expanding its solution to meet industry demands.