

Kiwetinohk Energy Corp.

Alt-FEMP Pilot Program 2024 Performance Report

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Executive Summary

Kiwetinohk Energy Corp. (KEC) is an oil and gas production company with assets in Alberta, Canada. KEC was approved by the Alberta Energy Regulator (AER) on April 28, 2023, to implement a pilot alternative Fugitive Emission Management Program (alt-FEMP) that covered a selection of KEC's facilities and multi-well sites in Alberta. The facilities are regulated under Section 8 of AER Directive 060 and have distinct legal locations referred to here as sites or legal subdivisions (LSDs). The multi-well sites are a different kind of site that require annual audio, visual, and olfactory (AVO) inspections (instead of OGI surveys per a default FEMP under AER Directive 060), but will also benefit from continuous monitoring based on site size. As per the approved alt-FEMP, Qube Technologies (Qube) deployed continuous monitoring sensors at each alt-FEMP site (sites with facilities and multi-well sites) to continuously detect and measure methane emissions.

For this alt-FEMP, follow-up OGI inspections were proposed to be performed every four months at the top 30% and bottom 10% of sites ranked by total emission rates according to four months of Qube screening data. Importantly, 9 facilities located on 3 distinct sites were designated to be in the Control Region, operating a default FEMP to support the evaluation of the alt-FEMP.

IMPORTANT NOTE: Due the wildfires in the summer of 2023, the pilot program had a delayed start to June. For tables where 2023 and 2024 data are compared, all 2023 data reflects only a partial year in the data.

With the alt-FEMP pilot program screenings and surveys completed, KEC will continue to use the data collected to track progress towards methane reduction targets and inform areas of improvement. This report summarizes data collected during the alt-FEMP screenings, follow-up OGI surveys and Control Region OGI surveys. The schedule of the program was as followed:

	* Site Level Screening	** OGI Surveys	Status
2023 Continuously / Daily	Continuous monitor screening by Qube, using their fixed sensors to screen 22 multi-well sites and 20 sites housing 34 facilities.	OGI follow-up surveys as needed to perform fugitive emission localization and repair at sites where fixed sensor alarm thresholds (1 g/s) were exceeded due to emissions (this threshold was changed in April 2024).	Completed
Q3 2023	2 months (July 8 th , first day Qube data was available – August 31 st) of continuous monitor screening by Qube, using their fixed sensors to screen 22 multi well sites and 20 sites housing 34 facilities.	Followed by OGI follow-up surveys at the top 30% and bottom 10% of screened sites (multi-well sites and sites with facilities) ranked by total emission rate (the sum of all relevant months of measurements for each site) for fugitive emission localization and repair.	Completed
Q4 2023	2.5 months (September 1 st – November 15 th) of continuous monitor screening by Qube, using their fixed sensors to screen 22 multi-well sites and 20 sites housing 34 facilities.	Followed by OGI follow-up surveys at the top 30% and bottom 10% of screened sites (multi-well sites and sites with facilities) ranked by total emission rate (the sum of all relevant months of measurements for each site) for fugitive emission localization and repair.	Completed
2024 Continuously / Daily	Continuous monitor screening by Qube, using their fixed sensors to screen 27 multi-well sites and 17 sites housing 29 facilities	Qube baseline adjustment was completed in 2024 to reduce false alarm detections.	Completed
Q1 2024	Continuous monitoring by Qube continued throughout Q1 2024 with baseline readjustment.	Alarm campaign based on the requirement to follow up on alarms. There was a subsequent readjustment of the baseline and an increasing of the alarm threshold.	Completed

Q2 2024	4 months (January 1 st – April 30 th) of continuous monitor screening by Qube, using their fixed sensors to screen 27 multi-well sites and 17 sites housing 29 facilities.	Followed by OGI follow-up surveys at the top 30% and bottom 10% of screened sites (multi-well sites and sites with facilities) ranked by total emission rate (the sum of all relevant months of measurements for each site) for fugitive emission localization and repair.	Completed
Q3 2024	4 months (May 1 st – August 31 st) of continuous monitor screening by Qube, using their fixed sensors to screen 27 multi-well sites and 17 sites housing 29 facilities.	Followed by OGI follow-up surveys at the top 30% and bottom 10% of screened sites (multi-well sites and sites with facilities) ranked by total emission rate (the sum of all relevant months of measurements for each site) for fugitive emission localization and repair.	Completed
Q4 2024	3 months (September 1 st – November 30 th) of continuous monitor screening by Qube, using their fixed sensors to screen 27 multi-well sites and 17 sites housing 29 facilities.	Followed by OGI follow-up surveys at the top 30% and bottom 10% of screened sites (multi-well sites and sites with facilities) ranked by total emission rate (the sum of all relevant months of measurements for each site) for fugitive emission localization and repair.	Completed

1. Screening Data

Table 1 shows the total emissions that were detected via Qube in 2023 and 2024. Also summarized in this table is the number of sites that were screened and the number of sites with detectable emissions. Sites where a methane concentration was detected but an emission rate could not be calculated due to environmental conditions are not considered in the sum of emission rates detected.

Please note that the total emissions presented in Table 1 are expected to include fugitive, vented, and sporadic operations-related emissions.



The detailed screening data is provided in an Excel attachment with this report, and the tables summarizing required data for each screened site are provided in Appendix B

Table 1. Combined summary of screening data for 2023 and 2024.

Year	2023 (July onward)	2024
Number of sites screened	42	44
Number of sites with detections	42	44
Percentage of screened sites with detections (%)	100	100
Number of detections during screening	43,017	104,205
Total volume identified (m ³)	463,711	838,243
Average total volume per site with screening detections (m ³)	11,040.74	18,628.6

2. Follow-up Data

Table 2 summarizes statistics regarding the OGI follow-up surveys of the alt-FEMP region conducted after a screening campaign. The raw detailed follow-up data is provided in an Excel attachment (Appendix A).

OGI has the capability to localize emissions to a source-level. Also, the OGI operator can normally determine the emission type. Table 3 shows the emission source equipment types for all identified emissions.



Table 2. Summary of OGI follow-up data. Note that 2023 data reflects a partial deployment year. Note that the data field “average time between detection and follow-up to site” was removed since this metric is not meaningful in the context of a continuous monitoring deployment.

Year		2023 (July onwards)	2024
Number of follow up site visits		51	80
Percentage of screened sites followed-up on (%)		60%	44%
Percentage of sites where follow up surveys were completed which had OGI detections (%)		60%	44%
Percentage of follow-up sites with OGI detections (including fugitive and venting detections)		79%	83%
Number of follow-up surveys where no emissions were found		30	14
Issues affecting follow-up times		Qube data interpretation and alarm processing Vendor procurement and deployment	Qube data interpretation and alarm processing Vendor procurement and deployment
Percentage of follow-up sites that are recurring (for the calendar year – following-up on a site more than once)		42%	25%
Identified emission source types per follow-up per screening campaign (vent, fugitive, methane slip, other)		2	2
Number of detections by emission source type (n)	Fugitives	94	151
	Vents	166	127
	Total	260	278
Volume of detections by emission source type (m ³ /day)	Fugitives	526.3	604

	Vents	1,622.1	871
	Total	2,148.4	1475
Average emissions per follow-up site (m ³ /day)		65	42.1
Identified emission source equipment types per follow-up per screening campaign (e.g., tank, compressor seal)		13 equipment types	14 equipment types
Number of detections by equipment type (n)		See Tables 3	See Tables 3
Volume of detections by equipment type (m ³ /day)			
Number of recurring leaks observed (if the leak occurred more than once per year)		2	0

Note that 2024 source attributions are different from the 2023 source attributions. In the 2024 reporting year, KEC reviewed individual OGI reports and assigned appropriate equipment groupings. The most notable changes are the inclusion of valves, open-ended lines, threaded connections and other connection related emissions into the “other” category.

Table 3. Number and volume (m³/d) of emission detections by equipment type.

Identified emission source equipment types	2023		2024	
	Number of detections by equipment type	Volume of detections by equipment type (m ³ /d)	Number of detections by equipment type	Volume of detections by equipment type (m ³ /d)
controlled tank	4	74.0	16	177.6
dehydrator	9	42.2	0	0
engine	0	0	1	3.3
flare stack	0	0	1	5.5
header	0	0	0	0
heater	1	2.7	1	1.6
Meter	17	69.3	2	6.4
Other	38	228.7	118	619.2
pig sender/receiver	0	0	0	0
pipeline – aboveground	14	60.8	72	226.5
pipeline - buried	0	0	0	0
pneumatic instrument	54	455.0	29	198.9
pneumatic pump	11	110.0	2	0.4
reciprocating compressor	53	550.7	8	72.2
screw compressor	0	0	0	0
separator	14	106.7	0	0
surface casing vent	0	0	1	1.2
sweetening process	5	28.5	3	5.3
treater	0	0	0	0
uncontrolled tank	28	359.1	15	126.4
vent stack	0	0	0	0
wellhead	12	60.8	9	30.4
Total	260	2148.4	278	1475



3. Emissions Summary

3.1 OGI Survey Summary

Figure 1 shows the emission rate distribution for site-total emissions detected during OGI survey campaigns of the alt-FEMP region, aggregating all methane emissions measured during that OGI campaign. The graph allows one to discern how many site-total emission measurements, by OGI, reported an emission rate within a certain range.

Figure 2 below shows the emission rate distribution for individual emissions detected during OGI survey campaigns. The graph allows one to discern how many individual OGI measurements had an emission rate within a certain range.

Figure 1: Distribution of site-total emission rates measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.



Figure 2: Distribution of individual emissions, by rate, measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.



Figure 3 below shows the emission rate distribution for individual fugitive emissions detected during OGI survey campaigns. The graph allows one to discern how many individual fugitive emission measurements reported an emission rate within a certain range.



Figure 3: Distribution of fugitive emissions, by rate, measured during OGI survey campaigns (e.g. follow-up) of the alt-FEMP region.



3.2 Control vs. alt-FEMP Summary

Table 4 compares several metrics related to the sites surveyed and emissions detected via OGI surveys in the alt-FEMP vs. Control regions for the duration of the program. The average rates in the table are calculated per site per survey (e.g. the control site was surveyed six times in the two years and the average of these six was taken).

Table 4. Comparison of the alt-FEMP and Control regions.

Item	alt-Femp Region	Control Region
Number of site visits in region	80	12
Number of sites in region with emissions detected via OGI	66	11
Percentage of sites in region with emissions detected via OGI (%)	83%	92%
Number of Emissions Detected at Surveyed Sites	278	55
Number of Surveyed Sites with Fugitive Emissions Detected	57	8
Percentage of Surveyed Sites with Fugitive Emissions Detected (%)	71%	67%
Number of fugitives detected via OGI in region	151	30
Number of vents detected via OGI in region	127	25
Total emission rate for region's detected emissions (m ³ /day)	1475	458
Total emission rate for region's detected fugitives (m ³ /day)	604	129
Total emission rate for region's detected vents (m ³ /day)	871	329
Average emission rate per site with emissions (m ³ /day)	42.1	152.7
Average emission rate for region's detected fugitives (m ³ /day)	5.5	4.3
Number of region's fugitives repaired in a given year	146	30



Percentage of region's fugitives repaired in a given year (%)	97%	100%
Average Days to Repair	18	14
Rate of Fugitive Emissions Repaired (m3/d)	587	129

4. Emission Reduction Summary

The fugitive emission data collected during the alt-FEMP was used to generate the as-found “measured fugitive emission distribution”. This consisted of all fugitive emissions recorded during surveys of both the alt-FEMP and control regions. Figure 6 shows a comparison of the as-found “measured fugitive emission distribution” to the “assumed fugitive emission distribution” employed in the modelling to initially used to design the approved alt-FEMP. Additionally, the minimum detection limit (MDL) at 99% probability of detection (PoD) for the screening technology is displayed for reference.

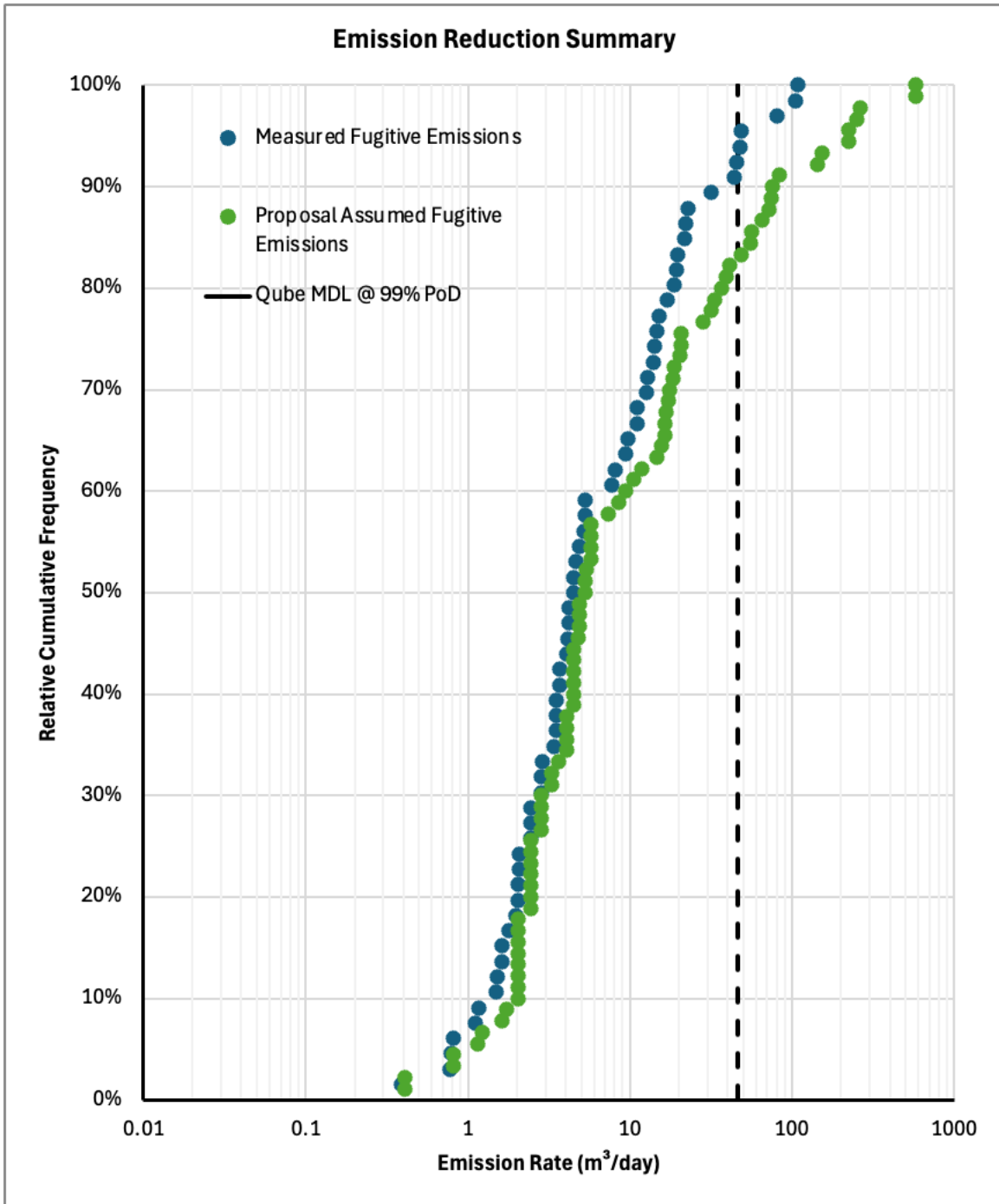


Figure 4: Cumulative distribution curve of as-found fugitive emissions (blue dots) and proposal assumed fugitive emissions (green dots) used in the modelling with the Qube detection threshold (dotted black line).

A default Directive 60 FEMP program and the executed KEC alt-FEMP Pilot program were re-modelled using the as-found fugitive distribution using the AroFEMP software (Arolytics). The original model resulted in the Default program emitting 56% more methane, and the updated model resulted in the Default emitting 26% more methane. The change in model performance could be due to the change in the emission distribution where the as-found emissions distribution had smaller emissions.

5. Technology Limitations

A. Atmospheric variability

Qube's IIoT device must be positioned within a leak's plume to acquire fugitive emissions measurements. The presence of wind is a crucial element, as Qube relies on atmospheric transport of methane from the source to the measurement device. If the wind speed is too low, blowing in the wrong direction, or if there is significant vertical transport of air, the plume might miss the device and the leak might go undetected. Fortunately, atmospheric conditions change regularly, so even if conditions are unsuitable at any given moment, several steps can be taken to maximize the chance that leaks will be detected in the shortest amount of time. Qube deploys multiple systems at larger facilities to ensure that even if the wind does change direction, there is likely a device downwind to detect the plume and a device upwind to determine whether an emission was a true onsite versus offsite emission. An understanding of the prevailing wind direction and nearby obstacles is used when positioning devices (in Alberta, the wind generally blows from the west). To account for vertical transport, environmental sensors are used to adapt quantification estimates for different atmospheric stability classes.

B. Calibration

Figaro's TGS2611 sensors exhibit an exponential response to gas; they are very sensitive at the low end with a low logarithmic drop off in resolution as gas concentration increases. Each sensor is actively calibrated for temperature and humidity. The process for developing calibration curves involves releasing a known quantity of methane in a temperature and humidity-controlled chamber and systematically changing the temperature and humidity while measuring the response from the sensor. Each TGS2611 sensor will exhibit a slightly different response to methane so we individually capture and set offset ('zero') and span values during the calibration procedure. This process allows each sensor to have its own unique calibration to provide repeatable results. Sensors are recalibrated after deployment to account for background methane present at sites. Figaro's TGS2611 sensor is also cross-sensitive to carbon monoxide, and although we do not anticipate carbon monoxide to be present in large quantities at Kiwetinohk's facilities, an additional calibration curve has been developed to net out the effect of the presence of carbon monoxide on the methane sensor.

C. Communications

Timely communication of data from the IIoT devices to the cloud is critical to ensure that leaks are identified soon after they arise. If the communications module fails or if data is transmitted too intermittently, actionable information might not be acquired in a sufficiently timely manner. While Qube has tested the communications module extensively, all systems will be monitored daily for the duration of this pilot to ensure that data is being properly transmitted to the cloud. Should any issues arise, an alarm will be triggered, and a technician will be dispatched to the IIoT device to address the problem and retrieve any transferred data. Qube has recently developed a fleet health dashboard that determines when data was last transmitted from each device and will be used throughout this project to ensure that device communication is optimized and maintained at a high level of uptime.

D. Confounding sources

Distinguishing fugitive emissions from vented emissions is an outstanding challenge for Qube and one that is currently being worked on through AI/ML models. Qube will continue to use these detections to refine the classification models as part of its technology.

Qube's sensors may detect methane emissions that originate from non-target oil and gas facilities or from unrelated sources such as livestock or wetlands. Qube will work to carefully understand these potential confounding sources for each facility and will combine data from multiple devices to ascertain whether emissions are originating off-lease. If a situation occurs in which significant and potentially off-lease emissions are detected, Qube will take action to investigate and notify responsible parties.

E. Distance

A necessary distance trade-off must be established for each facility. If Qube's IIoT devices are deployed too close to the facility, measurement data might only be available for a subset of the facility, and the device would provide a myopic view of overall emissions. Alternatively, devices that are positioned too far downwind might not detect emissions as downwind pollutant mixing ratios become rapidly dispersed and are known to decrease exponentially with distance. Qube will navigate this trade-off by deploying a greater number of devices within a conservative range of 10 to 100 metres from possible sources.

F. Source height

Qube continues to model the effect of source height on detection capability and understands that there may be limitations in instances where emissions are released from an anomalous source height (e.g., flare stack) where a device cannot be placed far enough away for adequate wind carrying to enable device detection. Throughout existing deployments, Qube has been able to identify flare stack emissions from other facilities, however, close monitoring from potential flare sources will be considered throughout this project, and Kiwetinohk will ultimately be responsible for any flare stack emissions. Modeling shows that Qube's devices should have adequate detection capability on standard tank heights within the Kiwetinohk facilities.

G. Number of devices

Qube has not yet determined the optimal number of devices to deploy at each facility type and has based recommendations on current deployments of similar sizes and complexity and internal modeling to optimize device counts per site. Deploying too few devices may lead to incomplete data and could lead to missed leaks, in extreme cases, however, Qube is considering parameters such as detection capability from controlled release testing to ensure that an adequate number of devices is deployed at each site for confident detection. Although the true number of devices required depends on facility size, Qube will be deploying three to eight devices per facility in this project, depending on individual site sizes and complexity.

H. Power

During winter months, device power can occasionally become an issue due to low solar flux and possible snow or ice accumulation on the solar panels. Qube will monitor power availability daily through the fleet health dashboard and will send a notification to Kiwetinohk if a technician or operator is required to clear off solar panels or replace batteries as and when required.

I. Temperature and humidity

Qube's system has been designed to operate in conditions from -40°C to $+45^{\circ}\text{C}$ and at relative humidity ranging from 20 to 99%. Qube's devices had no operational issues in field conditions where temperatures reached a low of -46°C and provides confidence that operation outside of these windows is not a concern for functionality. A typical year in Alberta does not see many days that fall outside of these conditions, so we do not consider temperature or humidity to be a significant concern.

6. Success of the alt-FEMP

During the 2023 deployment of the Qube sensors, wildfires disrupted the field season causing delays and installations that were not successful. Early in 2024 the Alt-FEMP program was adjusted to address the deployment issues and remodeled for comparison against a default program. The site adjustments and 2024 deployments were successfully executed for the second year of the program.

Engagement with field operations: active participation of field operations staff within any LDAR program is essential to the program's success. KEC and Qube conducted monthly review meetings together to review the Qube data from the previous month, review any anomalous emissions which were detected, and determine if there were any sites which were not trending as expected. In addition, KEC staff received daily emails from Qube which outlined the detections of the previous 24 hours, enabling KEC to quickly review any large emissions and ensure all equipment was running as expected.

By working closely with Qube, we were able to improve the alarm detection thresholds of the deployed systems and drastically reduce the false alarms and greatly reduce the resource use on reviewing Qube data. The Qube sensor alarm thresholds were adjusted to a literature informed baseline. This significantly reduced the number of alarms from 8173 in 6 months of 2023 down to 639 for the full 2024 monitoring year. (See Appendix B)

KEC validated a reduction in vented emissions between 2023 and 2024 through the Qube detections. This is outside of the goals of the alt-FEMP but the reduction in venting observed via the Qube sensors is consistent with the calculated venting reduction through KEC's emission reduction projects.

7. Nonperforming Program Elements

Emission source attribution was consistently a challenge throughout the alt-FEMP where vent and potential methane slip signals were difficult to separate from fugitive emissions signals. The continuous emission data time series required significant processing and interpretation across all parties was challenging and time consuming.

8. Additional Control Measures

Engagement with field operations: active participation of field operations staff within any LDAR program is essential to the program's success. KEC and Qube conducted monthly review meetings together to review the Qube data from the previous month, review any anomalous emissions which were detected, and determine if there were any sites which were not trending as expected. In addition, KEC staff received daily emails from Qube which outlined the detections of the previous 24 hours, enabling KEC to quickly review any large emissions and ensure all equipment was running as expected.

9. Additional Information

The Rimbey area and assets that were a part of the 2023 Alt-FEMP proposal have been divested. In early 2024 a submission to restructure the Alt-FEMP included new sites that would replace Rimbey Alt-FEMP sites.

10. Key Performance Indicators

- KEC was successful in implementing alternative technologies to conduct LDAR screening, where emissions were detected at 66 out of 80 site visits.
- In 2024, a total of 2297.6 m³/day of methane was found to be emitting by the screening technology. Of which, 587.0 m³/day was identified as fugitive emissions when followed-up with OGI and subsequently repaired.
- 97% of fugitive emissions sources were repaired under the alt-FEMP. 3% of fugitive detections require full facility shutdown to complete safely and remain in a delay of repair status.
- The average days to repair in the Alt-FEMP region was 18 compared to 14 in the control region. The Alt-FEMP and control region had 83% and 80% (respectively) of their repairs completed within a 30-day period.
- Upon remodelling the alt-FEMP program with the as found fugitive distribution, the alt-FEMP still performed better than the default.

- Outside the scope of this alt-FEMP, Qube’s technology provided additional value to KEC’s upstream operations by validating venting reductions achieved through venting reduction projects. Use of the Qube devices provided a second layer of validation that venting reduction projects completed by KEC achieved the expected reductions, and provided additional information on site baselines to inform future reduction project opportunities.

Appendix A: Raw Detailed Data

Please refer to the attached excel file of the raw data collected during the screening and follow-up surveys titled “KEC-AER-AppendixA”

Appendix B: CEMS Data Table

Please refer to the attached excel file titled “KEC_Report AppendixB_Screening Data Site Tables”