

Murphy Oil Corporation

alt-FEMP Pilot Program 2024 Performance Report

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Executive Summary

On June 2, 2023, the Alberta Energy Regulator (AER) approved a proposal from Murphy Oil Corporation (Murphy Oil) for an alt-FEMP pilot program. Murphy Oil is an independent oil and natural gas exploration and production company whose alt-FEMP facilities are located in Alberta. The alt-FEMP covers two full compliance years ending on December 31, 2024. This report meets the requirements laid out in the alt-FEMP approval letter.

For methane detection, this alt-FEMP utilized GreenPath Energy, now Montrose Environmental Group (Montrose), optical gas imaging cameras (OGI) along with site-level emission-screening by Flux Lab's truck-based ExACT technology operated by Vertex Energy (Vertex).

With the pilot alt-FEMP screenings and surveys completed, Murphy Oil 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:

<u>Quarter-Year</u>	<u>Site Level Screening</u>	<u>OGI Surveys</u>	<u>Status</u>
Q3 2023		Comprehensive OGI surveys at all triannual sites.	Completed
Q3 2023	Truck-based, site-level screening by Vertex of alt-FEMP facilities	Comprehensive OGI follow-up surveys at the top 40% of all screened LSDs ranked by total emission rate for fugitive emission localization and repair.	Completed
Q4 2023	Truck-based, site-level screening by Vertex of alt-FEMP facilities	Comprehensive OGI follow-up surveys at the top 40% of all screened LSDs ranked by total emission rate for fugitive emission localization and repair.	Completed
Q2 2024	Truck-based, site-level screening by Vertex of alt-FEMP facilities	Comprehensive OGI follow-up surveys at the top 40% of all screened LSDs ranked by total emission rate for fugitive emission localization and repair.	Completed
Q3 2024	Truck-based, site-level screening by Vertex of alt-FEMP facilities	Comprehensive OGI follow-up surveys at the top 40% of all screened LSDs ranked by total emission rate for fugitive emission localization and repair.	Completed
Q4 2024	Truck-based, site-level screening by Vertex of alt-FEMP facilities	Comprehensive OGI follow-up surveys at the top 40% of all screened LSDs ranked by total emission rate for fugitive emission localization and repair.	Completed

1. Screening Data

Table 1 summarizes various statistics regarding the screening campaigns across the alt-FEMP. Please note emissions detected during the screenings can be a combination of fugitive, vented and sporadic operations-related emissions. The detailed screening data is provided in an Excel attachment with this report, and the tables summarizing each site's total and individual emissions detected during each screening are provided in Appendix B and C, respectively.

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

<u>Parameter</u>	<u>2023</u>	<u>2024</u>
Number of sites screened	50	94
Number of screened sites with detections	47	89
Number of detections during screenings	47	89
Percentage of screened sites with detections (%)	94%	95%
Average emissions per screened site with a detection (m ³ /day)	42.1	44.5
Total emission rate identified (m ³ /day)	1980	3964.3
Number of sites followed-up on	26	40
Percentage of sites followed-up on vs. screened (%)	48%	43%
Number of follow-up sites with no screening detections	4	1
Number of follow-up emissions with emission source not detected by the screening technology	4	8
Average time between detection and follow-up to site (days)	57	26
Percentage of follow-up sites that are recurring (%)	50%	30%

Number of emissions from the screenings that were followed-up on	22	39
Number of emissions from the screenings that were followed-up and identified as fugitive emissions	11	17
Total emission rate of fugitives identified and fixed for the calendar year (m ³ /day)	26.1	18

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 with this report.

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 including the number and volume for each equipment type.

Many equipment categories for emissions could have been classified as either ‘separator’ or ‘pneumatic instrument’ thus causing a discrepancy in these categories between 2023 and 2024.



Table 2. Summary of OGI follow-up data.

Year		2023	2024
Number of sites followed-up on for the year		26	40
Percentage of screened sites followed-up on (%)		52%	43%
Percentage of sites with screening detections followed-up on (%)		55%	44%
Number of follow-up surveys where no emissions were found		0	0
Average time between detection and follow-up to site (days)		57	26
Percentage of follow-up sites that are recurring (for the calendar year – following-up on a site more than once)		50%	30%
Identified emission source types per follow-up per screening campaign (vent, fugitive, methane slip, other)		Fugitives and Vents	Fugitives and Vents
Number of detections by emission source type (n)	Fugitives	22	29
	Vents	312	336
	Total	334	365
Volume of detections by emission source type (m ³ /day)	Fugitives	56.0	93
	Vents	405.0	838
	Total	461.0	931

Average emissions per follow-up site (m ³ /day)	18	23
Identified emission source equipment types per follow-up per screening campaign (e.g., tank, compressor seal)	5	9
Number of recurring leaks observed (if the leak occurred more than once per year)	5	0

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				
dehydrator				
flare stack				
header				
heater				
meter			2	4.2
other			3	7.2
pig sender/receiver				
pipeline - aboveground				
pipeline - buried				
pneumatic instrument	294	210.9	10	31.3
pneumatic pump	1	0.4	1	2.6
reciprocating compressor	27	212.5	120	355.7
screw compressor				
separator	3	4.5	152	286.1
surface casing vent			55	140.9
sweetening process				
treater				
uncontrolled tank	7	30.2	7	86.4
vent stack				
wellhead	2	2.5	15	16.9
Total	334	461.0	365	931.3



3. Emissions Summary

3.1 Screening Summary

Figure 1 shows the distribution for site-total methane emission rates detected during screening campaigns in 2023 and 2024, capturing all types of methane emissions (fugitives, vents, methane slip and others). The graph allows one to discern how many site-total emission measurements reported emission rates within a certain range (e.g. emissions with rates between 0 and 100 m³/day where individual emissions on a single site from one screening are summed).

Figure 2 shows the distribution for individual emission rates detected during the 2023 and 2024 screening campaigns. Screening technologies are generally unable to determine the type of methane emission measured (fugitives, vents, methane slip and others). The graph allows one to discern how many individual emission measurements had an emission rate within a certain range (e.g., emissions with rates between 0 and 100 m³/day).

Screening Site-Emissions Distribution

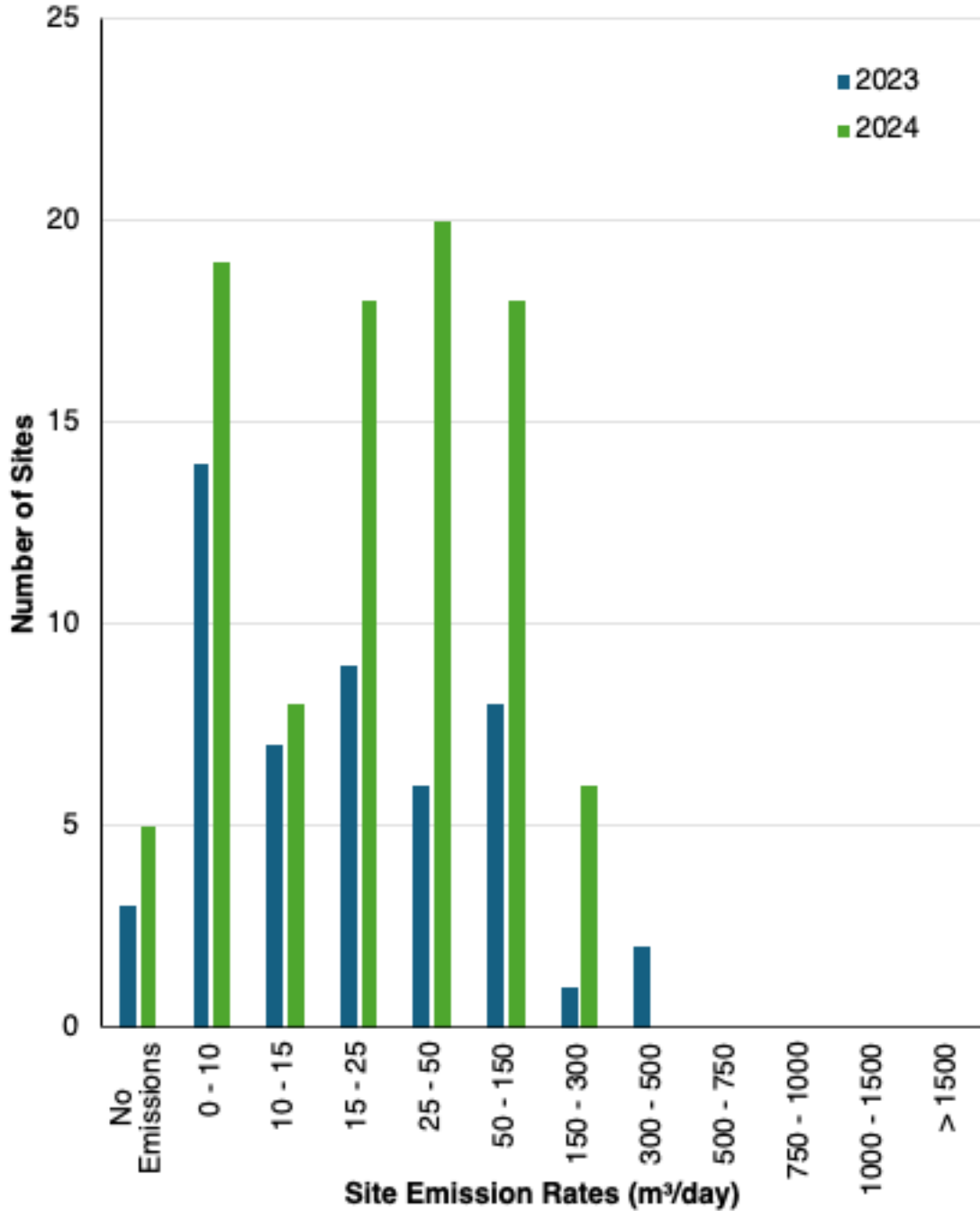


Figure 1: Distribution of site-total emission rates measured during screening campaigns.



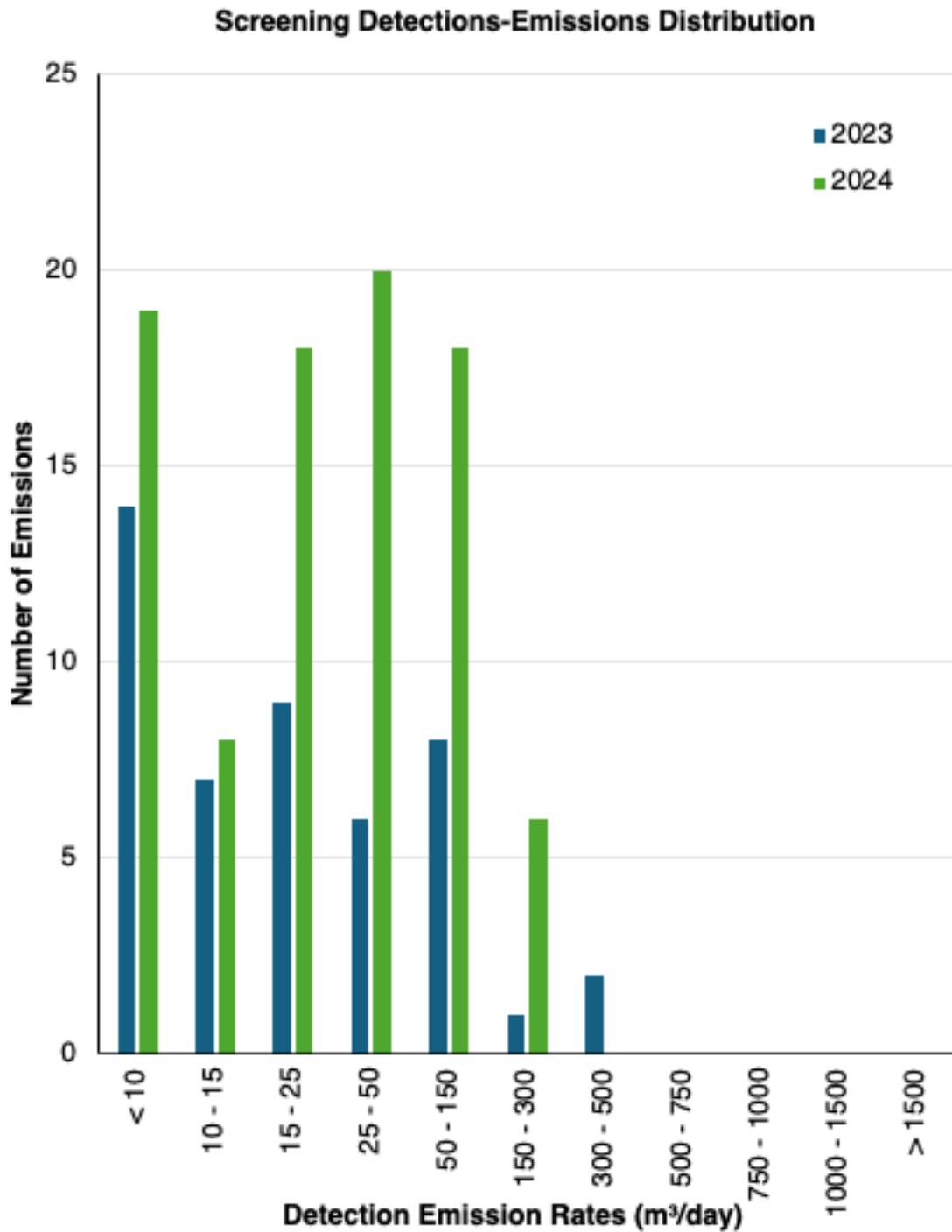


Figure 2: Distribution of individual emissions, by rate, measured during screening campaigns.



In general, screening technologies cannot discern fugitive emissions from other emission types, thus a graph depicting the emissions distribution specifically for fugitives detected during screenings could not be generated.

3.2 OGI Survey Summary

Figure 3 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 4 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.

Survey Site-Emissions Distribution

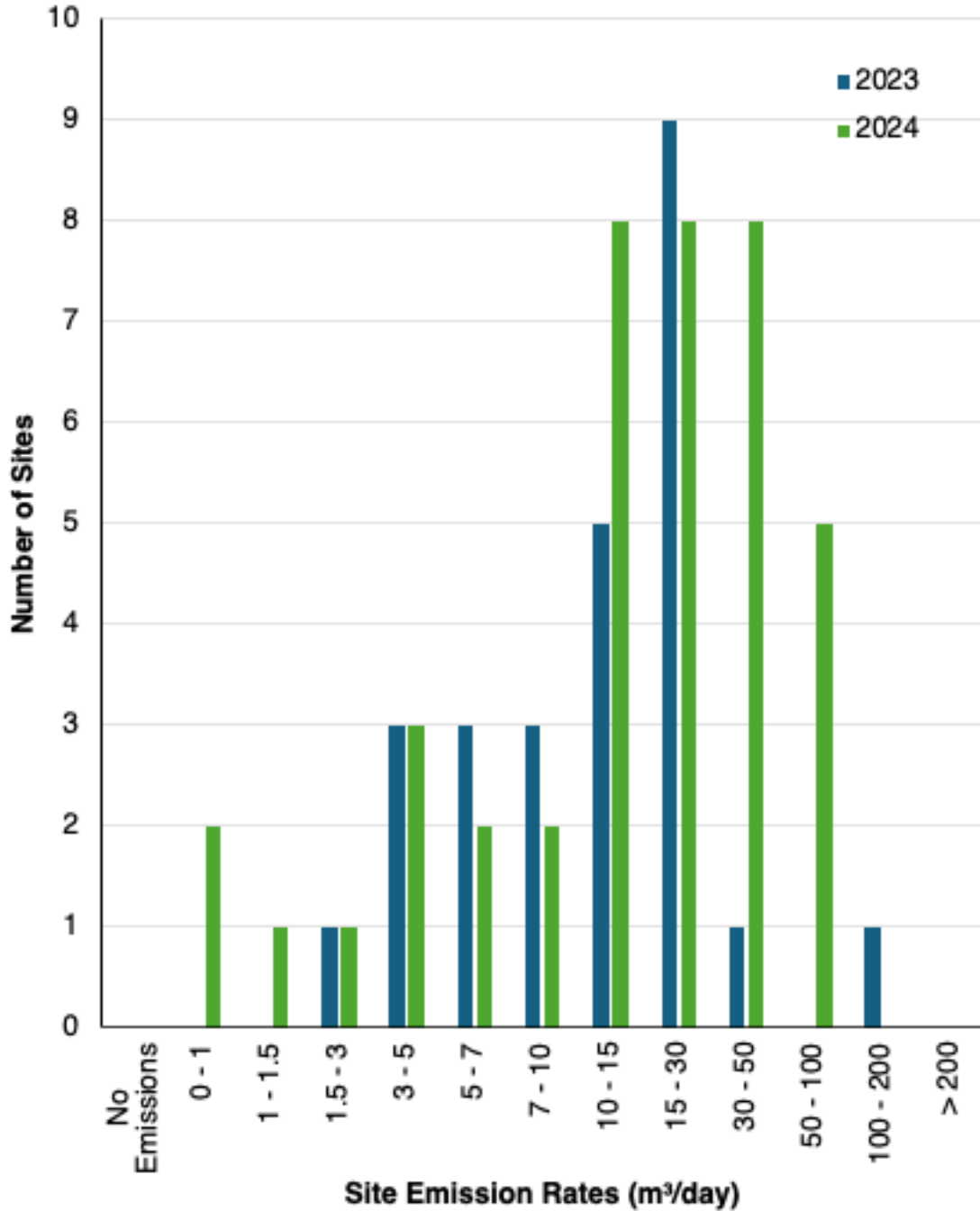


Figure 3: Distribution of site-total emission rates measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.



Survey Detections-Emissions Distribution

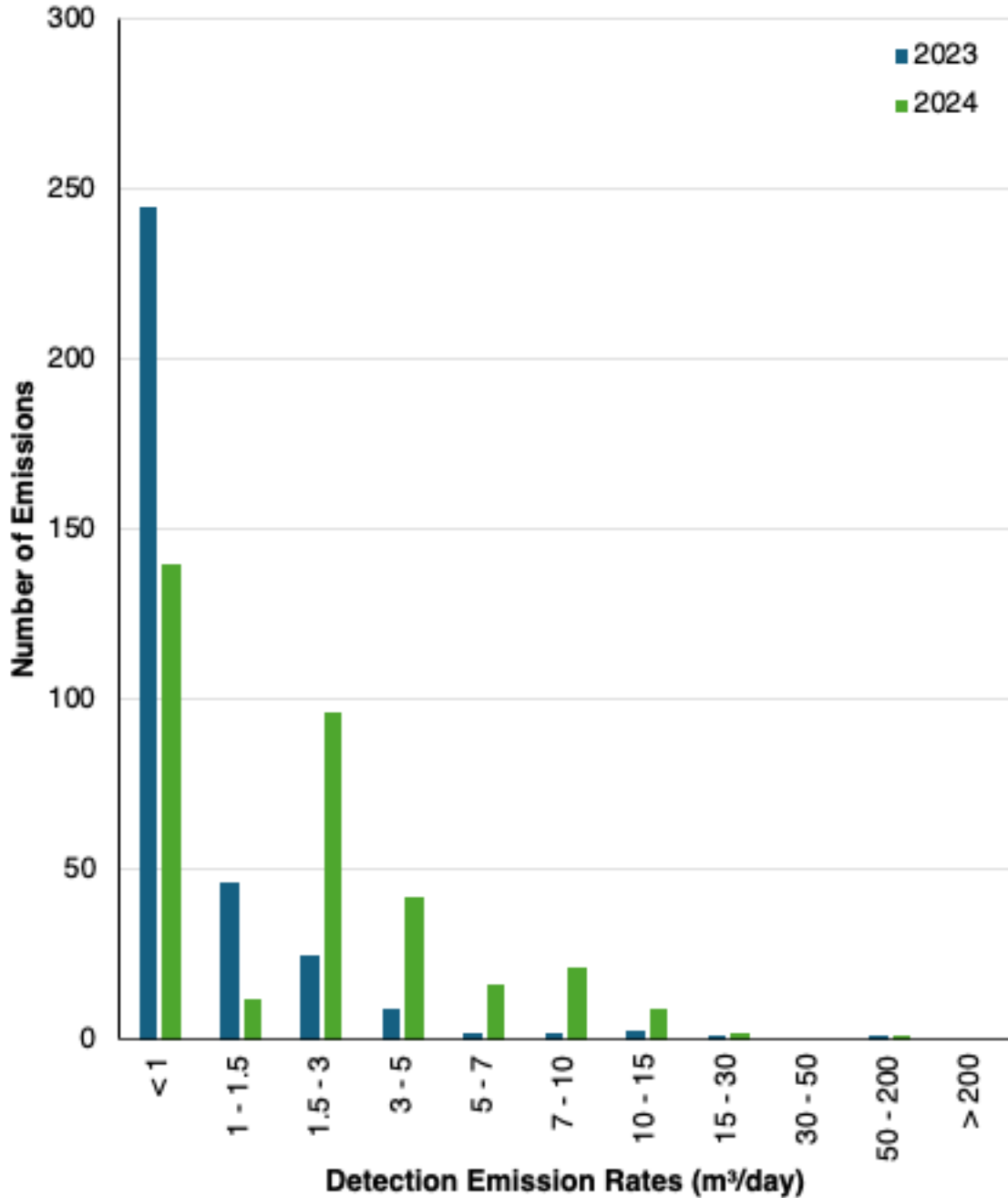


Figure 4: Distribution of individual emissions, by rate, measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.



Figure 5 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.



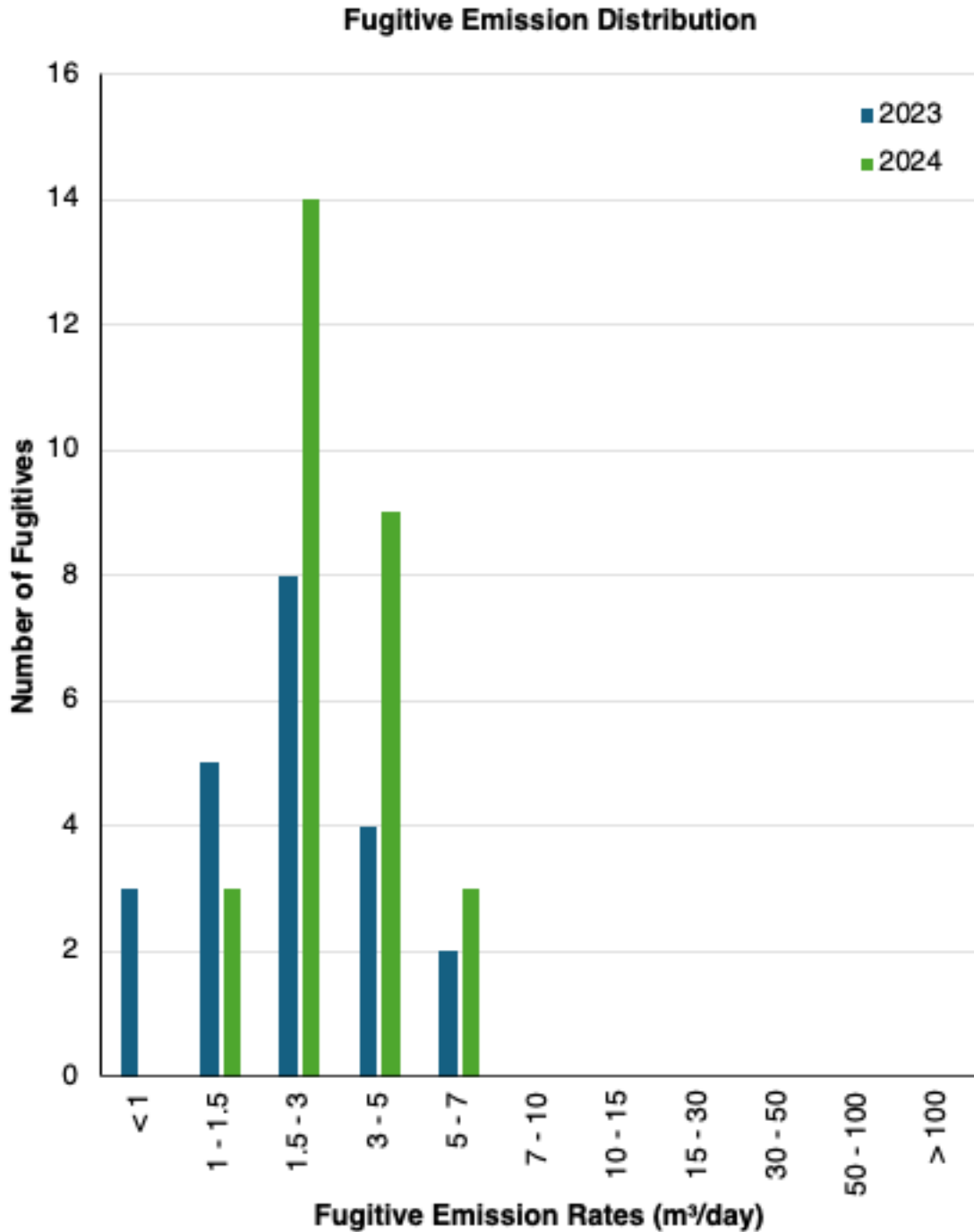


Figure 5: Distribution of fugitive emissions, by rate, measured during OGI survey campaigns (e.g. follow-up) of the alt-FEMP region.



3.3 2023 Independent OGI Survey

In April 2023, an independent OGI survey was completed at all triannual sites in the alt-FEMP, including sites in both the Control and alt-FEMP regions. Table 4 summarizes this OGI survey data and Table 5 provides the number and volume of emission detections by equipment type for this OGI survey.

Table 4. Summary of April 2023 independent OGI survey data.

Year	2023	
Number of sites surveyed	22	
Number of sites with detections	10	
Percentage of sites with detections (%)	45.5	
Number of detections	12	
Identified emission source types per follow-up per screening campaign (vent, fugitive, methane slip, other)	Fugitive	
Number of detections by emission source type (n)	Fugitives	12
	Vents	N/A
Volume of detections by emission source type (m ³ /day)	Fugitives	27.05
	Vents	N/A
Identified emission source equipment types per follow-up per screening campaign	5	
Total number of detections	12	
Total volume of detections (m ³ /day)	27.05	
Average time between survey date and repair (days)	128.3	
Volume of fugitives identified and fixed for the calendar year (m ³)	15.4	

Table 5. Number and volume of detections by equipment type for the April 2023 independent OGI survey.

Identified emission equipment source types	Number of detections	Volume of detections (m ³ /day)
wellhead	2	2.26
separator	2	1.87
reciprocating compressor	5	12.74
pneumatic pump	2	4.56
tank	1	5.62
Total	12	27.05

3.4 Control vs. alt-FEMP Summary

Table 6 compares several metrics related to the sites surveyed and emissions detected via OGI surveys in the alt-FEMP vs. Control regions for 2024. 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 6. Comparison of the alt-FEMP and Control regions.

Item	alt-FEMP Region	Control Region
Number of Sites Surveyed	40	7
Number of Surveyed Sites with Emissions Detected	40	7
Percentage of Surveyed Sites with Emissions Detected (%)	100%	100%



Number of Emissions Detected at Surveyed Sites	365	284
Number of Surveyed Sites with Fugitive Emissions Detected	17	5
Percentage of Surveyed Sites with Fugitive Emissions Detected (%)	42.5%	71.4%
Number of Fugitive Emissions Detected	29	15
Number of Vent Emissions Detected	336	269
Total Rate of Emissions Detected (m ³ /day)	931	621
Total Rate of Fugitive Emissions Detected (m ³ /day)	93	45
Total Rate of Vent Emissions Detected (m ³ /day)	838	576
Average Fugitive Rate per Site with Fugitive Emissions Detected (m ³ /day)	40.5	88.7
Average Fugitive Rate for all Fugitive Emissions Detected (m ³ /day)	2.75	2.4
Number of Fugitive Emissions Repaired	6	4
Percentage of Fugitives Repaired (%)	21%	27%
Number of Sites Surveyed	40	7
Average Time to Repair (days)	63	193

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. Figure 6 shows a comparison of the as-found “measured fugitive emission distribution” to the “assumed fugitive emission distribution” employed in the modelling initially used to design the approved alt-FEMP. Additionally, the minimum detection limit (MDL) at 90% probability of detection (PoD) for the screening technology is displayed for reference.

A default Directive 060 FEMP program and the executed program were re-modelled using the as-found fugitive distribution using the AroFEMP software (Arolytics). The traditional default FEMP was predicted to have emitted 21% less in fugitive emissions than the alt-FEMP by the re-modelling. As can be seen in Figure 6, the as-found distribution would need supplementation for proper re-modelling of the programs. The as-found distribution also contained much smaller proportion of large fugitive emissions, also influencing the result.

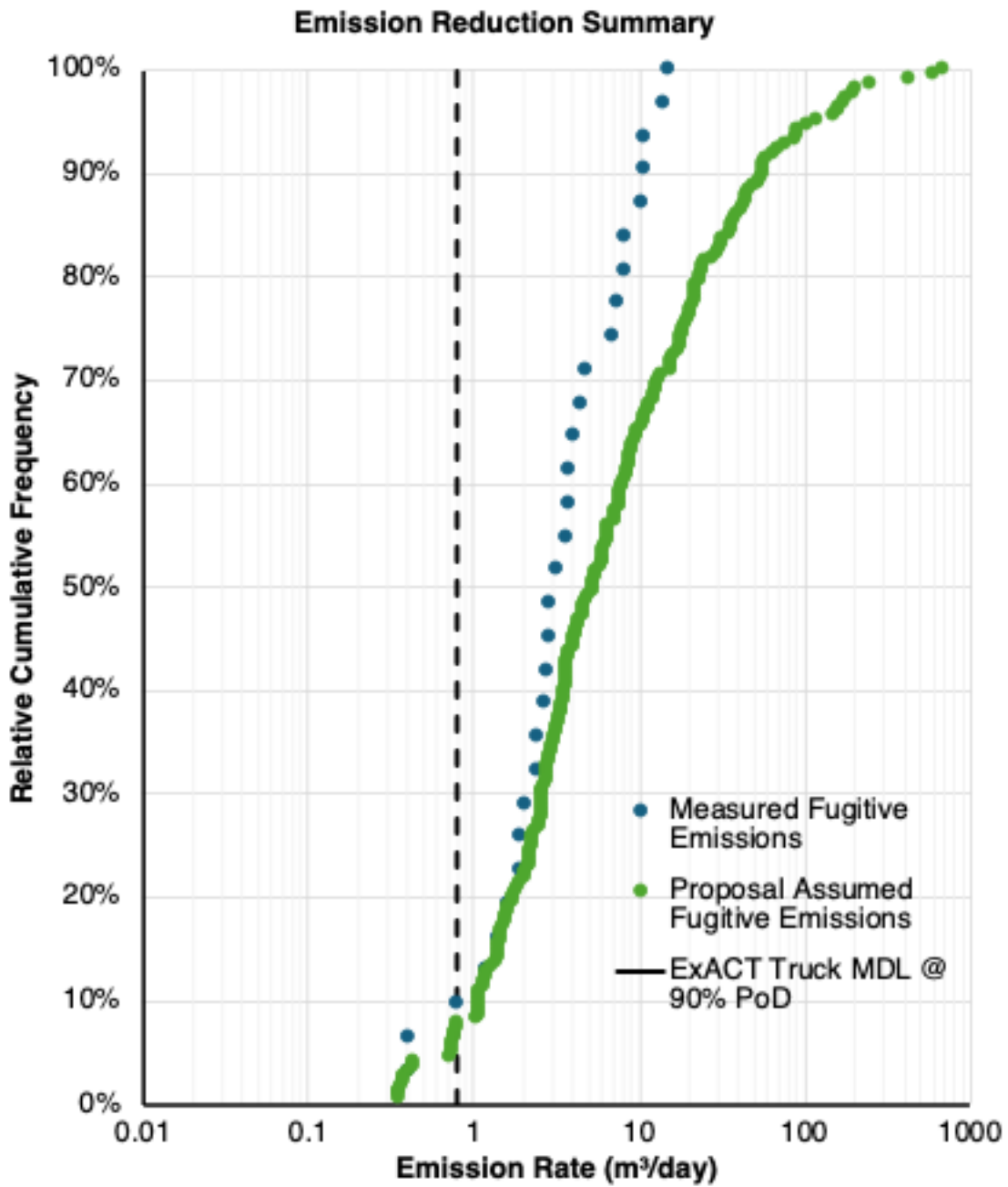


Figure 6. Comparison of relative cumulative frequencies for the “as-found” measured fugitive emissions versus the proposal-assumed fugitive emissions.

5. Technology Limitations

The ExACT technology operated by Vertex is not impacted by cloud cover or shadows. ExACT can only reliably measure methane emissions in wind speeds of 0.8 metres per second or greater. The vehicle must be able to get downwind of an emission source for detection to occur. There are no limitations in required operational temperatures (ranges from -40°C to +40°C). ExACT can operate in moderate rain and snow-covered conditions without limitations. Can operate up to 1500ppm of methane. Heavy tree-cover may impact the dispersion of plumes and their ability to be detected.

6. Success of the alt-FEMP

The alt-FEMP was designed to meet methane emission equivalency to a default FEMP using alternative site screening technologies combined with OGI surveys. The execution of this program has been successfully completed.

7. Nonperforming Program Elements

Although OGI follow-up surveys were able to be completed within 60 days of each screening campaign's completion in 2023, the processing time for ExACT screening data was longer than expected and contributed to a longer average time between the screening and OGI follow-up work. This was greatly improved for 2024 and the follow-up time decreased from 57 days to 26.

The 2024 Q2 screening was delayed by several weeks as a truck sensor was damaged during loading until a replacement was sourced. There was no further effect on the data collected outside of the delay.

8. Additional Control Measures

Any sites that were missed during screenings were automatically added to be followed-up on by OGI survey.

9. Additional Information

N/A

10. Key Performance Indicators

- Murphy Oil was successful in implementing alternative technologies to conduct LDAR screening, where emissions were detected at 136 of the 144 screened sites.
- A default D060 program would result in 48 site visits compared to the 40 that were visited with OGI under the alt-FEMP showcasing an efficient LDAR program execution.
- In 2023 and 2024, a total of 5944 m³/day of methane was found to be emitting by screening technologies on 136 detections. Of which, 149 m³/day was identified as fugitive emissions when followed-up with OGI.
- On average, leak repairs were completed 63 days after an OGI follow-up under the alt-FEMP. In the Control Region, on average, leak repairs were completed after 193 days. Due to the small number of fugitives, each of these values were heavily weighted by 2 or 3 fugitives that had delays in repair.
- 21% of fugitive emissions sources were repaired under the alt-FEMP in 2024.
- Table 6 gives a comparison of the alt-FEMP and control regions for 2024.

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 “Murphy 2024 femp-screening-data.xlsx”.

Appendix B: Screening Data – Site-total Emissions by Campaign

See attached “Murphy AER-altFEMP-PerformanceReport-Appendix.xlsx”. Note that any truck screenings are typically given as a site-total rate and not individual detections.

Appendix C: Screening Data – Individual Emissions

See attached “Murphy AER-altFEMP-PerformanceReport-Appendix.xlsx”. Note that any truck screenings are typically given as a site-total rate and not individual detections.