Cenovus Energy

Conventional Full-Scale Alt-FEMP

Directive 060 Full-Scale Alt-FEMP Final Performance Report

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Executive Summary

Cenovus Energy (CVE) is a Canadian energy company headquartered in Calgary, Alberta. CVE contracted Arolytics to conduct methane emissions equivalency modelling for all 513 of CVE's conventional upstream oil and gas facilities (on 379 sites). Guided by this modelling, CVE was issued regulatory approval by the Alberta Energy Regulator (AER) to implement a full-scale alternative Fugitive Emissions Management Program (alt-FEMP) at all 513 facilities as of July 25, 2023. The alt-FEMP was designed to achieve greater fugitive emissions reductions than a default program under AER Directive 060 and was approved until December 31, 2024.

The program design for the approved alt-FEMP requires one OGI survey of all triannual facilities in spring 2023 and Bridger Photonics, Inc. (Bridger) aerial-based screenings of all facilities twice in 2023 and twice in 2024. Each aerial screening is followed by a comprehensive follow-up OGI survey targeting the top emitting sites ranked by total emission rates (as determined by the aerial screening) such that 25% of all facilities in the alt-FEMP are surveyed. Table 1 below details the alt-FEMP's screening and follow-up activity completed in 2023 and 2024.

The Bridger aerial screening technology detected all types of emissions at the site level. Following the screening campaign, emissions were attributed to a site or legal subdivision (LSD) and the LSDs were ranked highest to lowest by their total detected emission rates. A top portion of these sites were then visited for emissions localization and repair, via OGI, where fugitive emissions were differentiated from vented emissions and fugitive emission sources were repaired per AER Directive 060 requirements. The portion of sites designated for follow-ups was chosen such that 25% of the total facility list was included in each follow-up.

This report summarizes data collected during CVE's 2023-2024 alt-FEMP screening and OGI survey campaigns.

Table 1: CVE's Proposed 2-year (January 2023 - December 2024) Alt-FEMP Methodology.

Timing	Site-Level Screening	OGI Surveys	Status
Q2 2023	N/A	Conduct one OGI survey of all triannual facilities (per Directive 060 Section 8.10.2.1 – Table 4).	Completed
Q3 2023	Aerial-based screening by Bridger - July 2023	Comprehensive follow-up OGI surveys at the top-emitting screened sites based on ranking all screened sites by total emission rate. The number of sites designated for follow-up were chosen such that 25% of all 513 facilities received a follow-up survey.	Completed
Q4 2023	Aerial-based screening by Bridger - October 2023	Comprehensive follow-up OGI surveys at the top-emitting screened sites based on ranking all screened sites by total emission rate. The number of sites designated for follow-up were chosen such that 25% of all 513 facilities received a follow-up survey.	Completed
Q2 2024	Aerial-based screening by Bridger - June 2024	Comprehensive follow-up OGI surveys at the top-emitting screened sites based on ranking all screened sites by total emission rate. The number of sites designated for follow-up will be chosen such that 25% of all 513 facilities receive a follow-up survey.	Completed
Q4 2024	Aerial-based screening by Bridger - October 2024	Comprehensive follow-up OGI surveys at the top-emitting screened sites based on ranking all screened sites by total emission rate. The number of sites designated for follow-up will be chosen such that 25% of all 513 facilities received a follow-up survey.	Completed

2 Screening Data

Table 2 shows various statistics from the 2023 aerial screening campaigns conducted by Bridger. The screening campaigns were conducted at the site level and any emissions detected were not differentiated between their type (i.e. fugitive or vent). The follow-up statistics refer only to the OGI emissions at the top sites with identified emissions.

The detailed data from screenings is provided in an Excel attachment with this report.

Table 2: Combined summary of screening data for 2023 and 2024 ("site" indicates LSD).

Parameter	**2023**	**2024**
Number of sites screened	789	901
Number of screened sites with detections	361	350
Number of detections during screenings	777	666
Percentage of screened sites with detections (%)	46%	39%
Average emissions per screened site with a detection (m^3/day)	361.9	159.8
Total emission rate identified (m^3/day)	135,020	94,306
Number of sites followed-up on	134	163
Percentage of sites followed-up on vs. screened (%)	17%	18%
Number of follow-up sites with no screening detections	0	10
Number of follow-up emissions with emission source not detected by the screening technology	0	11
Average time between detection and follow-up to site (days)	39	30
Percentage of follow-up sites that are recurring (%)	58%	39%
Number of emissions from the screenings that were followed-up on	771	410
Number of emissions from the screenings that were followed-up and identified as fugitive emissions	267	300
Total emission rate of fugitives identified and fixed for the calendar year (m^3/day)	1,030	6,738

3 Follow-up Data

Table 3 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 4 shows the emission source equipment types for all identified fugitive emissions including the number and volume of emissions for each equipment type.

Table 3: Summary of OGI Follow-up Data ("site" indicates LSD).

Parameter		**2023**	**2024**
Number of sites followed-up on for the year		134	163
Percentage of screened facilities followed-up on (%)		29%	28%
Percentage of sites with screening detections followed-up on (%)		61%	43%
Number of follow-up surveys where no emissions were found		52	10
Average time between detection and follow-up to site (days)		39	30
Percentage of follow-up sites that are recurring (for the calendar year – following-up on a site more than once)		58%	39%
Number of detections by emission source type (n)	**Fugitives**	267	512
	Vents	312	576
	Total	579	1,088
Volume of detections by emission source type (m^3/day)	**Fugitives**	2,235	14,876
	Vents	5,205	7,879
	Total	7,440	22,755
Identified emission source equipment types per follow-up per screening campaign (e.g., tank, compressor seal)		See Table 4	See Table 4
Total number of detections including methane slip (Ref: Table 4)		579	1,124
Total volume of detections including methane slip (m^3/day) (Ref: Table 4)		7,440	22,818
Number of recurring leaks observed (if the leak occurred more than once per year)		N/A	N/A
Total emission rate of fugitives identified and fixed for the calendar year (m3/day)		1,030	6,738

Table 4: Number and Volume (m^3/day) of Emission Detections by Equipment

Identified emission equipment source types	2023		2024	
	Number of detections	Volume of detections (m^3/d)	Number of detections	Volume of detections (m^3/d)
Controlled tank	19	614.4	31	1,122.6
Dehydrator	11	162.3	18	255.8
Flare stack	2	4	7	31.7
Header	12	21.9	0	0
Heater	4	2.9	40	191.9
Meter	7	61.6	12	127.1
Other	54	227.6	191	10,158.4
Pig sender/receiver	0	0	5	9.8
Pipeline - aboveground	2	3.1	1	88.2
Pipeline - buried	0	0	0	0
Pneumatic instrument	114	513.6	120	1,338.4
Pneumatic pump	18	264.6	32	348.9
Reciprocating compressor	199	2,520.0	440	5,557.78
Screw compressor	10	105.7	11	46.1
Separator	49	272.8	55	323.6
Surface casing vent	0	0	7	102.3
Sweetening process	1	7.8	0	0
Treater	0	0	0	0
Uncontrolled tank	64	2,627.8	134	2,731.1
Vent stack	0	0	11	339.2
Wellhead	13	30	9	44.6
Total	**579**	**7,440**	**1,124**	**22,818**

4 Emission Summary

4.1 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 m^3/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 m^3/day).

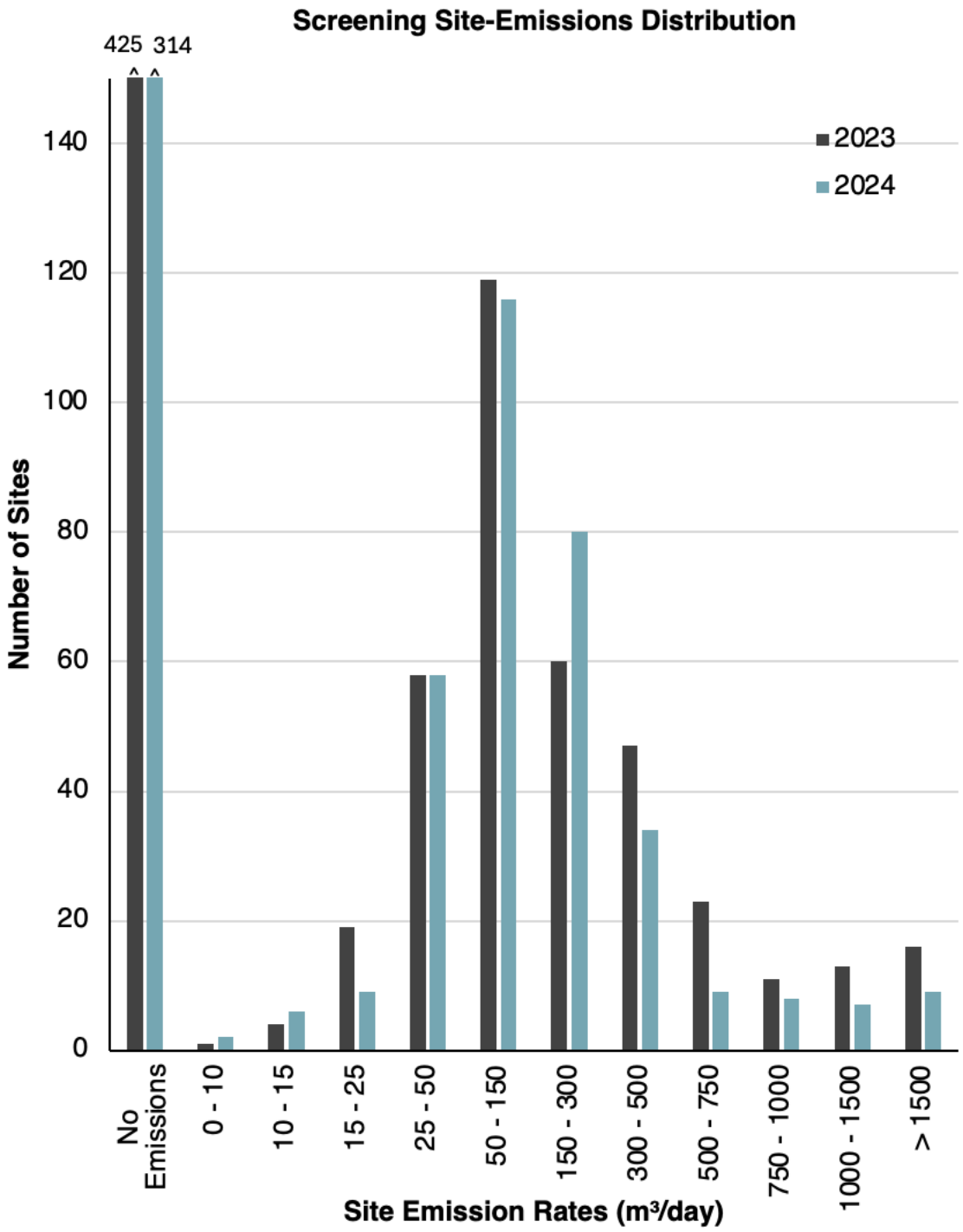

Figure 1: Distribution of site-total emission rates measured during screening campaigns.

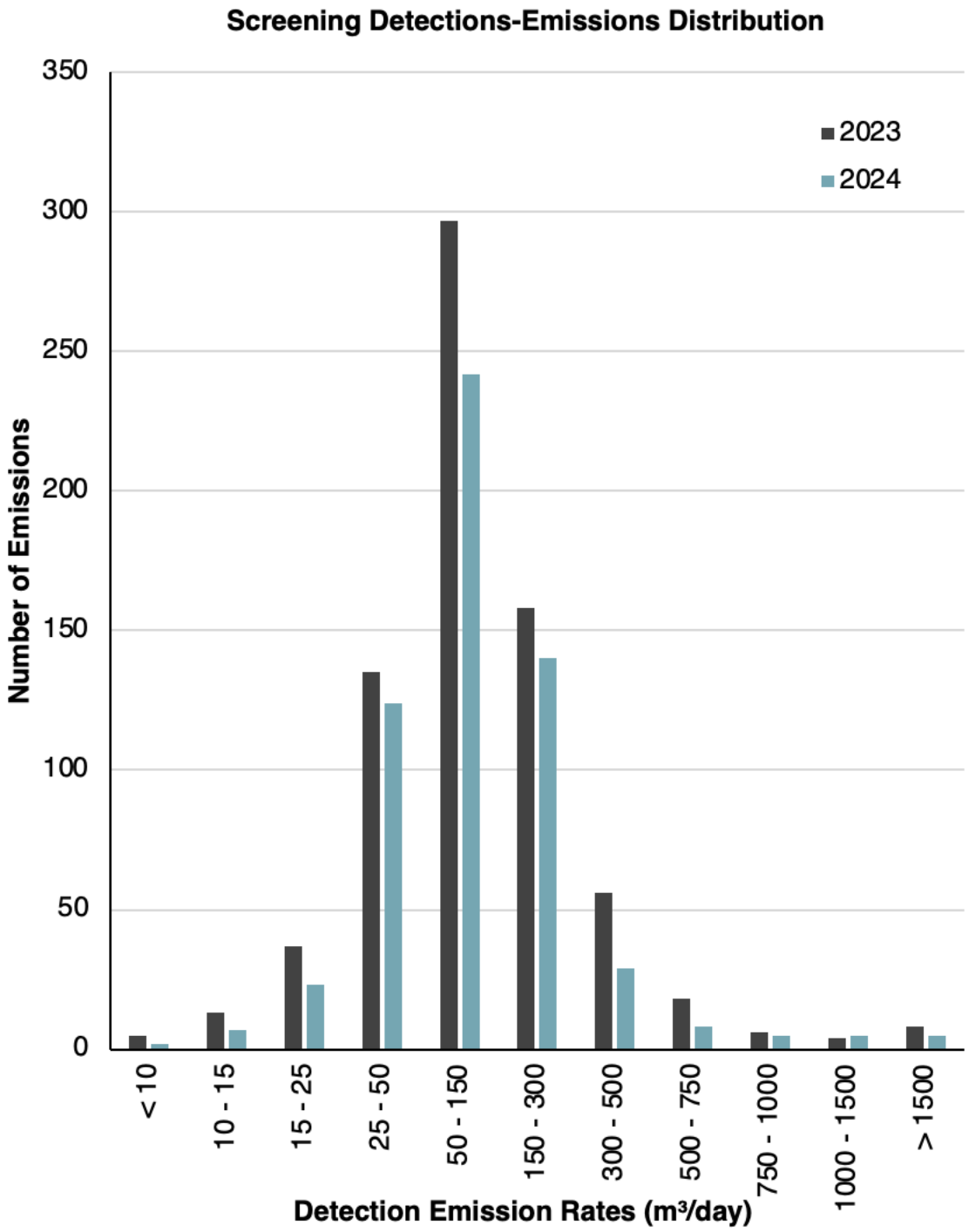

Figure 2: Distribution of individual emissions, by rate, measured during screening campaigns.

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.

4.2 OGI Survey Summary

Figure 3 shows the emission rate distribution for site-total emissions detected during 2023 and 2024 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 shows the emission rate distribution for individual emission rates detected during the 2023 and 2024 OGI survey campaigns of the alt-FEMP region. The graph allows one to discern how many individual emission measurements, by OGI, reported an emission rate within a certain range.

Figure 5 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.

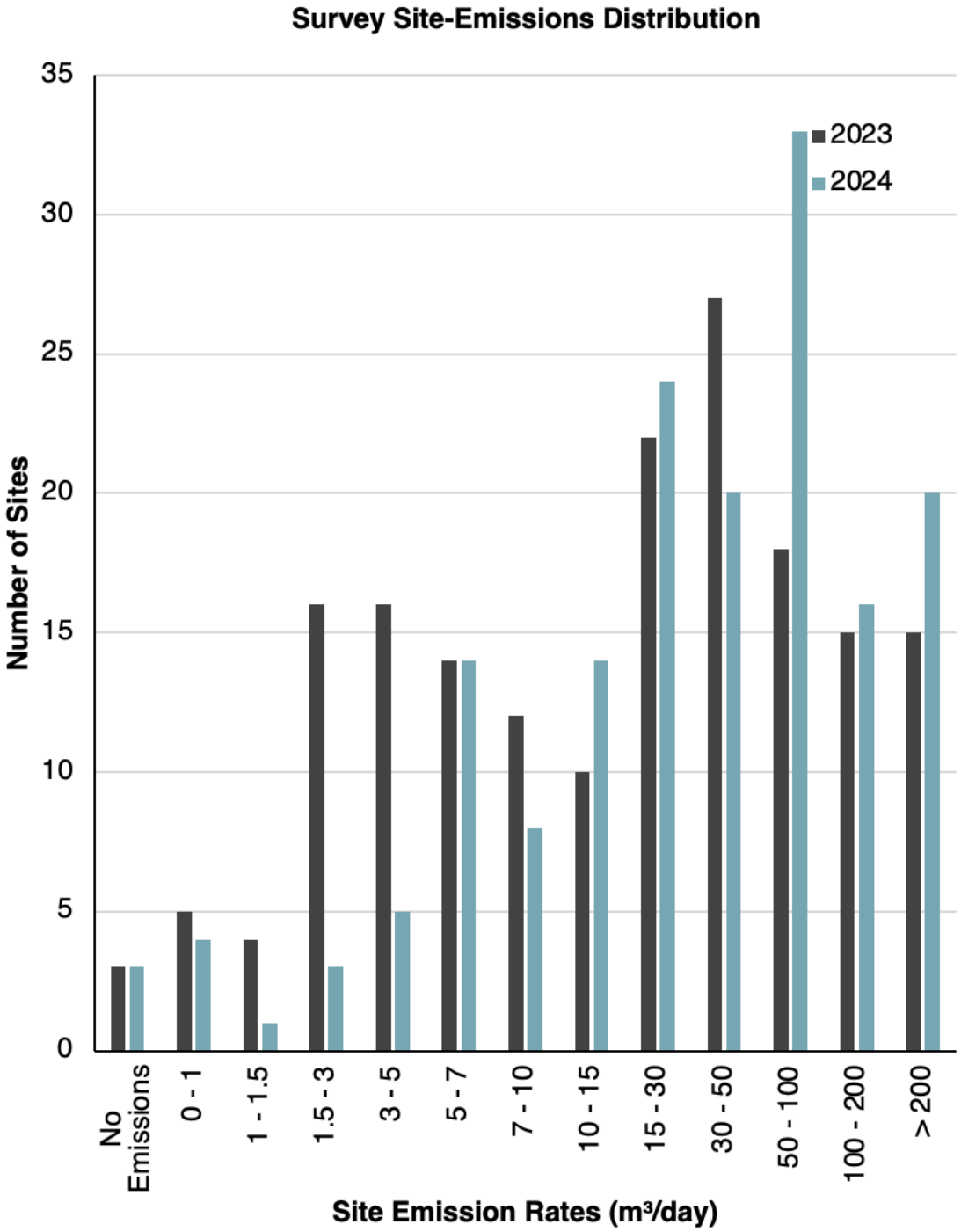

Figure 3: Distribution of site-total emission rates measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.

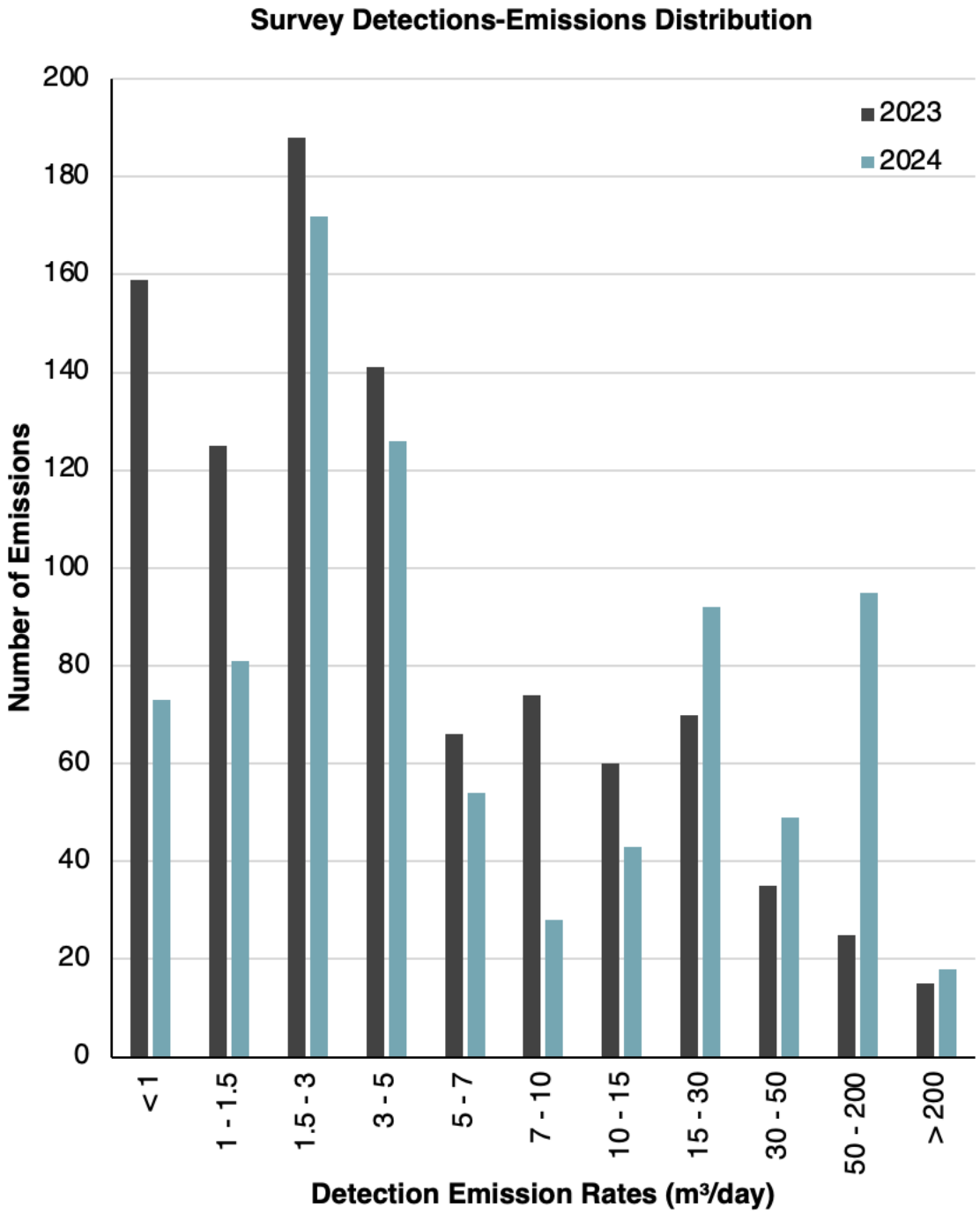

Figure 4: Distribution of individual emissions, by rate, measured during OGI survey campaigns (e.g. follow-up and independent campaigns) of the alt-FEMP region.

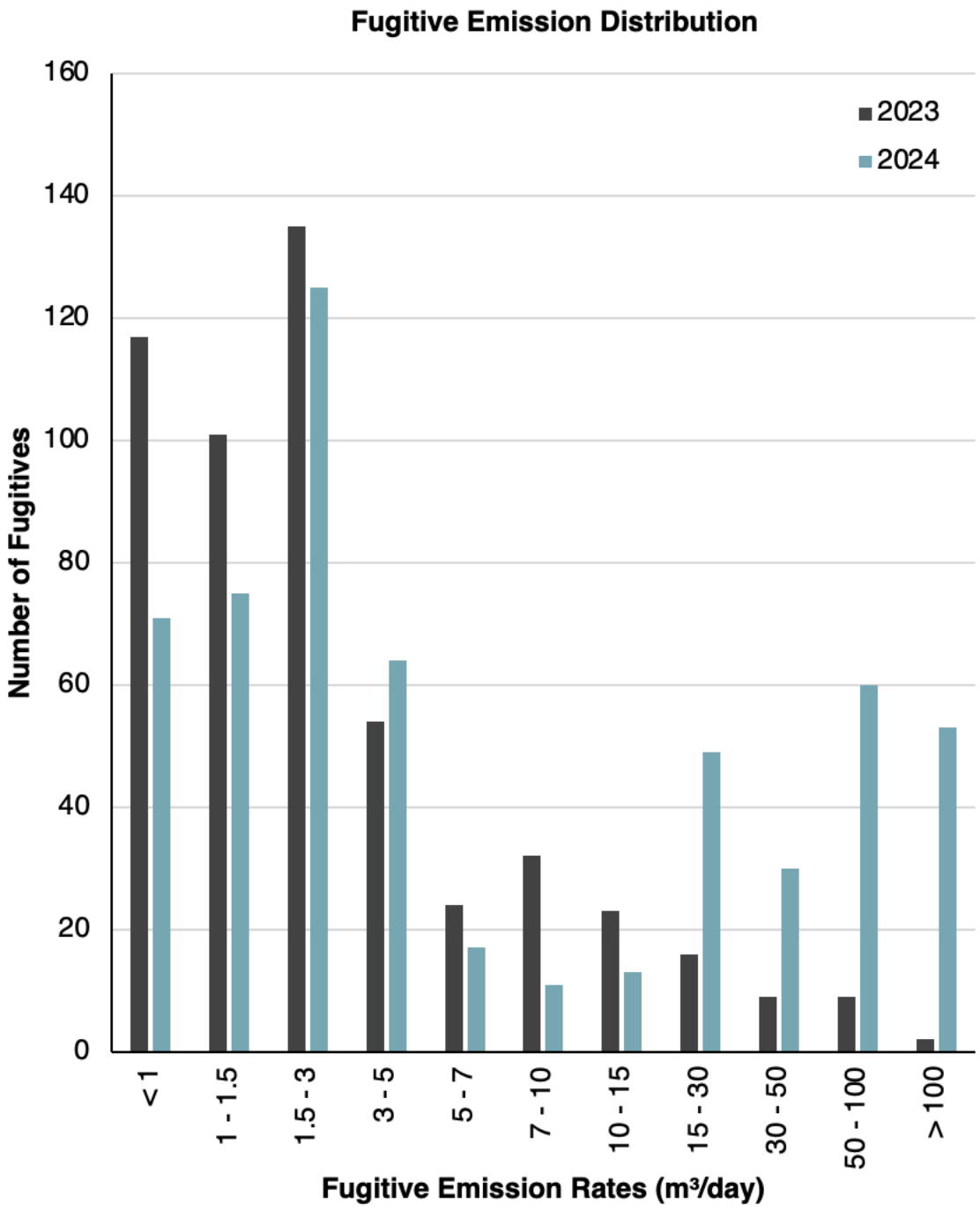

Figure 5: Distribution of fugitive emissions, by rate, measured during OGI survey campaigns (e.g. follow-up) of the alt-FEMP region.

5 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 OGI surveys of the alt-FEMP region. 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 Bridger's technology is displayed for reference (40 m^3/day). Note that the "assumed fugitive emission distribution" represents facility scale emissions while the "measured fugitive emission distribution" represents individual emission source scale emissions. The "measured fugitive emission distribution" has also been aggregated to the site scale and plotted on Figure 6 to allow a better comparison to the facility scale "assumed fugitive emission distribution" (there was insufficient information to aggregate the measured emissions to the facility scale).

Since the performance of an alt-FEMP is heavily dependent on the fugitive emission distribution it is valuable to consider whether the distribution used to predict the alt-FEMP performance matches that seen during the alt-FEMP execution. Figure 6 allows a comparison of the fugitive emission distribution used to predict that the alt-FEMP would perform better than the default FEMP against the fugitive distribution seen during the execution of the alt-FEMP. Thus, this plot provides some insight into whether the true alt-FEMP performance would still exceed that of the default FEMP given the fugitive emission distribution observed during the alt-FEMP execution.

In this case, the observed fugitive emission distribution is very similar to the assumed distribution with a characteristic "heavy tail" for the largest emission rates. When considering the site scale fugitive emissions, the distribution consists of noticeably larger emissions than the assumed fugitive distribution. Since alt-FEMP performance increases relative to the default FEMP with the presence of a "heavy tail" distribution and with larger overall emission rates, it is likely that the alt-FEMP met or exceeded the performance of the default FEMP. This is supported by the modelling outlined below.

A default Directive 060 FEMP program and the executed CVE alt-FEMP were re-modelled using the as-found fugitive distribution using the AroFEMP software (Arolytics). Based on this re-modelling, the alt-FEMP was predicted to emit 11% less total fugitive methane emissions than the traditional default FEMP.

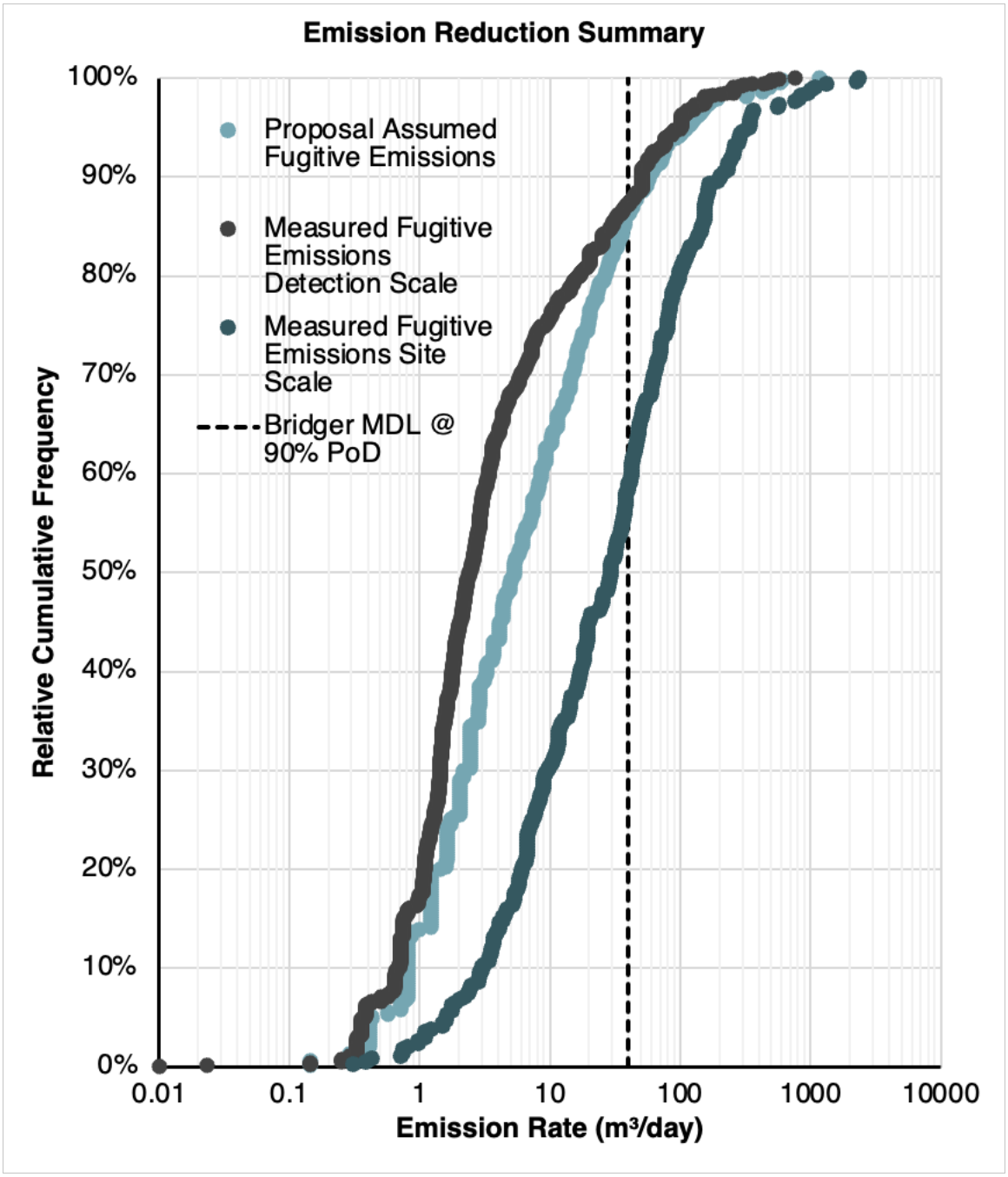

Figure 6: Comparison of relative cumulative frequencies for the "as-found" measured fugitive emissions versus the proposal-assumed fugitive emissions. Dashed line indicates Bridger MDL of 40 m^3/day.

6 Technology Limitations

The two technologies deployed for emission detection and quantification were Bridger Photonics' Aerial LiDAR for screening and the FLIR GF320 OGI camera for follow-up, with 90% probabilities of detection of 40 m^3/day and 7 m^3/day respectively. These technologies detected and quantified numerous methane emissions below the stated 90% PoD for the respective technologies. This does not provide a reason to suspect that the performance of the technologies in this alt-FEMP was less than expected.

Bridger's detection sensitivity depends on factors including flight speed, flight altitude, measurement swath width, and wind speed. Many of these factors can be controlled by Bridger to adjust the sensitivity as required. Bridger's GML is an active, laser-based system, rather than a passive remote sensor that relies on the environment, so conditions such as cloud cover or shadows that can impair other aerial sensor technologies do not negatively impact GML. Regarding operations at northern latitudes, GML is moderately limited by snow cover and standing water. While GML will detect methane when there is snow on the ground, the detection sensitivity of the data is degraded. With standing water, Bridger's laser 'bounces' off and, as a result, no measurement is made. In several areas of Alberta, the muskeg landscape holds pockets of water in the warmer months. Based on testing and commercial projects completed in Alberta, the muskeg landscape has not negatively impacted Bridger's GML measurements. As a result of high winds rapidly dispersing emissions, Bridger limits its survey operations to ground wind speeds less than or equal to 25 mph. Bridger also implements a wind speed protocol to detect emissions at the lower end of GML's detection sensitivity. To avoid Bridger's limitations in snow, Bridger will only implement GML in snow-free months (between late Spring and early Winter). Bridger will also limit its survey operations to average ground wind speeds less than or equal to 25 mph.

The 2023 Bridger screening was delayed in the Rainbow Lake area due to flight restrictions resulting from wildfire smoke and aerial firefighting in the summer of 2023. The screenings could have been delayed to a later date without flight restrictions and with less smoke in which case the detections and measurements would not have been directly impacted. In this case CVE opted to proceed with full OGI surveys in place of the Bridger screening and 25% follow up. The Bridger screening technology cannot be used over snow, however, as the Bridger screenings were conducted in the summer months this limitation had no impact on the execution of the alt-FEMP or the detections and measurements produced by the Bridger screenings.

7 Success of the Alt-FEMP

The alt-FEMP was successfully executed as planned including both the screening and follow-up campaigns with the exception of the summer 2023 screening in the Rainbow Lake region. The Rainbow Lake screening could not be completed and in its place all sites that were not screened instead received a full OGI survey – a more conservative approach than the planned alt-FEMP – ensuring the performance of the alt-FEMP met expectations. Cenovus exceeded the 25% follow-up requirement in both years of the alt-FEMP and repaired 67% of all detected fugitives by the time of this report.

8 Nonperforming Program Elements

Wildfires in July 2023 led to no-fly zones for extended periods of time, which prevented Bridger from performing an aerial screening in the Rainbow Lake region. As a result, 14 CVE facilities on 8 sites in the Rainbow Lake region did not receive an aerial survey in the month of July 2023. In place of the planned screening and follow-up, a full OGI survey was conducted at all 8 Rainbow Lake sites that could not receive the intended aerial screening. These Rainbow Lake sites were then excluded when determining the list of follow-up sites for the July 2023 Bridger screening. This allowed CVE to mitigate the impact from wildfires on the alt-FEMP. Wildfires did not impact the execution of the alt-FEMP in 2024.

9 Additional Control Measures

Any sites that were missed during screenings were automatically added to the list to be followed-up on by OGI survey. CVE performed an annual review of their assets to ensure that the list of assets in the alt-FEMP was adjusted to account for any acquisitions / divestitures or activation / deactivation of sites during the alt-FEMP.

10 Key Performance Indicators

- The alt-FEMP was successfully executed in accordance with the approved alt-FEMP with the exception of 14 Rainbow Lake facilities in July 2023 due to wildfire smoke.
- The impacts of wildfire smoke on the alt-FEMP were successfully mitigated by implementing the more conservative approach of performing full OGI surveys at all Rainbow Lake sites affected by wildfire smoke.
- CVE was successful in implementing alternative technologies to conduct LDAR screening, where emissions were detected at 350 of the 901 site screenings in 2024.
- In 2024, a total of 94,306 m^3/day of methane was found to be emitting by screening technologies on 666 detections. Of which, 14,876 m^3/day was identified as fugitive emissions when followed-up with OGI.
- On average, leak repairs were completed 44 days after an OGI follow-up under the alt-FEMP with 54% of repairs being completed in less than 30 days. The average time to leak repair was similar in 2024 (46 days) and 2023 (42 days).
- 67% of fugitive emissions sources were repaired under the alt-FEMP.
- See Table 5 for additional key performance indicators for the alt-FEMP in 2024.

Table 5: Various Key Performance Indicators for the 2024 Alt-FEMP.

KPI	2024 Alt-FEMP
Number of Sites Surveyed	163
Number of Surveyed Sites with Emissions Detected	153
Percentage of Surveyed Sites with Emissions Detected (%)	94%
Number of Emissions Detected at Surveyed Sites	1,124
Number of Surveyed Sites with Fugitive Emissions Detected	99
Percentage of Surveyed Sites with Fugitive Emissions Detected (%)	61%
Number of Fugitive Emissions Detected	512
Number of Vent Emissions Detected	576
Total Rate of Emissions Detected (m3/day)	22,755
Total Rate of Fugitive Emissions Detected (m3/day)	14,876
Total Rate of Vent Emissions Detected (m3/day)	7,879
Average Fugitive Rate per Site with Fugitive Emissions Detected (m3/day)	201.9
Average Fugitive Rate for all Fugitive Emissions Detected (m3/day)	22.8
Number of Fugitive Emissions Repaired	305
Percentage of Fugitives Repaired (%)	60%

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 “Appendix_A.xlsx”.

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

Please refer to the attached excel file of the site-total screening data titled “Appendix_B.xlsx”.

Appendix C: Screening Data – Individual Emissions

Please refer to the attached excel file of the individual emission screening data titled “Appendix_C.xlsx”.