Cenovus Energy – Deep Basin

Site-level Methane Emissions Management Program (SMEMP)

Directive 060 Alt-FEMP Pilot Performance Report

May 19th, 2020 – December 31st, 2022

March 23, 2023

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1 Executive Summary

Cenovus Energy (Cenovus) contracted Arolytics to conduct methane emissions equivalency modelling for five Alberta regions in which Cenovus owns and operates upstream oil and gas facilities. Regulatory approval was issued for Alternative Fugitive Emissions Management Programs (alt-FEMPs) in East Clearwater, West Clearwater, Kaybob, and Grande Prairie areas. Cenovus' operations in the Edson area required Default OGI and were required to act as a Control region.

The program design for the approved Alt-FEMPs for each of the four regions required using the Gas Mapping LiDAR technology from Bridger Photonics, Inc. (Bridger) to screen facilities for methane emissions two times annually. Based on the findings of Bridger's surveys, more thorough Optical Gas Imaging (OGI) surveys were conducted at all sites with emissions greater than 500 m^3/day as well as 10% of all LSDs, selecting those with the greatest emission rates below 500 m^3/day. Fugitive leaks located with OGI at these sites were to be repaired, and vent reduction projects were to be planned to reduce vented emissions at these sites by ~67% in order to achieve total methane emission reductions equivalent to, or exceeding, the fugitive emission reductions that would have been achieved by implementation of a default FEMP.

Cenovus' two-year Alt-FEMP pilot ended as of Dec 31st, 2022. The Leak Detection and Repair (LDAR) data has since been analyzed to understand the performance of the alt-FEMP relative to the model-estimated emission reduction targets and the control region, and to fulfill the remaining alt-FEMP performance report requirements.

This alt-FEMP performance report summarizes the cumulative methane emission reductions achieved through fugitive repairs and vent mitigation projects from the start of the pilot program (May 19th, 2020) until December 31st, 2022. These reductions are compared to the total model-predicted reductions for the full 2.5-year pilot (from May 19th, 2020 – December 31st, 2022) and between the regions employing the alt-FEMP and the control region.

2 Methods

2.1 Datatsets and Inputs

Listed below are the datasets and inputs considered in this report:

- GreenPath Energy OGI methane detection and repair datasets from 2020 to December 31st, 2022.
- Voluntary vent mitigation project lists maintained by Cenovus.
- Model-estimated emission reductions from August 2021 modelling report that used updated inputs. (These are the same model estimates we used for comparison in the Year 1 progress report).
- In this report, Year 1 of the Alt-FEMP pilot ranges from May 19th, 2020 - May 18th, 2021; Year 2 ranges from May 19th, 2021 – May 18th 2022; Year 2.5 ranges from May 19th, 2022 – Dec 31st, 2022.

2.2 Calculations

2.2.1 Fugitive Methane Reductions

For Year 1 fugitive reductions, the number of days between the repair date and the end of Year 1 (May 18th, 2021) was calculated. For Year 2 fugitive reductions the number of days between the repair date and May 18th, 2022 was calculated. For Year 2.5 fugitive reductions, the number of days between the repair date and May 18th, 2023 was calculated. For fugitive reductions over the entire 2.5 year term of the pilot alt-FEMP, the number of days between the repair date and December 31st, 2022 (end of alt-FEMP) was calculated. The number of days for which the leak was repaired was then multiplied by the quantified leak rate (in m^3/day) to arrive at the total reductions achieved per repair. All reductions achieved per repair were summed for each region. For these calculations, all repaired leaks were assumed to remain repaired.

To enable a comparison between the performance in the control region and the performance in the alt-FEMP regions – which have different numbers of facilities and different proportions of facility subtypes – the reductions per "facility day" were also calculated. "Facility days" is the sum of the total number of days that each facility was in the FEMP. This provides an evaluation of the fugitive reductions per facility, per day that the facility was included in the FEMP, that can be compared between regions with different facility counts that may have varied with time throughout the FEMP.

2.2.2 Supplementary Vent Mitigation Methane Reductions Calculation

For Year 1 vent reductions, the number of days between the project implementation date and the end of Year 1 (May 18th, 2021) was calculated. For Year 2 vent reductions, the number of days between the project implementation date and December 31st, 2021. The emission reductions achieved by the project (in m^3/day) were then multiplied by the number of days since the implementation date. All reductions achieved per vent mitigation project were summed for each region. All vent mitigation projects implemented in Year 1 were considered to be operational and achieving the same level of emission reductions per day throughout all of Year 2 until December 31st, 2021.

2.2.3 Model Predicted Alt-FEMP and Default Program Methane Reductions Calculation

The values from the August 2021 model report, which used updated model inputs based on actual Cenovus LDAR data, were used to perform this calculation. These are the same model estimates that were used for comparison in the Year 1 progress report. Since the original model only considered the first year of the Alt-FEMP, the predicted fugitive and vented emission reductions were only considered and compared to actual alt-FEMP results for each year individually.

2.3 Assumptions & Considerations

2.3.1 Calculations

There are inaccuracies involved in deriving the targeted reduction values for the 2-year pilot as described in section 2.2. The preferred approach would have been to model the full length pilot from the start. Multiplying the one year predicted reductions by the number of years in the alt-FEMP does not account for the reductions in the second and 2.5 years that occur as a result of the repairs in the first year. This method would under predict the total reductions by a very large amount. Due to this, the model results are only valid for a one year timespan and can only be compared to evaluations of the alt-FEMP over a one year timespan, i.e. the model results can be compared to the alt-FEMP performance for year 1 or year 2 or year 2.5, but not the performance over the full 2.5 years of the alt-FEMP.

Note that year 2.5 covers the span from May 19th, 2022 to December 31st, 2022 which is less than a full year. For any evaluations of year 2.5 only screenings, surveys and repairs completed within this timeframe were considered, thereby placing year 2.5 at a disadvantage relative to the other years of the alt-FEMP and any annual model predictions. However, for reductions calculations, the repairs that occurred from May 19th, 2022 to December 31st, 2022 were calculated such that they accumulated reductions until May 18th, 2023, thereby giving year 2.5 one full year to accrue reductions and reducing the disadvantage for year 2.5. This disadvantage should be considered when reviewing results for year 2.5.

In addition, Cenovus divested a large portion of its East Clearwater and West Clearwater assets in mid 2021 leading to a drop from 420 sites to 292 sites in the alt-FEMP. Meanwhile, the model predicted reductions always included the full 420 sites. Therefore, any comparison of actual emission reductions after July 2021 to actual reductions before July 2021, or modelled reductions, will place the reductions after July 2021 at an unfair disadvantage (due to a lower facility count). However, the evaluations of reductions per facility day do not suffer from this unfair bias as they account for the change in infrastructure over time. This disadvantage should be considered when reviewing any comparison for results after July 2021.

2.3.2 Modelling

Arolytics' model is a predictive software model of real-world emissions using the best available data to describe the emissions from a client's facilities over a defined time period. The modelling presented in this report employed actual Cenovus LDAR data to generate updated Cenovus specific model input parameters to ensure the model results were as accurate as possible. However, due to the random nature of leak occurrence, the variability in leak rates, detections, and repairs, and the uncertainty in each of these factors, there is also uncertainty in the emissions predictions of the model, particularly when assessing emissions on an absolute (i.e., m^3) basis. Given the fact that the model reports approximate average emissions applicable to an extensive time period while real-world emissions data is collected over a very brief time period, there is likely to be a discrepancy between any absolute emissions estimated by the model and real-world emission measurements collected during a FEMP.

Arolytics recommends programs be compared on a relative basis, for example: *the model predicted the alt-FEMP would achieve X% greater total emissions reductions than a default OGI program, and on a per-facility basis the alternative program reduced X% greater emissions compared to the default program in the control region*.

Future work will include sensitivity analyses to better understand the impact of input parameters and their uncertainties on modeled FEMP performances, with a focus on the impact on alt-FEMP performances relative to default FEMP performances.

2.3.3 Recurring Leaks

Because there are no unique component/leak identifiers to determine whether repairs stay repaired, all leaks are considered indefinitely repaired after the repair date. This may not be reflective of what realistically occurred, however, it should not have a significant impact on the reduction calculations.

3 Screening and Survey Details

3.1 Type of Screening

Two aerial screenings were performed in each of 2020, 2021 and 2022 using the Gas Mapping LiDAR technology from Bridger Photonics, Inc. (Bridger).

3.2 Dates of Screening

1) Screening #1: July 21-28, 2020
2) Screening #2: Sept 28 – Oct 11, 2020
3) Screening #3: July 6-16, 2021
4) Screening #4: Oct 11-22, 2021
5) Screening #5: July 4-15, 2022
6) Screening #6: October 15-21, 2022

3.3 Summary of Screening Results

Table 1 displays a summary of the six screenings that were performed throughout the alt-FEMP. This summary shows that there is significant variation in the number of sites found to be emitting and the total number of emission sources from one screening survey to the next. The number of sites emitting, and the total number of emission sources vary by as much as 55% and 42% respectively. This suggests that the performance of a FEMP may vary significantly throughout time (from one year to the next) and is unlikely to perform consistently throughout the entire length of the program.

Note that Cenovus divested a large number of facilities in the East and West Clearwater regions in 2021. As a result, the number of sites that required screening dropped from 420 in July 2021 to 291 in October 2021.

Table 1: Summary of screening campaign results where "site" indicates LSD.

Screening	Date	Number of Sites Screened	Number of Sites Emitting	Total Number of Emissions Sources	Average Time from Screening Detection to Follow-up (days)
1	Jul-2020	417	139	297	51
2	Oct-2020	417	216	397	37
3	Jul-2021	420	176	339	84
4	Oct-2021	291**	156	322	50
5	Jul-2022	292**	117	266	41
6	Oct-2022	292**	172	379	29

** Note: A large divestiture of facilities from the East and West Clearwater regions reduced the number of sites included in the alt-FEMP from 420 to 291 between July and October 2021.

3.4 Summary of Follow-up Surveys

Table 2 provides a summary of the six follow-up surveys that were performed following the screening campaigns throughout the alt-FEMP.

Table 2: Summary of follow-up survey results and leak repairs throughout the alt-FEMP.

Follow-Up	Number of Surveys with Leaks	Number of Surveys with Vents	Number of Surveys without Leaks or Vents	Number of Leaks Repaired	Number of Repairs Delayed	Average Time from Survey to Repair (days)
1	11	24	10	27	23	100
2	20	42	1	55	28	140
3	20	58	1	47	42	183
4	24	57	4	47	35	91
5	24	32	4	62	46	65
6	11	13	27	78	26	25
Total	110	226	47	316	200**	95

** Note: 49 of the 200 delayed repairs required a shutdown for repair

Discussions with GreenPath – the follow-up OGI provider – revealed that the OGI follow-up reports and data that they provide to Cenovus do not track leaks and repairs in a way that allows identification of recurring leaks. GreenPath is currently investigating whether it is possible to determine the number of recurring leaks using identifiers that are currently only used in the background of their data management system.

The 10% largest leaks identified in the follow-up OGI accounted for 69.5% of all fugitive emission rates discovered. This indicates that Cenovus's leak distribution is very typically heavy tailed and well suited to the use of screening technologies such as Bridger's GML. Of the 45 leaks in the top 10%, 33 are from gas plants or compressor stations, 6 are from other facility types, and 6 are from an undetermined facility type. Compressor station leaks accounted for 38% and gas plant leaks for 31% of all fugitive emission rates discovered in the alt-FEMP. This reveals that the compressor stations and gas plants (typically facilities requiring triannual OGI surveys) are the largest contributors to fugitive emissions of all the facility subtypes. This information can be used to prioritize the inspection and repair of these facility types to maximise the fugitive emission reductions achieved by a FEMP.

4 Emission Reduction Summary

Emissions reductions were calculated as the estimated emission rate of the leak that was repaired multiplied by the length of time between when the leak was repaired and the end of the FEMP (Dec 31, 2022) or the end of the year of interest (ex: May 19, 2020 – May 19, 2021 for the first year). Table 3 shows an overview of the model predicted and actual measured emission reductions. These results demonstrate that the actual performance of the alt-FEMP in terms of fugitive reductions each year was approximately 4-10x greater than the model predicted reductions. In addition, the actual alt-FEMP fugitive reductions each year were 30-230% greater than the model predicted default FEMP reductions. This demonstrates that the alt-FEMP was far more effective than expected and was able to achieve the methane reductions target (modelled default reductions = 355,248 m^3/year) without any contribution from supplementary vent mitigation. Though the supplementary vent reductions fell well below the expected amounts, this did not have an impact on the success of the alt-FEMP. This is discussed further in sections 6 and 7.

The reductions evaluated per facility day are shown in Table 4. Only five of the 12 alt-FEMP region and year combinations underperformed the model predicted default FEMP performance (most often by a small margin) while 7 of the region and year combinations outperformed the model predicted default FEMP performance (typically by a large margin and in some cases by up to 20x). Most importantly, for all alt-FEMP regions combined, the actual alt-FEMP reductions were significantly greater than the model predicted default FEMP reductions in each year.

Given the variation in performance between individual years, the best evaluation of overall emissions reductions performance is over the entire length of the program. These results are shown in Table 5 and also demonstrate that the alt-FEMP outperformed the default FEMP in the control region in reductions per facility day, in this case by 16%.

These results suggest that the alt-FEMP was superior to the default FEMP by 16% which is contradictory to the model results which predicted that the alt-FEMP would achieve approximately one third the reductions of the default FEMP. The model results in Table 3 were generated by the updated modelling that was performed in Spring of 2020 with input parameters generated using the Cenovus specific OGI survey data and baseline input parameters tailored to each of the five regions. Despite these model updates the model still under predicted the performance of the alt-FEMP both on an absolute scale and relative to the default FEMP, as evidenced by the results in Table 3 and Table 5. On average, the control region achieved 63% greater reductions per facility day than the model predicted – average actual annual reductions per facility day / model predicted reductions per facility day – while the alt-FEMP region achieved 700% greater reductions per facility day than the model predicted. This demonstrates that performance of both the default FEMP and the alt-FEMP were underpredicted, however, the alt-FEMP was underpredicted to a much large extent than the default FEMP.

Table 3: Summary of model predicted methane reductions and actual methane reductions for the pilot alt-FEMP.

		Pilot alt-FEMP Model Reductions: 1 Year Model		Pilot alt-FEMP Actual Reductions		
Region	**Emission Type**	**Model-Predicted Alt-FEMP Reductions (m^3)**	**Model-Predicted Default Program Reductions (m^3)**	**Year 1 Actual Reductions (m^3) (2020/05 – 2021/05)**	**Year 2 Actual Reductions (m^3) (2021/05 – 2022/05)**	**Year 2.5 Actual Reductions (m^3) (2022/05 – 2023/05)**
East Clearwater	Fugitive	50,222	171,125	139,257	213,969	415,340
	Vented	3,916,342	0	5,627	16,026	0
	Total	3,966,564	171,125	144,884	229,995	415,340
Grande Prairie	Fugitive	5,021	35,748	220,569	71,991	660,475
	Vented	1,789,874	0	91	31,736	0
	Total	1,794,895	35,748	220,660	103,727	660,475
Kaybob	Fugitive	12,251	63,859	71,721	31,653	48,434
	Vented	1,067,192	0	7,095	53,086	0
	Total	1,079,443	63,859	78,816	84,739	48,434
West Clearwater	Fugitive	53,388	84,516	79,417	157,676	38,345
	Vented	2,468,461	0	0	34,172	0
	Total	2,521,849	84,516	79,417	191,848	38,345
All Alt-FEMP Regions	Fugitive	120,882	355,248	512,586	475,288	1,214,645
	Vented	9,241,869	0	12,813	135,020	0
	Total	9,362,751	355,248	525,399	610,308	1,214,645
Edson (Control)	Fugitive	NA	49,189	37,101	126,049	77,251
	Vented	NA	NA	NA	NA	NA
	Total	NA	49,189	28,132	125,553	453,109

** Note: The Year 2.5 Actual Reductions are calculated using leak detection and repair data from May 19th, 2022 to December 31st, 2022 (end of Alt-FEMP), less than a full year, which places year 2.5 at a disadvantage relative to other evaluations of annual reductions.

Ideally the model would predict a ratio of alt-FEMP to default FEMP reductions that is equivalent to the real-world data and equivalence could be evaluated based on whether the modelled alt-FEMP and default FEMP reductions are equal. However, AroFEMP models the best-case scenario for the default FEMP while taking a more conservative approach when modelling alt-FEMPs and as a result should always under predict the alt-FEMP reductions relative to the default FEMP. This is a deliberately conservative approach which leads to alt-FEMP designs that will outperform expectations.

While improving the model to align with real world results is desirable, determining which parameters are responsible for the discrepancy between modelled and real-world results is currently not feasible. Altering certain model parameters in an attempt to generate model results that align with the actual pilot alt-FEMP performance is likely to result in an unrealistic model setup that could produce an unrealistic benefit for the alt-FEMP. To avoid this unintentional bias, the model employed the most up to date and accurate Cenovus specific data available and did not manipulate any inputs for the purpose of reducing the discrepancy between model and real-world results. Since the discrepancy between the model and the real-world results cannot currently be reconciled, the performance of the alt-FEMP can be evaluated more accurately by comparing it to the performance of the control region.

Table 4: Fugitive emission reductions per facility day calculated from actual results for each year of the alt-FEMP and as predicted by the model for the alt-FEMP and the default FEMP. Yellow coloured cells indicate individual years in individual regions that underperformed the model predicted default program while green coloured cells indicate performance greater than the model predicted default program.

	Pilot alt-FEMP Model Reductions: 1 Year Model		Pilot alt-FEMP Actual Reductions		
Region	Model-Predicted Annual Alt-FEMP Reductions per Facility Day (m^3/facility day)	Model-Predicted Annual Default Program Reductions per Facility Day (m^3/facility day)	Year 1 Actual Reductions per Facility Day (m^3/facility day) (2020-05 - 2021-05)	Year 2 Actual Reductions per Facility Day (m^3/facility day) (2021-05 - 2022-05)	Year 2.5 Actual Reductions per Facility Day (m^3/facility day) (2022-05 - 2023-05)
East Clearwater	0.46	1.58	1.28	3.38	10.25
Grande Prairie	0.15	1.06	6.57	2.14	19.67
Kaybob	0.38	1.99	2.23	0.98	1.51
West Clearwater	0.88	1.39	1.30	2.78	0.71
All Alt-FEMP Regions	0.51	1.51	2.18	2.56	7.56
Edson (Control)	N/A	1.42	1.07	3.63	2.23

Table 5: Total actual pilot program fugitive emission reductions and reductions per facility day, by region. Evaluated for full duration from May 19, 2020 – Dec 31, 2022. Actual reductions per facility day for different regions can be compared while actual reductions for different regions cannot be compared.

Region	Full Pilot Program Actual Reductions (m^3)	Full Pilot Program Actual Reductions Per Facility Day (m^3/facility day)	Triannual to Annual Facility Ratio (3x:1x) According to Directive 060 Table 4
East Clearwater	1,201,174	6.09	0.32
Grande Prairie	1,261,496	14.29	3.55
Kaybob	390,563	4.64	0.45
West Clearwater	956,636	6.30	0.37
All Alt-FEMP Regions	3,817,034	7.32	0.52
Edson (Control)	573,505	6.29	0.67

5 Technology Limitation

It is well understood that Bridger's GML technology cannot currently detect and measure methane emissions if there is snow on the ground. As the screenings were conducted in the months of July and October with no snow, this limitation did not cause any disruptions to the screenings or interfere with the screening data collected by Bridger. However, it was noted that the screenings should ideally be separated by a larger amount of time to allow more time for thorough follow-up inspections and avoid repeatedly screening the same fugitive emissions. As a result, Cenovus has planned to conduct any further Bridger screenings in the months of June and October.

Using Cenovus Energy's 2022 OGI data for all conventional infrastructure, Bridger's GML would have detected 18 of the largest leaks at a rate of 70.8 m^3/day or greater, Bridger's currently advertised minimum detection limit (MDL). This is an emission rate of approximately 3666 m^3/day (~52% of the total measured emission rates in 2022) that would have been detected by Bridger's technology.

However, the results from the pilot alt-FEMP suggest that Bridger's screenings are also effective at revealing leaks below the MDL of 70.8 m^3/day. In the pilot alt-FEMP 90% of the leaks that were identified during follow-up at the sites flagged by Bridger were below 70.8 m^3/day, demonstrating that the Bridger screenings led to the discovery of many leaks below the accepted MDL. The leaks below Bridger's MDL only accounted for 30% of the total emission rates discovered throughout the alt-FEMP. This demonstrates that the use of Bridger aerial screening technology still led to the discovery of many leaks (430) below the stated MDL of 70.8 m^3/day and that the leaks above the MDL account for the majority (70%) of fugitive emissions. Therefore, Bridger is very well suited to identifying the leaks with the greatest impact on overall fugitive emissions while still being effective at revealing smaller leaks with a lesser but significant impact on overall fugitive emissions.

6 Success of the Alt-FEMP

The control and alt-FEMP performance in the pilot program were evaluated by analyzing the emissions reduction volumes. As previously discussed, Table 3 demonstrates that the actual performance of the alt-FEMP in terms of fugitive reductions each year was approximately 4-10x greater than the model predicted reductions. This can also be seen in Figure 1 which displays the model-predicted and actual alt-FEMP reductions. In addition, the actual alt-FEMP fugitive reductions each year were 30-230% greater than the model predicted default FEMP reductions as can be seen in Figure 2. This demonstrates that the alt-FEMP was far more effective than expected and was able to achieve the methane reductions target (modelled default reductions = 355,248 m^3/year) without any contribution from supplementary vent mitigation.

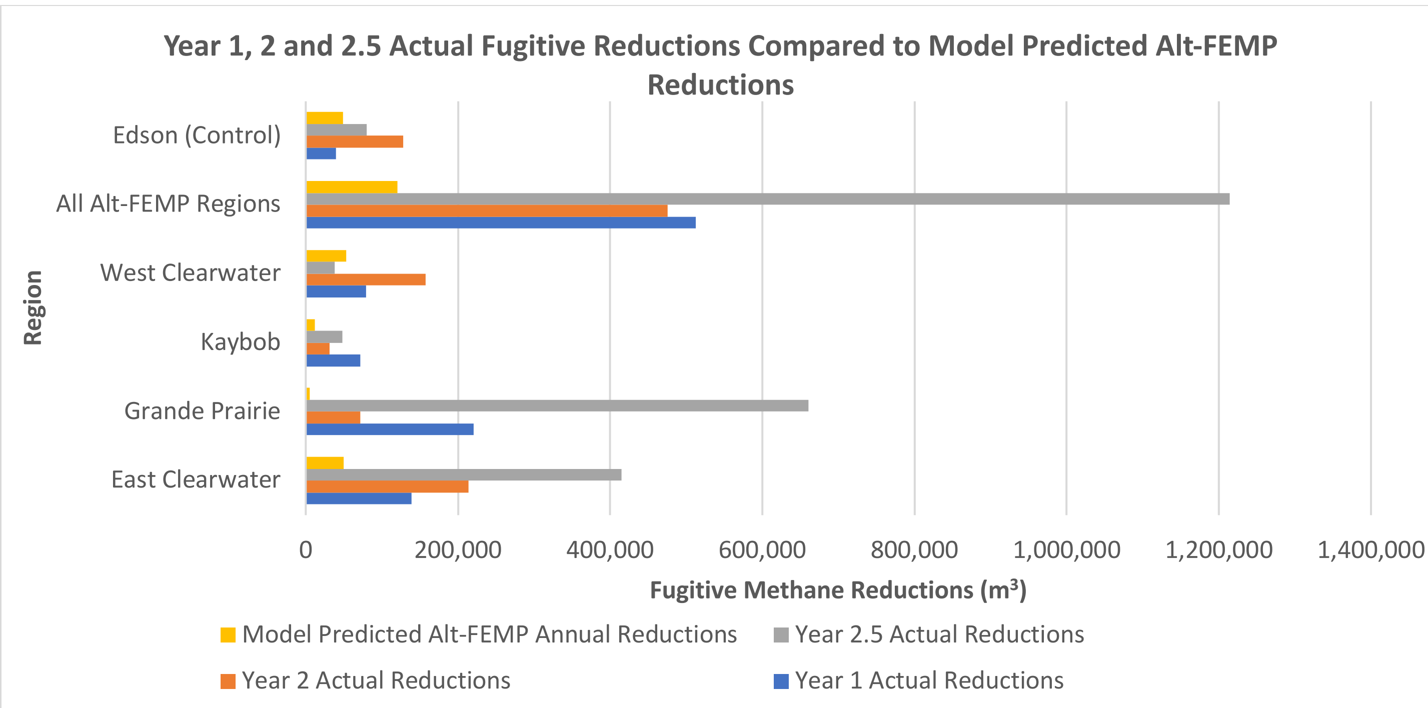

Figure 1: Plot of model-predicted annual fugitive methane reductions and actual fugitive methane reductions for each year and each region in the alt-FEMP. This demonstrates that the actual reductions in all regions (alt-FEMP and control) were greater than predicted by the model. The Alt-FEMP regions outperformed the predicted reductions by a much larger margin than the control region.

While the supplementary vent mitigation targets were not achieved, it is important to note that the vent mitigation was included in the alt-FEMP for the purpose of increasing the total methane emission reductions to be equivalent to, or greater than, the default FEMP emission reductions since the alt-FEMP (without vent mitigation) was expected to underperform the default FEMP. As the actual alt-FEMP fugitive reductions were greater than the targeted default FEMP reductions, no supplementary vent mitigation was required to achieve equivalence with the default FEMP. Nevertheless, the alt-FEMP still reduced an additional 147,833 m^3 of vented methane emissions beyond the necessary methane emissions reductions.

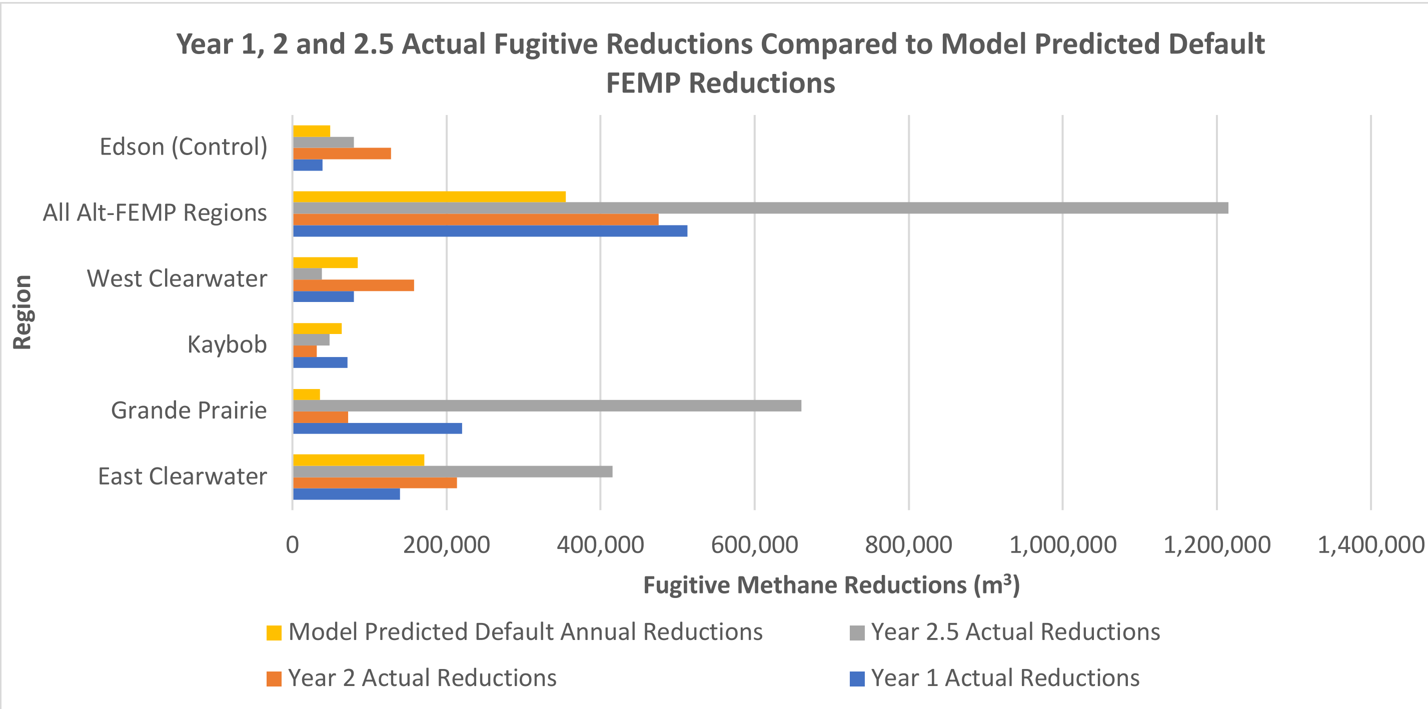

Figure 2: Plot of model-predicted annual fugitive methane reductions for the default FEMP and actual fugitive reductions for each year and each region in the alt-FEMP. In some specific years and regions, the actual alt-FEMP reductions fell below the model-predicted default reductions, however, when considering all alt-FEMP regions together, the actual alt-FEMP reductions were considerably greater than the model-predicted default reductions.

The reductions evaluated per facility day are shown in Table 6 and Figure 3. While some years of the individual alt-FEMP regions underperform relative to the modelled default FEMP or the actual control region performance, it is important to note that there are differences between these regions and the infrastructure within them that could lead to different default performance as well. The model does not fully account for these differences and therefore may over or underpredict the performance of the default FEMP in different regions depending on the infrastructure properties. As the properties of the control region infrastructure (ex: triannual to annual ratio) do not match those of the individual alt-FEMP regions the control region may also under or over perform relative to the default FEMP in the alt-FEMP regions. Furthermore, performance from one year to the next is highly variable (as seen in Table 6) with variations of at least 125% throughout the full length of the alt-FEMP for all regions.

Table 6: Fugitive emission reductions per facility day calculated from actual results for each year of the alt-FEMP and as predicted by the model for the alt-FEMP and the default FEMP. Yellow coloured cells indicate individual years in individual regions that underperformed the model predicted default program while green coloured cells indicate performance greater than the model predicted default program. (Repeat of Table 4)

	Pilot alt-FEMP Actual Reductions			**Pilot alt-FEMP Model Reductions: 1 Year Model**	
Region	**Year 1 Actual Reductions per Facility Day (m^3/facility day) (2020-05 - 2021-05)**	**Year 2 Actual Reductions per Facility Day (m3/facility day) (2021-05 - 2022-05)**	**Year 2.5 Actual Reductions per Facility Day (m^3/facility day) (2022-05 - 2023-05)**	**Model-Predicted Annual Alt-FEMP Reductions per Facility Day (m^3/facility day)**	**Model-Predicted Annual Default Program Reductions per Facility Day (m^3/facility day)**
East Clearwater	1.28	3.38	10.25	0.46	1.58
Grande Prairie	6.57	2.14	19.67	0.15	1.06
Kaybob	2.23	0.98	1.51	0.38	1.99
West Clearwater	1.30	2.78	0.71	0.88	1.39
All Alt-FEMP Regions	2.18	2.56	7.56	0.51	1.51
Edson (Control)	1.07	3.63	2.23	N/A	1.42

To demonstrate the effect of the different infrastructure properties on the performance in each region, the reductions per facility day for each region have been plotted versus the percentage of triannual facilities in each region in Figure 4. This plot demonstrates how the performance of the different regions varies and suggests that it is at least in part a function of the proportion of triannual facilities in the region. For this reason, it is most appropriate to compare the performance of the control region to the combination of all alt-FEMP regions as these are the closest to having the same proportion of triannual facilities.

Due to the performance variation with time and the fact that the properties of all alt-FEMP regions combined are most similar to the properties of the control region, the best overall evaluation of the alt-FEMP performance considers all alt-FEMP regions combined over the entire length of the alt-FEMP. These results are tabulated in Table 7. The performance in the control region can then serve as a measure of the expected default FEMP performance had it been implemented in the alt-FEMP regions. This comparison is displayed in Figure 5.

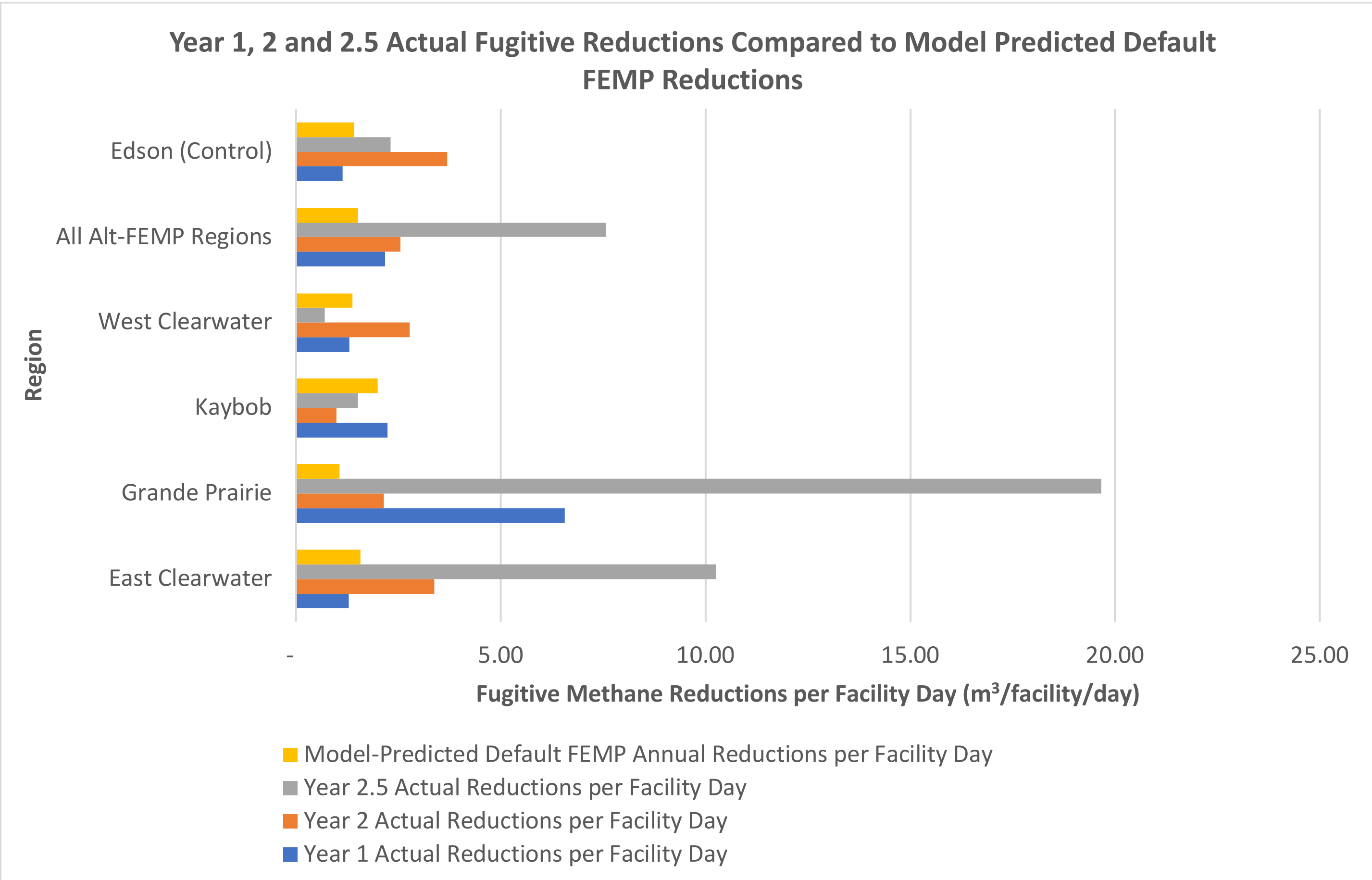

Figure 3: Plot of model-predicted annual fugitive methane reductions per facility day for the default FEMP and actual fugitive methane reductions per facility day for each year and each region in the alt-FEMP. This demonstrates that the alt-FEMP reductions per facility day were most often greater than the predicted default reductions. Also, the alt-FEMP reductions were significantly greater than the predicted default reductions when considering all alt-FEMP regions combined.

The performance of the default FEMP in the control region is likely slightly better than what would be achieved in the alt-FEMP regions given that a higher proportion of triannual facilities typically leads to better default FEMP performance and the control region has a slightly higher proportion of triannual facilities than the alt-FEMP region. Comparing the reductions per facility day for all alt-FEMP regions to those of the control region (7.32 vs 6.29 m^3/facility day) suggests that the alt-FEMP outperformed the default FEMP by 16%. This is a significant difference which suggests that the alt-FEMP was capable of reducing an equivalent, or greater, amount of fugitive emissions compared to the default FEMP. Therefore, the alt-FEMP successfully met the primary objective of reducing the same amount of methane emissions as a default FEMP. This program was successful in demonstrating that alternative technologies can be utilized to cost effectively detect and manage methane emissions.

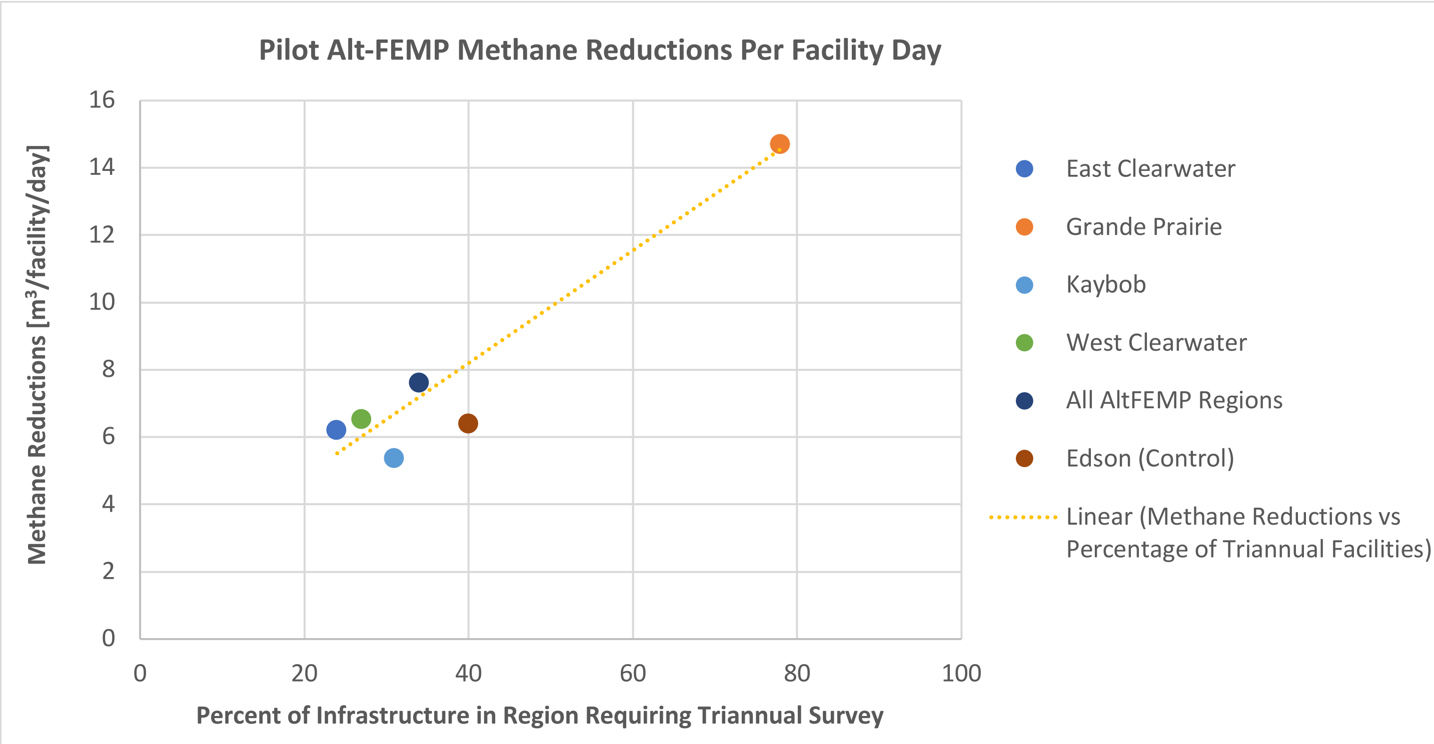

Figure 4: Plot of pilot alt-FEMP methane reductions per facility day by region. Evaluated for full duration from May 19, 2020 – Dec 31, 2022.

Table 7: Total actual pilot program fugitive emission reductions and reductions per facility day, by region. Evaluated for full duration from May 19, 2020 – Dec 31, 2022. Actual reductions per facility day for different regions can be compared while actual reductions for different regions cannot be compared. (Repeat of Table 5)

Region	Full Pilot Program Actual Reductions (m^3)	Full Pilot Program Actual Reductions Per Facility Day (m^3/facility day)	Triannual to Annual Facility Ratio (3x:1x) According to Directive 060 Table 4
East Clearwater	1,201,174	6.09	0.32
Grande Prairie	1,261,496	14.29	3.55
Kaybob	390,563	4.64	0.45
West Clearwater	956,636	6.30	0.37
All Alt-FEMP Regions	3,817,034	7.32	0.52

Edson (Control)	573,505	6.29	0.67

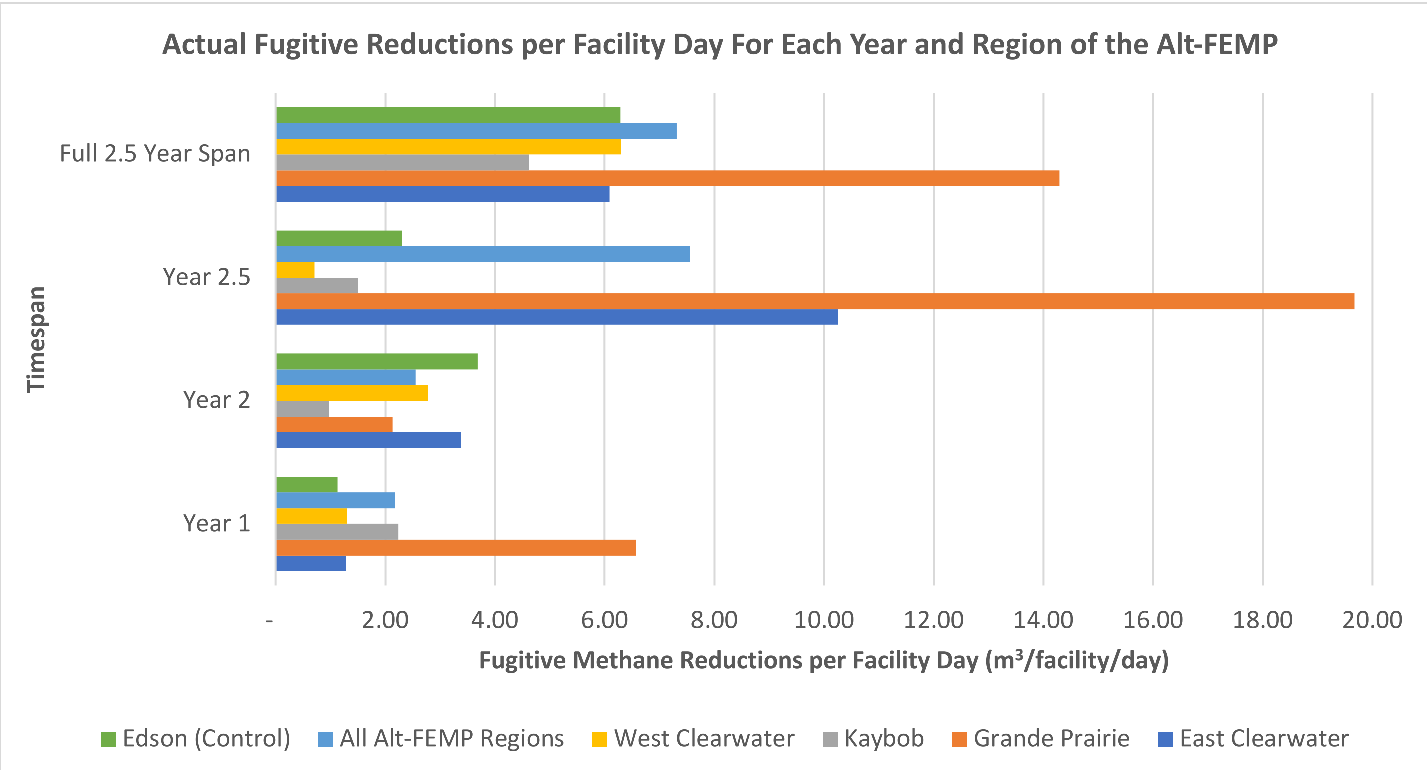

Figure 5: Plot of actual fugitive emission reductions per facility day for each year of the Alt-FEMP and for the entire duration of the alt-FEMP, and for each region. This plot shows that the performance of the alt-FEMP regions relative to the control region (employing the default FEMP) varies from year to year, in some cases quite drastically. However, over the entire span of the alt-FEMP (~2.5 years), the alt-FEMP achieved greater reductions per facility day than the control region.

7 Nonperforming Program Elements

The supplementary vent reductions fell well below the expected amounts as shown in Figure 6. This was primarily due to the unforeseeable complications arising from the COVID-19 pandemic which led to drastic reductions in budget and discretionary spending. However, it is important to note that the supplementary vent mitigation targets were very ambitious and set such that they would reduce a vast amount (~26x) more fugitive emissions than the default FEMP. However, the purpose of the supplementary vent mitigation was to supplement the alt-FEMP fugitive emissions reductions such that the total methane emission reductions would be equivalent to the fugitive methane reductions that would have been achieved by the default FEMP. This strategy was employed as it was expected that the alt-FEMP would underperform the default FEMP. Since the actual alt-FEMP fugitive reductions were greater than the targeted default FEMP reductions, no supplementary vent mitigation was required to achieve equivalence with the default FEMP.

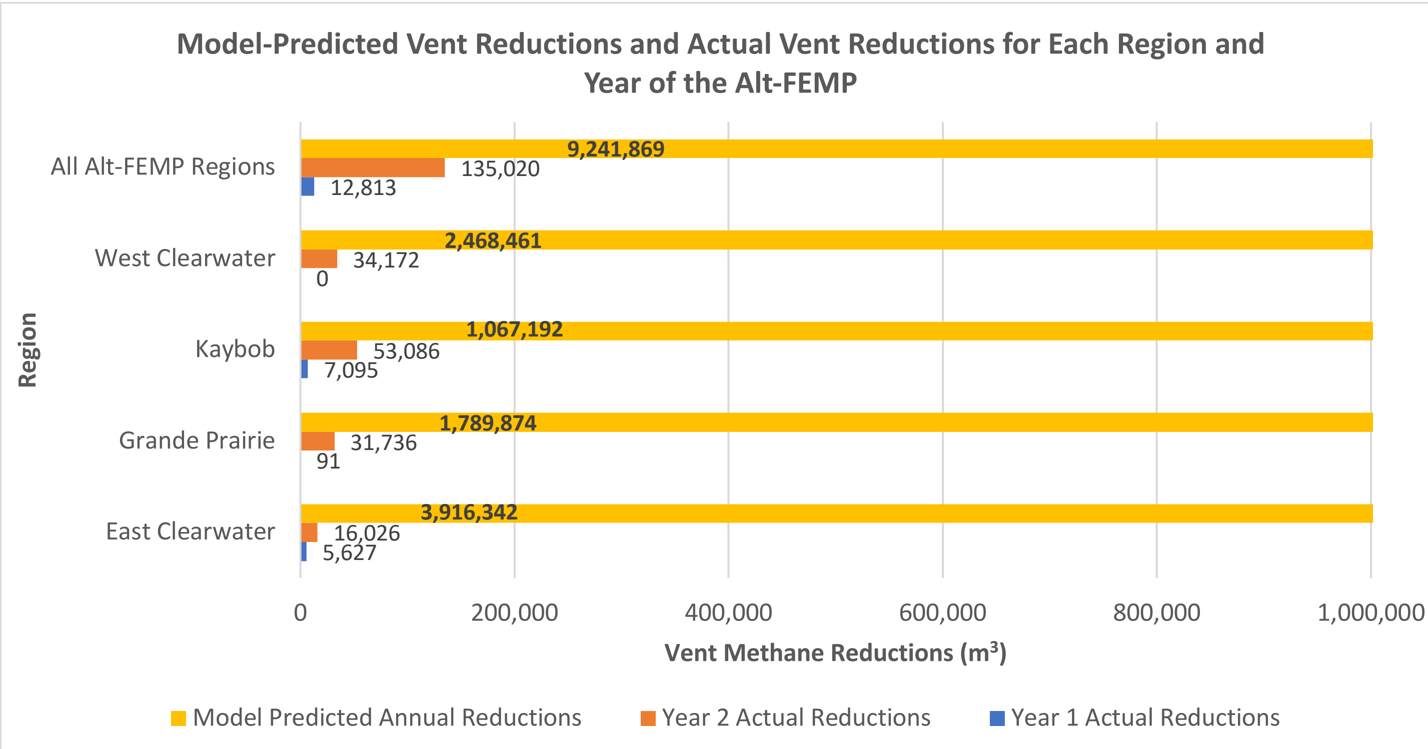

Figure 6: Plot of model-predicted annual vent reductions and actual vent reductions for the first two years and each region in the Alt-FEMP. The predicted vent reductions were very ambitious and actual vent reductions were much lower than predicted.

Not all repairs were completed within the required 30 days of the leak being discovered by the follow-up survey. Of the 200 delayed repairs (>30 days after discovery) 49 of them required a shutdown and were justifiably delayed. However, overall, the proportion of all repairs in a follow-up that are delayed has decreased from the beginning of the alt-FEMP to the end, as demonstrated in Figure 7. This indicates that the alt-FEMP became more successful at repairing fugitive emissions within 30 days. Figure 7 also shows that the total number of repairs from a given follow up campaign has been increasing overall from the start to the end of the alt-FEMP.

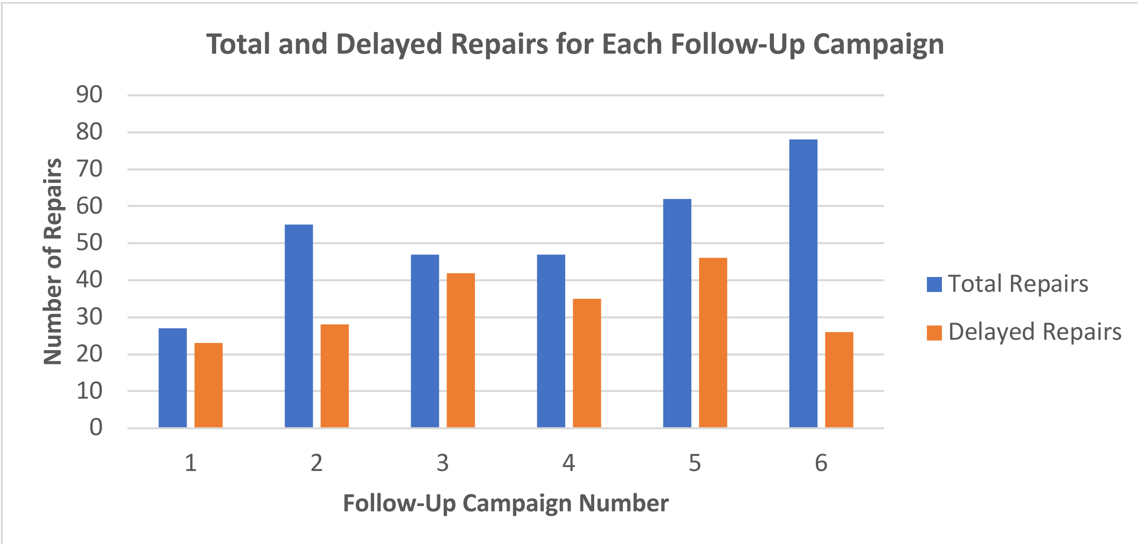

Figure 7: Plot of total and delayed repairs for each of the six follow up campaigns throughout the alt-FEMP.

In addition, both the average time from screening to follow-up and the average time from follow-up to repair have been trending downwards significantly since the third screening and follow-up campaign. This is demonstrated in Figure 8. The average days from follow-up to repair dropped below the 30-day requirement in the sixth follow-up campaign, indicating significant improvements towards complying with the 30 day repair timeframe. Figure 9, a plot of the days to repair for each completed repair throughout the alt-FEMP, supports this improvement by demonstrating a strong and consistent downward trend in the days to repair throughout the alt-FEMP.

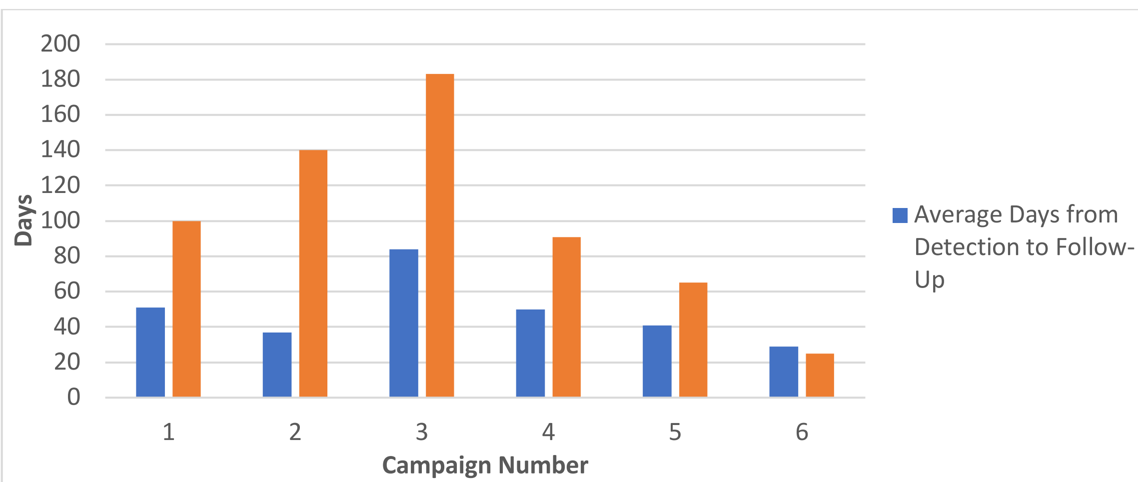

Figure 8: Plot of average days from screening detection to follow-up survey and average days from follow-up survey to repair for each of the six screening and follow-up campaigns.

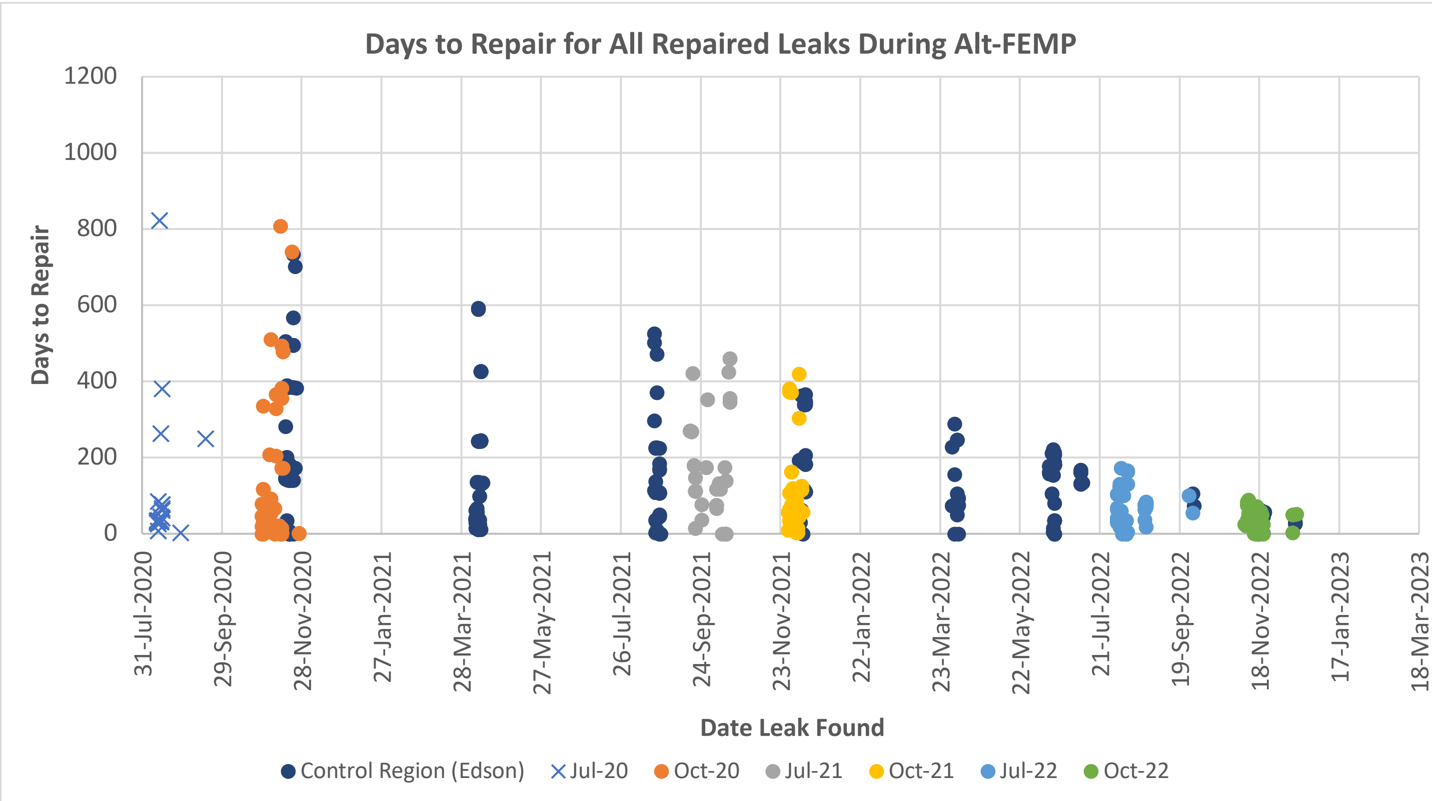

Figure 9: Plot of days from OGI survey to repair for each repair completed through the alt-FEMP. Repairs for the control region (Edson) are labelled "Control Region (Edson)" while all other data corresponds to the compilation of all alt-FEMP regions. This data is grouped by the date of the screening to which the OGI survey corresponds, as indicated in the legend.