



CANADIAN NATURAL FUGITIVE EMISSIONS STUDY USING AERIAL DETECTION TECHNOLOGY

F0160789

Abstract

Fugitive emissions are unintentional releases of hydrocarbons to the atmosphere. In oil and gas operations the major component of these fugitive emissions is methane¹. Leak Detection and Repair (LDAR) is the process of finding the sources of these fugitive emissions and repairing them and managing them under a company's Fugitive Emissions Management Program (FEMP). Research has shown only a small percentage of components are leaking and require repair and it is highly inefficient and costly to inspect every component using handheld Optical Gas Imaging (OGI) cameras^{2,3}. New technologies and methods are being evaluated as alternatives to OGI, for implementation in an Alternative Fugitive Emissions Management Program (Alt-FEMP). These Alt-FEMP technologies are being developed to find leaks faster, more efficiently and at a lower cost than business-as-usual methods.

¹ Picard, D. (1996). Fugitive emissions from oil and natural gas activities. IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines), pp.103-127.

² https://www.bridgerphotonics.com/blog/how-much-can-operators-save-using-gas-mapping-lidar-emissions-detection?utm_source=chatgpt.com

³ Components such as valves, connectors, pump seals, pressure relief devices and open-ended lines – Alberta Energy Regulator Manual 015, Estimating Methane Emissions (2020), pp.39

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1.0 Executive Summary

Canadian Natural Resources Limited (Canadian Natural) has deployed an Alternative Fugitive Emissions Management Program (Alt-FEMP) pilot in three regions of Alberta: Heavy Oil⁴, NW Alberta and SE Alberta. The Alt-FEMP pilots were approved under section 8.10.6 of the Alberta Energy Regulator's (AER) *Directive 060: Upstream Petroleum Industry Flaring, Incinerating, and Venting* (D060), whereby the AER will consider innovative and science-based alternatives to the base Fugitive Emissions Management Program (FEMP) requirements in D060. The primary element of the base FEMP requirements is regular fugitive emissions surveys using approved technologies like Optical Gas Imaging (OGI) cameras or organic vapor analyzers.

Canadian Natural's Alt-FEMP pilots deployed Bridger Photonics Inc.'s (Bridger) Gas Mapping LiDAR (GML) which was conducted via aerial remote sensing, and the University of Calgary's (U of C) Portable Methane Leak Observatory (PoMELO) methane detection technology, in addition to on-site investigation by Canadian Natural staff with OGI cameras when additional information is required.

Bridger, a methane detection technology company based in Bozeman, Montana, specializes in aerial methane detection. GML is deployed from fixed-wing aircraft to scan facilities from the air, detect methane emissions, estimate each emission's point source, and quantify the associated emission rates.

U of C, based in Calgary, Alberta, developed a vehicle-based methane detection technology. The PoMELO systems are deployed on Canadian Natural vehicles, and operated by Canadian Natural's FEMP technicians, to scan facilities from the ground, detect methane emissions, estimate each emission's point source, and quantify the associated emission rates.

The major learning from the project was understanding how Bridger's technology was best used in combination with other ground-based survey technologies and OGI. We can correlate the Bridger data with known or routine reported vent volumes from internal production accounting systems to rule out routine reported vents (i.e. not fugitive emissions) and prioritize ground-based follow ups.

Because Bridger data aids in the prioritization of ground-based follow-up, the sites with the largest emissions (particularly those that are anomalous with reported vent) can be investigated first.

2.0 Project Description

2.1 Introduction – *Including an outline of technology or process that is the focus of the Project*

Fugitive emissions are unintentional releases of hydrocarbons to the atmosphere. In oil and gas operations the major component of these fugitive emissions is methane⁵. Leak Detection and Repair (LDAR) is the process of finding the sources of these fugitive emissions and repairing them. Research has shown only a small percentage of equipment components such as fittings,

⁴ Refers to Lloydminster and Bonnyville Heavy Oil area.

⁵ Picard, D. (1996). Fugitive emissions from oil and natural gas activities. IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines), pp.103-127

connectors, etc. are leaking and require repair and it is highly inefficient and costly to inspect every equipment component using handheld OGI cameras⁶. Innovative and science-based approaches are being evaluated as alternatives to the base FEMP technologies, using novel and emerging technologies and methods to perform an Alt-FEMP. These Alt-FEMP technologies are being developed with the goal of finding leaks faster, more efficiently and at a lower cost than business-as-usual methods

2.2 Background of the Project – *Description of the general problem or opportunity area that is the focus of the Project, the history behind the Project, team and partners involved, etc.*

Conventional LDAR methods, the base FEMP technologies, are inefficient and costly. This project focuses on assessing the Alt-FEMP technologies in relation to the base FEMP, and whether they are a more efficient and cost-effective process for leak detection.

2.3 Project objectives – *Including the objectives from original Contribution Agreement and any evolution/revisions made to the objectives over the course of the Project)*

The following were the Project objectives we were attempting to achieve:

- ✓ Understand and de-risk a full-scale Bridger GML technology operation in the cold heavy oil and conventional gas areas of Alberta.
- ✓ Develop best practices for data management to maximize the methane mitigation opportunity of Alt-FEMP technologies.
- ✓ Design an efficient and effective Alt-FEMP that uses the full capabilities of these technologies.
- ✓ understand the safety, technical performance and cost-effectiveness of these technologies compared to the current methods mandated by AER Directive 60 and Manual 16
 - OGI alone
 - U of C PoMELO surveys over a select number of sites

2.4 Performance/success metrics identified in the Contribution Agreement – *Include a discussion of any evolution/revisions made over the course of the Project*

Canadian Natural and Bridger worked closely together to improve the reporting format and data delivery. Improvements were made in integration of high-resolution imaging with public aerial imaging base maps, and individual location summary reports or presentation to field Operations personnel.

⁶ https://www.bridgerphotonics.com/blog/how-much-can-operators-save-using-gas-mapping-lidar-emissions-detection?utm_source=chatgpt.com

2.5 Discussion on any changes in the Project during the lifecycle of the ERA funded Project scope – *Including any changes to corporate structure of the company or Project consortium since commencement of the Project*

Bridger conducted GML data acquisition in Canada in 2022 with its second generation of sensor hardware, GML 2.0. This is an updated version of the first-generation sensors flown in Canada during 2021. The vast majority of design changes are to improve the manufacturability and maintenance of the sensors. For 2022 deployments, flight parameters were designed to achieve similar sensor performance as the first-generation hardware. While current models suggest GML 2.0 has the capability to operate in some snow conditions, several rounds of field testing are still required to confirm its performance. Given the scheduled data acquisition window for the 2022 CNRL project was in June, snow performance was not a factor.

2.6 Technology risks – *Discussion of the technology risks, and how they evolved from the beginning of the Project to Project conclusion. Please include a discussion of all identified risks and whether mitigation strategies worked, and whether challenges arose that were not identified as risks*

No technology risks have been encountered.

3.0 Project Work Scope

3.1 Experimental procedures/methodology

The pilots were approved by the AER for 2-year period and commenced in 2021 for three different areas which are:

Heavy Oil (Lloydminster/Bonnyville)

- Cold Heavy Oil Production with Sand (CHOPS)
- Base FEMP program primarily includes annual survey facilities

Southeast Alberta (SE AB)

- Light and medium crude oil and natural gas
- Base FEMP program includes annual and tri-annual (three times a year) survey facilities

Northwest Alberta (NW AB)

- Light and medium crude oil and natural gas
- Base FEMP program includes annual and tri-annual (three times a year) survey facilities

The pilots conducted a combination of surveys with Bridger and PoMELO. It should be noted that PoMELO surveys involved the proprietary PoMELO gas sensing instruments mounted on vehicles owned by Canadian Natural and operated by Canadian Natural employees who were trained by the U of C in use of the technology. To localize a leak initially flagged by Bridger and/or PoMELO surveys, close range OGI inspections were conducted, carried out by the same Canadian Natural employees responsible for operating PoMELO (each PoMELO unit had an onboard OGI camera). For the remainder of this report, the method describing vehicle mounted surveys will be referred to as "PoMELO" and close-range follow-up OGI inspections will be referred to as "OGI".

During a Bridger survey, all sites had a flyover and locations with emissions detected in the original flight received a second flyover (typically less than 5 days apart) for persistence evaluation. Once all routine aerial scans were complete, the resultant data was processed by Bridger who create emission details reports which were sent to Canadian Natural. If a Bridger survey detected persistent (across the two survey days) site-level emission rates greater than 500 m³/day⁷ methane, the site was flagged for follow-up.

⁷ This number is the screening alerting threshold of the Bridger technology. It is referenced in the Canadian Natural Alt-FEMP Performance Report: <https://static.aer.ca/prd/documents/about-us/femp-cnrl-lloyd-alt-report.pdf>, pp.3

3.2 Technology development, installation and commissioning description

GML performance is statistical in nature. Bridger was involved in a fully blinded controlled methane release study⁸ with active oil and gas facilities before this pilot. That study found that Bridger's detection sensitivity was 0.56 kg methane/hr per m/s wind with an offset of 0.31 kg methane/hr for a 50% probability of detection. For the production sector, Bridger's stated sensitivity is 2.8 kg methane/hr (150 scfh) with 95% probability of detection under all operational conditions. Additionally, in the fully blind study, Bridger was able to quantify the controlled releases with a bias of only -8% and only +/-31% standard deviation (1-sigma) using on-site wind data. Bridger was able to achieve these results even under very challenging survey conditions: (a) wet, muddy ground, (b) flying at the top of their operational flight altitude range, and (c) turbulent wind conditions. A more recent blind release study⁹ found Bridger's detection sensitivity with a 90% probability of detection of 0.41 (kg/h)/(m/s) wind speed at 675' above ground level (AGL). Both studies were performed using the first generation GML. Bridger's GML 2.0 sensors, which are being used in Canada, have improved detection sensitivity¹⁰.

3.3 Overall Project achievements relative to stated objective and performance metrics

In this section, Canadian Natural will provide a quantitative summary of the close-range follow-up OGI inspections performed in the Heavy Oil, NW AB, and SE AB Alt-FEMP pilot areas in 2021 and 2022, respectively. The tables describe follow-up OGI investigations of PoMELO and Bridger surveys. Note: Bridger results will first trigger a follow-up with PoMELO, and occasionally this PoMELO follow-up deems OGI unnecessary. These cases do not count as an OGI follow-up investigation of a Bridger survey.

Table 1: Summary of 2021 follow-up survey performance metrics - Heavy Oil

Heavy Oil	PoMELO	Bridger	Total
Surveys that triggered OGI follow-up	459	161	620
Number of follow-up surveys where a leak was found	237	113	350
Number of follow-up surveys where a vent was found	222	48	270

Table 2: Summary of 2022 follow-up survey performance metrics - Heavy Oil

Heavy Oil	PoMELO	Bridger	Total
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⁸ Johnson, M. R., Tyner, D. R., & Szekeres, A. J. (2021). Blinded Evaluation of Airborne Methane Source Detection Using Bridger Photonics LIDAR. *Remote Sensing of Environment*, 259, 112418.

<https://doi.org/10.1016/j.rse.2021.112418>

⁹ <https://doi.org/10.1525/elementa.2022.00080>

¹⁰ It is referenced in the Canadian Natural Alt-FEMP Performance Report:

<https://static.aer.ca/prd/documents/about-us/femp-cnrl-lloyd-alt-report.pdf>, pp.32

Surveys that triggered OGI follow-up	316	105	421
Number of follow-up surveys where a leak was found	228	65	293
Number of follow-up surveys where a vent was found	88	40	128

Table 3: Summary of 2021 follow-up survey performance metrics - NW AB

NW AB	PoMELO	Bridger	Total
Surveys that triggered OGI follow-up	847	35	869
Number of follow-up surveys where a leak was found	129	1	130
Number of follow-up surveys where a vent was found	718	34	752

NW AB	PoMELO	Bridger	Total
Surveys that triggered OGI follow-up	718	20	738
Number of follow-up surveys where a leak was found	69	1	70
Number of follow-up surveys where a vent was found	649	19	668

SE AB	PoMELO	Bridger	Total
Surveys that triggered OGI follow-up	752	37	789
Number of follow-up surveys where a leak was found	484	0	484
Number of follow-up surveys where a vent was found	268	37	305

SE AB	PoMELO	Bridger	Total
Surveys that triggered OGI follow-up	643	15	658
Number of follow-up surveys where a leak was found	129	7	136
Number of follow-up surveys where a vent was found	514	8	522

3.4 Analysis of results

3.4.1 Heavy Oil

As presented in Tables 1 and 2, approximately 25% of the surveys that triggered follow-ups were Bridger surveys.

3.4.2 NW AB and SE AB

Due to the reduced scope of Bridger in the NW AB and SE AB Alt-FEMP pilots, which was limited to the sweet gas facilities, we see a reduced proportion of the overall percentage of Bridger surveys that triggered follow-ups. Qualitatively, Bridger still played a key role in prioritizing the second PoMELO surveys in these Alt-FEMP pilot areas.

4.0 Commercialization

4.1 Discussion of any advancements made toward commercialization, commercial deployment or market adoption

Prior to commencement of this project, Bridger’s aerial survey technology was commercially available but was only being used in Alberta and Canada on small scale pilot operations that began in 2019¹¹.

Execution of the project has contributed to the advancement of the market adoption of Bridger’s aerial survey technology in Alberta as the project represents one of the first commercial-scale field demonstrations for the technology in the province.

Based on data gathered and lessons learned during the first set of Bridger flights, Canadian Natural and Bridger worked closely together to improve the reporting format and data delivery. Improvements were made in presentation of location level total emission roll-ups, integration of high-resolution imaging at the time of detection with public aerial imaging base maps, and individual location summary reports for presentation to field Operations personnel.

4.1.1 Provide an update on the achievement of performance/success metrics outlined in the Contribution Agreement.

Table 7: Summary of Project Performance Metrics

Success Metric	Commercialization Target	Project Target	Overall Achievement
Survey follow-up cost reduction	> 30%	13%	0%

¹¹ A) https://globalmethane.org/challenge/bridger.html?utm_source=chatgpt.com, B) https://www.bridgerphotonics.com/blog/aerial-laser-technology-leads-methane-emission-reductions-canadian-oil-and-gas-operations?utm_source=chatgpt.com

Bridger GML data translated to direct actionable mitigation without OGI	80%	20%	0%
Compliance cost reduction	> 50%	25%	0%
Schedule adherence	> 90%	75%	> 90%

See further discussion in section 5.2.

4.1.2 Provide an update on the technology readiness level (TRL) advancement from the beginning of the Project to completion.

Execution of the project constitutes one of the first Commercial-Scale Field Demonstration (TRL 8) in Alberta of the technology for Alt-FEMP. Following the project, the technology is considered to be at a TRL 9, Commercial Implementation.

5.0 Lessons Learned

5.1 Discussion of any challenges, delays or obstacles encountered during the Project

Milestone #1: In 2021, Bridger was successful in completing the surveys on schedule for Heavy Oil. Forest fire smoke in British Columbia interfered with Bridger's ability to complete the remainder of the 2021 surveys for Edson, Grand Prairie, and Red Deer (NW and SE Alberta) on schedule. The remaining surveys were completed in October as the smoke decreased.

Milestone #2: No challenges were experienced during the execution of Milestone 2.

5.2 Important lessons learned, including learnings around business, government policy, regulation, commercialization, technology development, etc.

Bridger GML data could not be translated to direct actionable fugitive emissions mitigation without further ground-based surveys. Survey data from Bridger flights is difficult to differentiate between routine methane venting, non-routine methane venting, and fugitive emissions. Therefore, all emissions deemed actionable required PoMELO and/or OGI follow-up before mitigation efforts could commence. For this reason, the performance metric of Bridger GML data translating to direct actionable mitigation without OGI was unrealized.

Considering the ground-based follow-up requirements, coupled with Bridger survey costs, the performance metrics of survey follow-up cost reductions and compliance cost reductions were also unrealized.

The major learning from the project was understanding how Bridger’s technology was best used in combination with other ground-based survey technologies and OGI. Bridger surveys are completed with re-flights over locations with emission point sources detected during the first pass. A re-flight looks for the same emissions from the same point sources to flag an emission as either “persistent” or “intermittent”. An emission point source identified on the first flight, but not on the re-flight, is deemed intermittent. Similarly, a new point source first seen during the re-flight, but not during the first flight, is also deemed intermittent. A point source identified during both the first flight and the re-flight is deemed persistent. A persistent emission can be either a routine reported vent, or a fugitive emission. An intermittent emission is more likely to be a non-routine reported vent. Combining this data of emission point source persistency with reported vent volumes from internal production accounting systems and reported vent volumes, Canadian Natural’s FEMP technicians were able to use Bridger survey results to assist in understanding emissions anomalies and prioritize ground-based follow-ups. Bridger data aids in improving prioritization of ground-based follow-up, with the goal of targeting sites indicating the largest potential source of emissions.

6.0 Environmental Benefits

Canadian Natural makes no representations or statements relating to the present or future benefits of studied or reviewed technologies on the environment, CO₂ emissions, climate change or the like.

7.0 Economic and Social Impacts

7.1 Description of the projected economic impacts in Alberta, including revenues, cost savings, job creation, investment attraction, economic diversification, tax revenue, etc., based on the outcomes of the Project.

Canadian Natural estimates that Bridger’s GML could play a role in overall methane emissions management, including fugitives, for an operator or regulator. In these pilots, a cost efficiency was not realized compared to the current base D-060 FEMP requirements. In the future, if the economics change, Bridger technology could potentially be part of a multiple technology Alt-FEMP that reduces equivalent methane at a lower overall cost.¹²

¹² This implies that using Bridger technology together with other technologies would possibly reduce overall costs which has not achieved yet. Considering the ground-based follow-up requirements, coupled with Bridger survey costs, the performance metrics of survey follow-up cost reductions and compliance cost reductions were also unrealized.

7.2 Description of how the Project has resulted in increased innovation capacity in the province through training of highly skilled personnel, knowledge development, postsecondary partnerships, research organizations, startup companies, etc.

The development of technologies such as Bridger for the identification and quantification of methane emissions increases the innovation capacity in Alberta and advances the adoption of alternative methane technologies.

As a result of the work by Canadian Natural and industry peers prior to and during the project, technology companies in Alberta that design and build software to model emissions reductions, have had an influx of business. As data was gathered throughout this Project it was used to improve the modelling ability of emissions reductions for all clients, setting Alberta up to be a world leader in these new types of technologies.

During the project Canadian Natural increased the knowledge and training of FEMP technicians by training them on how to operate PoMELO and training technical office staff in how to analyze and manage both PoMELO and Bridger data.

7.3 Discussion of how the Project impacted local communities, underserved communities, and/or indigenous groups.

Improved identification, measurement and mitigation of methane emissions will benefit the surrounding communities by reducing the total amount of GHG emissions.

7.4 Discussion of any other equity, diversity and inclusion related Project work and outcomes.

This project did not include any equity, diversity and inclusion related Project work and outcomes.

8.0 Scientific Achievements

8.1 List of all applied for or obtained patents, published books, journal articles, conference presentations, student theses, etc., based on work conducted during the Project.

The project has not resulted in Canadian Natural applying for or obtaining any patents, publications or presentations.

9.0 Overall Conclusions

9.1 Summary of the Project outcomes and resulting GHG emissions reductions attributed to this Project in Alberta and/or abroad.

Based on the data summarized in Tables 2, 4, and 6 (2022 follow up survey performance metrics in Heavy Oil, NW AB, and SE AB), a total of 1817 surveys were conducted using PoMELO and Bridger technologies, triggering OGI follow-up. Bridger's advanced aerial detection capability allowed for rapid scanning across large areas, complementing PoMELO's broader survey coverage. Together, these technologies provided a comprehensive approach to leak and vent identification, underscoring the effectiveness of Canadian Natural's implementation of the Alt-FEMP initiative. In conclusion, Canadian Natural's Alt-FEMP initiative has met its main objective of understanding how Bridger's technology was best used in combination with other ground-based survey technologies and OGI.

The main benefit of using Bridger Alt-FEMP technology lies in its high-resolution aerial detection capability, which allows for the rapid identification of methane leaks and vents with precise geolocation. This enables operators to:

- Quickly scan large areas without needing boots on the ground, making it ideal for remote or hard-to-access sites.
- Pinpoint emission sources accurately, reducing the time and cost required for ground teams to locate and repair issues.
- Support timely follow-up actions, which enhances overall program efficiency and helps maintain regulatory compliance.

In summary, Bridger significantly boosts detection speed and accuracy, making it a valuable complement to ground-based technologies like PoMELO.

10.0 Next Steps

10.1 Discussion about the next steps for the technology/process/innovation, including potential follow-up Projects

Canadian Natural recognizes that the role of Alt-FEMP technologies beyond conventional OGI may continue to be important; however, any next steps will depend on the specifics of future regulatory developments. At this time, no commitment can be made until greater clarity is provided.

10.2 Long-term plan for commercialization of the Project technology/learnings

No long-term plans for commercialization.

10.3 Commercialization-related actions to be undertaken within two years of Project completion

No commercialization-related action will be taken.

10.4 Potential partnerships under development with technology integrators, adopters, etc.

No potential partnerships are under development.

11.0 Communications plan

11.1 Summary of key knowledge-sharing or communications activities undertaken during the Project and who the primary audience is.

Knowledge-sharing activities conducted during the Project consisted of application and reporting requirements to the Alberta Energy Regulators (AER) as the Alt-FEMP pilot was completed. These communications are public record under the AER requirements.

Knowledge-sharing activities aimed at industry during the project were initially planned for industry forums and presentations. Due to the effects of COVID, these activities were delayed and ultimately did not fit with the projects timing.

Canadian Natural has also been meeting with other members of industry to share progress and learnings on the Alt-FEMP project.

11.2 Plans for communicating information about the Project, Project findings, and results or the underlying technology with third parties, including a description of communication tools that will be used.

Not Applicable.

12.0 Literature reviewed

12.1 List of literature reviewed in an appropriate citation format (if applicable)

Johnson, M. R., Tyner, D. R., & Szekeres, A. J. (2021). Blinded Evaluation of Airborne Methane Source Detection Using Bridger Photonics LIDAR. *Remote Sensing of Environment*, 259, 112418. <https://doi.org/10.1016/j.rse.2021.112418>

Picard, D. (1996). Fugitive emissions from oil and natural gas activities. *National Greenhouse Gas Inventories*, pp 103-127

13.0 Appendices and References

13.1 Bridger Photonics Gas Mapping LiDAR (GML)

<https://www.bridgerphotonics.com/gas-mapping-lidar-for-aerial-methane-detection>

13.2 University of Calgary PoMELO Emissions Management System

<https://pomelo-methane.ca/>

13.3 Alberta Energy Regulator Alternative Fugitive Emissions Management Program Approvals

<https://www.aer.ca/protecting-what-matters/holding-industry-accountable/industry-performance/methane-performance/alternative-fugitive-emission-management-program-approvals>

Heavy Oil: <https://static.aer.ca/prd/documents/about-us/cnrl-executive-summary-lloyd.pdf>

NW AB: <https://static.aer.ca/prd/documents/about-us/cnrl-executive-summary-nw.pdf>

SE AB: <https://static.aer.ca/prd/documents/about-us/cnrl-executive-summary-se.pdf>

13.4 Alberta Energy Regulator Manual 015

[Estimating Methane Emissions](#) (2020), pp.39