Karen Knutson
Vice President & General Manager, Government Affairs

February 13, 2023

Via online submission: www.regulations.gov

The Honorable Michael S. Regan
Administrator
Mail Code 28221T
1200 Pennsylvania Avenue NW
Washington, D.C. 20460

Re: Docket ID Number: EPA-HQ-OAR-2021-0317

Chevron Corporation ("Chevron" or "we") is one of the world's leading integrated energy companies. We believe affordable, reliable and ever-cleaner energy is essential to achieving a more prosperous and sustainable world. In the United States (U.S.), Chevron has active exploration and production operations for crude oil and natural gas in several states and the Gulf of Mexico; manufactures transportation fuels, lubricants, petrochemicals and additives; and develops technologies that enhance our business and the industry. We are focused on lowering the carbon intensity in our operations and growing lower carbon businesses along with our traditional business lines.

Our strategy is clear – leverage our strengths to safely deliver lower carbon energy to a growing world. Effective methane management is important for lower carbon intensity oil and gas production. Globally, Chevron has adopted an upstream methane intensity target of 2.0 kilograms carbon dioxide equivalent per barrel of oil equivalent ($kgCO_{2e}$/boe) by 2028, which is a 53% reduction from our 2016 baseline, and has been working to deploy advanced methane detection technologies in upstream operations. Our action plan, examples of our global emission reduction projects, and sample technology deployments are outlined in our 2022 methane report[1].

While implementation of our methane action plan is ongoing, our U.S. onshore operations have some notable early successes. In 2021, the methane intensity for our U.S. onshore production sector was 64% lower than the U.S. sector average, based on data from the U.S. Greenhouse Gas Reporting Program (GHGRP). Our advanced technology trials have shown that the success of certain technologies is tied to the unique characteristics of the assets and geography where the solution is deployed. In the Permian Basin, we trialed eight options using a technology evaluation framework and selected an aerial vendor for wider deployment across the basin.

The proposed rule by the Environmental Protection Agency (EPA) under this docket focuses on emissions of methane and volatile organic compounds (VOCs) from the U.S. onshore oil and gas industry by building upon current standards of performance for new, reconstructed, and modified sources (OOOOb) and establishing emission guidelines for existing sources (OOOOc). Chevron believes that methane reduction is possible in the energy industry, and in other key

---

[1] https://www.chevron.com/-/media/shared-media/documents/chevron-methane-report.pdf

sectors, through the adoption of industry best practices, advancement in measurement technologies, and methane regulations. Chevron supports effective regulation of methane for new and existing sources, including:

- *Measurement Reporting and Verification (MRV) programs*: Methodologies need detection technology performance specifications, measurement protocols and verification to ensure consistent quantification and reporting of methane emissions across all covered operators and sectors. Currently, there is greater measurement uncertainty with methane emissions than with CO_2 emissions. A robust MRV framework will need emission factors, engineering estimates and the use of advanced technologies.
- *Technological innovation*: Policy should flexibly incorporate advanced technologies, such as aerial and drone monitoring, that can detect and measure methane emissions most effectively, particularly from super-emitters that have a disproportionate impact on overall emissions. Policy frameworks should be based on realistic current capabilities of measurement technologies.
- *All sectors contributing*: Improving methane performance is important for oil and natural gas (24% of global methane emissions), as well as other sectors, which make up the remaining 76%. Policy should apply to all key sectors.
- *Performance-based regulation*: When jurisdictions pursue effective methane regulations, they should set appropriate methane targets based on industry best practices, including reasonable minimum equipment standards, while providing flexibility for companies to determine the optimal way to meet those targets.

We support many of the emission reduction provisions outlined across the proposals for OOOOb and OOOOc and are committed to working with EPA on this important topic. Based on our methane management experience, we would like to highlight a few areas where EPA could improve the proposed rule before finalization to focus resources more effectively on reducing emissions across the sector.

Alternative Technologies
Advanced methane detection technologies like flyovers have improved and become more accessible since EPA drafted leak detection and repair requirements for OOOOa. Since then, operators like Chevron have increasingly used advanced technologies as part of voluntary screening programs at scale to help better understand and reduce methane emissions. In 2022, Chevron conducted methane detection flyovers for approximately 950 facilities in the U.S. Through collaborations like The Environmental Partnership,[2] many operators of different sizes and site types have found that aerial technologies are useful to monitor operations and yield actionable information to mitigate methane emissions.

We appreciate that EPA has included a framework for advanced technologies in this proposed rule and recognize the challenges of developing modeling-based comparisons between optical gas imaging (OGI) and newer technologies for screening sites. However, we are concerned that the current proposal disincentivizes broad adoption of alternative technologies that are becoming more prevalent across the industry.

The proposed rule includes a nine-month review timeline by EPA for approval of alternative technologies. We support an ongoing alternative technology approval process as new technology emerges and urge EPA to consider the approaches described below to accelerate

---

[2] https://theenvironmentalpartnership.org/collaboration-on-remote-sensing-technologies/

technology review. For operators, the EPA approval of a technology would be the first step in a deployment process that includes contracting, personnel training, and procurement activities that would likely occur after the approval date, given uncertainties in the EPA approval processes and timelines. As a comparison point, the Alberta Energy Regulator estimates a processing time of 60 days[3] for applications under its alternative fugitive emissions management program. A final rule could address some of these timeline concerns through pre-approval of a few widely deployed technologies, conditional approvals of technology based on vendor-specified detection limits or existing state program approvals while EPA reviews applications, or more expedited review timelines under the final rule.

The proposed matrix includes significantly higher frequencies for advanced technologies compared to OGI, which may be driven by modeling assumptions around the detection effectiveness of OGI rather than differences in the real-world emission reduction potential of the advanced technologies. Other research[4] on OGI performance shows that the actual probability of detection varies based on surveyor experience, meteorological conditions, and other factors. A side-by-side comparison study[5] in Canada concluded that one alternative technology, Bridger Photonics, found more emissions overall than OGI due to the alternative technology's ability to detect additional sources, particularly at heights. Since OGI is not quantitative, the researchers in the Canadian study needed a second tool to measure methane emissions detected with OGI.

As part of our analysis of the alternative technology provisions of the OOOOb and OOOOc proposed rule, Chevron selected Highwood Emissions Management[6] (Highwood) to provide modeling assistance because of their primary contribution to the development of a technology comparison software (LDAR-SIM), prior work with a diverse range of stakeholders (oil and gas companies, regulatory agencies, vendors, and the Environmental Defense Fund), and successful achievement of regulatory approvals for alternative technologies based on equivalency demonstrations in Alberta and Colorado.

Appendix 1 includes a report developed by Highwood that compares emissions detected between aerial surveys with Bridger Photonics and ground-based OGI surveys across Chevron's assets in the Permian Basin. The report also models emission distributions from two studies that represent a low[7] and high[8] case for inclusion of 'fat-tail' emission sources. This analysis found that equivalency between OGI and alternative technologies with a specific method minimum detection threshold will vary based on the emission distribution used in the model. However, there are important cross-distribution findings for technologies like Bridger Photonics, with detection limits of ≤4 kg/hr. In its proposed rule, EPA included monthly (12x/year) frequency for this class of technologies, while the Highwood modeling study concludes that alternative monitoring frequencies of 3x/year + 1 OGI/year, 4x/year, or 4x/year + 1 OGI/year are sufficient for equivalency, depending on the emission distribution used in the model. While Highwood used a different model (LDAR-SIM) than EPA (FEAST), we believe that

---

[3] https://www.aer.ca/regulating-development/rules-and-directives/directives/submission-checklist-for-alternative-femp-proposals
[4] Zimmerle D.; et al. Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. *Environmental Science and Technology*. **2020**, *54 (18)*, 11506-11514.
[5] Tyner, D.R.; et al. Where the Methane Is – Insights from Novel Airborne LiDAR Measurements Combined with Ground Survey Data. *Environmental Science and Technology*. **2021**, *55*, 9773-9783.
[6] For further information on work by Highwood is available at https://highwoodemissions.com/projects/.
[7] Zavala-Araiza, D.; et al. Reconciling divergent estimates of oil and gas methane emissions. *PNAS*. **2015**, *112 (51)*, 15597-15602.
[8] Cusworth, D.H.; et al. Intermittency of Large Methane Emitters in the Permian Basin. *Environmental Science and Technology*. **2021**, *8 (7)*, 567-573.

the primary difference for equivalency results is due to the use of an empirical, field-experience based input for OGI in the Highwood model that accounts for expectations that OGI surveys will not necessarily identify every emission.

As a result, we recommend that EPA revise its equivalency table for compressor stations and central tank batteries, as shown in a redline in Appendix 2, to include a single category for all low detection limit technologies (≤4 kg/hr) with a minimum screening frequency of quarterly (4x/year) for alternative technologies, combined with an annual (1x/year) OGI survey. While we believe that equivalency could be achieved in many situations without the annual OGI survey, its inclusion should help address stakeholder concerns around smaller-size emissions while focusing the majority of resources on finding the largest emissions. We believe this revised frequency recommendation is supported by more realistic modeling of OGI effectiveness across a range of emission distributions, our field experience with advanced technologies, and potential data needs for other EPA programs that are discussed in the next section.

In our view, a final rule that expeditiously reviews and approves advanced detection technology will facilitate performance improvement and have broader influence beyond the U.S. oil and gas onshore production sector. Within the U.S., the utilization of these technologies at scale in the oil and gas production sector would likely provide cost-effective solutions that could be applied in other methane-emitting sectors. If made available internationally, we believe this could enhance capabilities in other countries to improve methane performance in support of efforts like the Global Methane Pledge. Advanced technologies can help drive overall reductions in methane intensity and will be a component of methane management at scale.

Related EPA Rulemakings
EPA has several related current and future rulemakings on aspects of methane emissions in the oil and gas industry, including changes to emissions reporting in the GHGRP and implementation of a methane fee under the Methane Emission Reduction Program (MERP) of the Inflation Reduction Act (IRA). In its proposal, EPA states that “the implementation of the Methane Emissions and Waste Reduction Incentive Program is outside the scope of this supplemental proposed rule” but “acknowledges the potential interplay between the provisions in this proposed rule and the Methane Emissions and Waste Reduction Incentive Program and invites comment on approaches for examining the economic impacts of these programs individually and collectively.”

We believe there is an important synergy between leak detection technology decisions made by EPA under OOOOb and OOOOc and the need to align with measurement-informed methane reporting at the national scale for the GHGRP and MERP programs. Based on our experience with piloting 13 advanced methane detection technologies globally since 2016 and completing demonstration projects for the GTI Energy Veritas protocol[9], we believe that alternative technologies, emissions factors for smaller sources, and consistent protocols will all be important prerequisites for measurement-informed reporting in the sector. As it is not a quantitative technology, OGI will likely be unable to provide the empirical data for emission reporting across source categories beyond equipment leaks and pneumatic controllers, for which scientific studies have developed leak/no-leak emission factors. The EPA Science Advisory Board also noted the potential interplay between information collected under OOOOb and OOOOc and mechanisms to create measurement-informed inventories.

---

[9] veritas.gti.energy

In our view, a more holistic consideration of technology needs across EPA programs for methane emissions in the oil and gas sector will highlight the need to incentivize the use of alternative technologies within OOOOb and OOOOc. The current proposed rule includes a higher frequency, up to monthly, compared to quarterly for OGI, which could create a disincentive for utilization by many operators in the industry, which may in turn influence the type of data available for the GHGRP and MERP. We encourage EPA to consider the technology needs for related agency programs as it finalizes the survey matrices for alternative technologies for this rulemaking.

State Program Equivalency for OOOOc Emission Guidelines
Many state agencies have already implemented regulations to reduce VOC and methane emissions from the same source categories included in OOOOb and OOOOc. The approach in the proposed rule requires that states demonstrate equivalency with OOOOc guidelines on a source category basis and applies other criteria, including that the form of standards be the same. This may lead to duplicative recordkeeping and implementation requirements across existing programs. We encourage EPA to consider options for state equivalency assessments with more flexible criteria, including demonstration on an overall emission reduction basis. We acknowledge that such a change may be more administratively burdensome for EPA initially in review of state plans, but it is expected to streamline regulation and focus resources on emission management and reduction versus duplicative recordkeeping and reporting in states with existing rules.

Super-Emitter Response Program
Multiple peer-reviewed studies have demonstrated a distribution of emissions with a ‘fat tail’, or a small number of large emissions that account for a disproportionate amount of total emissions. We appreciate that EPA is looking for ways to address the largest emissions, such as a proposed threshold of 100 kg/hr. When credible information of emissions at that magnitude from our assets are available, Chevron would like to be notified as soon as possible. We have gained experience with notification programs through voluntary technology trials with multiple operators, such as a project with the Oil and Gas Climate Initiative for satellite-based monitoring in Iraq[10], The Environmental Partnership, and Project Astra, as well as receiving third-party data through the Permian MAP project. We share the following experiences that could help to increase the timeliness, actionability, and emission reduction effectiveness of notification programs:

- The utility of the screening data for an operator decreases as more time passes after the detection. In our experience, data received a month or more after the detection occurred is harder for operators to understand and assess. Timely receipt of detection data from third parties is key for operators to utilize the data to inform emission reductions.
- Technologies that can localize emissions to specific pieces of equipment will be more useful to direct follow-up activities than approaches that provide only site-level or regional information. Receiving detection data that covers multiple operators, multiple sites, or is subject to atmospheric data that is not widely available cannot be interpreted easily or accurately by operators and may cause a delay in potential emission reduction responses.
- While remote sensing technologies provide information on methane emissions, identification of the operator and emission source often requires additional sources of data and information. In our experience with multi-operator campaigns, the operator of a site can be initially misidentified due to asset transfer, plume drift from a nearby site, or other factors. Additionally, unlike well locations, national, widely-available databases of other facilities, such as tank batteries or compressor stations, do not exist. This could lead to a situation

[10] https://www.ogci.com/wp-content/uploads/2023/01/OGCI_Iraq_Whitepaper_jan23.pdf

where operators are routinely in a position of proving a negative or redirecting to another operator.

- Variability in oil and gas facility emissions is expected. A snapshot observation of a facility may capture an intermittent event, like a blowdown, above the 100 kg/hr threshold without that being indicative of the long-term average emissions from that facility. The EPA Science Advisory Board recommended a measure of persistence at the facility be included in defining responses to account for this type of situation. Additionally, there is an error bar associated with quantification from all remote sensing data that will depend on the type of equipment used and the conditions at the time. The magnitude of the error bar varies widely across technologies, so notifications should include and quantification should account for the range of uncertainty associated with the measurement.

Considering the challenges of this first of its kind program, the concept of addressing 'super-emitters' via a clearinghouse of data providers and operators seems to lend itself to a voluntary initiative. We would appreciate the opportunity to discuss alternative concepts with EPA that could address 'super-emitters' expeditiously. Regardless of the final form of a program at EPA (regulatory, voluntary, etc.) or other forums, successful remote monitoring programs should be focused on reducing emissions by providing timely data access, facilitating collaborative learning, and minimizing administrative elements surrounding detections. A collaborative tone for the program may improve these program elements and lead to faster emissions reductions.

Associated Gas Flaring

Associated gas flaring is an important issue for the upstream oil and gas industry, and we are pleased that EPA is looking to address the important topic of routine flaring as part of its regulatory package. For our Permian Basin operations, Chevron has been a leader on flaring performance[11] due to careful consideration of gas-takeaway ability in our planning process and not putting wells on production until takeaway is available. We are also encouraged by the progress that other operators have made in reducing their flaring volumes. For example, the gas flare intensity[12] for participating operators in The Environmental Partnership decreased from 3.04% in 2019 to 0.82% in 2021. In our view, EPA should build on the successful industry best practices to reduce routine flaring, which are underpinned by access to infrastructure and takeaway capacity to market the gas. Approaches to reduce non-routine flaring require different policy considerations, which we would be happy to share if EPA is considering regulations on this important issue.

Conclusion

Chevron believes that methane management is critical to a lower carbon future and that methane reductions are possible in the energy industry and in other key sectors. Thank you for the opportunity to submit these comments to the rulemaking docket. If you have questions regarding the comments above, please contact Jay Thompson at (202) 408-5844 or thompsonjr@chevron.com.

Sincerely,

Karen Knutson

Karen Knutson
Vice President & General Manager, Government Affairs

---

[11] https://www.gaffneycline.com/sites/g/files/cozyhq681/files/2020-06/Tackling%20Flaring_Final.pdf
[12] https://theenvironmentalpartnership.org/annual-reports/2022-annual-report/

Technical Report

Appendix 1

LDAR-Sim Modeling

Alternative technology matrix modeled in LDAR-Sim

Date
February 2023

Prepared for
Chevron

Chevron

Executive Summary

The Environmental Protection Agency (EPA) proposed supplemental methane rules are poised to drastically shift how oil and gas companies utilize alternative methane detection technologies, such as aerial flyovers. The requirements for using alternative methane detection technologies under the proposed rules are summarized in equivalency matrices and are based on simulation modelling using The Fugitive Emissions Abatement Simulation Toolkit (FEAST) model. FEAST modelling of the mitigation performance of traditional leak detection and repair (LDAR) methods (Optical Gas Imaging (OGI) cameras and Audio Visual Olfactory (AVO) inspections) informed the requirements (minimum detection limits and screening frequency) of alternative screening methods (aircraft, drones, satellites, etc.) for them to be considered equivalent as part of the approval framework and for use instead of these traditional methods.

While many details of how FEAST was used by EPA remain unknown, there appears to be an inconsistency with modelled and real-world performance of traditional methane detection methods like OGI. These inconsistencies could lead to proposed regulations which put an undue burden on alternative screening technologies to perform at unrealistic levels, discouraging their widespread adoption.

Chevron has been conducting voluntary Bridger Photonics aerial flyovers over a collection of assets in the Permian Basin and has shared the associated data with Highwood Emissions Management (Highwood) to further investigate equivalency. Highwood used this data to inform simulation modelling using the Leak Detection and Repair Simulator (LDAR-Sim) and investigated the proposed EPA alternative screening matrices, exploring more realistic performance of traditional methods (OGI) and the associated equivalent alternative screening-based programs.

Highwood parameterizes OGI performance differently than that done by the FEAST modelling. A probability of detection curve is used to inform the OGI methods minimum detection limit. A spatial coverage parameter is applied to represent areas on sites inaccessible and/or difficult to monitor via OGI. Depending on various factors such as the leak sizes used in simulation, an OGI program parameterized using Highwood standard assumptions mitigates ~24-25% less than an OGI-based program parameterized using the assumptions made by the EPA during FEAST modelling. These modelling results demonstrate that the OGI performance parameterization applied by the EPA / FEAST was an over representation of the mitigation capabilities of OGI methods.

LDAR-Sim modelling was also used to investigate the performance of alternative screening technologies in comparison to OGI based programs. Modeling showed that, when assuming the Highwood standard assumptions of OGI performance parameterization, an alternative screening program with a minimum detection limit (MDL) of 4 kilograms (kg)/hr methane or smaller, can achieve emissions reduction equivalency with fewer annual screenings than what is required by the proposed EPA rule.

While it is imperative to ensure alternative screening technologies can perform adequately to meet emissions reductions targets, it is important to not over-represent the capabilities of the traditional methods they are being compared against. The simulation modeling carried out by Highwood and detailed in this report indicate that FEAST modeling did over-estimate the performance capabilities of traditional methods and that alternative screening methods can achieve emissions reduction equivalency with fewer annual screenings than those proposed by the EPA.

Table of contents

1 Glossary

The following key definitions are applied throughout this report:

- **Technology**: A gas sensing instrument, optionally configured with a deployment platform and/or ancillary instruments (e.g., anemometers, positioning), that can be used to gather data on emissions.
- **Work practice**: A description of how a technology is used to collect information about emissions, including operating procedures (e.g., distance from source, measurement time, environmental envelopes for sure, production segments)
- **Method**: The combination of a technology, a work practice, and analytics for use in an LDAR Program. An LDAR Program has at least one method (in cases where only one method is used, method and LDAR Program are synonymous).
- **Leak Detection and Repair Program (LDAR Program)**: An LDAR Program is the systematic implementation of one or more methods across a collection of assets. The program describes the method, or combination of methods, to be used for each facility, along with survey frequency, repair response, and reporting standards. Ultimately, it is the LDAR Program that results in emissions mitigation, not the technologies or methods in isolation.

2 Introduction

On November 11th, 2022, the Environmental Protection Agency (EPA) posted supplemental rules on methane regulations. A key component of these proposed rules is an "alternative screening matrix" which outlines the minimum detection limit (MDL) and survey frequency which alternative monitoring technologies (aircraft, drones, satellites, etc.) must employ to be considered equivalent with traditional methane monitoring methods (Optical Gas Imaging (OGI) cameras and Audio Visual Olfactory (AVO) inspections). Figure 1 presents the proposed alternative screening matrix.

Table: Survey matrix for alternative periodic screening (facilities subject to quarterly OGI monitoring).

Minimum Screening Frequency	Minimum Detection Threshold of Screening Technology[1]
Quarterly + Annual OGI	≤1 kg/hr
Bimonthly	≤2 kg/hr
Monthly	≤4 kg/hr
Bimonthly + Annual OGI	≤10 kg/hr
Monthly + Annual OGI	≤30 kg/hr

[1] Based on a probability of detection of 90 percent.

Figure 1 The alternative screening matrix proposed by the EPA for sites which would require quarterly OGI surveys. This report focuses only on these quarterly OGI required sites.

The requirements detailed in this matrix were based on The Fugitive Emissions Abatement Simulation Toolkit (FEAST) modeling by EPA and aimed to compare the mitigation performance of traditional methane detection methods with alternative methane detection technologies with varying MDLs. While many details of how FEAST was used remain unknown, there appears to be an inconsistency between modeled performance and the real-world performance of traditional methane detection methods like OGI and AVO.

On behalf of Chevron, Highwood Emissions Management (Highwood) has investigated the performance of the proposed leak detection and repair programs in LDAR-Sim. Chevron performs screening of a collection of assets in the Permian Basin on a voluntary basis with Bridger Photonics flyovers and has shared the associated empirical data with Highwood for this study. In addition to the incorporation of this data, the modeling performed and detailed in this report aimed to leverage Highwood's carefully thought-out approach to OGI modeling. Highwood is the primary contributor to LDAR-Sim, an open-source simulation software that has gained prominence and is used broadly across North America by regulators (e.g., AER, CDPHE), industry groups (e.g., API, COGA), standards associations (e.g., MiQ), investors), and diverse innovators.

The primary goal of this report is to share the results from Highwood's LDAR-Sim model simulations and provide feedback on ways to improve the proposed alternative screening matrix based on realistic assumptions of the performance of traditional methane detection methods.

3 LDAR-Sim Modeling Overview

The Leak Detection and Repair Simulator (LDAR-Sim) is an open-source, agent-based numerical model developed at the University of Calgary used to predict emissions reduction effectiveness and costs of different LDAR programs and work practice configurations. LDAR-Sim works by building a "virtual world" of oil and gas infrastructure and emissions sources that is informed by empirical measurement data and historical environmental data. Different LDAR programs, which consist of unique methods, are then applied to the virtual world to predict emissions reductions, and compare performance amongst the programs. LDAR-Sim accounts for local environmental conditions and is built on actual site data. In this investigation, historical weather in the Permian Basin and Chevron site locations inform the modeled virtual world.

LDAR-Sim was first used to replicate the parameterization and associated modeling carried out by FEAST which informed the supplemental EPA rules. After this "base case" was established, LDAR-Sim was then used to explore parameterizations which re-modeled EPA / FEAST programs using Highwood assumptions. These two modelling results were compared to provide recommendations on adjustments to the alternative screening matrix.

In modelling results (Section 4), programs which contain "_EPA" are based on EPA's FEAST modelling assumptions while programs which end in "_HW" are based on Highwood modelling assumptions. The following sections provide a brief overview of the most notable modeling / parameterization assumption differences between Highwood / LDAR-Sim and EPA / FEAST.

3.1 OGI performance

OGI methods are a key part of simulation modelling as they form the foundation of programs based around traditional methods and are frequently supplemental to programs based around alternative methods. An important parameterization is the method detection limit (MDL) of the OGI method. Based on the technical memorandum detailing the use of FEAST modelling to inform the EPA supplemental rule[1], FEAST modelling assumes 100% detection for leak rates greater than or equal to 0.0167 g/s[1], an MDL not in line with recent studies[2]. Highwood assumes a probability of detection (PoD) curve based on Zimmerle et al., 2020 as the OGI method MDL.[2] The probability of detection curve was fit using many field trials of OGI operators attempting to identify leaks and assigns the probability of detecting an emission based on a single input, in this case, emission rate. This probability of detection curve has a 95% probability of detection for emissions greater than or equal to 0.181 g/s.

3.2 Spatial coverage

The methods used in programs (refer to glossary) parameterized using Highwood modeling assumptions consider spatial coverage. The spatial coverage parameter is a value from 0-1 and is a representation of the average proportion of a site the method can effectively survey. For example, a value of 0.8 indicates that the method will find a leak 100% of the time in 80% of the site. In practice, spatial coverage accounts for emission sources that see reduced successful observations from a given monitoring technology. FEAST modelling does not consider spatial coverage, so all EPA programs shown in the results sections of this report assume a spatial coverage of 1.0 across all methods.[1] In modeled “Highwood” programs, routine OGI methods assume spatial coverage of 0.75, follow-up OGI methods assume spatial coverage of 0.85 (to reflect it is a more targeted survey based on emission detection information provided by an assumed previous, screening method) and screening methods assume a spatial coverage of 0.99 (based on conversations with technology vendors). The value of 0.99 attributed to screening methods is indicative of the performance of fixed wing aircraft (as opposed to other potential screening methods like mobile ground labs), such as the flyovers performed by Bridger Photonics across the Chevron sites being modeled.

3.3 Environmental constraints

To our knowledge, FEAST modelling did not consider operational windows of the methane detection methods based on weather conditions. The LDAR-Sim model confirms each simulated day if a method can operate based on the operational envelopes of the methods and that given day’s weather conditions for both traditional and alternative detection methods.

3.4 Leak generation rate / leak production rate

The parameter which informs the probability that a site will have a leaking component on a given day is known as the leak generation rate in FEAST modeling and the leak production rate in LDAR-Sim modeling. For this investigation, a leak production rate was calculated using Chevron’s OGI survey data in the Permian Basin.

3.5 Leak rate distribution

Both FEAST and LDAR-Sim modeling rely on leak rate distributions to inform the size (rate) of leaks added to the simulation. LDAR-Sim adds leaks to a given site on a component level.

The chosen leak rate distribution used has a marked impact on simulation results. It is important to consider the basin being represented, as different basins have differing leak rate distributions. A theoretical basin dominated by large emissions will benefit more from screening methods like aerial surveys which can rapidly detect large sources, while the same methods deployed in basins prone to smaller emissions may be less effective.

To explore the impact leak rate distributions (and their associated basin) have on simulation results, Highwood modeled LDAR program equivalency using three leak rate distributions:

1. An empirical leak rate distribution based on Zavala-Araiza, 2015 which is built from bottom-up and top-down measurements of emissions from sites in the Barnett Shale.[3] This distribution is often used in LDAR-Sim modeling to represent basins prone to “medium to small” emissions unlike those typically seen in the Permian basin.
2. An “augmented” version of the Cusworth, 2021 distribution which is built from top-down measurements of emissions from sites in the Permian Basin.[1,4] The “augmented” Cusworth distribution used in LDAR-Sim modeling is the same as the “augmented” Cusworth distribution used in FEAST modeling (the associated FEAST technical memo provided the mean and standard deviation of the log-normal distribution which were input directly into LDAR-Sim). The goal of augmentation was to account for smaller leaks which were potentially underrepresented in the original Cusworth distribution.
3. A leak rate distribution based on emission rates recorded by Bridger Photonics flyovers of Chevron sites in the Permian Basin from 2021-2022, data provided to Highwood for this report.

The leak rate distributions used are shown as cumulative density functions in Figure 2.

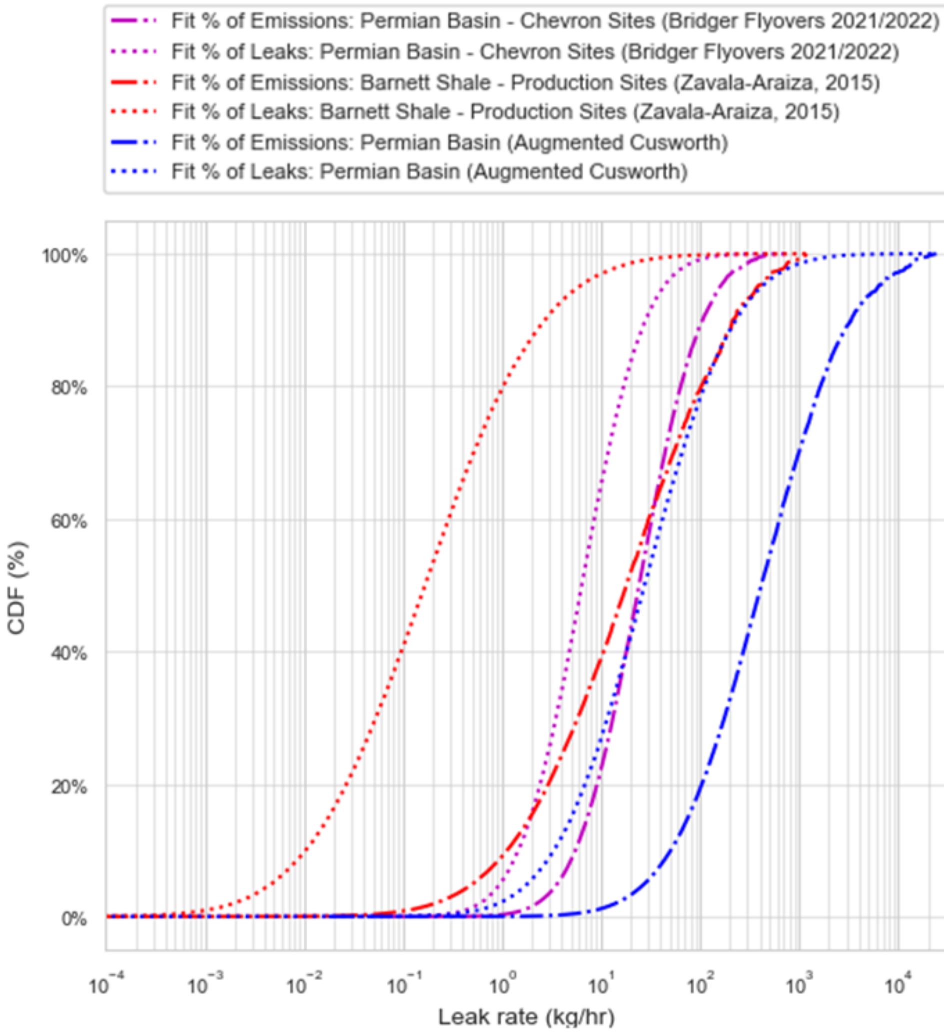

Figure 2. Cumulative distribution function of emission data from Bridger flyovers and peer reviewed empirical studies used to inform leak sizes in LDAR-Sim modelling. “Fit % of Emissions” (dashed-dotted lines) refers to what proportion of total emissions from the given distribution can be attributed to leaks of a given size, for example, when referring to the ”Emissions” CDF of the Zavala-Araiza, 2015 study (red dot-dash line), we see that 40% of emissions are due to leaks 10 kg/hr or smaller. “Fit % of Leaks” (dotted lines) refers to the proportion of individual leak sizes in each distribution. For example, when referring to the ”Leaks” CDF of Zavala-Araiza, 2015 study (red dotted line), we see that 40% of individual leaks in the distribution are 0.10 kg/hr or smaller. The separation of the “Fit % of Emissions” and “Fit % of Leaks” CDFs provides evidence that a small proportion of large leaks cause most of the total leak-based emissions.

Highwood believes the peer reviewed distributions used in modeling are representative bracketing cases of basins prone to smaller leaks (Zavala-Araiza, Barnett Shale) and larger leaks (augmented Cusworth, Permian Basin). The leak rate distribution created using Chevron provided Bridger Photonics flyover data occupies a “middle ground” between the “brackets” of the peer reviewed distributions as shown by the position of its associated CDFs in Figure 2. While both the augmented Cusworth distribution and the Chevron provided Bridger based distribution are sourced from aerial flyovers of Permian Basin sites, the Bridger based distribution is weighted towards smaller emissions than the augmented Cusworth distribution, which is based on multiple operators.

It is important to note that all distributions used do not distinguish between vented and fugitive emissions. Incorporating additional data to account for fugitive vs. vented emissions was outside the scope of this report. In the modelling, the presence of vented emissions in the data will only lead to higher emission and mitigation values evenly across all modeled LDAR programs than what would be expected using a distribution based only on fugitive emissions. Therefore, program to program comparisons using these distributions are valid.

Lastly, it should be noted that intermittency of leaks generated in the simulation will have an impact on the mitigation performance of modeled programs. Currently, LDAR-Sim does not have this functionality implemented, and all leaks introduced were considered persistent. The modeling performed by the EPA using FEAST also considered all introduced leaks persistent.

4 Results

4.1 LDAR-Sim program naming background

All programs proposed in the alternative screening matrix (Figure 1) were modeled with LDAR-Sim and the results of these programs average mitigation in kilograms (kg) of methane per site per year is shown in Figure 3. Programs were named based on the MDL of the screening method, annual screening frequency, and if an annual OGI inspection was included. For example, "P_4kg_4x_OGI" indicates a program with a screening method with an MDL of 4 kg/hr, conducting quarterly screenings, and a supplemental annual OGI method (1x / year). If "_OGI" is not present in a program's name, there is no supplemental annual OGI method.

All programs assume the spatial coverages Highwood would typically assign (Section 3.2) save for "P_OGI_EPA", which represents a quarterly OGI program parameterized using all EPA assumptions used in FEAST modelling: an MDL of 0.02 g/s and a spatial coverage of 1.0. Conversely, "P_OGI_HW" represents a quarterly OGI based program parameterized using Highwood assumptions: MDL represented by a PoD curve with a 95% detection of rates larger than 0.182 g/s and a spatial coverage of 0.75. **Highwood believes "P_OGI_HW" is a more accurate representation of OGI performance in field-based work programs**, hence the dashed grey bar referencing this program's mitigation in Figure 3 and Figure 4 to serve as a comparative baseline for comparing other programs that include alternative technologies.

4.2 LDAR-Sim modelling using the Zavala-Araiza distribution simulation ("smaller" emissions)

Figure 3 shows the emissions mitigation in average kg/year/site of all modeled programs. Blue stars have been placed next to programs designed to replicate the "tiers" of the EPA proposed alternative screening matrix (Figure 1). The remaining programs are explorations into what different combinations of MDL, survey frequency, and supplemental OGI survey of alternative screening-based programs, could achieve equivalency with a quarterly OGI program.

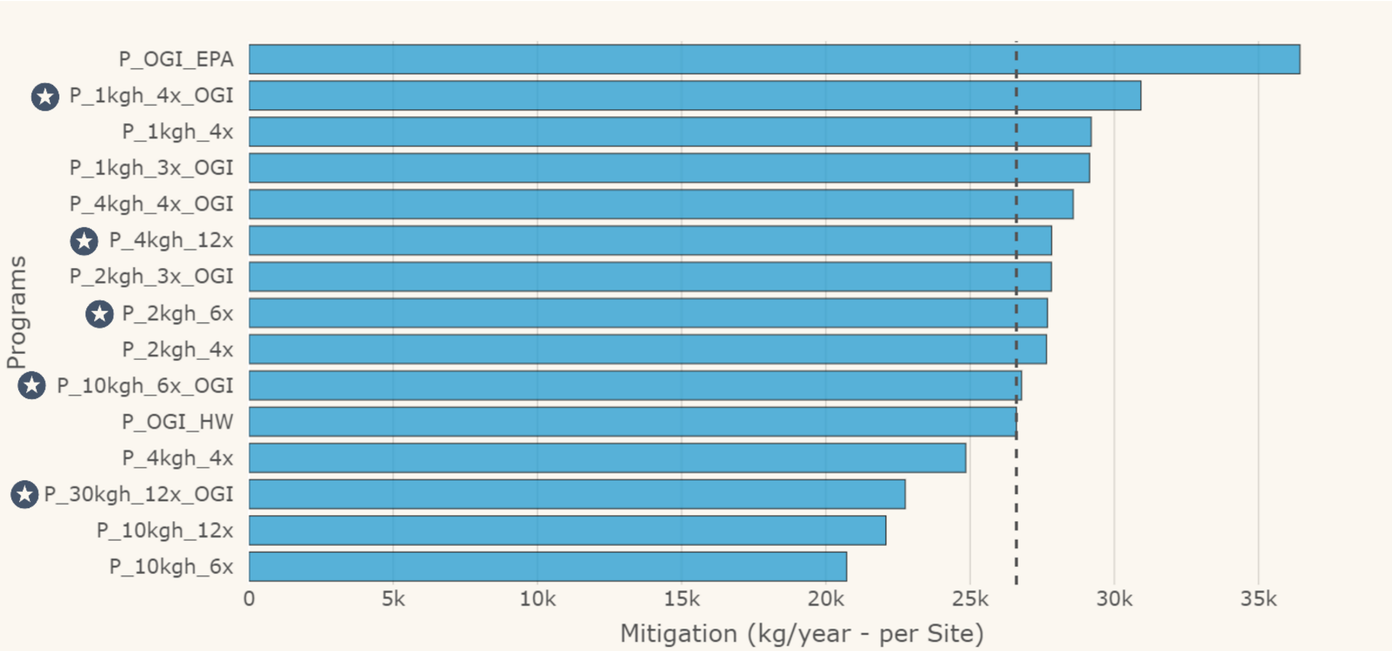

Figure 3. Exploratory simulation to evaluate survey frequency requirements when leak rates are informed by the Zavala-Araiza leak rate distribution (representative of basins prone to smaller leaks). Programs were named based on the minimum detection limit of the screening technology, screening frequency, and if an annual OGI inspection was included or not. “EPA” and “HW” OGI-based programs differ by how the OGI minimum detection limit was parametrized and the presence or absence of spatial coverage. Programs highlighted with stars are the equivalent programs proposed by EPA’s alternative screening matrix (Figure 1).

Main takeaways of the Zavala-Araiza (basins prone to smaller leaks) based simulation modeling results presented in Figure 3 are as follows:

- Applying Highwood assumptions to OGI performance results in a decrease in mitigation from 36 tons of methane/year/site (P_OGI_EPA) to 27 tons of methane/year/site (P_OGI_HW).
- According to EPA’s FEAST modeling, all programs identified with a blue star are equivalent with “P_OGI_EPA”. However, we were not able to reproduce this result in LDAR-Sim when considering the Zavala-Araiza distribution. This happens because sampling leaks from this distribution introduces fewer large leaks into the system when compared with how emissions were parametrized in FEAST. Those large emissions benefit screening methods, particularly at higher MDL ranges, that can rapidly detect the larger emission sources.
- Under Highwood assumptions screening technologies with an MDL of 30 kg/hr or higher could not achieve equivalency using a quarterly OGI program (either with Highwood or EPA / FEAST assumptions) even with monthly screenings.
- **Using Highwood assumptions, programs with screening methods with an MDL between 1kg/hr and 4 kg/hr could achieve equivalency with a quarterly OGI program using lower screening frequencies than those proposed by EPA.**

To expand on the final bullet point, the following matrix which displays methods with less frequent screenings which can still achieve equivalency with a quarterly OGI program (assuming Highwood parameterization) for basins characterized by the Zavala-Araiza distribution (most emissions due to “smaller” emissions):

Table 1. Proposed matrix for basins with most methane due to smaller emissions in the Zavala-Araiza distribution.

Minimum Detection Threshold of Screening Technology	Minimum Screening Frequency Proposed by Supplemental EPA Rule	Minimum Screening Frequency based on Highwood LDAR-Sim Modeling
≤1 kg/hr	Quarterly + Annual OGI (P_1kgh_4x_OGI)	Triannual + Annual OGI (P_1kgh_3x_OGI) or Quarterly (P_1kgh_4x)
≤2 kg/hr	Bimonthly (P_2kgh_6x)	Triannual + Annual OGI (P_2kgh_3x_OGI) or Quarterly (P_2kgh_4x)
≤4 kg/hr	Monthly (P_4kgh_12x)	Quarterly + Annual OGI (P_4kgh_4x_OGI)
≤10 kg/hr	Bimonthly + Annual OGI (P_10kgh_6x_OGI)	Bimonthly + Annual OGI (P_10kgh_6x_OGI)

4.3 LDAR-Sim modelling using the augmented Cusworth distribution simulation (“larger” emissions)

Figure 4 presents the results of the simulation model using the augmented Cusworth distribution designed to represent emissions in basins prone to larger emissions, like has been reported in the literature for the Permian Basin. This same distribution was used by the EPA in FEAST modeling to inform the alternative screening matrix to represent “large emitters”.[1] Program nomenclature and labeling (presence or absence of blue stars) logic is consistent with Section 4.2, however, the exploratory programs investigating alternative, but equivalent, work practices differ to account for the larger leaks.

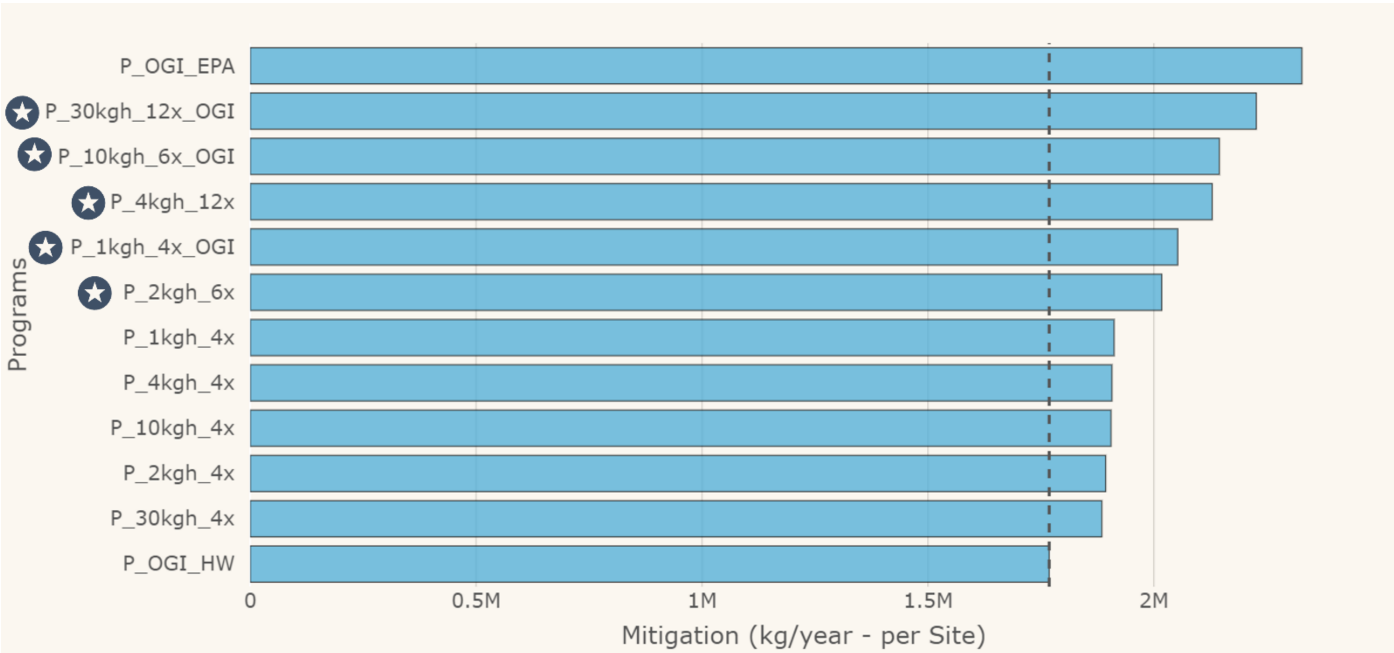

Figure 4. Exploratory simulation to evaluate survey frequency requirements when leak rates are informed by the Augmented Cusworth distribution (same distribution used by the EPA FEAST modeling, representative of basins prone to larger leaks). Programs were named based on the minimum detection limit of the screening technology, screening frequency, and if an annual OGI inspection was included or not. “EPA” and “HW” OGI-based programs differ by how the OGI minimum detection limit was parametrized and the presence or absence of spatial coverage. Programs highlighted with stars are the equivalent programs proposed by EPA’s alternative screening matrix (Figure 1).

As Figure 4 demonstrates, in basins dominated by large emitters, **quarterly screenings with an MDL up to 30kg/hr can achieve emissions mitigation equivalency with a quarterly OGI program (parameterized with Highwood assumptions).**

4.4 LDAR-Sim modelling using a distribution based on Bridger Photonics flyovers of Chevron Permian Basin Sites (Chevron specific emissions)

Figure 5 presents the results of LDAR-Sim modeling using a leak rate distribution informed by Bridger Photonics flyover emissions data of Chevron sites in the Permian Basin, provided to Highwood for this report. Program nomenclature and exploratory programs are consistent with those in Section 4.3.

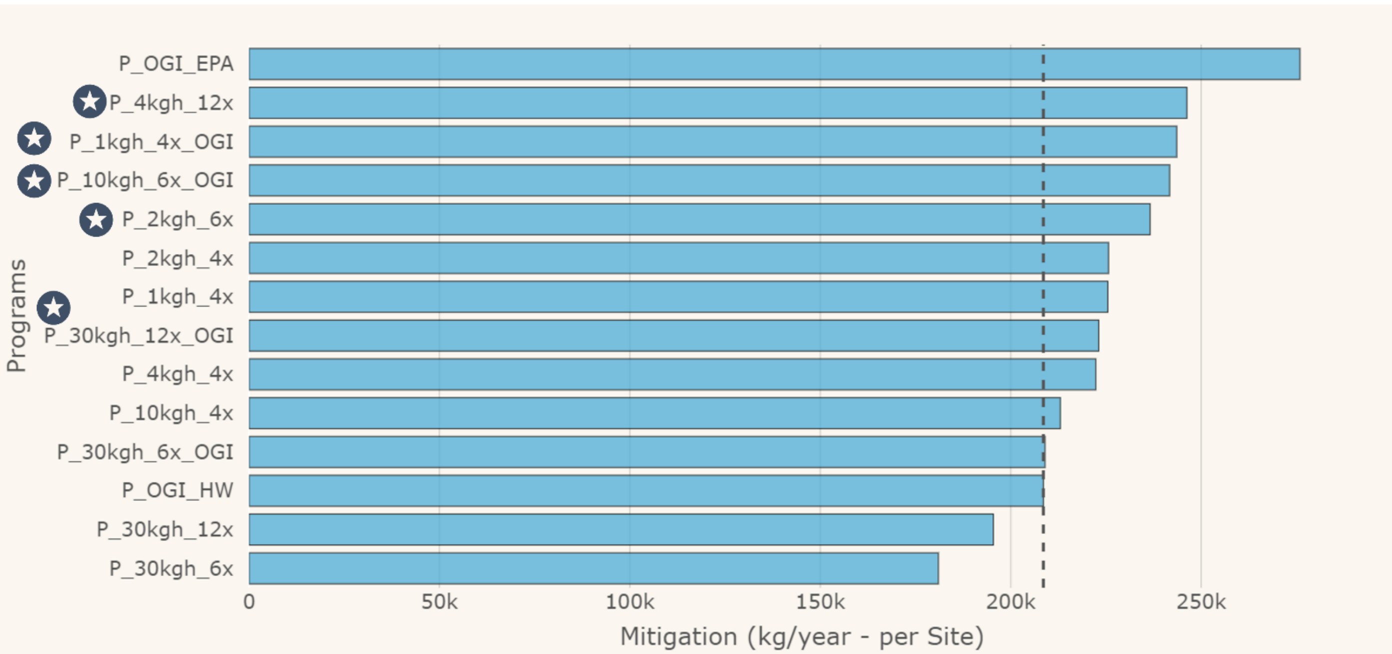

Figure 5. Exploratory simulation to evaluate survey frequency requirements when leak rates are informed by an emission distribution based on data collected by Bridger Photonics aerial flyovers of Chevron sites in the Permian Basin. Programs were named based on the minimum detection limit of the screening technology, screening frequency, and if an annual OGI inspection was included or not. “EPA” and “HW” OGI-based programs differ by how the OGI minimum detection limit was parametrized and the presence or absence of spatial coverage. Programs highlighted with stars are the equivalent programs proposed by EPA’s alternative screening matrix (Figure 1).

The main difference in the results shown in Figure 5 compared to those in Figure 4 is that when assuming a leak rate distribution based on Bridger Photonics flyover data of Chevron Permian Basin sites, programs with an MDL of 30 kg/hr will only be equivalent with a quarterly OGI based program (assuming Highwood parameterization) if they have a supplemental OGI method. “P_30kghr_4x” was equivalent with a quarterly OGI program in the augmented Cusworth simulation (Figure 4) while “P_30kghr_6x” is not equivalent with a quarterly OGI based program in the Chevron simulation (Figure 5), despite two additional screenings per year.

Both simulations using leak rate distributions sourced from Permian Basin Sites (Figure 4 and Figure 5) show that an LDAR program based on quarterly screening with an MDL of 10 kg/hr will achieve equivalent emissions reductions to a quarterly OGI based program parameterized using standard Highwood assumptions.

5 Conclusions

1. Assumed leak rate distributions have a marked impact on equivalence demonstration of screening technologies with conventional technologies such as OGI inspections. In this report, Highwood evaluated equivalence under three leak rate distributions (Zavala-Araiza, Augmented Cusworth, and a distribution of emissions from Chevron sites in the Permian basin), and in all cases, **screening programs with an MDL of 4 kg/hr or lower can achieve emissions reduction equivalency with fewer annual screenings than what is proposed by EPA.**

2. FEAST modelling carried out by the EPA likely overestimated the emissions detection performance capabilities of OGI method. Assuming leak sizes typical of a basin prone to smaller leaks (the Barnett Shale), the Highwood parameterized OGI program mitigates, on average, 27 tons of methane/year/site compared to the EPA parameterized OGI program which mitigates, on average, 36 tons of methane/year/site. The simulation using a leak rate distribution fit using measurements from Bridger Photonics aerial flyovers of Chevron sites in the Permian Basin, showed the Highwood parameterized OGI program mitigates, on average, 209 tons of methane/year/site compared to the EPA parameterized OGI program which mitigates, on average, 276 tons of methane/year/site.

3. In simulations using leak rate distributions fit using emissions measurements of sites in the Permian Basin, an LDAR program based on quarterly screening with an MDL of 10 kg/hr will achieve equivalent emissions reductions to a quarterly OGI based program parameterized using standard Highwood assumptions.

Appendix – Simulation parameter tables

Global Level Parameters (apply equally to all programs)

Global Parameters	Description of Parameter	Justification & Source
Number of simulations, temporal resolution, and duration, as applicable	# of simulations: 5 simulations Temporal resolution: 5 years	Multiple simulations were run to better-constrain results. Additional simulations could be requested, but past experience has shown that minor improvements are observed by further increasing this number.
Empirical fugitive and vented data source(s)*	See section 2.3	Zavala-Araiza et al. (2015) Augmented Cusworth (2021) - Modified version from EPA modeling.
Leak production behavior	It assumed an LPR of 0.0089, which represents 364 sources per year for every 100 sites.	LPR was estimated based on historical LDAR data from Chevron facilities.

Global Parameters	Description of Parameter	Justification & Source
Natural leak removal behavior*	365 days. This number represents leak removal from the leaks pool due to routine maintenance, refits, retrofits, and other unintentional leak repairs.	Most programs are performed annually, and it was assumed that most leaks would be repaired in this time frame. Past experience has shown that changes in this parameter impact overall emissions (baseline), but mitigation comparison should not be affected.
Site list and characteristics (count, source, types, etc.)	500 sites	-
Describe assumptions made to model the fraction of repairable vs. non-repairable emissions	Only fugitive emissions were considered, and all leaks tagged were considered repairable.	-
Weather data basis	Historical weather data from 2019/2020 containing total precipitation, wind data, temperature, and cloud coverage was downloaded as an ERA5 NetCDF4 file for the facilities region.	Variables were chosen to reproduce environment constraints faced by the different methods evaluated. Data source: https://cds.climate.copernicus.eu/

Source / component scale inspection parameters

LDAR Program Parameters	Description of Parameter HW Programs	Description of Parameter EPA programs	Justification and/or Source
Detection probability mechanism	The probability of detection is a function of the leak rate. The probability detection of a leak with OGI is calculated using a sigmoidal probability function based on empirical data. The list of parameters [x_o, σ] that define the minimum detection limit of OGI used was [0.24, 0.39].	100% detection for leaks higher than 0.0167 g/s	Zimmerle et al., 2020 / EPA Report *(Modeling Fugitive Emissions from Production Sites Using FEAST)*
Relevant operational envelopes assumed in modeling	Precipitation (mm): [0.0, 0.5] Temp (°C): [-40.0, 40.0] Wind(m/s): [0.0, 10.0]	Precipitation (mm): [0.0, 0.5] Temp (°C): [-40.0, 40.0] Wind(m/s): [0.0, 10.0]	Zimmerle et al., 2020
Spatial coverage	The probability that an agent can locate a leak. It was modeled as 0.75 to account for sources that cannot be identified by OGI cameras, such as elevated sources. For follow-up surveys, coverage was defined as 0.85	Modeled as 1.0	-
Time from detection to repair	30 days	30 days	EPA Supplemental Rule

Site scale inspection parameters

LDAR Program Parameters	Description of Parameter HW Programs	Description of Parameter EPA programs	Justification and/or Source
Spatial coverage	The probability that the technology will locate a site level emission. It was modeled as 0.99 to account for sources that the screening technology cannot identify.	N/A	Typical value adopted for screening technologies was used, based on vendor feedback.
Follow-up delay	Time between flagging a site in a screening and follow-up survey with OGI was modeled as 14 days		EPA Supplemental Rule
Relevant operational envelopes assumed in modeling	Precipitation (mm): [0.0, 0.5] Temp (°C): [-40.0, 40.0] Wind(m/s): [0.0, 10.0]	Precipitation (mm): [0.0, 0.5] Temp (°C): [-40.0, 40.0] Wind(m/s): [0.0, 10.0]	-

References

1. Coburn, J. & Stott, R. *Modeling Fugitive Emissions from Production Sites Using FEAST*. https://subscriber.politicopro.com/f/?id=00000184-6640-d9a6-a994-6e543ef30001#page=223.
2. Zimmerle, D. *et al.* Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. *Environ. Sci. Technol.* **54**, 11506–11514 (2020).
3. Zavala-Araiza, D. *et al.* Reconciling divergent estimates of oil and gas methane emissions. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 15597–15602 (2015).
4. Cusworth, D. H. *et al.* Intermittency of Large Methane Emitters in the Permian Basin. *Environ. Sci. Technol. Lett.* **8**, 567–573 (2021).

Appendix 2: Proposed Alternative Matrix Approach Redline

Chevron offers the following suggested redlines to capture the best method of combined usage for OGI and alternative screening technologies based on the data referenced in our comment letter. For brevity, only a redline of OOOOb is provided, but the counterpart redlines to OOOOc are also suggested. Suggested deletions are in red strikethrough text, (~~example~~), suggested additions are in red text (example). Black text would remain unchanged from the proposal.

Table 1 to Subpart OOOOb of Part 60—Alternative Technology Periodic Screening Frequency at Well Sites, Centralized Production Facilities, and Compressor Stations Subject to AVO Inspections with Quarterly OGI or EPA Method 21 Monitoring

Minimum Screening Frequency	**Minimum Detection Threshold of Screening Technology***
Quarterly + Annual OGI	~~≤ 1 kg/hr~~ ≤ 4 kg/hr
~~Bimonthly~~	~~≤ 2 kg/hr~~
~~Monthly~~	~~≤ 4 kg/hr~~
Bimonthly + Annual OGI	≤ 10 kg/hr
Monthly + Annual OGI	≤ 30 kg/hr

We believe that many of the equivalency considerations for central tank batteries and compressor stations would also exist for single and multi-wellhead only sites that are addressed in Table 2 of OOOOb. We encourage EPA to update modeling, detection limit thresholds, and frequencies for these sources based on similar considerations.