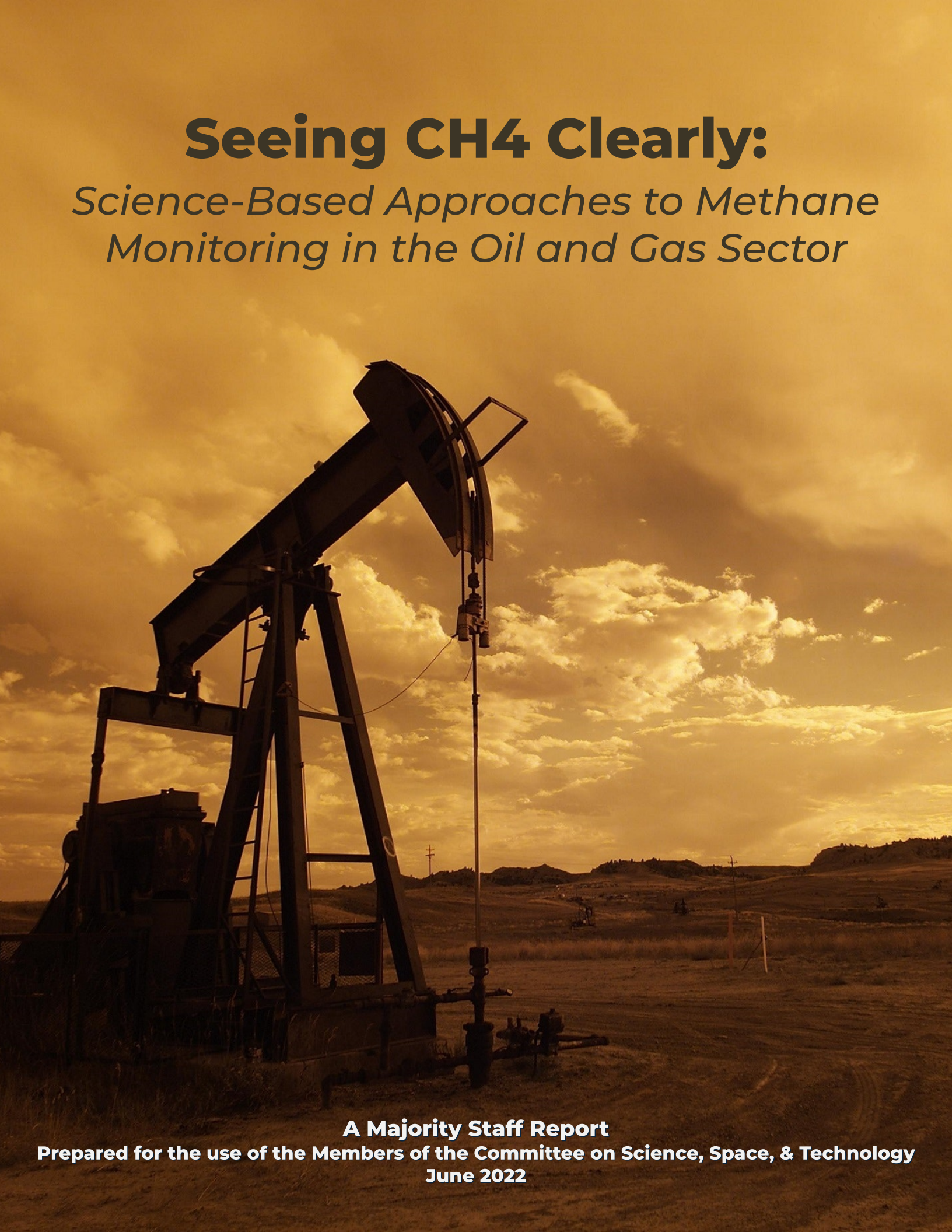
Seeing CH4 Clearly:

Science-Based Approaches to Methane Monitoring in the Oil and Gas Sector



A Majority Staff Report

Prepared for the use of the Members of the Committee on Science, Space, & Technology

June 2022

Committee Jurisdiction

Under House Rule X, the Committee on Science, Space, and Technology has oversight jurisdiction over "laws, programs, and Government activities relating to nonmilitary research and development." Additionally, the Committee possesses legislative jurisdiction over "All energy research, development, and demonstration;" "Environmental research and development;" and "Scientific research, development, and demonstration." The Committee staff's perspective and recommendations are guided by these jurisdictional parameters, as well as the Committee's priorities and longstanding interest in promoting scientific efforts to combat climate change.

House Rule X is available at https://rules.house.gov/sites/democrats.rules.house.gov/files/117-House-Rules-Clerk.pdf.

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Executive Summary

In early 2021, the Committee on Science, Space, and Technology initiated an investigation into methane leaks and strategies for detecting them in the oil and gas sector. The purpose of the investigation was to inform the role of the Federal research and development enterprise in reducing and quantifying methane emissions.

Committee staff conclude that oil and gas companies are failing to design, equip, and inform their Methane Leak Detection and Repair (LDAR) activities as necessary to achieve rapid and large-scale reductions in methane emissions from their operations. The sector's approach does not reflect the latest scientific evidence on methane leaks. Oil and gas companies must change course quickly if the United States is to reach its methane reduction targets by the end of this decade.

The Committee staff's key findings can be summarized as follows:

I. **Oil and gas companies are failing to address super-emitting leaks.** Recent scientific research has established that a small group of massive, "super-emitting" methane leaks is disproportionately responsible for methane emissions from the oil and gas sector. But today's operator-led LDAR programs lack the capability to effectively mitigate methane emissions from super-emitters. They do not define the size of a super-emitting leak, identify and track super-emitting leaks when they occur, assess how much super-emitting leaks contribute to their overall methane emissions, or use observations on super-emitters to inform their approach to leak detection in the future. By not prioritizing methane super-emitters, oil and gas companies are missing opportunities for rapid emissions reductions.

II. **Oil and gas companies are failing to use quantification data to mitigate methane leak emissions.** Commercially available LDAR technologies are capable of quantifying the size of methane leaks from oil and gas operations, and oil and gas companies have performed extensive pilots of these technologies in the Permian Basin. While today's technologies possess certain limitations, the data they provide is already accurate and precise enough to help oil and gas companies that are seeking to reduce methane leaks, better understand their methane emissions profiles, and measure their progress. But oil and gas companies largely are not incorporating methane quantification data into their LDAR programs for operational and analytical purposes.

III. **Oil and gas companies are deploying innovative LDAR technologies in a limited and inconsistent manner.** Oil and gas companies can realize sweeping methane mitigation benefits by deploying innovative LDAR technologies comprehensively across their operations. While many oil and gas companies are deploying these technologies at varying scales and frequencies, most deployments remain in the pilot phase with scopes that are too narrow to support emissions reductions on a timeline that meets the urgency of the climate crisis.

The Committee staff also learned that oil and gas companies have internal data showing that methane emission rates from the sector are likely significantly higher than official data reported to EPA would indicate. A very significant proportion of methane emissions appear to be caused by a small number of super-emitting leaks. One company experienced a single leak that may be equivalent to more than 80% of all the methane emissions it reported to EPA – according to EPA's prescribed methodology – for all of its Permian oil and gas production activities in 2020.

The Committee staff recommend that the Federal government:

1. Create a new Federal program to conduct accurate methane measurement surveys – a Methane Census – over major oil and gas basins in the United States on a regular basis, and consider how the data from these surveys can be assessed alongside existing methane inventory data
2. Help develop voluntary, consensus technical standards to assist oil and gas sector stakeholders in using quantification data to estimate aggregate methane emissions
3. Create a new Federal program to strengthen methane detection capabilities and reduce measurement uncertainty
4. Develop consensus best practices for oil and gas companies to use when evaluating the adoption and implementation of innovative LDAR technologies
5. Create a Methane Emissions Measurement and Mitigation Research Consortium to encourage research partnerships and information sharing between industry, academia, non-profit organizations, and other stakeholders in the oil and gas sector
6. Commission a report from the National Academies of Sciences, Engineering, and Medicine to articulate a science-based strategy for the use of greenhouse gas detection and monitoring capabilities at Federal agencies to detect methane emission events, including super-emitters
7. Ensure that Federal regulations to control methane from the oil and gas sector enable technology diversity and scientific innovation in LDAR technologies

Oil and gas companies possess the following opportunities to address methane leaks:

1. Join the United Nations Environment Programme's Oil and Gas Methane Partnership 2.0 Framework
2. Accelerate the comprehensive deployment of innovative LDAR technologies
3. Adopt science-based LDAR strategies to maximize methane emissions reductions from oil and gas operations as rapidly as possible

Investigation Scope and Objectives

This report assesses whether additional Federal research programs and investments are required to achieve large-scale reductions in methane emissions from the oil and gas sector, consistent with America's methane reduction targets for the next decade and beyond.

Permian Basin

The Committee chose to focus its oversight on operators in the Permian Basin due to the centrality of that region as a source of oil and gas sector methane emissions. The Permian, which extends across 55 counties amidst a vast expanse in West Texas and Southeast New Mexico, accounted for 42.6% of U.S. oil production and 16.7% of U.S. natural gas production in December 2021.[1] Methane emissions resulting from oil and gas production are correspondingly large: a recent scientific study concluded that "the Permian Basin is likely the largest observed methane-emitting [oil and gas] basin in the United States."[2]

Innovative Leak Detection and Repair Technologies

A major objective of the Committee's investigation was to understand the capabilities and limitations of innovative Leak Detection and Repair (LDAR) technologies so that capability gaps and opportunities for Federal research investment could be identified. Innovative LDAR technologies have the potential to accelerate methane emissions reductions from the oil and gas sector and serve as an indispensable tool for the detection and quantification of methane leaks. However, as a general principle, Committee staff do not express a preference regarding the merits of one type of deployment method relative to another or endorse the capabilities of any specific vendor's technology relative to their competitors. This report does not identify specific innovative LDAR companies, but rather discusses innovative LDAR technologies according to their method of deployment, which allows for useful generalizations.

EPA Rulemaking

In November 2021, the EPA issued a proposed rule to directly regulate methane emissions from existing sources in the oil and gas sector for the first time, as well as strengthen the emission reduction requirements that already exist for methane emissions from new and modified sources.[3] This rulemaking reflects a clear need for robust Federal regulations to ensure that the oil and gas industry moves swiftly towards large-scale reductions in methane emissions from its operations. These forthcoming regulations will be an essential pillar of America's drive to achieve the targets set forth in the Global Methane Pledge.

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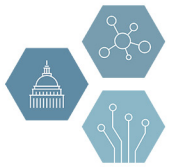
[1] Federal Reserve Bank of Dallas. "Permian Basin." *Energy in the Eleventh District,* 13 May 2022, accessed here: https://www.dallasfed.org/research/energy11/permian.aspx#Region.

[2] Zhang, Yu Zhong, et al. "Quantifying methane emissions from the largest oil-producing basin in the United States from space." *Science Advances,* vol. 6, issue 17, 22 April 2020, accessed here: https://doi.org/10.1126/sciadv.aaz5120.

[3] Environmental Protection Agency. "EPA Proposes New Source Performance Standards Updates, Emissions Guidelines to Reduce Methane and Other Harmful Pollution from the Oil and Natural Gas Industry." 2 Nov. 2021, accessed here: https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-proposes-new-source-performance.

We note, however, that the substance of the EPA's rulemaking is not the subject of this report. While there is considerable overlap between the policy matters that the Committee seeks to assess and some of the technical questions that the EPA confronts in its rulemaking, the Committee's focus lies squarely with Federal scientific research and the role that Federal research programs and investments can play in promoting methane emissions reductions from the U.S. oil and gas sector. The Committee staff's findings, and the subsequent policy recommendations that are derived from them, are rooted in the Committee's legislative and oversight jurisdictions.



Investigation Methodology

Committee staff undertook a broad review of the oil and gas sector's current practices related to methane leak detection and repair, methane leak emissions, and the use of innovative LDAR capabilities. This section describes the definitions, methods, assumptions, and sources of information used to inform our review.

Committee Outreach

Over the course of an 18-month investigation, the Committee staff consulted extensively with a broad range of experts and stakeholders to ensure that our understanding of the issues was comprehensive, consistent with the latest scientific data, and reflective of current practices. We engaged in discussions with academic experts, scientific researchers, not-for-profit organizations, innovative LDAR vendors, industry trade associations, and oil and gas companies. These discussions provided invaluable insights into the challenges that confront efforts to detect, quantify, and reduce oil and gas sector methane leaks, as well as the areas that would benefit from Federal research investment and support. We thank all of the experts and stakeholders that helped inform the development of this report through their expertise, their experience, and their perspectives.

As a part of its investigation, the Committee also requested information directly from oil and gas companies pertaining to their methane leak detection and repair programs, methane leak emissions, and use of innovative leak detection and repair technologies. On December 2, 2021, Chairwoman Johnson sent letters to ten operators in the Permian Basin.[4] Each letter contained an Information Request consisting of a series of questions and document requests. Chairwoman Johnson sent letters to the following operators:

- Admiral Permian Resources Operating, LLC
- Ameredev II, LLC
- Chevron Corporation
- ConocoPhillips
- Coterra Energy Inc.
- Devon Energy Corporation
- ExxonMobil Corporation
- Mewbourne Oil Company
- Occidental Petroleum Corporation
- Pioneer Natural Resources Company

The Committee identified the ten operators based upon a holistic review of several factors, including their level of production in the Permian, their reported methane emissions for 2020 under the EPA's Greenhouse Gas Reporting Program (GHGRP), and the size and frequency of the methane leaks detected within their operations by aerial surveys conducted in 2020 through

[4] House of Representatives Committee on Science, Space, and Technology. "Letters to Permian Basin Oil and Gas Companies Seeking Methane Leak Emission Data", 2 Dec. 2021, archived here: https://science.house.gov/letters-to-permian-basin-oil-and-gas-companies-seeking-methane-emission-data.

the Environmental Defense Fund's PermianMAP project.[5] These factors were designed to ensure that the Committee's review would encompass the largest producers in the Permian while also creating a representative cross-sample of the Permian oil and gas sector, including companies of different sizes, companies both publicly-traded and privately-held, and companies that have recently expanded the scope of their Permian operations as well as traditional producers.

By the end of January 2022, all ten operators had provided initial narrative responses to Chairwoman Johnson's letter. Between February and May 2022, the Committee staff engaged in a series of follow-up meetings with a number of the operators to discuss their responses in greater detail. The operators also provided additional documents and records during this period that were responsive to Chairwoman Johnson's request. The Committee staff appreciate the willingness of these ten companies to engage with the Committee and to provide detailed information regarding their perspectives on methane leaks, their leak detection and repair practices, and their evaluation and deployment of innovative leak detection and repair technologies. In the end, the Committee staff reviewed over 500 pages of relevant documents. We consider all ten operators to have been appropriately responsive to Chairwoman Johnson's letter and Information Request.

Definitions

The definition of a "methane leak" and the defined scope of "leak detection and repair" activities are the subject of ongoing debate. Throughout its investigation, the Committee defined these terms broadly:

- **Methane Leak:** Any release of methane that results from a malfunction or an abnormal operating condition, including both unintentional [i.e., fugitive] emissions and emissions resulting from malfunctions or abnormal operating conditions among vented sources and combustion sources.
- **Leak Detection and Repair (LDAR) Program:** Any program or activity that is intended to monitor, detect, or repair methane leaks, or monitor, detect, quantify, or mitigate methane emissions resulting from methane leaks, including through the implementation of operational changes.

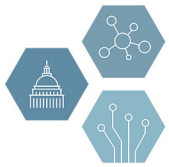
The Committee also employed a simple definition to differentiate between "innovative" and "traditional" LDAR technologies:

- **Innovative LDAR Technology**: Any instrument-based LDAR technique that is not currently approved for purposes of regulatory compliance under the applicable EPA regulations (40 CFR part 60, subpart OOOOa).[6] The definition essentially considers all LDAR technologies other than the two techniques currently approved by EPA – the use of OGI cameras or Method 21 – to be innovative for purposes of this analysis.

[5] Environmental Protectional Agency. "Greenhouse Gas Reporting Program." 2020, accessed here: https://www.epa.gov/ghgreporting; Environmental Defense Fund. "Permian Methane Analysis Project." 2022, accessed here: https://permianmap.org/.
[6] 40 CFR § 60.OOOOa, accessed here: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-60/subpart-OOOOa.

Oil and gas sector LDAR technologies are extremely diverse from a technological perspective. They extend from traditional optical gas imaging (OGI) cameras to innovative LDAR technologies, which include novel ground-based, drone-based, aircraft-based, and satellite-based methane sensor systems, as well as accompanying data analytics platforms that process methane detection data.[7] Many innovative LDAR technologies are systems comprised of multiple novel components, including the sensors that detect methane emissions, the deployment methods that support the sensors, and the data analytics platforms that use defined parameters, assumptions, data inputs, and models to quantify emission rates. We use the term "innovative LDAR technologies" throughout this report to capture both individual technologies and the complex systems within which they operate for methane leak detection and repair.

[7] See EPA's August 2021 Methane Detection Technology Virtual Workshop for examples of innovative LDAR technologies. Environmental Protection Agency. "EPA Methane Detection Technology Workshop." 23-24 Aug. 2021, accessed here: https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-methane-detection-technology-workshop.



Scientific Overview: Methane and the Oil and Gas Sector

The Committee staff's approach throughout this investigation has been guided by the best available science regarding oil and gas sector methane emissions. A central question is whether the sector's approach to methane leaks is similarly rooted in scientific fact.

Methane and Climate Change

Methane (CH_4) is the second-largest contributor to atmospheric warming since the beginning of the industrial era, trailing only carbon dioxide and accounting for approximately 30% of global warming since the Industrial Revolution.[8] Methane is a short-lived climate pollutant with an atmospheric lifetime lasting only about a decade. However, for the duration of its lifetime, methane is a far more potent greenhouse gas than carbon dioxide, with a global warming potential that is 84-87 times greater than CO_2 over a 20-year timeframe and 28-36 times greater than CO_2 over a 100-year timeframe.[9] Methane's short but extremely powerful atmospheric lifetime carries significant policy implications. Immediate action to reduce atmospheric concentrations of methane would rapidly reduce the rate of overall atmospheric warming, providing a unique opportunity to slow the pace of climate change, prevent the advent of devastating climate-related feedback loops, and gain additional time to achieve further long-term greenhouse gas emissions reductions.[10] In its most recent report, the Intergovernmental Panel on Climate Change asserted that in order to limit global warming to the crucial target of 1.5°C, methane emissions must be reduced by one third.[11]

Unfortunately, the past decade witnessed a substantial increase in atmospheric methane levels, culminating in the highest annual growth rate for methane on record in 2021.[12] Building upon the scientific consensus regarding methane's crucial role as an accelerant of climate change, the international community has increasingly identified methane mitigation as a central element of the global strategy to combat climate change. In November 2021, at the 26th UN Climate Change Conference of the Parties in Glasgow, Scotland, the United States and the European Union led more than 100 countries in formally launching the Global Methane Pledge, a multinational

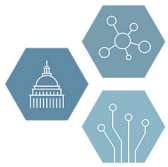
[8] United Nations Environment Programme and Climate and Clean Air Coalition. "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions." *United Nations Environment Programme*, 2021, accessed here: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions; International Energy Agency. "Global Methane Tracker 2022." *IEA*, February 2022, accessed here: https://www.iea.org/reports/global-methane-tracker-2022.

[9] International Energy Agency. "Methane Tracker 2021." *IEA*, January 2021, accessed here: https://www.iea.org/reports/methane-tracker-2021.

[10] United Nations Environment Programme and Climate and Clean Air Coalition. "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions." *United Nations Environment Programme*, 2021, accessed here: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions.

[11] Intergovernmental Panel on Climate Change. "Climate Change 2022: Impacts, Adaptation, and Vulnerability." *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,* 2022, accessed here: https://www.ipcc.ch/report/ar6/wg2/.

[12] National Oceanic and Atmospheric Administration. "Increase in atmospheric methane set another record during 2021." 7 April 2022, accessed here: https://www.noaa.gov/news-release/increase-in-atmospheric-methane-set-another-record-during-2021.



commitment to reduce global methane emissions 30% below 2020 levels by 2030.[13] If the Global Methane Pledge's targets are achieved, humanity can prevent 0.2 degrees Celsius of warming by 2050, a crucial step towards the larger goal of avoiding the worst impacts of climate change.[14] Thus, for the next decade and beyond, the effort to cut methane emissions will be a pivotal part of the fight against climate change.

Oil and Gas as a Source of Methane Emissions

In the United States, the rapid and large-scale reductions in methane emissions that are necessary to meet the goals of the Global Methane Pledge cannot be achieved without addressing methane emissions from the oil and gas sector. The energy sector represents the second largest source of anthropogenic methane globally, and the oil and gas sector is the largest global energy-based methane emitter, responsible for nearly 70% of all fossil fuel-related methane emissions through extraction, processing and distribution.[15] Similar trends exist in the United States. Oil and gas sector operations are the second-largest source of anthropogenic methane emissions in the U.S., responsible for an estimated 30% of all methane released due to human activities domestically.[16] Since the U.S. is one of a group of eight countries that are estimated to emit nearly half of all global methane emissions, domestic oil and gas operations make a significant contribution to rising atmospheric methane levels globally.[17]

Yet even while continuing to emit methane at a disturbing pace, the U.S. oil and gas sector holds great promise as a part of the country's methane mitigation strategy. Indeed, compared to the other large domestic sources of methane – agriculture and landfills – oil and gas operations offer the most straightforward path to the kind of rapid emissions reductions that are required to reach America's 2030 commitments.[18] This can be explained primarily by two factors: cost-effectiveness and technological feasibility.

Methane is the main component of natural gas. Natural gas accounts for about a quarter of global electricity generation, and in 2020 – despite the global pandemic – the United States alone consumed 30.5 trillion cubic feet of natural gas.[19][20] Thus, methane is distinguished as a formidable climate pollutant when released into the atmosphere, but a valuable commodity when gathered and stored properly. As such, investments that reduce methane losses in the oil and gas

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[13] Climate and Clean Air Coalition. "Global Methane Pledge." 2022, accessed here: https://www.globalmethanepledge.org/
[14] *Id*.
[15] United Nations Environment Programme and Climate and Clean Air Coalition. "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions." *United Nations Environment Programme*, 2021, accessed here: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions.
[16] Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks." 14 April 2022, accessed here: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[17] *Id*.
[18] Environmental Protection Agency. "Overview of Greenhouse Gases." 16 May 2022, accessed here: https://www.epa.gov/ghgemissions/overview-greenhouse-gases.
[19] Energy Information Administration. "Natural gas explained." 24 May 2022, accessed here: https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php.
[20] Energy Information Administration. "In 2020, U.S. natural gas prices were the lowest in decades." *Today in Energy*, 7 January 2021, accessed here: https://www.eia.gov/todayinenergy/detail.php?id=46376.

sector supply chain are revenue generators. One recent research study reviewed a range of economically and technically feasible methane mitigation strategies by sector and concluded that "the majority of economically feasible actions come from the oil and gas sector… oil and gas measures dominate the [potential] avoided warming from economically feasible actions."[21] The International Energy Agency (IEA) asserts that a significant percentage of methane emission reductions from the oil and gas sector would, in fact, impose no cost upon the sector at all due to the market value of the secured natural gas.[22]

Furthermore, it is technologically feasible today for oil and gas operators to implement policies that would achieve widespread emissions reductions. The IEA estimates that existing technologies are capable of eliminating roughly three-quarters of global methane emissions arising from oil and gas operations.[23] A sweeping 2021 report on methane from the UN Environment Programme (UNEP) concluded that nearly half of all "readily available" emission reduction technologies apply to the fossil fuel sector, "in which it is relatively easy to reduce methane at the point of emission and along production/transmission lines."[24]

As a result of the economic and technical feasibility of widespread mitigation, oil and gas sector methane emissions are considered the low-hanging fruit of large-scale methane emissions reductions. Oil and gas operations are the place where the most progress can be achieved the fastest, a critical opportunity in an arena where success will be judged in years as well as decades.

Traditional Methods for Estimating Oil and Gas Sector Methane Emissions

Despite the favorable conditions for mitigation, oil and gas sector methane emissions remain an acute problem. Much of this paradox can be explained through the science of methane emissions from oil and gas operations: how they are calculated, how they are characterized, and how recent scientific advances have changed the way they can be understood and eliminated.

It has long been acknowledged that different parts of the oil and gas supply chain emit methane into the atmosphere under certain operational circumstances. The traditional procedure for estimating aggregate methane emissions from oil and gas infrastructure involves the use of "emission factors." These are engineering estimates of the amount of methane that would be expected to be released from a given component or type of equipment (such as valves, flanges, seals, and other connectors) under normal operating conditions. A study commissioned by EPA and the Gas Resources Institute in 1996 first recommended this approach for methane as part of a landmark, 15-volume report *Methane Emissions from the Natural Gas Industry:*

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[21] Ocko, Ilissa, et al. "Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming." *Environmental Research Letters*, vol. 6, no. 5, 4 May 2021, accessed here: https://iopscience.iop.org/article/10.1088/1748-9326/abf9c8.

[22] International Energy Agency. "Methane Tracker 2021." *IEA*, January 2021, accessed here: https://www.iea.org/reports/methane-tracker-2021.

[23] *Id*.

[24] United Nations Environment Programme and Climate and Clean Air Coalition. "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions." *United Nations Environment Programme*, 2021, accessed here: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions.

> "The techniques used to determine methane emissions were developed to be representative of annual emissions from the natural gas industry. However, it is impractical to measure every source continuously for a year. Therefore, emission rates for various sources were determined by developing annual emission factors for typical sources in each industry segment and extrapolating these data based on activity factors to develop a national estimate, where the national emission rate is the product of the emission factor and the activity factor."[25]

For oil and gas sector methane emissions, the emission factors approach was applied right away to support policy recommendations of massive consequence. The original 1996 report used emission factors to estimate the annual methane emissions of the U.S. natural gas industry for 1992 and found that 1.4% (+/- 0.5%) of gross natural gas production is lost to the atmosphere as methane emissions. Based upon this data, the report concluded:

> "…natural gas contributes less potential global warming than coal or oil, which supports the fuel switching strategy suggested by the IPCC and others."[26]

Regulatory agencies around the world, including the U.S. Environmental Protection Agency (EPA), still require oil and gas operators to use emission factors as the basis of their methane emission calculations. EPA's emission factor approach today is derived from rigorous engineering tests, is regularly updated to reflect more recent research, and allows operators to calculate emissions according to a consistent and stable methodology. EPA also factors in data from the limited direct measurements performed over oil and gas infrastructure using pre-approved observational tools in developing its estimates of methane emissions from the sector. When major abnormal leak events like the 2015 Aliso Canyon leak are identified and made known to EPA, the agency accommodates direct observations from those events in their inventories. But it must be understood that *emission factors are not actual real-world measurements of methane emissions*. Rather, they are based on static operating conditions that substitute narrow formulas for direct measurement, and are therefore vulnerable to mistaken assumptions and changing circumstances. A methane inventory based primarily on emission factors does not necessarily reflect actual emissions.

Scientific Advances and Inventory Underestimations

The heavy reliance on emission factors for taking inventory of methane leaks was a necessary concession at a time when the deployment of large-scale measurement capabilities within oil and gas basins was simply unrealistic. Indeed, until recently it would have been extraordinarily difficult on a technical and practical level to attempt any kind of broad alternative emission estimate. Recent technological advances, however, have made quantification a viable option.

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[25] Environmental Protection Agency. "Methane Emissions from the Natural Gas Industry Volume 1: Executive Summary." June 1996, accessed here: https://www.epa.gov/sites/default/files/2016-08/documents/1_executive ummary.pdf.
[26] *Id*.

In recent years, scientists have been able to use newly sophisticated methane detection and quantification technologies to actually measure methane emissions from oil and gas operations. In particular, so-called "Top-Down" studies – which utilize platforms such as aircraft, satellites and tower networks to survey large areas, detect methane emissions, and quantify the size of those emissions – have provided researchers with the kind of broad, large scale measurement data that is necessary to infer aggregate emissions across large oil and gas basins. Academic researchers and non-profit organizations have embraced these methods and the insights they provide into the real-world characteristics of methane emissions from oil and gas operations.

The findings of this recent scientific research have been extraordinary. Measurement data across a range of studies has painted a consistent portrait of a much larger and more dangerous problem than previously understood. Since 2018:

- A landmark synthesis study in 2018 concluded that the EPA's Greenhouse Gas Inventory (EPA GHGI) – which is derived from emission factor estimates, and which EPA describes as providing "a comprehensive accounting of total greenhouse gas emissions for all man-made sources in the United States"[27] – underestimated methane emissions from the U.S. oil and gas supply chain by more than 60%.[28]
- An April 2020 study analyzed satellite data and determined that methane emissions from the Permian Basin exceeded the "bottom-up" estimate, based on EPA GHGI data, by "more than a Factor of 2."[29]
- A March 2021 study evaluated survey data from Japan's Greenhouse Gas Observing Satellite (GOSAT) and found that EPA's GHGI underestimates methane emissions from the oil and gas sectors by 90% and 50% respectively.[30]
- A May 2021 study assessed seasonal data on atmospheric ethane and deduced that the EPA GHGI underestimated oil and gas sector methane emissions by 48-76% nationally.[31]
- A March 2022 study reviewed aerial survey data and concluded that methane emissions from the New Mexico Permian Basin were a staggering 6.5 times larger than the corresponding EPA GHGI estimate.[32]

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[27] Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks." 14 April 2022, accessed here: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[28] Alvarez, Ramón, et al. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science,* vol. 361, Issue 6398, pp. 186-188, 21 June 2018, accessed here: https://doi.org/10.1126/science.aar7204.
[29] Zhang, Yu Zhong, et al. "Quantifying methane emissions from the largest oil-producing basin in the United States from space." *Science Advances,* vol. 6, issue 17, 22 April 2020, accessed here: https://doi.org/10.1126/sciadv.aaz5120.
[30] Maasakkers, Joannes, et al. "2010–2015 North American methane emissions, sectoral contributions, and trends: a high-resolution inversion of GOSAT observations of atmospheric methane." *Atmospheric Chemistry and Physics,* vol. 21, issue 6, pp. 4339-4356, 22 Mar. 2021, accessed here: https://doi.org/10.5194/acp-21-4339-2021.
[31] Barkley, Zachary, et al. "Analysis of Oil and Gas Ethane and Methane Emissions in the Southcentral and Eastern United States Using Four Seasons of Continuous Aircraft Ethane Measurements." *JGR Atmospheres,* 5 May 2021, accessed here: https://doi.org/10.1029/2020JD034194.
[32] Chen, Yuanlei, et al. "Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey." *Environmental Science and Technology*, vol. 56, no. 7, pp. 4317-4323, 23 Mar. 2022, accessed here: https://doi.org/10.1021/acs.est.1c06458.

In simple terms, the U.S. oil and gas sector is emitting methane on a vastly larger scale than was previously known, and by a considerable amount more than the official inventory estimates maintained by the U.S. Government.

Methane Leaks

Recent scientific research has also coalesced around a consensus explanation for the systematic underestimation of oil and gas methane emissions. According to scientific measurement data, the largest sources of oil and gas methane emissions do not occur under the normal operating conditions that provide the basis for emission factors. Instead, the largest amount of methane is emitted when equipment does not work as designed and something goes wrong. It is these circumstances – which can broadly be characterized as *malfunctions and abnormal operating conditions* – that primarily facilitate methane emissions from the oil and gas sector. And it is these circumstances that are not properly captured by existing inventory estimates. As the 2018 synthesis study noted, "sampling methods underlying conventional inventories systematically underestimate total emissions because they miss high emissions caused by abnormal operating conditions (e.g., malfunctions)."[33] The phenomenon arising from such conditions is commonly known as *methane leaks*.

Crucially, not all methane leaks are alike. In recent years, researchers have utilized measurement data to establish that a small subset of massive methane leaks are responsible for a disproportionate amount of the oil and gas sector's total methane emissions. Though relatively few in number, these large-emission events – known as *super-emitting leaks* – are so enormous that they constitute one of the main drivers of contemporary oil and gas sector methane emissions:

- A study published in 2019 found that less than 0.2% of the methane-emitting infrastructure in California is responsible for over a third of the state's entire methane inventory.[34]
- A 2021 study used aerial survey data from the Permian Basin to conclude that 20% of emission sources were responsible for 60% of detected methane emissions during the survey.[35]
- Data released jointly by two scientific non-profit organizations in January 2022 revealed that super-emitting leaks may have contributed as much as 50% of total methane emissions from the Permian Basin between 2019 and 2021.[36]

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[33] Alvarez, Ramón, et al. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science,* vol. 361, Issue 6398, pp. 186-188, 21 June 2018, accessed here: https://doi.org/10.1126/science.aar7204.
[34] Duren, Riley, et al. "California's Methane Super-emitters." *Nature,* Vol. 575, pp. 180-184, 6 Nov 2019, accessed here: https://doi.org/10.1038/s41586-019-1720-3.
[35] Cusworth, Daniel, et al. "Intermittency of Large Methane Emitters in the Permian Basin." *Environmental Science and Technology Letters,* vol. 8, no. 7, pp. 567-573, 2 June 2021, accessed here: https://pubs.acs.org/doi/10.1021/acs.estlett.1c00173.
[36] Carbon Mapper, Environmental Defense Fund. "Dozens of "super-emitting" oil and gas facilities leaked methane pollution in Permian Basin for years on end." 24 Jan. 2022, accessed here: https://carbonmapper.org/dozens-of-super-emitting-oil-and-gas-facilities-leaked-methane-pollution-in-permian-basin-for-years-on-end/.

- A study published in February 2022 used satellite data to determine that a tiny number of "ultra-emitters" in the oil and gas sector were likely responsible for as much as 8-12% of global methane emissions from oil and gas operations.[37]
- A March 2022 study concluded from aerial survey data that a mere 12% of emission sources were responsible for 50% of detected methane emissions from the New Mexico Permian Basin during the survey.[38]

The predisposition of oil and gas operations to experience super-emitting leaks during malfunctions and abnormal operating conditions creates a so-called "tail-heavy" emission distribution, with a small number of extremely large leaks at the far end of the statistical distribution bearing the responsibility for much of the sector's aggregate methane emissions.

Beyond their sheer size, oil and gas sector methane leaks possess unique characteristics that must be understood. One of the most critical characteristics is *intermittency*. Researchers have found that many oil and gas processes tend to produce intermittent leaks, which essentially means that the leaks are prone to stopping and starting irregularly for extended periods of time. By contrast with persistent leaks, which emit methane steadily and continuously until they are repaired, intermittent leaks are extremely variable and unpredictable. In practice, they often manifest in almost random distribution patterns, making them far more liable to escape detection and very difficult to accurately profile. But they represent a substantial source of methane emissions. A 2021 study utilizing aerial survey data from the Permian Basin found that "highly intermittent sources" constituted 66% of all emission sources and 48% of all methane emissions.[39] Some of these intermittent sources may be attributable to routine process and maintenance emissions, but others are almost certainly methane leaks, and indeed are likely to include super-emitting leaks. The role of intermittent super-emitters is a well-established facet of oil and gas sector methane leaks, and aerial survey findings released earlier this year noted the frequent presence of large methane leaks that were "shorter in duration" at super-emitting facilities.[40] The precise contributions of intermittent super-emitters remain difficult to pinpoint, however, due to their unpredictability and the difficult challenge of using periodic surveys to detect and identify them throughout complex oil and gas supply chains.

The incidence of super-emitting and intermittent leaks has implications for the kinds of survey data needed to build a national profile of methane emissions. First, large numbers of measurements are required to develop accurate profiles of methane leak emissions from oil and gas operations. The fact that a small number of leaks contribute disproportionately to aggregate leak emissions increases the importance of conducting large sample size measurement surveys in

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[37] Lauvaux, Thomas, et al. "Global assessment of oil and gas methane ultra-emitters." *Science*, vol. 375, issue 6580, pp. 557-561, accessed here: https://doi.org/10.1126/science.abj4351.

[38] Chen, Yuanlei, et al. "Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey." *Environmental Science and Technology*, vol. 56, no. 7, pp. 4317-4323, 23 Mar. 2022, accessed here: https://doi.org/10.1021/acs.est.1c06458.

[39] Cusworth, Daniel, et al. "Intermittency of Large Methane Emitters in the Permian Basin." *Environmental Science and Technology Letters,* vol. 8, no. 7, pp. 567-573, 2 June 2021, accessed here: https://pubs.acs.org/doi/10.1021/acs.estlett.1c00173.

[40] Carbon Mapper, Environmental Defense Fund. "Dozens of "super-emitting" oil and gas facilities leaked methane pollution in Permian Basin for years on end." 24 Jan. 2022, accessed here: https://carbonmapper.org/dozens-of-super-emitting-oil-and-gas-facilities-leaked-methane-pollution-in-permian-basin-for-years-on-end/.

order to detect and quantify as many super-emitters as possible. Second, and relatedly, larger measurement surveys will actually tend to increase emission estimates, because more super-emitters will be detected and the heavy-tailed emission distribution that characterizes methane leaks will be pulled further towards the extreme. This non-normal emission distribution is a vital feature of the problem. As one expert told the Committee staff, "methane leaks do not obey conventional statistics."

Implications of the Scientific Consensus for Methane Mitigation

Recent scientific research into the characteristics of methane leaks can inform the oil and gas sector's efforts to mitigate them:

- Due to the disproportionate role of super-emitting leaks in driving overall emissions from the sector, the focus of private sector LDAR programs should be super-emitting leaks. LDAR programs can best achieve swift, large-scale reductions in methane emissions if they are designed and equipped to detect and repair super-emitting leaks as quickly as possible, despite the relatively small number and frequently intermittent nature of such leaks. Tailoring LDAR programs to address super-emitters is a far more efficient way to cut methane emissions than prioritizing all methane leaks equally.

- Reorienting LDAR programs requires a better understanding of the characteristics of super-emitting leaks within oil and gas infrastructure. Quantification data is a prerequisite for identifying super-emitters, developing more accurate operator emission profiles based upon the existence of super-emitters, and anticipating the sources of super-emitters in order to survey them more frequently and make proactive operational changes to prevent them altogether. LDAR programs must be capable of quantifying methane leak emissions, both in the aggregate and at the level of individual super-emitting leaks.

- Methane leaks require a higher frequency of methane detection surveys than is mandated under current Federal regulations. Infrequent handheld LDAR surveys largely do not capture malfunctions and abnormal operating conditions, which give rise to persistent and intermittent super-emitting leaks. Innovative LDAR technologies, from aerial flyover and satellite sensors to drones and ground-based continuous monitoring sensors, hold tremendous promise for increasing the frequency of methane detection surveys and quantifying methane leaks. Innovative LDAR technologies are crucial to achieving large-scale emission reductions.

Finding #1: Oil and Gas Companies Are Failing to Address Super-Emitting Leaks

Overview

Existing oil and gas sector LDAR programs are failing to mitigate methane emissions from super-emitting leaks. The principal cause of this failure is the unwillingness of oil and gas companies to prioritize super-emitting leaks within their LDAR activities. In the view of the Committee staff, there are simple, concrete steps that companies can take today, using existing tools and methods, that would make significant progress towards reducing super-emitting leaks. But the companies remain tethered to a traditional "find and fix" approach that treats all methane leaks equally, despite the scientific evidence establishing that super-emitting leaks are one of the most significant drivers of sector-wide methane emissions.

Failure to Define Super-Emitting Leaks

The first step towards addressing super-emitting methane leaks is to define the size of a "super-emitter." The absence of an internal super-emission threshold indicates that oil and gas companies cannot formally distinguish the small subset of super-emitting leaks from the far larger mass of methane leaks within their operations. The lack of a definition also makes it far more challenging for operators to develop a more sophisticated understanding of their own super-emitting leaks. Assessing the characteristics, sources, and operational circumstances of super-emitters would help operators prioritize LDAR resources towards their prevention and rapid detection. Without a threshold definition of super-emitting leaks, however, such a thorough analysis – and the strategic direction that could be gained from it – is difficult to accomplish.

Based upon the Committee's findings, the oil and gas sector is failing to define the size of super-emitting methane leaks. Of the ten operators that provided information to the Committee, nine out of ten revealed that they lack any internal definition of a super-emitting leak, whether persistent or intermittent. Only one operator cited an actual size threshold for a super-emitting leak. Furthermore, many of the operators confirmed that they lack any useful internal classification of super-emitting leaks at all, either referencing broadly unrelated state reporting thresholds or simply acknowledging that they do not categorize super-emitting leaks in any manner.

At present, no formal consensus exists – either among regulators or within the scientific community – regarding a single, universal definition of a super-emitting methane leak. However, the lack of an industry-wide definition does not explain the failure of specific companies in the oil and gas sector to adopt internal definitions for their own purposes. Numerous scientific studies in recent years have made practical assumptions about the size of super-emitting leaks that can serve as models for oil and gas companies. For example, a 2017 study defined super-emitters as methane leaks with an emission threshold at or above 26 kilogram per hour (kg/hr) because such leaks "correspond to the highest-emitting 1% of sites in the site-based distribution, accounting for 44% of total site emissions" in the study's data set.[41] Many subsequent studies

[41] Zavala-Araiza, Daniel, et al. "Super-emitters in natural gas infrastructure are caused by abnormal process conditions." *Nature Communications*, vol. 8, no. 14012, 16 Jan. 2017, https://doi.org/10.1038/ncomms14012.

have adopted the same definition.[42] While the Committee staff does not endorse any particular definition for super-emitting leaks, we do note that the extensive scientific usage of 26 kg/hr as a threshold could provide a sensible approach for the private sector.

Case Study: A Flawed Definition of Super-Emitting Leaks

Only one operator indicated that it has established an internal size definition of a super-emitting leak. It is a positive step to affirm any threshold, and the Committee staff recognizes this operator's efforts. But the company's definition is flawed and does not offer significant value as a tool to assess methane super-emitters.

The operator defines super-emitting leaks in the Permian Basin as follows: "an unauthorized release of gas through venting and flaring into the environment as a result of an upset emission event or planned/unplanned maintenance activity over a reportable quantity (5,000 lbs. of natural gas)." It says that this definition is "in accordance with" a definition established by the Texas Commission on Environmental Quality (TCEQ). But the company did not offer a denominator of time (e.g. per hour, per day) to allow the metric to be expressed as a rate, which is critical to understanding the urgency of a leak from both a climate and localized safety perspective. If we assume the company is otherwise keeping with the TCEQ General Air Quality Rules, the period of time over which a "reportable quantity" is emitted in order to qualify as a "reportable emissions event" would be 24 hours:

> *Reportable emissions event--Any emissions event that in any 24-hour period, results in an unauthorized emission from any emissions point equal to or in excess of the reportable quantity as defined in this section.*

5000 lbs/24 hours is equivalent to 94.5 kg/hour, a figure nearly four times the 26 kg/hr threshold preferred by researchers. Additionally, the operator's metric refers to natural gas, rather than methane. While methane is the most prevalent constituent in natural gas, anywhere from 10-30% of natural gas is from non-methane components, such as ethane, butane, propane, carbon dioxide, volatile organic compounds (VOCs), and water vapor. To use the terms interchangeably for any kind of numeric threshold is imprecise. This operator's definition is an example of the perils of using ill-fitting traditional methods for the detection, analysis, and mitigation of super-emitting leaks.

Failure to Identify and Track Super-Emitting Leaks

Defining super-emitting methane leaks is a prerequisite to identifying and tracking them. Experts confirmed to the Committee staff that properly tracking super-emitting leaks is critical to mitigating methane pollution, and that gathering precise and specific data is the simplest way for companies to gain greater insights into the characteristics of super-emitting leaks within their operations. Choosing not to collect such data is effectively a choice to remain blind to the problem.

[42] For example: Cusworth, Daniel, et al. "Intermittency of Large Methane Emitters in the Permian Basin." *Environmental Science and Technology Letters,* vol. 8, no. 7, pp. 567-573, 2 June 2021, accessed here: https://pubs.acs.org/doi/10.1021/acs.estlett.1c00173.

The Committee staff have determined that oil and gas operators are making that choice. All ten operators conceded that they do not identify, track, or maintain records in any organized manner regarding super-emitting methane leaks within their Permian operations. These statements are even more striking in light of the fact that innovative LDAR technologies, which can identify and provide the data necessary to track super-emitters, are available for deployment today. Many of these innovative technologies quantify the size of methane leaks and can therefore identify super-emitters for operators quickly, making their documentation simply a matter of recording and organizing the data. The opportunity for operators to classify super-emitting leaks is clear. Operators simply must be willing to seize it.

Case Study: An Operator's Dismissal of Tracking Super-Emitters

One of the operators wrote to Chairwoman Johnson:

> *Our aim is to identify and mitigate emission leaks. As such, the company does not maintain documentation around large-emission methane leaks separately from other leaks identified by monitoring conducted at our sites. … Since leak detection and repair are our objectives, [the company] does not maintain a list of all intermittent, large-emission methane leaks identified by our monitoring technologies…*

This operator appears to believe that the identification and tracking of super-emitting methane leaks should be viewed distinctly from the larger need to "identify and mitigate emission leaks." The company's approach neglects the vital role that super-emitter data must play in supporting science-based LDAR approaches, and it does not reflect the current scientific evidence regarding the causes of oil and gas sector methane emissions.

Failure to Assess the Contribution of Super-Emitting Leaks to Overall Methane Emissions

One of the primary reasons to identify and track super-emitting methane leaks is to understand the contributions that super-emitters make towards a particular operator's aggregate methane emissions. Scientists have conducted extensive research into the immense role played by super-emitters as a driver of oil and gas sector methane emissions, but these studies tend to gather data on a large geographic scale, encompassing a multitude of operators within a particular oil and gas field, basin, or region. For individual companies, understanding the share of methane emissions that results from super-emitting leaks specific to their own facilities and equipment would help them assess the performance of their assets, evaluate the success of LDAR programs and technologies, improve the quality of assertions about the sustainability and climate intensity of their products, and develop emissions mitigation strategies. To act comprehensively against super-emitting leaks in an informed manner, each company needs to grasp the problem unique to its own operations.

The Committee's findings indicate that the oil and gas sector cannot do so. All ten operators asserted that they do not presently assess the contribution that super-emitters make towards their

aggregate methane emission in the Permian Basin. When it comes to the role of their own super-emitters in the Permian, all ten operators are in the dark.

For specific companies to evaluate the role of super-emitting leaks in driving total methane emissions within their operations, they must be prepared to perform statistical analyses of emission quantification data regarding both super-emitters and aggregate methane emissions. The process for doing so is technically challenging, but it is achievable using existing technology, as scientific researchers have amply demonstrated. At a minimum, even rudimentary efforts to assess methane emissions derived from super-emitters (along with their rate of occurrence) would still provide companies with valuable insights into the impact that such leaks would be likely to have on their overall emissions profile. Simply grasping the overall scale of super-emitting methane leaks, even imprecisely, would likely enhance the understanding that companies possess concerning the emissions profile of their operations.

Failure to Prioritize Super-Emitting Leaks within LDAR Design and Implementation

Beyond gathering and analyzing data, there are concrete actions that oil and gas operators can take – rooted in the latest science and utilizing existing technologies – which would strengthen their LDAR efforts against super-emitting leaks. Distinguishing the relative size of methane leaks cannot be done using the traditional tools of regulatory LDAR programs such as handheld optical gas imaging (OGI) cameras, which lack the capability to quantify emissions. Innovative LDAR technologies must be deployed over oil and gas operations as a foundation of a super-emitter mitigation strategy. But the deployment of these technologies, while necessary, is not sufficient. Just as important is the framework in which companies deploy them, and the processes that are put in place by companies to effectively utilize them.

- The first essential aspect of an LDAR framework for super-emitting methane leaks is to achieve as high a frequency of detection surveys as possible, with a scope that encompasses an operator's entire infrastructure. More comprehensive and more frequent surveys are among the simplest and most effective steps that oil and gas operators can take to reduce the impact of super-emitting leaks. The goal is simply to ensure that monitoring systems are in place to detect super-emitting leaks as fast as possible wherever they might appear. Given the high cost and labor-intensive nature of handheld OGI surveys, the only practical way to achieve the necessary scope and frequency is to deploy innovative LDAR technologies using platforms that are capable of monitoring large distances at a higher tempo, such as fixed-wing aircraft, ground-based sensor networks, helicopters, drones, and/or satellites.

- It is also critical that companies properly utilize the data generated by innovative LDAR technologies to prioritize super-emitting leaks in repair efforts. Many innovative technologies can provide operators with data regarding the size of individual methane emission events within their operations. But the operators themselves must accept the validity of these measurements, integrate the measurement data into their repair procedures, and respond to super-emitting leaks as quickly as possible. Operators must implement an analytical framework that emphasizes larger leaks as the primary focus of

LDAR programs. In the absence of that framework, all leaks will be treated equivalently and a vital opportunity to cut one of the largest sources of methane emissions will be lost.

- Finally, it is essential that oil and gas companies employ the measurement data at their disposal to prioritize the root causes of super-emitters, in terms of both LDAR responses and operational changes. Operators can employ that quantification data in support of numerous actionable steps, such as identifying facilities and types of equipment that are more likely to experience super-emitting events; redirecting limited LDAR resources in a more efficient and targeted manner towards aspects of the company's infrastructure with a higher prevalence of super-emitters; and devising operational changes that target areas of high super-emitter vulnerability, such as replacing particular pieces of equipment with less susceptible alternatives. These types of actions hold tremendous promise for the mitigation of methane leak emissions. But to implement them, operators must accept the need for data regarding super-emitting leaks and act on that data.

In terms of the frequency and scope of LDAR surveys, the Committee staff is encouraged to observe so much interest among operators in voluntarily exploring the use of innovative technologies to bolster their LDAR efforts. However, as will be discussed later in this report, it must be noted that most of these activities remain in the realm of pilot testing programs, rather than the comprehensive, scaled-up operational programs that are necessary to achieve major methane reductions. There is still a long way to go before widespread deployment can truly achieve large-scale emissions reductions.

Even where oil and gas companies are deploying innovative LDAR technologies at greater frequency and scope, flawed approaches are undermining the ability of LDAR programs to target super-emitting leaks. In response to Chairwoman Johnson's request for information regarding any "specific LDAR procedures or initiatives" in their LDAR programs designed to address methane super-emitters, and intermittent super-emitters specifically, the ten operators provided lean answers and scant evidence of deliberate effort to mitigate super-emitters. Several argued that the same longtime practices associated with traditional LDAR programs, such as Audio, Visual and Olfactory (AVO) inspections, can be refocused to address super-emitting methane leaks as well. Some cited the use of remote operational monitoring systems that can detect equipment disruptions which may indicate leaks, without acknowledging that such systems cannot themselves distinguish between the small number of super-emitters and the far larger mass of tiny leaks. A few operators argued that distinct procedures to address super-emitting leaks were simply unnecessary, as traditional practices were sufficient to solve the problem, or declined to specify any targeted procedures at all. These responses indicate a troubling lack of initiative on the part of the oil and gas sector to proactively implement LDAR practices designed to reduce super-emitting leaks.

Case Study: An Operator's Rejection of Focused Procedures for Intermittent Super-Emitters

In response to Chairwoman Johnson's question regarding LDAR practices for intermittent super-emitters, one operator argued that "boots-on-the-ground" inspections represented the most effective method for mitigation:

> *Though [the company] does not characterize leaks by their intermittency or scale, the company performs LDAR surveys to identify and thereby reduce the impact of any leaks found, regardless of size or duration. [The company] believes lease operator training and in-person inspections (a/k/a "boots-on-the-ground" inspections) are the best way to deter releases. … Training and in-person inspections will allow [the company] to respond to an intermittent, large-emission methane leak if one should occur in the future.*

But these types of inspections are inadequate for reducing super-emitting leaks at scale. In the view of the Committee staff, "boots-on-the-ground" LDAR methods cannot on their own be scaled up to solve the problem of super-emitting methane leaks, whether intermittent or persistent.

There is one significant exception to this lack of progress. The Committee staff does acknowledge that some oil and gas companies are taking an encouraging first step by using the measurement data from innovative LDAR technologies to prioritize the largest methane leaks for repair. The use of measurement data in this manner represents a tangible shift in a positive direction.

But other operators do not appear to use the measurement data at their disposal in this way. Instead, they take the traditional "find and fix" approach, regardless of any data that suggests the relative size of a leak. This "find and fix" approach treats all methane leaks equivalently, regardless of the size of their emissions. While the goal of repairing every methane leak is surely commendable in the abstract, an LDAR framework that fails to distinguish between the large mass of tiny methane leaks that occur constantly and the small group of super-emitting methane leaks that are responsible for a disproportionate amount of oil and gas methane emissions is deeply flawed. Any oil and gas company that fails to utilize measurement data it already has to prioritize super-emitting leaks is wasting an opportunity to reduce its methane emissions.

Other than the basic step taken by some operators to direct repair surveys towards larger leaks, the oil and gas sector appears to be doing very little to devise LDAR procedures and practices for the purpose of mitigating super-emitting methane leaks. A large part of this failure is rooted in a reluctance on the part of the operators to redesign their existing LDAR procedures around super-emitter data and intermittency data derived from innovative LDAR technologies. This data offers tremendous potential to improve the ability of LDAR programs to detect more super-emitting leaks and organize LDAR responses more effectively to ensure successful repair. But to maximize its impact, operators must be willing to apply it in the context of super-emitters. For example, some innovative LDAR technologies distinguish between persistent and intermittent leaks. But if operator LDAR programs fail to record, track and follow-up on intermittent leaks, many of these leaks – including the super-emitters among them – are likely to fall through the cracks if they cannot immediately be repaired.

Case Studies: The Importance of Integrating Data on Intermittent Super-Emitters into LDAR Procedures

In its response to Chairwoman Johnson, one operator noted that it currently does evaluate measurement data from an aerial survey vendor to prioritize larger leaks for mitigation. However, this operator also acknowledged that while the vendor provides data regarding leak intermittency, the operator has not developed distinct LDAR procedures for responding to intermittent leaks as opposed to persistent leaks. Moreover, the operator stated that it does not distinguish intermittent leaks in its LDAR system, despite the risk that intermittent leaks may be far more difficult to detect and repair during follow-up surveys after the initial detection due to the erratic and unpredictable nature of their emission releases.

The Committee staff believe that this could significantly undermine the ability of this operator's LDAR program to reduce methane emissions from intermittent super-emitters. If the company does not distinguish large intermittent leaks internally, it cannot track which of those leaks managed to avoid detection during initial follow-up surveys and therefore require additional follow-up. As a result, intermittent super-emitters could be allowed to resume emitting methane until another detection survey happened to detect the leak again.

Internal methane leak data obtained by the Committee from a different operator highlights the risks of failing to account for intermittent leaks. According to aerial survey data generated on that company's behalf in 2021, a significant percentage of emission events recorded in two aerial surveys – 28% and 37%, respectively – were investigated by the operator after detection, but could not be found in follow-up surveys with handheld optical gas imaging (OGI) devices. This second operator disclosed that it only pursues OGI follow-up for persistent emissions and large intermittent emissions. Thus, it is likely that these "unidentified" emissions were large, intermittent leaks.

The fact that intermittent super-emitters likely constitute a substantial percentage of the second operator's leak profile demonstrates the limitations of the first operator's approach. Large intermittent leaks are frequent but may not re-appear in a single follow-up survey. LDAR programs must develop procedures to anticipate and address them specifically.

Similarly, the oil and gas sector appears to be making little effort to use measurement data to inform operational changes and the more efficient deployment of traditional LDAR resources towards the root causes of super-emitting leaks. In their responses, a number of operators did detail longstanding efforts to improve the operational efficiency of their facilities and equipment, in some cases with assistance from innovative LDAR technologies. These initiatives are worthy endeavors. The missing element, however, is the focus on super-emitting methane leaks specifically as the aim of targeted operational changes to mitigate leak emissions. The problem, once again, is that determining the operational changes capable of reducing the prevalence and duration of super-emitting leaks requires concrete, reliable data on super-emitters within an operator's infrastructure. Without such data, it is extremely difficult to understand what types of operational changes directly concentrate their impact on super-emitters, and where LDAR resources can be shifted to survey operational aspects more vulnerable to super-emitters at a greater frequency. Data and practice must go hand-in-hand to develop more effective LDAR efforts for mitigating super-emitting methane leaks.

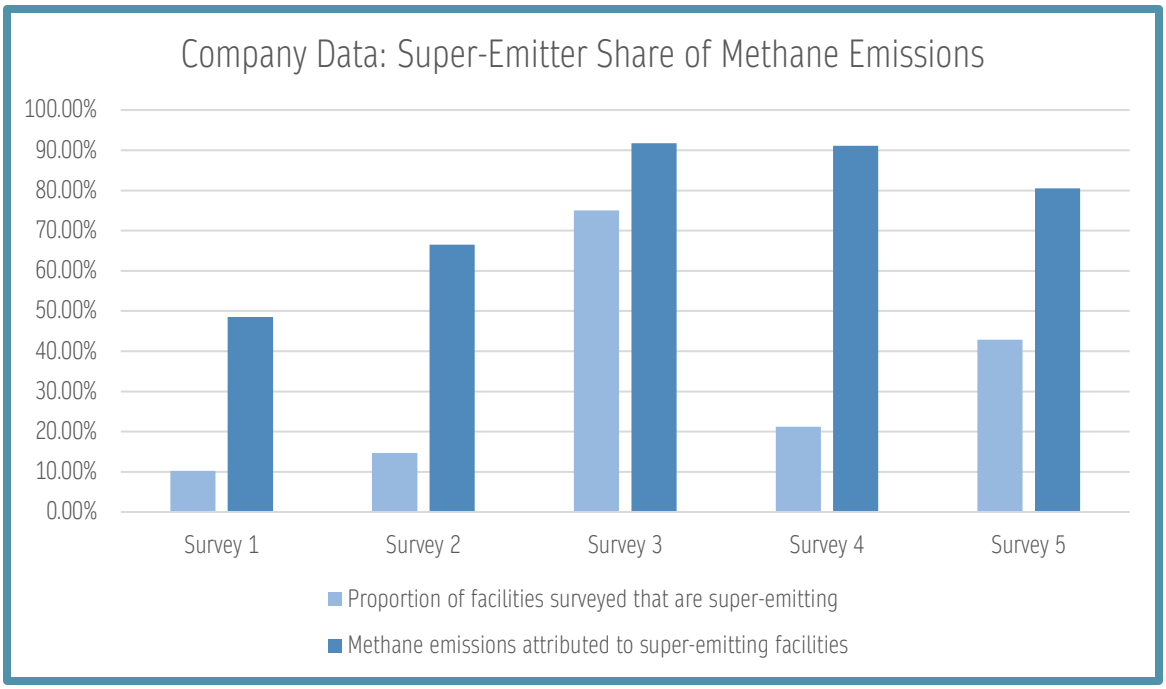
Super-Emitting Methane Leaks: Internal Company Data

Committee staff obtained the results of nine methane detection surveys conducted for several operators in the Permian Basin. These surveys, which were commissioned by the operators, used innovative LDAR technologies to detect methane leaks and quantify the size of their emissions. The data confirms unequivocally what recent scientific research has indicated: super-emitting leaks are an immense driver of oil and gas methane emissions, and they are emitting methane at extraordinary levels.[43]

Five surveys were selected for closer analysis due to their relatively broad scope. The combined emission rates of facility-level super-emitting leaks in the five surveys ranged from 189.4 kg/hr to 1,353.8 kg/hr. The survey that detected the fewest number of super-emitters was also the survey that was most narrow and limited in scope, supporting the scientific view that large numbers of measurements are critical to properly characterize the emission distribution of oil and gas operations. Meanwhile, a larger survey of a different company's assets, an aerial survey conducted in 2021, detected 18 distinct super-emitters within the company's operations over just three days of flyovers, ranging in size from roughly 26 kg/hr to over 400 kg/hr.

The company data also reveals the disproportionate share of methane emissions contributed by super-emitting leaks as a share of an operator's aggregate leak emissions. Among the five surveys, facility-level super-emitters were responsible for between 49% and 91% of all detected emissions in each survey, despite constituting a small number of overall leaks. In an aerial survey of one operator's facilities, just 4 super-emitting facilities were responsible for 49% of all detected methane emissions. In a different aerial survey, just 5 super-emitting facilities were responsible for 67% of all detected methane emissions. In a drone survey of an operator's facilities, just 7 super-emitting facilities were responsible for 91% of all detected methane emissions.

[43] For purposes of this analysis, the Committee staff has defined a super-emitting leak as any emission event equal to or greater than 26 KG/HR. When emission rate data was originally calculated in Standard Cubic Feet Per Hour (SCFH), the Committee converted SCFH to KG/HR using a simple calculation whereby the rate of emitted gas in SCFH was multiplied by 0.0192 kg/scf and then multiplied again by 0.8 to represent a standardized fractional methane content of 80% methane.



The single largest leak in any survey reviewed by the Committee emitted 413.9 kg/hr. This one leak was so large that its emission rate turned out to be roughly 26% larger than the combined emission rates for *all* non-super-emitting leaks detected in the survey. The leak is an illustration of why it is so critical to focus methane reduction strategies on mitigating super-emitters: in this instance, the operator could achieve greater emissions reductions by detecting and repairing a single leak than by repairing the two dozen small leaks that were also detected.

The Committee also observed that the largest leak identified during one of the surveys was an intermittent super-emitter. It was recorded emitting at 66 kg/hr one evening in 2021, but the leak had ceased on its own the following day. Without continuous monitoring, it is difficult to know whether this facility experiences large but sporadic emissions events.

A 2020 drone survey demonstrated how LDAR quantification data can inform future leak mitigation strategies. That survey identified a pattern: out of seven facility-level super-emitters, five of them – including the three largest leaks, all larger than 100 kg/hr – were caused by compressors. Researchers have identified other equipment types as leading sources for super-emitting leaks as well, including flares and tanks, and we do not suggest that compressors are particularly leak-intensive based upon this one data set. Such a data point can serve as a foundation for further research and analysis by this specific operator in order to develop a more accurate understanding of its own leak emission profile, and to isolate potential problems that may lend themselves to operational changes to avoid leaks.

After reviewing this data, the Committee staff do not have any doubt that many oil and gas companies are aware of the threat posed by super-emitting methane leaks within their own operations. Their own internal data confirms it. Operators that conduct methane detection surveys using innovative LDAR technologies are likely to confirm that a small number of very large methane leaks are responsible for a disproportionate share of overall methane emissions.

They know how grave the super-emitter problem is. And yet, they are still failing to take the simple steps necessary to make it a mitigation priority. The oil and gas sector cannot avoid responsibility for confronting super-emitting methane leaks by claiming that the science is uncertain, as their own data says otherwise.

Finding #2: Oil and Gas Companies Are Failing to Use Quantification Data to Mitigate Methane Leak Emissions

Overview

The Committee has determined that the capability to quantify methane emissions exists, but the oil and gas sector is not operationalizing it.

In the view of the Committee staff, quantification represents an immensely valuable tool to understand the scale of the methane leak problem and inform solutions to address it. While existing quantification tools may possess some technical limitations that will require further research and development to address, they can nevertheless be used by oil and gas companies – right now – to obtain extremely useful information about the size of methane leaks and the total methane emissions from their operations in a given basin, as well as the sources of those emissions and their operational emission profile. By rejecting the use of quantification data for reasons that are not scientifically justified, the oil and gas sector has chosen to remain in the dark about the alarming reality of its methane leak problem and the need to reduce methane leak emissions at a far more rapid pace. Unless the sector embraces methane leak quantification immediately, it will not be able to achieve the rapid and large-scale decline in methane emissions that is necessary for America to reach its methane reduction goals.

Survey of Innovative LDAR Quantification Capabilities for Oil and Gas Operators

In response to Chairwoman Johnson's request for information regarding their deployment of innovative LDAR technologies, the ten oil and gas operators provided detailed descriptions of the technologies currently being piloted or scaled-up within their Permian operations. Many of these technologies can quantify the size of methane emission events, including those events caused by malfunctions and abnormal operating conditions.

Oil and Gas Operator Current Permian Deployments of Innovative LDAR Technologies with Quantification Capabilities

Operator	Technology Deployed w/ Quantification Capability?	Type of Sensor Platform	Status	Does Operator Use Data to Quantify Methane Emissions?
Admiral Permian Resources	Yes	Ground-Based Continuous Monitoring	Pilot Program	No
Ameredev	Yes	Ground-Based Continuous Monitoring	Pilot Programs	No
Chevron	Yes	Aerial Survey	Basin-Wide Deployment	No
ConocoPhillips	Yes	Ground-Based Continuous Monitoring	Pilot Programs	No
Coterra Energy	Yes	Aerial Survey;	Basin-Wide Deployment; Pilot Programs	No

		Ground-Based Continuous Monitoring		
Devon Energy	Yes	Aerial Survey; Ground-Based Continuous Monitoring	Basin-Wide Deployment; Pilot Program	No
ExxonMobil	Yes	Aerial Survey	Basin-Wide Deployment	No
Mewbourne Oil	Yes	Aerial Survey; Ground-Based Continuous Monitoring	Pilot Program; Basin-Wide Deployment	No
Occidental Petroleum	Yes	Aerial Survey; Ground-Based Continuous Monitoring; Satellite	Basin-Wide Deployment; Pilot Programs; Pilot Program	No
Pioneer Natural Resources	Yes	Aerial Survey	Basin-Wide Deployment	No

All the oil and gas companies the Committee surveyed have been piloting innovative LDAR technologies that can quantify methane leak emissions in the Permian. Some are launching basin-wide deployments. Indeed, several experts observed to Committee staff that widespread pilot efforts are underway nationwide, and that 2021 witnessed a notable shift from pilot deployments to large-scale deployments among certain operators. But not one of the ten operators acknowledged using quantification data for the purpose of estimating basin-wide methane emissions, calculating emissions reductions, or developing a more accurate emissions profile for their Permian operations based upon the quantification of emission sources.

Importance of Quantifying Methane Leak Emissions

Recent scientific research has left little doubt that we are in the dark regarding the true size of oil and gas sector methane emissions. Indeed, emission factors fail to account for the essential characteristics of oil and gas methane leaks to such a degree that one expert called them "actively misleading" in terms of the scale of oil and gas methane emissions. But supplementing emission factor engineering calculations with frequent, high-resolution, real-world measurements – quantification data – is the key to understanding the problem and learning the observable ground truth.

The benefits of quantifying methane leak emissions though direct observations are enormous. Quantification data allows for much more accurate calculations of overall leak emissions from oil and gas operations. Since the fundamental shape of oil and gas methane emissions is characterized by a heavy-tailed emission distribution that is dominated by a relatively small number of super-emitting leaks, the only way to fully understand it is to conduct widespread and frequent emissions measurements throughout oil and gas infrastructure. Detecting and quantifying as many super-emitters as possible in order to properly characterize the magnitude of the tail is the key to understanding total emissions with greater accuracy. As a result, the quantification data derived from large measurement surveys – whether basin-wide aerial surveys, multi-facility fixed-sensor continuous monitoring systems, or any other innovative LDAR

platform – provides the most accurate estimate that can currently be generated for actual methane emissions from oil and gas operations.

Case Study: A Missed Opportunity to Use Quantification Data in LDAR Analysis

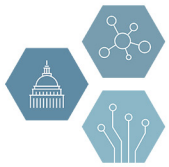
The Committee reviewed information from one operator pertaining to an analysis of aerial survey data generated on the operator's behalf over two surveys in 2021. This operator analyzed the individual emission events detected during each survey and examined all confirmed methane leaks by segment: production, gathering and boosting, and pipeline or gathering line. However, the operator did not break down the leaks themselves and did not incorporate quantification data into its evaluation. The operator confirmed to the Committee staff that quantification is not included in its aerial survey analysis, even though the aerial survey vendor provides it.

This is a missed opportunity for the operator to use quantification data to deepen its understanding of methane leak emissions within its operations. For example, it would be extremely valuable to assess the number and size of super-emitting leaks by segment, which could yield important insights into their causes, the need for certain operational changes, and the prioritization of LDAR resources. It would be similarly beneficial to assess the number and size of intermittent super-emitters by segment. This is the type of analysis that is required to reorient LDAR programs towards mitigating the biggest sources of methane emissions in an informed, data-driven manner.

Quantifying methane emissions can support an array of beneficial outcomes. Measurement data allows for more precise and informed analyses of methane emission sources from oil and gas operations, targeted to specific segments, specific facilities, and even specific types of equipment. It can inform operational changes to eliminate circumstances that are more likely to produce super-emitting leaks. It can enable the reorientation of LDAR resources to emphasize more frequent inspections covering infrastructure with a greater propensity to experience super-emitters. It can provide the necessary data for operators to conduct cost-benefit calculations for innovative LDAR technologies on the basis of the savings that can be realized if captured gas were brought to market instead of leaking, which can be critical to help operators assess the financial incentives of adopting novel LDAR solutions.

In addition, quantification is needed for measurable, performance-based mechanisms by which oil and gas companies can respond to market demands for reduced methane emissions from their operations. The business case for methane quantification is growing stronger with each passing year. Shareholders deemed "socially responsible investors" are evaluating companies on Environmental, Social, and Corporate Governance (ESG) metrics.[44] Financial institutions and third-party ratings providers evaluate companies using available data on carbon emissions, pollution, use of renewable energy, and more, allowing shareholders and potential investors to compare companies' performance to their peers and make investment decisions in line with their

[44] Corporate Finance Institute. "ESG (Environmental, Social and Governance)." 6 May 2022, accessed here: https://corporatefinanceinstitute.com/resources/knowledge/other/esg-environmental-social-governance/.



values.[45] The market valuation of ESG funds is massive and growing rapidly, with an estimated $330 billion in assets under management estimated at the end of 2021.[46]

Similarly, a Responsibly Sourced Gas (RSG) designation allows oil and gas companies to boost their ESG metrics by obtaining a certification from a third-party program attesting to the company's environmental performance. No industry-wide standard for RSG currently exists, but more and more oil and gas companies are seeking RSG designation and affixing a 1-2% premium on RSG gas over non-certified products.[47] The move towards such certifications demonstrates that consumers and shareholders are interested in being more informed about the climate impact of the energy products they are using and investing in.[48] In addition, the European Commission is moving toward formal preference for RSG. It proposed legislation in the European Union in late 2021 that would require new, detailed information from gas suppliers on emissions measurement, reporting, verification, and mitigation strategies. It has also laid plans for more stringent methane regulations for Europe by 2025.

Methane emissions quantification seems indispensable for objectively assessing whether oil and gas companies are meeting ESG and RSG standards throughout the oil and gas supply chain. As a result, quantifying methane emissions will be an important economic consideration for oil and gas companies, and a capability that would be in their self-interest to utilize if they have a good story to tell investors and shareholders. The appeal of using quantification in this arena is already becoming apparent. For example, in May 2022, Chevron shareholders approved a shareholder resolution directing the company to assess the reliability of its methane measurement data. The resolution, supported by the owners of 98% of the company's stock, directed the company to inform its investors if company measurement data for methane emissions differed from publicly reported data.[49] It will be difficult for Chevron to fully align with the position of its shareholders without embracing LDAR quantification tools.

Innovative LDAR Quantification Capabilities

The benefits of quantifying oil and gas sector methane leak emissions are clear, but the capabilities are contested. Traditional LDAR technologies such as OGI cameras, which are approved for Federal regulatory purposes, cannot quantify methane emissions. Can innovative LDAR technologies do it? This is the heart of the matter. After consulting with a broad range of researchers and stakeholders across the oil and gas spectrum, the Committee staff has concluded

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[45] Huber, Betty and Comstock, Michael. "ESG Reports and Ratings: What They Are, Why They Matter." *Harvard Law School Forum on Corporate Governance*, 27 July 2017, accessed here: https://corpgov.law.harvard.edu/2017/07/27/esg-reports-and-ratings-what-they-are-why-they-matter/.

[46] Norman, Greg, et al. "ESG: 2021 Trends and Expectations for 2022." *Harvard Law School Forum on Corporate Governance*, 25 Feb. 2022, accessed here: https://corpgov.law.harvard.edu/2022/02/25/esg-2021-trends-and-expectations-for-2022/.

[47] Freitas Jr., Gerson. "'Responsibly Sourced' Gas Finds a Niche, But Some Cry Greenwashing." *Bloomberg,* 19 Jan. 2022, accessed here: https://www.bloomberg.com/news/articles/2022-01-19/natural-gas-trying-to-rebrand-as-greener-pitches-responsibly-sourced-fuel.

[48] ETF Trends. "These Institutional Investors Are Showing ESG Enthusiasm." *NASDAQ*, 20 Jan. 2022, accessed here: https://www.nasdaq.com/articles/these-institutional-investors-are-showing-esg-enthusiasm.

[49] Anchondo, Carlos. "Exxon, Chevron shareholders approve climate proposals." *E&E News,* 26 May 2022, accessed here: https://subscriber.politicopro.com/article/eenews/2022/05/26/exxon-chevron-shareholders-approve-climate-proposals-00035227.

that existing quantification capabilities possess real limitations but nevertheless *are capable of quantifying methane emissions from oil and gas operations and supporting methane mitigation activities*.

Quantification data serves two goals: measuring the size of individual methane leaks and calculating aggregate methane emissions from the entire set of measurements. To measure the size of individual emission events, innovative LDAR technologies deploy sensors to detect methane concentrations and then use data analytics, based upon set parameters, equations, and models, to convert the underlying concentration data into a quantified methane emission rate for each event. While the sensitivity of the sensors plays an important role in determining the threshold above which methane emissions can be reliably detected by a given technology, the data analytics are the key element in interpreting the size of an individual methane leak. Depending on the type of deployment platform utilized by an LDAR system, a large number of measurements may be taken over a given area during a given period. For example, thousands of individual measurements can be taken during an aerial survey conducted using fixed-wing aircraft, while certain ground-based fixed sensor networks can monitor continuously over a period of months or longer.

These large sets of individual measurements can then be aggregated to inform a total methane emission rate over a covered area and attribute relative emission rates to different sources within that area. In this instance, a "covered area" can refer to any subset of oil and gas infrastructure that is encompassed within a methane detection survey or system, from a single facility to a set of facilities to an operator's entire basin-wide infrastructure. The basis for these aggregate emission calculations is the multitude of individual emission measurements taken by an innovative LDAR system. The calculations require considerable statistical expertise to perform, particularly for large areas. These types of analyses have served as the foundation of much of the recent scientific research that has revolutionized our understanding of the scale of oil and gas sector methane emissions. They have also provided invaluable insights into the sources of oil and gas sector methane emissions by segment and asset type.

The distinction between the quantification of individual methane leaks and the quantification of aggregate methane emissions represents the crux of the disagreement over the value of quantification data.

Existing innovative LDAR technologies possess genuine limitations that significantly reduce the accuracy and/or precision of the quantification data regarding individual emission measurements. A number of experts informed us that the uncertainty bands for individual methane measurements can be very large; common uncertainty bands can be at least +/- 20-30% per measurement, and in some instances as wide as +100% and -50%. According to a range of stakeholders, the primary causes of the significant uncertainty for individual quantification measurements arise from the difficulties encountered by LDAR technologies when integrating complex environmental factors into their quantification models and data analytics. In particular, the challenge of accurately modeling wind conditions was widely cited as one of the foremost shortcomings with contemporary quantification capabilities. Additional limitations can revolve around modeling the distance of a sensor from an emission source or the stability of a sensor's

measurements, depending on the deployment platform being used. All of these factors represent aspects of methane quantification that would benefit from additional research investments.

But these limitations, as real as they are in terms of quantifying individual emission events, tell only part of the story of quantification's value. In terms of individual emission measurements, it is important to remember that super-emitting methane leaks are so large that they can still be quantified accurately enough to inspire confidence regarding the relative enormity of a leak, even if the exact size remains uncertain. This is a critical caveat to the legitimate concerns about quantification uncertainty. While such measurements remain subject to wide uncertainty bands, the sheer magnitude of super-emitters means that existing quantification technologies can reliably quantify their general size and provide invaluable support for more efficient operator LDAR programs, targeted operational changes, and a more accurate understanding of methane leak profiles.

In addition, experts told the Committee staff that while some innovative LDAR technologies are more mature than others, each type of system can be valuable for quantification purposes if deployed and interpreted effectively. For example, the quantification capabilities of aerial survey technologies are quite advanced regarding detected super-emitters, but their periodic surveys represent only a snapshot in time based upon a limited number of measurements. By contrast, the quantification capabilities of ground-based continuous monitoring technologies are generally subject to larger uncertainty bands, but their ability to broadly quantify super-emitters is nevertheless extremely valuable due to the sheer number of measurements that they are able to take on a continuous basis, which allows for the detection and quantification of more large leaks at a more rapid pace than periodic surveys. If understood properly, quantification data can be *useful* even if it is also *uncertain*.

Furthermore, a range of experts told Committee staff that despite the uncertainties associated with individual measurements, innovative LDAR technologies that exist today are indeed capable of accurately quantifying total methane emissions from a particular area. The reason is simple: emission quantification estimates based upon a large number of measurements are subject to far less uncertainty than the uncertainty associated with each individual emission measurement might suggest. Over the course of many measurements, the average of the individual measurements gravitates towards the mean of the entire set of measurements, and the uncertainty of the overall data declines substantially. Thus, larger sample sizes and repeat measurements reduce uncertainty within aggregate emission estimates substantially, even to the point where more frequent, less accurate measurements may produce better aggregate emission estimates than less frequent, more accurate measurements. A significant amount of research, including from the oil and gas sector itself, endorses this point. For example, a presentation made by ExxonMobil at the American Geophysical Union's annual meeting in 2020 – based upon the company's own internal research using quantification data from innovative LDAR technologies, and provided to the Committee – concluded that even when individual measurements are unreliable, a large group of measurements can produce statistically significant results regarding site-level methane emissions.

Oil and Gas Sector Failure to Apply Methane Quantification

Contrary to the science, the oil and gas sector appears extremely reluctant to accept the value of quantification data for the mitigation of methane leaks. Many oil and gas companies currently possess information that clearly and unequivocally quantifies their operational methane emissions with real-world measurements. But while all ten operators are deploying technologies that collect quantification data, not one of them reported using quantification data to support operational decision-making, to improve their basin-wide methane emissions estimates, or to calculate emissions reductions that may result from changes they have implemented.

Why isn't the oil and gas sector using methane emissions quantification data to strengthen its LDAR initiatives and accelerate emissions reductions from its operations? In their responses to the Committee, the ten operators argued that they were unwilling or unable to use – for almost any purpose related to methane leaks – the quantification data at their disposal. Their positions, while distinct from operator to operator, broadly rested upon three arguments:

- Individual emission measurements are subject to considerable uncertainty
- Quantification data lacks the accuracy required to act on it
- The use of quantification data is unnecessary to achieve the objectives of methane leak detection and repair

Uncertainty

Several operators cited the large uncertainty bands associated with emission measurements from innovative LDAR technologies in explaining their resistance to the use of quantification data. While they acknowledged that the detection sensors themselves were quite reliable at detecting emission events above a certain threshold, they noted that individual measurements possessed a great deal of uncertainty, leaving them reluctant to utilize quantification data as a part of their LDAR activities or to analyze quantification data in order to inform operational changes. The sole exception, as noted previously, was the willingness of several operators to use quantification data to prioritize immediate LDAR responses to larger emission detections. But those operators rejected the idea that the technology was capable of quantifying the actual size of each emission event with enough certainty to apply the data to other contexts and uses.

Case Studies: Oil and Gas Operator Perspectives on Quantification Uncertainty

Operator #1:

> *The ability to estimate and quantify methane emissions utilizing innovative LDAR technologies continues to evolve. To date, [the company's] focus has been on the evaluation of innovative LDAR technologies to find and fix leaks on a broader scale in order to improve the company's emissions performance. ... There are ongoing efforts to advance quantification capability, but it should be noted that these estimates are based on algorithms and dispersion modeling and are subject to varying levels of uncertainty.*

Operator #2:

> *While we have identified encouraging progress in methane detection technology, there are currently limitations in obtaining direct measurements of emissions. Today, direct measurement faces uncertainties and challenges related to modeling wind conditions and plumes, complexities of data management infrastructure, accounting for changing conditions at a site over different time periods, scalability, and ability to provide timely data.*

Operator #3:

> *...emission rates predicted by modeling are not necessarily a good representation of actual emission rate. Therefore, [the company] primarily uses the methane concentration and duration of the change in concentration to identify leaks. It does not rely on any quantification of actual emissions.*

Some of the concerns expressed by the operators about measurement uncertainty are legitimate. Methane monitoring and detection would greatly benefit from further technological and analytical advances to reduce the uncertainty bands associated with quantifying individual methane leaks. But these concerns take too narrow a view about the impact of uncertainty on the usefulness of quantification data. The use of quantification data to determine aggregate methane emissions over a covered area of oil and gas infrastructure is scientifically robust, as numerous peer-reviewed scientific papers have demonstrated in recent years. And despite a degree of uncertainty, innovative LDAR technologies can still quantify methane super-emitters with enough accuracy to prompt immediate on-the-ground repairs and support the development of far more realistic leak emission profiles for oil and gas infrastructure.

Inaccuracy

A number of operators went even further and explicitly questioned the accuracy of the quantification data being generated by innovative LDAR technologies deployed over their operations. These operators argued that existing quantification capabilities contain serious enough technical limitations that their measurement data should effectively be viewed as inaccurate, and therefore unable to be relied upon for any purpose related to LDAR analysis or the calculation of aggregate emissions. They cited a variety of technical factors to explain their rejection of the use of quantification data and emphasized that their evaluation of innovative LDAR performance depended upon factors distinct from quantification capability.

Case Studies: Oil and Gas Operator Perspectives on Quantification Accuracy

Operator #1:

> *[The company] is evaluating methodologies to perform direct measurement of the methane emission reductions from its operations, which is not required currently by applicable regulations or adopted by the industry. To date, [the company] has been unable to perform reliable measurement of fugitive emissions due to the limited frequency of current field-wide applications and the limited spatial coverage of site-level fixed sensors. Nearly every value used to estimate emissions introduces significant statistical error, with duration of a leak having the highest level of error.*

Operator #2:

> *In summary, [the company] does not use any of these technologies to quantify emissions from its operations, as we believe they cannot accurately do so.*

These concerns about accuracy miss the point. Given the statistical distribution of the sources of methane emissions from the oil and gas sector, the most important feature of successful methane mitigation is the ability to rapidly detect, identify, and repair super-emitting methane leaks. For these applications, a high level of accuracy is not required. Operators must simply use the data to reliably distinguish large leaks above a certain threshold with relative confidence so that they can be isolated and repaired as an LDAR priority. If the relative size of emission events can be quantified with even a rough level of accuracy, those measurements can inform policy responses effectively.

Necessity of Quantification

Finally, many of the operators contended that quantification data is unnecessary to achieve their goals for methane leak mitigation, which are limited to the successful implementation of a "find and fix" LDAR approach. These operators suggested that the main value of innovative LDAR technologies is merely to widen the physical area over which LDAR surveys can be conducted in a cost-effective manner. They argued that their focus remains detecting, verifying, and repairing

all methane leaks as quickly as possible. Correspondingly, quantification is superfluous to those objectives because it is not necessary to assess the size of a leak before responding to it and it is not necessary to measure aggregate methane emissions from their operations in order to reduce them.

Case Studies: Oil and Gas Operator Perspectives on Quantification Utility

Operator #1:

> *Importantly, [the company's] LDAR program is intended to effectively identify fugitive methane emissions and mitigate them even in the absence of quantification; currently, the program is neither designed for, nor capable of, accurately measuring those emissions.*

Operator #2:

> *The main objective with these technology pilots is to expeditiously identify, investigate and repair leaks associated with malfunctions and abnormal operating conditions that could indicate a possible exceedance of regulatory or permit conditions, resulting in faster emissions mitigation. At this time, [the company] does not believe that any of these technologies can provide quantification of emissions. Further, we do not use any of these methods to quantify and/or report emissions of methane. It is possible that advances in these technologies may ultimately result in better quantification over time, but our focus remains on detection and repair as the means to mitigate methane emissions.*

The concerns expressed by oil and gas companies about the necessity of quantification as a part of their methane mitigation activities take a far too limited view of the challenges inherent to reducing methane emissions. LDAR programs that treat all methane leaks equally are not properly designed to achieve rapid emissions reductions. The one-size-fits-all approach to leaks represents an imprudent approach to LDAR, which should prioritize the largest, super-emitting leaks that help to drive sector-wide methane emissions.

Quantification is one of the most powerful tools available to oil and gas companies to inform targeted, focused strategies to cut methane leak emissions. It is essential for developing more detailed and accurate leak emission profiles for different aspects of oil and gas infrastructure, which can reveal the emission sources and circumstances that produce a higher risk of super-emitting leaks. It is essential for identifying operational changes that can eliminate the common causes of super-emitters before such leaks occur. It is essential for implementing targeted LDAR procedures for super-emitters so that such leaks can be identified, categorized, and repaired as expeditiously as possible. Finally, it is essential for gauging the progress that oil and gas companies are making in achieving methane emissions reductions by providing accurate comparative data over long periods of time.

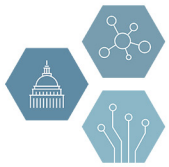
If the oil and gas sector does not quickly reverse course and aggressively integrate quantification data into its approach to reducing operational methane emissions, the consequences will be profound. The sector's resistance to quantification is not supported by science. Quantification is ready, right now, to serve as a vital tool in the methane mitigation toolbox.

Refining Methods for Quantifying Aggregate Methane Emissions

One legitimate challenge for oil and gas companies in quantifying aggregate methane emissions from their operations is the need for complex statistical analysis to turn a set of individual measurements into an overall emissions profile. While the scientific community has made considerable strides in recent years to develop methodologies for estimating methane emissions based upon survey measurement data, these methodologies continue to be refined and require a great deal of statistical expertise to carry out. A few of the largest oil and gas companies may have sufficient scientific and technical resources to perform these analyses based on the quantification data already in their possession. But many operators may require technical assistance to translate the quantification data from innovative LDAR technologies into a broader estimate of the total methane emissions from their facilities and equipment.

Valuable efforts are underway to refine and standardize methodologies for utilizing individual measurements to see the bigger picture of oil and gas sector methane emissions. In 2020, the United Nations Environment Programme (UNEP) and Climate and Clean Air Coalition (CCAC) issued the Oil and Gas Methane Partnership (OGMP) 2.0 Framework, a voluntary methane reporting framework for the oil and gas sector that is designed to serve as an international "'gold standard' for methane emissions reporting and performance."[50] In order to adhere to the OGMP 2.0 Framework, participating oil and gas companies are called upon to implement increasingly rigorous and comprehensive quantitative methods for site-level measurement, and to attempt to reconcile different methane emissions estimates using measurement data.[51] These activities are essential, but they can be technically challenging for oil and gas operators without sufficient internal statistical expertise. Technical and methodological challenges represent an area where further Federal research and support for the oil and gas sector could facilitate the use of quantification data in estimating aggregate methane emissions.

[50] United Nations Environment Programme and Climate and Clean Air Coalition, "Oil and Gas Methane Partnership 2.0." Nov. 2020, accessed here: https://www.ogmpartnership.com/.
[51] *Id*.



Finding #3: Oil and Gas Companies Are Deploying Innovative LDAR Technologies in a Limited and Inconsistent Manner

Overview

The Committee has determined that the oil and gas sector is deploying innovative LDAR technologies too slowly and too inconsistently. The Committee staff welcome the recent actions by many oil and gas companies to initiate voluntary pilot programs to evaluate innovative LDAR technologies. But most of these pilots are too narrow in scope to achieve real methane emissions reductions, and there is no guarantee that temporary pilots will lead to permanent universal deployments. Additionally, the oil and gas sector's approach to innovative LDAR technologies lacks consistency, with substantial differences among operators regarding the performance metrics and standards used to assess the capability and suitability of different technologies. Different operators should have the flexibility to adapt innovative LDAR capabilities to their distinctive operational profile. But the lack of consensus in the sector about a framework for evaluating innovative LDAR technologies is an obstacle to their widespread and timely adoption. The oil and gas sector's reticence to prioritize the deployment of innovative LDAR technologies at scale does not reflect the urgency of the moment and the need to achieve rapid methane emission reductions.

Innovative LDAR Deployments and Pilots

The ten oil and gas operators provided detailed descriptions of the innovative LDAR technologies previously or currently being piloted or scaled up within their Permian operations since 2016. All ten operators asserted that they currently use at least one innovative LDAR technology to detect methane leaks within their operations. A summary of operator responses can be found in Appendix I at the end of this report. [52]

Recent years have witnessed a considerable amount of activity regarding the deployment of innovative LDAR technologies in the Permian Basin. Across all operators, over 40 innovative LDAR technologies were piloted on some level. But these pilots have resulted in at most ten permanent deployments, with at most six being implemented comprehensively or planned to do so. While pilot programs are important for operators to determine which platform produces the most useful data and which may be cost effective, they do not result in significant emissions reductions. The heavy emphasis on pilot-phase projects means that oil and gas company implementation of innovative LDAR technology remains in a relatively nascent stage.

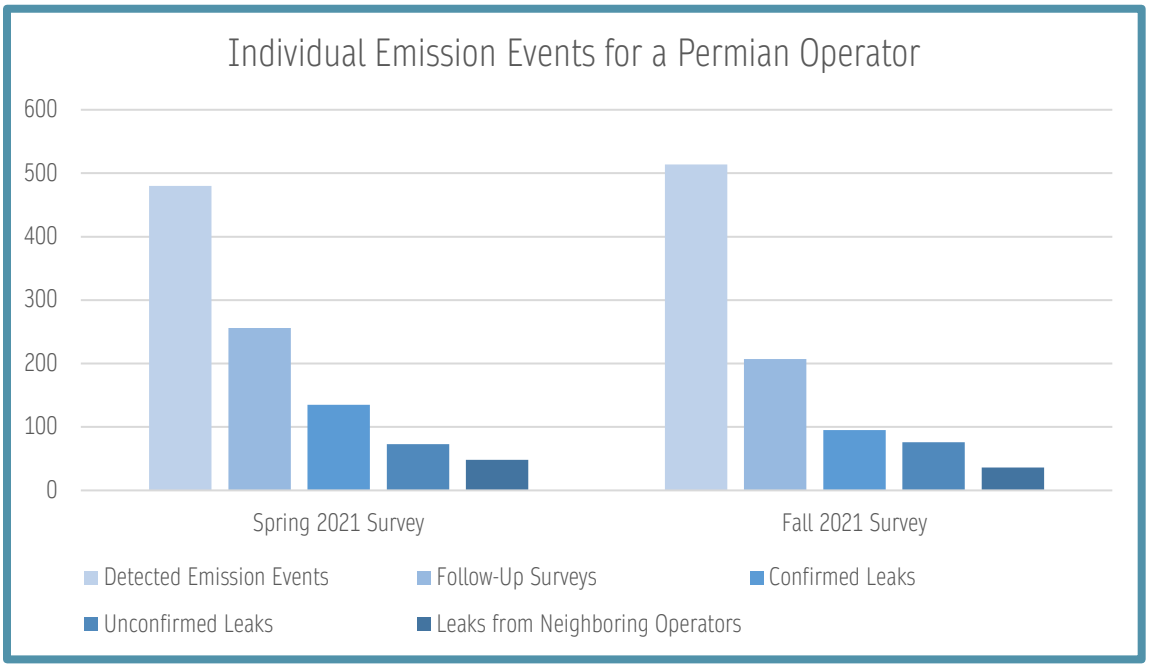
In 2021 and 2022, several companies scaled up the deployment of certain technologies – mostly aerial surveys – to encompass their entire basin-wide infrastructure in the Permian. The Committee staff recognize that these deployments are voluntary, and we are encouraged by the

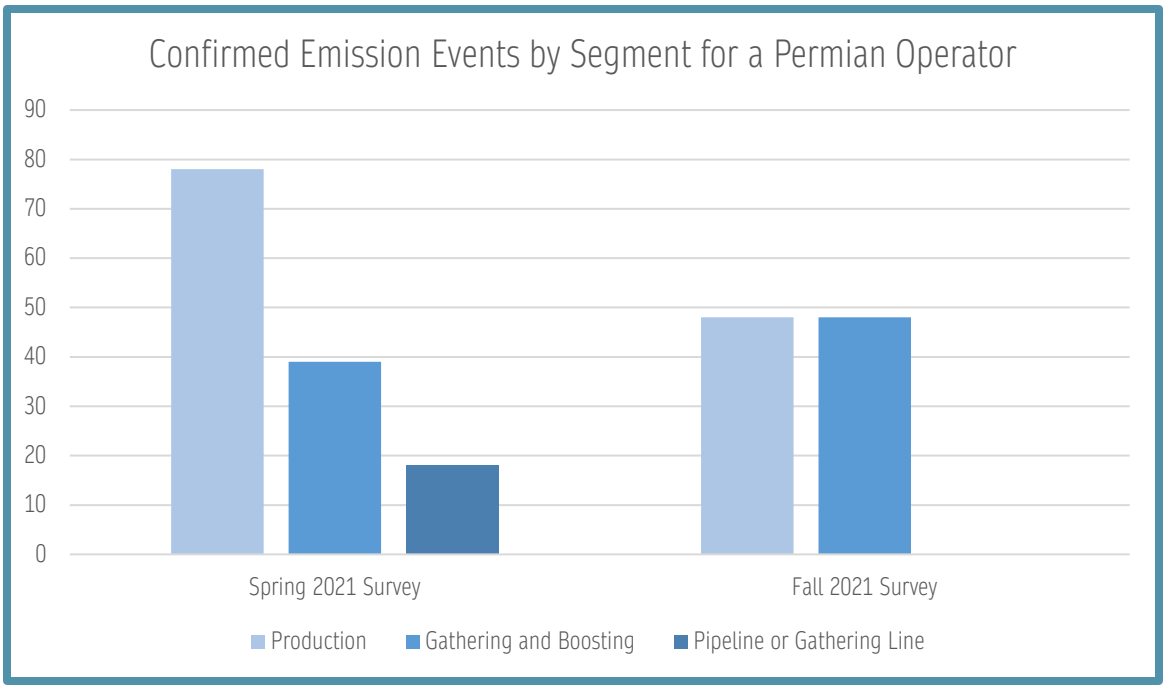
[52] In addition to their own unique innovative LDAR deployments, a number of operators noted their participation in two multi-operator pilot projects in the Permian: Project Astra and Project Falcon. Project Astra is currently assessing the effectiveness and methodology for shared networks of fixed methane emission monitors between operators. Project Falcon is currently evaluating the effectiveness of ground-based, continuous monitoring sensors at the facility level. Due to their experimental nature and limited scope for each operator, we do not include them as "deployments" by individual operators for the purposes of this analysis.

willingness of oil and gas companies to shift in this direction. But the scale of technology deployments largely remained constant during the entire period reviewed by the Committee between 2016 and 2022, notwithstanding the commercial debut of many new innovative LDAR technologies over those years. Moreover, large oil and gas companies appear to be deploying more quickly than the much wider group of small operators in the sector, who may not have the resources to invest in innovative LDAR methods.

While the need to evaluate the effectiveness of innovative technologies before adopting them is certainly justified, the pace of the transition from pilot to comprehensive deployment is incompatible with the need for the sector to align its performance with the nation's methane targets over the next decade. So long as the large majority of operator actions on innovative LDAR implementation stop at the pilot phase, the resources directed towards innovative LDAR will not have a significant environmental impact.

Innovative LDAR data reviewed by the Committee staff underscore the great promise of these technologies for methane leak mitigation. For example, one operator provided summary data for the results of two basin-wide aerial detection surveys conducted in the spring and fall of 2021. The data, broken down by individual emission events and the supply chain segments where the events occurred, demonstrates the breadth at which such technologies can operate when they are deployed at scale.





While this data is limited to one operator over the course of two aerial surveys, it suggests that innovative LDAR technologies have a high detection rate and great potential to support prompt leak repairs. Both aerial surveys detected around 500 emission events in a short period of time, leading to the rapid repair of 135 methane leaks after the spring survey and 95 methane leaks after the fall survey. The surveys detected dozens of leaks at facilities owned by neighboring operators, who were subsequently notified. The surveys detected potentially intermittent leaks that could not be repaired in an initial follow-up OGI survey but were nevertheless documented by the operator for additional surveys in the near future. The surveys also provided insights into the sources of methane leaks, highlighting the prevalence of leaks in the production segment, which accounted for 58% of confirmed leaks in the spring survey and 50% of confirmed leaks in the fall survey. Finally, the surveys demonstrated especially promising success regarding methane leaks from pipelines and gathering lines. The aerial survey found 18 leaks in the spring survey and made repairs. The survey conducted the following fall did not identify a single leak.

"More frequent awareness… could be costly": A Thwarted Innovative LDAR Deployment

The perils of limiting innovative LDAR deployments to the pilot stage were illustrated by a pilot demonstration that was conducted by one of the ten operators in the Permian Basin in 2017. The Committee staff reviewed the operator's internal summary report of the pilot demonstration. The operator's perspective on the technology makes it clear that for oil and gas companies, success can be a riskier prospect than failure.

This operator commissioned a technology research unit to evaluate the capabilities, operational quality, and cost-effectiveness of an innovative fixed-sensor methane detection technology. Between March and June of 2017, the research team field tested the technology in various conditions. Based upon the results of those tests, the research team praised the technology's

capabilities and highlighted its potential value to the company in a formal report and presentation. The research team noted that:

- The technology "consistently met [the vendor's] claims regarding performance of hydrocarbon gas detection for methane and natural gas."
- The potential benefits of the technology's adoption for the company included reduced vehicle safety incidents, reduced exposures to dangerous hydrocarbons, improved environmental performance in terms of methane leaks, and decreased asset loss and damage to company infrastructure.
- There was a leak during the pilot demonstration due to an incorrectly installed vacuum breaker. Because the technology was deployed at the site, not only was the leak spotted immediately and repaired quickly, but operational personnel subsequently reported that "if the [technology] had not alerted them of the error, the issue would've likely persisted for weeks before it was identified and remedied."
- The innovative technology provided "more frequent coverage with a height advantage" than traditional OGI surveys used for regulatory compliance.
- The innovative technology was "economically viable" and would reach the cost "breakeven" point for the company in less than three years.

The research team explicitly endorsed the technology's permanent deployment by the company. It noted, "at the conclusion of the project, the team recommended adoption of the technology as the validated business drivers are expected to provide economic value as well as intangible benefits which will be quantified more fully over time."

Yet the operator's management team ultimately rejected the permanent deployment of the innovative LDAR technology. A clue as to why may be found in the report itself. Towards the end of its analysis, the research team identified two "near-term risks" to deploying the technology:

- "Government or public obtains information without understanding or correct interpretation of visuals"
- "More frequent awareness of gas emissions and leaks could lead to more action, which could be costly"

The point is brutally clear. The operator's technology experts were warning that the technology's biggest risk was not that it would fail, but rather that it would succeed – and in doing so, would find more methane leaks that the operator would then be responsible for, with all of the accompanying repair costs and reputational risks that might ensue. Enhanced methane detection would be cost-effective, would improve safety, would improve environmental performance – but it would also create a more accurate record of the operator's leak performance that would demand a response and could be damaging with the public if it became known. The fact that the innovative LDAR technology could detect methane leaks more effectively than traditional LDAR techniques was a factor that weighed *against* its adoption. Simply put, it would be safer for the operator to avoid finding more methane leaks than absolutely necessary.

By articulating these risks, this operator's research team captured a certain narrow viewpoint about the company's self-interest. The team itself did not consider these risks to be significant enough to outweigh the benefits of the technology. According to documents reviewed by the Committee staff, the research team was still arguing internally in favor of the technology's adoption as late as September 2017, months after the conclusion of the pilot demonstration, and the team supported an "adoption plan" to deploy the technology in high priority areas. But the operator clearly found the risks of the technology more compelling than the benefits. The company abandoned the use of the innovative LDAR technology after 2017, never deploying it on a broader scale or a permanent basis. In its response to Chairwoman Johnson, the company cited the complexity of "data management infrastructure" and the need for more research into "data management approaches" as its rationale for discontinuing the use of the technology. But the research team did not articulate any such concerns. Within the company, a decision was apparently made that it was better not to find too many methane leaks, whatever the consequences for the environment and climate.

Limited Tempo and Frequency of Innovative LDAR Deployments

Aerial detection surveys are the sensor platform that oil and gas companies appear closest to deploying broadly across their operations. Committee staff applaud those operators who have already started or plan to start conducting aerial surveys over their entire basin-wide operations in the Permian in 2022. However, the full emission mitigation potential of aerial surveys is not achieved unless the frequency of surveys is sufficient. Aerial detection surveys provide a snapshot in time for methane leaks, which are highly irregular and unpredictable. More frequent aerial surveys, therefore, are required to achieve greater emission reductions. Only one operator – Pioneer Natural Resources – told the Committee that it planned to conduct three or more aerial surveys annually over its Permian operations, while other operators described a commitment to less frequent semiannual surveys or stated that they had not yet determined the frequency of their planned aerial surveys. Operators should strive to conduct as many comprehensive aerial surveys on an annual basis as can practically be achieved.

It is also concerning that the deployment of ground-based fixed sensor systems – many of which have continuous monitoring capabilities – appears to be occurring at a slow pace. Unlike periodic and on-demand surveys, continuous monitoring systems can rapidly detect and identify intermittent leaks, including intermittent super-emitters. The challenge of intermittency, while it can be addressed in limited fashion through other innovative LDAR technologies, is best suited to a continuous monitoring approach, which can distinguish intermittent leak sources in real time despite their randomness and unpredictability. But the results of this investigation indicate that very few operators are prepared to scale up their deployments of ground-based continuous monitoring systems in the near future. While Mewbourne Oil stated that it is poised to do so, the other nine operators all remain in various stages of pilots, limited deployments, or no consideration at all of continuous monitoring technologies. It is unfortunate that the pace of adoption of continuous monitoring technologies does not appear to parallel other innovative LDAR technologies.

Case Study: An Operator's Analysis of Continuous Monitoring Capabilities

The Committee staff reviewed information provided by one of the ten operators regarding the company's internal analysis of innovative LDAR capabilities. This operator's research team tested six ground-based, fixed sensor LDAR technologies concurrently, all of which possessed at least some continuous monitoring capability.

The operator found promise in all six technologies, despite certain limitations. Three of the six technologies were already mature at detecting methane emissions; five of the technologies approached or achieved full continuous monitoring for emissions; five of the technologies were cost-effective for the operator; all six of the technologies were able to pinpoint the source of methane leaks with at least some degree of effectiveness; and four of the six technologies were able to quantify the size of methane leaks.

While further research and development will allow these continuous monitoring technologies to reach full maturity in the years to come, these test results illustrate that many of the technologies are ready to be adopted and deployed broadly now. Continuous monitoring at scale is realistic and achievable under current circumstances.

Absence of Integrated Multi-Tier Innovative LDAR Systems

None of the operators revealed any intention to develop an integrated multi-tier innovative LDAR approach. In conversations with Committee staff, multiple experts argued that different types of innovative LDAR technologies carry distinct strengths and weaknesses that make them better suited for some aspects of methane leak mitigation than others. For example, satellite systems have the greatest geographic reach, but the lowest resolution. Drones have considerable locational precision, but they are difficult to scale comprehensively. As a result, the preferred approach for oil and gas sector operations in the long term may be to incorporate different innovative LDAR technologies into an integrated system that utilizes different tiers of monitoring, detection, and quantification to enhance emission detection, reduce uncertainty, and accelerate the timeline to pinpoint and repair large methane leaks. At this time, neither industry nor government has established a comprehensive model for integrating disparate data sources on methane leaks while avoiding duplication. As such, a multi-tier LDAR program could be a difficult technical undertaking for any operator. But it is important nevertheless for the oil and gas sector to evaluate the feasibility of such an approach, given its potential to achieve dramatic reductions in operational methane emissions by maximizing the impact of the diverse range of innovative LDAR technologies available today. The absence of even early-stage consideration of multi-tier LDAR strategies on the part of the operators fails to recognize the potential benefits of the approach.

Multi-Tier LDAR Framework: A Model

An effective multi-tier integrated LDAR system could leverage the relative strengths of different technologies to identify and locate methane emissions.

- Ground-based fixed sensors deployed in areas of dense oil and gas infrastructure could monitor continuously and achieve the rapid detection of methane leaks
- Drones could be deployed to isolate emission sources
- Aerial surveys could periodically monitor vast geographic expanses and remote facilities
- Satellite monitoring could quickly alert operators to the largest super-emitting leaks
- Quantification data from each platform could be compared and analyzed to reduce the uncertainty and improve the accuracy of operator estimates regarding aggregate methane emissions from their operations.

Inconsistent Performance Metrics for Innovative LDAR Technologies

The ten operators also provided information regarding their frameworks for evaluating the performance of innovative LDAR technologies. Across the seven operators that provided substantive answers on their innovative LDAR technology evaluation methods, there were dozens of distinct criteria. Three operators provided no clear evaluation methods or criteria in response to the Committee's question. The metrics described by operators largely fell into the categories of:

- Spatial resolution and precision
- Accuracy and reliability
- The technology's performance in different environmental conditions
- Ease of operation
- Cost
- Leak classification
- Platform functionality

Two operators said they compare innovative LDAR technologies holistically to traditional LDAR methods.

Case Study: Disparate Evaluation Metrics for Innovative LDAR Performance

Two anonymized quotes from operator responses serve to illustrate the range of operator sophistication regarding innovative LDAR evaluation criteria. One operator currently uses no consistent set of evaluation criteria:

> *"At this time, [OPERATOR] has not developed a framework to assess performance."*

By contrast, another operator has developed a detailed evaluation framework, comprising six specific metrics. For example:

> *"File formats that are easily filtered and shared with operations..."*
>
> *"... day-rates [that] are amortized over the number of sites visited in a pilot test to develop comparable cost estimates between technologies."*
>
> *"For our operations in the Permian, we have found technologies that can detect emissions at 10 kilograms per hour to be operationally useful to identify emission sources."*
>
> *"[OPERATOR] has a focus on reducing vehicle traffic to contribute to road safety in the Permian. Leak detection solutions that do not require vehicle-based travel for site access receive additional prioritization."*

While each operator must prioritize its own objectives in selecting a suite of LDAR technologies, the lack of broad consensus on the discrete performance standards that can be used to inform innovative LDAR decisions means that each individual operator is left to their own devices when deciding which technologies would be most effective in mitigating methane leaks. This is true when assessing the accuracy of a given technology, and also when determining which technology best meets the operator's unique requirements and vulnerabilities. Companies large and small, companies with vastly different levels of resources, companies requiring different levels of technical assistance, companies confronting different geographic requirements – all must develop their own metrics to appraise the large array of innovative LDAR technologies that are now available on the market. While the lack of a broad industry consensus is no excuse for any individual oil and gas company to act slowly, it is a contributing factor to the sector's general reluctance to rapidly scale up the use of these technologies and reduce their emissions.

One answer to this problem would be for the oil and gas sector to develop its own set of best practices and standards for the performance assessment of innovative LDAR technologies. But the Committee staff confirmed that an industry-wide set of best practices to assist operators in evaluating innovative LDAR technologies does not exist. Best practices could support operators in assessing the accuracy and reliability of different LDAR technologies, overcoming the

technical challenges associated with incorporating those technologies into their existing LDAR programs, and maximizing the impact of selected technologies once deployed. Best practices could also provide a sound methodology for operators to select the technologies most suitable for their operations and scale them appropriately. Industry-wide best practices could play an important role in accelerating the pace of widespread deployments for technologies with critical capabilities in reducing methane emissions from oil and gas operations.

Insights From Comparing Innovative LDAR Quantification Data with GHGRP Data

Oil and gas companies in the United States report data on their methane emissions to the EPA's Greenhouse Gas Reporting Program (GHGRP). The GHGRP requires the oil and gas sector, as well as a host of other industries, to report greenhouse gas emissions (GHG) data from large sources.[53] Reporting is required at the "facility level" except for certain suppliers of fossil fuels and industrial greenhouse gases. About 8,000 facilities across the U.S. are covered by the GHGRP. EPA presents GHGRP information through its public Facility Level Information on Greenhouse Gases Tool (FLIGHT).[54] Methane emissions are presented in megatons of CO2-equivalent / year. Consistent with the Intergovernmental Panel on Climate Change's Fourth Assessment Report, EPA uses a factor of 25 to convert the global warming potential of methane into a CO2 equivalent. Thus, one ton of CH4 is equal to 25 tons of CO2e under the existing methodology used by EPA.

How EPA defines a "facility" in the GHGRP varies according to what type of equipment is being evaluated.[55] For some types of upstream and midstream oil and gas infrastructure, a single, specific site is considered a facility. These include natural gas-fired power plants, processing plants, transmission stations, refineries, LNG facilities, and storage facilities. But for the category of Onshore Oil and Gas Production, (e.g. wells), GHGRP presents the aggregate GHG emissions for all of the emissions reported by each operator from all of their producing assets across the entire basin. Occidental Petroleum, for example, reported it had 14,929 wellheads in the Permian Basin. It claimed 2,107,191 megatons CO2e total methane emissions from these wellheads and other onshore oil and gas production in the Permian Basin for calendar year 2020. Similarly, emissions coming from the assets under the Onshore Oil and Gas Boosting category, which includes gathering pipelines and some compressor stations, are presented on a basin-wide basis for each operator. Pioneer Natural Resources, for example, reported 441,369 megatons of CO2e of aggregate methane emissions from oil and gas boosting in the Permian in 2020.

Since none of the oil and gas companies the Committee surveyed have yet deployed comprehensive continuous monitoring programs to track leaks over time, it is difficult to know how long any given methane leak has existed before being detected and remediated. Under the EPA's current regulatory framework, however, oil and gas operators are required to survey their facilities for leaks twice a year. Companies use the survey data they gather from this regulatory requirement to identify and target leaks for remediation.[56] By assuming that leaks are uniformly distributed under these conditions, researchers and industry alike frequently use an average duration of three months to estimate the lifetime of a leak from start to finish.

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[53] Large sources are those that emit greater than 25,000 MTCO2/year. 40 CFR § 98; Environmental Protection Agency. "Learn About the Greenhouse Gas Reporting Program (GHGRP)." 6 Oct. 2021, accessed here: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp.

[54] Environmental Protection Agency. "Facility Level Information on GreenHouse Gases Tool (FLIGHT)." Accessed here: https://ghgdata.epa.gov/ghgp/main.do.

[55] For more discussion about how EPA has considered defining "facility" for the oil and gas sector, see: Environmental Protection Agency. "Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry." *Technical Support Document*, May 2015, accessed here: https://www.epa.gov/sites/default/files/2015-05/documents/subpart-w_tsd.pdf.

[56] 40 CFR § 60.OOOOa. Accessed here: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-60/subpart-OOOOa.

By converting emission rates into units used by GHGRP, Committee staff compared the methane quantification data from detection surveys conducted for the operators and the emission factor-based methane data that those operators reported to the GHGRP.

Comparing Innovative LDAR Survey Data with GHGRP Data: Company A

Company A produced to the Committee survey data from an innovative LDAR methane detection survey performed in July 2021 in the Permian Basin. The survey identified 44 discrete sites which included tank batteries and wellpads. Some sites yielded multiple measurements, as the surveyor recorded emissions from individual pieces of equipment across single pads. The Company A site found to have the greatest emission intensity during this survey was a tank battery.

Permian Basin Tank Battery

Aerial image from Google Maps, May 25, 2022

The innovative LDAR company collected emissions data from five discrete pieces of equipment at the site. The equipment marked Number 5 in the image above, which appears to be a flare, registered a methane emission rate about 2.5 times higher than the 26 kg/hr rule of thumb

identified by researchers to characterize a "super-emitter."[57] This particular survey did multiple passes over the same sites to establish whether a leak was persistent, and leak Number 5 at the tank battery was indeed persistent. If we assume for comparative purposes that Company A's tank battery leak emitted methane for three months before detection, **this single facility emitted a quantity of methane equivalent to 11.5% of what Company A reported to the EPA GHGRP for the entirety of its Permian oil and gas production activities in 2020.** Furthermore, if only the largest-recorded leaks detected at each of the 44 sites continued to emit at their observed rates for three months, just that small group of leaks would account for **over 40%** of the methane emissions that Company A reported to the GHGRP for its total oil and gas production activities in the Permian in 2020.

Comparing Innovative LDAR Survey Data with GHGRP Data: Company B

Company B produced to the Committee survey data from an innovative LDAR methane detection survey performed in the Permian Basin. The October 2020 survey evaluated 33 discrete sites which included wellheads, tanks, compressors, gas treaters, flares, and vapor recovery units. Of the 33 sites, seven were emitting methane at a rate higher than 26 kg/hr. The Company B site found to have the greatest emission magnitude during this survey was a compressor station. It registered an emission rate more than five-fold higher than the super-emitter threshold of 26 kg/hr. If we assume that Company B's compressor station leak persisted for three months, **this single facility emitted a quantity of methane equal to nearly 17% of what Company B reported to EPA GHGRP** for the entirety of its Permian onshore oil and gas production activities in all of 2020.

Permian Basin Compressor Station

Aerial image from Google Maps, May 25, 2022.

[57] Once again, for these calculations the Committee staff has defined a super-emitting leak as any emission event equal to or greater than 26 KG/HR and assumed a fractional methane content in the natural gas of 80%.

Furthermore, if all 33 of the sites included in this detection survey continued to leak at their observed emission rates for three months, together they would account for **over 80%** of the methane emissions that Company B reported to the GHGRP for its oil and gas production activities in the Permian in 2020.

Comparing Innovative LDAR Survey Data with GHGRP Data: Company C

Company C produced to the Committee survey data from an innovative LDAR methane detection survey of company facilities in the Permian Basin performed in February 2021. Of the 42 sites where methane emissions were detected, 18 were emitting methane at a rate greater than 26 kg/hr. The Company C site with the largest emissions magnitude was a single tank battery. It registered as emitting at a rate massively larger than 26 kg/hour. If we assume that Company C's tank battery leak persisted for three months, **this facility emitted a quantity of methane equal to over 80% of what Company C reported to the EPA GHGRP for the entirety of its onshore oil and gas production activities in the Permian in 2020.**

Permian Basin Tank Battery

Aerial image from Google Maps, May 25, 2022

Furthermore, if all 42 sites with detected methane emissions continued to leak at their observed emission rates for three months, the combined emissions of just those sites would exceed the methane emissions reported by Company C to the GHGRP for onshore oil and gas production in the entire Permian Basin in 2020 by **more than three-fold.**

To be clear, it is not known how long any of the leaks identified during these innovative LDAR surveys persisted before being detected. In addition, the innovative LDAR companies that performed these detection surveys acknowledge that their quantification data comes with some uncertainty. But due to the limitations of the LDAR practices used by the ten operators, it is entirely plausible that super-emitters such as the ones highlighted in this analysis could persist for long periods of time before being detected as part of a regulatory survey. Furthermore, there is no Federal regulatory requirement to prioritize large leaks quickly once they are identified. And the detection threshold for these technologies is low enough, and reliable enough, to detect and quantify the very large majority of methane emissions over a given area.

Companies A, B, and C each oversee enormous numbers of wellheads, pneumatic controllers, and other types of oil and gas production equipment in the Permian Basin. The opportunities for super-emitting leaks to arise are vast. These detection surveys evaluated only a snapshot in time over a portion of the infrastructure that these companies currently operate in the Permian. And yet, under reasonable assumptions, the methane leaks that were detected and quantified in these surveys would – by themselves – account for a significant percentage of the total amount of methane that the production assets of these companies are supposed to be emitting in the Permian for an entire year, or even exceed that annual amount entirely. How many more super-emitters are occurring at any given moment in such a massive area? The data reviewed by the Committee supports the view that greenhouse gas inventories maintained by the Federal government are drastically underestimating the amount of methane being emitted from domestic oil and gas operations, and that many oil and gas companies are aware of the likely discrepancy.

Recommendations for Federal Agencies

Environmental Protection Agency

A host of academic studies and the internal company methane data highlighted in this report suggest that Federal greenhouse gas inventories such as the GHGI and the GHGRP are systematically underestimating methane emissions from the oil and gas sector. But without comprehensive measurement data encompassing all of the country's major oil and gas producing regions, the methane picture will remain too out of focus for targeted policy solutions. This critical data gap can only be addressed by a coordinated effort to supplement existing methodologies for estimating oil and gas sector methane emissions with actual quantification data reflecting real-world conditions.

The Committee staff recommend a new Federal research program to conduct regular methane measurement surveys over the major oil and gas producing basins in the United States. This Methane Census program should be overseen by the EPA. The Methane Census would utilize commercially-available innovative LDAR technologies to perform large-scale methane detection surveys covering the majority of oil and gas infrastructure in each basin and to quantify the size of the detected emissions. The Methane Census would gather data to improve the characterization of oil and gas sector methane emissions in several key aspects, including by segment and by emission source, as well as data regarding the aggregate emissions for each basin. The Methane Census would provide a consistent, reliable source of comprehensive data for domestic oil and gas sector methane emissions. It would also establish a baseline against which methane mitigation policies and voluntary industry actions could be evaluated over time.

The Committee staff also recommend that EPA develop a technical study to inform approaches to reconciling the data from the Methane Census with existing EPA data sources, such as the GHGI. This technical study would evaluate how the methane data sets would interact and how they could complement each other. The technical study would also identify discrepancies between different data sets that would require further analysis, as well as the factors contributing to those discrepancies.

Finally, there is a need for the Federal government to help develop protocols that can be voluntarily applied by other entities, including private sector companies, as they use quantification data to estimate aggregate methane emissions. There are real technical challenges to translating quantification data into an operations-wide picture of methane emissions. The Committee staff recommend that EPA partner with the National Institute of Standards and Technology (NIST) to support the development of voluntary, consensus frameworks, guidelines, or technical standards for estimating aggregate methane emissions using quantification data from commercially available technologies. These technical standards should be generalizable and suitable for adoption by a variety of stakeholders, and should incorporate existing measurement capabilities where available. EPA and NIST should support the development of these consensus technical standards in consultation with the private sector and be prepared to assist private sector entities with its implementation at their request.

Department of Energy

While innovative LDAR technologies are poised to play a critical role in large-scale methane detection and quantification for oil and gas companies, this report has noted that their capabilities remain limited in certain areas. Individual methane measurements, in particular, are subject to a considerable degree of uncertainty that limits the application of quantification data for certain purposes. The improvement of quantification capabilities would allow innovative technologies to better support tailored LDAR programs and detailed methane leak analysis based upon precise measurements. It could facilitate improved methane reporting by oil and gas operators to Federal, state and local regulatory bodies. Greater technological maturity would also help address some of industry's objections to incorporating quantification data into LDAR activities.

The Department of Energy is well positioned to address capability gaps among methane detection and quantification technologies. Previous DOE research and development programs, such as ARPA-E's Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR) program in 2014, were instrumental in developing the existing commercial market for innovative LDAR technologies.[58] The Committee staff recommend the creation of a new program at DOE specifically charged with strengthening the capabilities of methane detection and quantification technologies and addressing the sources of emission measurement uncertainty. This program should direct research investments towards the key capability limitations impacting methane quantification today, such as the influence of environmental factors like wind on quantification accuracy and the challenge of quantifying methane emissions amidst the temporal variability of methane leaks. The program should also support the advancement of data analytics processes to further improve quantification accuracy regarding emission events.

DOE is also equipped to work collaboratively with the oil and gas sector, the innovative LDAR sector and the academic community to foster engagement and support private sector proficiencies. The Committee staff recommend that DOE work with operators, innovative LDAR vendors and academic experts to develop a set of consensus best practices that oil and gas companies can use to inform their personalized decisions about which innovative LDAR technologies are best suited to their operations. These best practices would help operators evaluate the diverse array of innovative LDAR technologies currently available and consider how to incorporate them into their existing LDAR programs.

Finally, the Committee staff recommend that DOE oversee the creation of a Methane Emissions Measurement and Mitigation Research Consortium to bring together stakeholders across industry, academia, the non-profit sector, and all levels of government for the purpose of fostering closer interactions, encouraging research partnerships, and sharing information, research findings and effective LDAR approaches. The Consortium would facilitate more informed decisions about methane leaks and help inform research priorities in the Federal government and the broader scientific community. It would also build upon existing research partnerships and encourage them to continue on a more permanent basis.

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[58] Advanced Research Projects Agency – Energy. "Methane Observation Networks with Innovative Technology to Obtain Reductions." 16 Dec. 2014, accessed here: https://arpa-e.energy.gov/technologies/programs/monitor.

National Academies

Federal science agencies such as NASA, NOAA, and NIST oversee various scientific research and development programs to monitor and quantify greenhouse gases that utilize powerful measurement assets, including some assets that are set to begin operating in the coming years. The Federal government must consider to what degree any of these programs are equipped to detect methane super-emitters from the oil and gas sector and whether Federal programs and agencies can coordinate more effectively to deploy unique Federal scientific assets to improve our understanding of the scale and frequency of super-emitting leaks. The Committee staff recommend that the National Academies of Sciences, Engineering, and Medicine (NASEM) articulate a science-based strategy for the use of present and future greenhouse gas detection and monitoring capabilities, including ground-based, airborne, and space-based sensors and integration of data from other indicators, to detect methane emissions, including from super-emitters.

EPA Rulemaking: Methane Emissions from New, Modified, and Existing Sources

On November 15, 2021, EPA issued a proposed rule to strengthen the regulatory framework around methane emissions from new and modified sources in the oil and gas sector, and to directly regulate methane emissions from existing sources in the oil and gas sector for the first time.[59] The outcome of this rulemaking will likely impact technology developments for years to come. The rulemaking is not the Committee's focus, but there are opportunities to ensure the final product supports scientific innovation.

First, the Committee staff are concerned that the agency's initial treatment of innovative LDAR technologies does not reflect a technology-neutral approach. There is no single best technological approach to methane detection, quantification, and mitigation, and it is critical that EPA develop a regulatory framework that is flexible enough to incorporate novel technological capabilities that have not yet matured but will do so in the coming years. Given the wide range of innovative LDAR technologies and platforms already available on the market – aerial surveys, drones, satellites, ground-based fixed sensors – the agency's approach must allow for all different kinds of technologies to establish their efficacy, and for oil and gas companies to pursue detection technologies that best fit their needs as long as those technologies meet the agency's standards for performance validation.

In particular, it is absolutely vital that EPA's regulatory framework allows for and encourages the deployment of continuous monitoring technologies across oil and gas operations. Continuous monitoring is uniquely suited to mitigating intermittent methane leaks and targeting super-emitters rapidly. Innovative LDAR technologies with continuous monitoring capabilities should have every opportunity to demonstrate their compliance with regulatory requirements alongside other technologies.

[59] Environmental Protection Agency. "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." *Federal Register*, vol. 86, no. 217, pp. 63110-63263, 15 Nov. 2021, accessed here: https://www.federalregister.gov/d/2021-24202.

The draft rule offers a matrix framework as one potential approach to evaluating and approving innovative LDAR technologies for regulatory use, in which an LDAR technology with a lower detection threshold may satisfy regulatory requirements if it is deployed more frequently than a higher-resolution technology. This strategy appears to be promising. But EPA's initial proposal does not go far enough in recognizing the diversity of platforms and sensors that characterize innovative LDAR technologies and in particular, the opportunity to combine multiple technologies to form a comprehensive picture of an operator's emission profile. The agency should consider developing a more expansive and flexible matrix.

EPA currently uses the Alternative Means of Emission Limitation (AMEL) process to evaluate and approve new methane detection technologies for regulatory purposes. Proposed alternatives must show that they can achieve equal or greater emissions reductions relative to the existing standards. EPA should improve the AMEL process so that it is more expedient for innovative methane LDAR technologies to establish their ability to deliver methane emission reductions. LDAR technologies are improving rapidly as existing vendors enhance their offerings and new ones enter the market. A more workable AMEL process that reflects the pace of innovation will ensure greater accuracy, precision, frequency, and breadth of coverage. It will also enable more flexibility for oil and gas operators to select from a range of high-quality LDAR systems according to their own criteria.

Finally, the Committee staff urge EPA to implement a formal framework allowing third parties, including local communities, to report methane leaks to the agency for investigation by oil and gas operators. The maturation of innovative LDAR technologies has made it possible for third party actors to play an important role in oversight of oil and gas sector methane emissions. They can offer a valuable check on data being reported by operators and help ensure that the communities most impacted by localized emissions can contribute to the protection of their own health and safety.

Opportunities for Industry

Oil and gas companies need not wait for further Federal action before aggressively confronting methane leaks from their operations. There are simple, tangible steps that operators can take immediately to reduce methane emissions and increase transparency, entirely independent of any legislative or regulatory policies at the Federal level.

As a first step, there is a valuable opportunity for U.S. oil and gas companies to join the Oil and Gas Methane Partnership 2.0 (OGMP 2.0) Framework. As mentioned previously, this United Nations-sponsored collaboration between environmental groups, governmental organizations, and industry represents the gold standard for transparent, rigorous methane emissions reporting by the oil and gas sector. The OGMP 2.0 Framework provides an advanced methodology for companies to report their methane emissions and calls for the enhanced use of measurement techniques in methane reporting, while setting clear guidelines regarding how companies can adhere to the Framework and align their reporting methods with its best practices. The emission data reported by participating member companies is not disclosed publicly, but it will serve as an important data source for the International Methane Emissions Observatory (IMEO), a new joint UN-European Union initiative to improve understanding of global atmospheric methane levels.[60] Companies that join OGMP 2.0 can thus support global methane science in addition to showcasing greater transparency regarding their methane footprint.

Joining OGMP 2.0 would not impose any additional regulatory burdens on operators. It has minimal costs and clear benefits, both for companies and for the scientific community. Large oil and gas companies from all across the world have joined OGMP 2.0, including BP, Shell, and Total, but participation from U.S. oil and gas companies has noticeably lagged behind their European and international counterparts. Of the ten operators that provided information to the Committee, only Occidental Petroleum has committed to the OGMP 2.0 Framework. The Committee staff commend Occidental for making this voluntary commitment to greater transparency and rigor in its methane reporting. There is no reason why the other nine operators should not do the same if they wish to fully confront their methane emissions. Given that joining the OGMP 2.0 Framework is entirely voluntary and can be done at any time, oil and gas companies that decline to do so will face inevitable questions about their level of commitment to reducing methane emissions and whether they will be prepared to take further necessary actions in the future.

Oil and gas companies also have an opportunity to accelerate the pace of their deployment of innovative LDAR technologies. The oil and gas sector is moving too slowly and too inconsistently to deploy methane detection and quantification technologies at scale within their operations. Too many technologies remain in pilot phase limited deployments despite their emission reduction potential, which has been adequately demonstrated through controlled testing and peer deployments among other companies. Operators can move aggressively beyond pilot evaluations and towards full-scale deployments designed to achieve widespread emission reductions.

[60] United Nations Environment Programme. "Methane." Accessed here: https://www.unep.org/explore-topics/energy/what-we-do/methane.

Finally, oil and gas companies have an opportunity to adopt LDAR strategies and practices that are informed by the most up-to-date scientific research on oil and gas methane emissions. Companies can prioritize the rapid detection and mitigation of super-emitting leaks by defining, identifying, tracking, and characterizing super-emitters, and by designing and equipping their LDAR programs to target them. Companies can embrace the role of quantification as a pillar of methane LDAR and incorporate quantification data into how they prioritize leak mitigation. Companies can acknowledge that not all leaks are created equal, and that the greatest environmental benefit can be gained from prioritizing the largest leaks rather than adhering to outdated mindsets. If oil and gas companies are prepared to accept the science of methane leaks and act on it, the magnitude of benefits for the environment and the sector itself will be immense.

Appendix I: Permian Basin Innovative LDAR Deployments by Operator, 2016-Present

Admiral Permian Resources			
Technology	Status	Scope	Future Commitments
Ground-based continuous monitoring (1)	Ongoing	Pilot, limited scope	No Commitment

Ameredev			
Technology	Status	Scope	Future Commitments
Ground-based continuous monitoring (1)	Ongoing	Pilot, limited scope	No Commitment

Chevron			
Technology	Status	Scope	Future Commitments
Aerial survey (2)	Ongoing	Pilots, limited scope	1 platform selected for Comprehensive Permanent Deployment
Ground-based continuous monitoring (1)	Terminated	Pilot, limited scope	None
Drone survey (1)	Terminated	Pilot, limited scope	None

ConocoPhillips			
Technology	Status	Scope	Future Commitments
Aerial survey (1)	Terminated	Pilot, limited scope	None
Satellite survey (1)	Terminated	Pilot, limited scope	None
Helicopter survey (1)	Ongoing	Pilot, limited scope	No Commitment
Ground-based continuous monitoring (6)	Ongoing	Pilots, limited scope	1 platform selected for limited Permanent Deployment

Coterra Energy			
Technology	Status	Scope	Future Commitments
Aerial survey (2)	Ongoing (1)	Deployed comprehensively (1)	1 platform selected for Comprehensive Permanent Deployment on semiannual basis
	Terminated (1)	Pilot, limited scope (1)	
Ground-based continuous monitoring (3)	Ongoing (2)	Pilots, limited scope	No Commitment
	Terminated (1)		

Devon Energy			
Technology	Status	Scope	Future Commitments
Aerial survey (2)	Ongoing (1)	Deployed comprehensively (1)	1 platform selected for Comprehensive
	Terminated (1)	Pilot, limited scope (1)	

			Permanent Deployment on semiannual basis
Ground-based continuous monitoring (1)	Ongoing (1)	Pilot, limited scope	No Commitment

ExxonMobil			
Technology	**Status**	**Scope**	**Future Commitments**
Aerial survey (3)	Ongoing (1)	Deployed comprehensively (1)	1 platform selected for Comprehensive Permanent Deployment
	Terminated (2)		
Satellite survey (1)	Uncertain	Pilot, limited scope	No Commitment
Helicopter survey (1)	Uncertain	Pilot, limited scope	No Commitment
Drone survey (1)	Uncertain	Pilot, limited scope	No Commitment
Ground-based continuous monitoring (1)	Uncertain	Pilot, limited scope	No Commitment
Truck-mounted survey (1)	Uncertain	Pilot, limited scope	No Commitment

Mewbourne Oil			
Technology	**Status**	**Scope**	**Future Commitments**
Aerial survey (1)	Ongoing	Pilot, limited scope	No Commitment
Ground-based continuous monitoring (1)	Ongoing	Pilot, limited scope	1 platform selected for Comprehensive Permanent Deployment
Satellite survey (1)	Terminated	Pilot, limited scope	None

Occidental Petroleum			
Technology	**Status**	**Scope**	**Future Commitments**
Aerial survey (3)	Ongoing	Pilot, limited scope	Multiple platforms selected for Permanent Limited Deployment
Drone survey (1)	Ongoing	Pilot, limited scope	No Commitment
Ground-based continuous monitoring (2)	Ongoing	Pilots, limited scope	No Commitment
Satellite survey (2)	Ongoing	Pilots, limited scope	No Commitment

Pioneer Natural Resources			
Technology	**Status**	**Scope**	**Future Commitments**
Aerial survey (2)	Ongoing (1)	Deployed comprehensively (1)	1 platform selected for Comprehensive Permanent Deployment, three times per year
	Terminated (1)	Pilot, limited scope (1)	