PermianMAP Final Report

A look back at key findings and takeaways from the Permian Methane Analysis Project

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Acknowledgments
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Environmental Defense Fund
Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

Cover photo: Leslie Von Pless
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See the complete project at PermianMAP.org.

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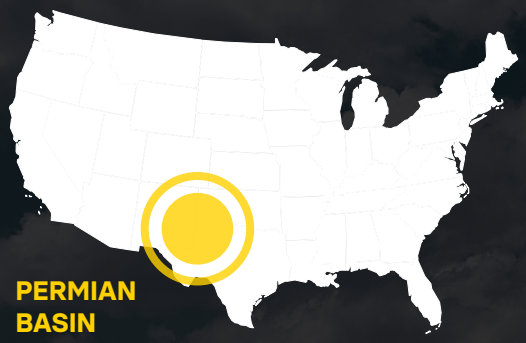
About PermianMAP

In 2019, Environmental Defense Fund launched the Permian Methane Analysis Project (PermianMAP), a first-ever, near real-time **methane monitoring** initiative in the world's largest oil field.

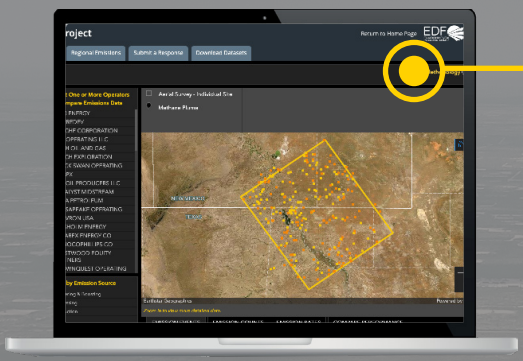


The Permian Basin covers 86,000 square miles of land across West Texas and Southeast New Mexico and is home to tens of thousands of well sites, processing facilities and other oil and gas infrastructure.

Methane is a potent greenhouse gas responsible for at least 25% of current global warming, and the oil and gas industry is one of the world's largest sources of methane emissions.

This potent climate pollutant is completely invisible to the naked eye – which makes **detecting methane** a unique challenge.

Researchers used a variety of scientific methods to **collect methane data and report emissions** coming from the region's oil and gas facilities.

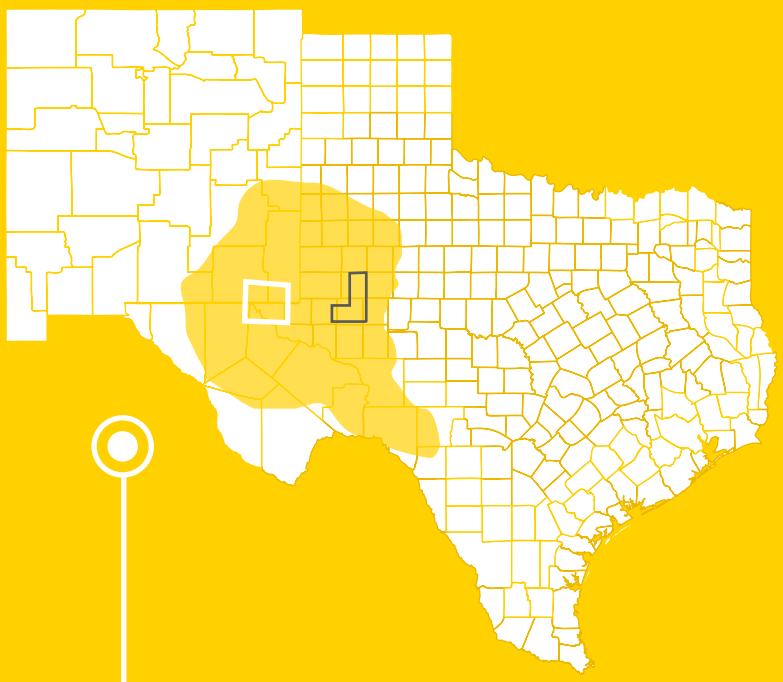


That data was made available to the public online as quickly as possible, enabling oil and gas companies, regulators and other stakeholders to get quality, scientifically **reliable methane emission insights** in a matter of weeks, as opposed to a matter of months of years.

This report highlights key insights and analysis collected between Sept. 2019 and Nov. 2021, including direct measurements taken during an unprecedented period of economic volatility due to the COVID-19 pandemic.

Learn more at PermianMAP.org.

Study Areas



PERMIAN BASIN
86,000 square miles

The majority of measurements are taken in a 10,000 square-kilometer grid that spans the Delaware Basin, a subsection of the broader Permian Region. This high-producing area contains only 10% of the region's active wells and produces 40% of its oil and gas.

We also studied a portion of Midland Basin in order to compare emissions across different subsections of the Permian.

More than 100 companies operate the 11,000 wells and midstream facilities in these study areas. They range from big operators to mid-sized players and small independents that may only own a few wells each.

Data Collection

AIRCRAFT

Researchers with Scientific Aviation first began collecting aerial methane data in late fall of 2019 and conducted more than 100 flights across the Basin throughout 2020 and 2021. Some flights encompassed the full perimeter of our 10,000 km2 study area. Others zeroed in on a cluster of randomly selected wells.

Carbon Mapper researchers partnered with the PermianMAP project in the summer and fall of 2021, detecting nearly 1,700 plumes over 26 flight days.

Leak Surveys Inc. (LSI), a veteran leak detection company, used a helicopter equipped with an infrared camera to conduct surveys of more than 3,000 flares across the entire Permian Basin to determine their contribution to the region's methane emissions.

CELL TOWERS

Methane sensors installed at five towers across the study area continuously measure atmospheric methane concentrations on a 24-7 basis. Using an atmospheric transport model, Pennsylvania State University researchers calculated weekly and monthly averages of regional methane emissions.

MOBILE LABORATORY

Equipped with a mobile methane detection vehicle and an infrared camera, a University of Wyoming team randomly surveyed dozens of individual well sites to identify the specific locations and equipment that may be emitting abnormal volumes of methane.

This approach captures site-level emissions that are often undetectable by aircraft. While the individual emission rates measured are low, the large number of these sites existing in the Permian indicate that even these low magnitude abnormal emissions can add up to large amounts in total. The ground team also gathered data on volatile organic compounds emitted from oil and gas facilities.

SATELLITE

We compared PermianMAP data with measurements taken from the TROPOMI satellite project, which EDF analyzed along with a coalition of international scientists and found similar estimates.

By the Numbers

2,740 TOTAL # OF EMISSION SOURCES DETECTED

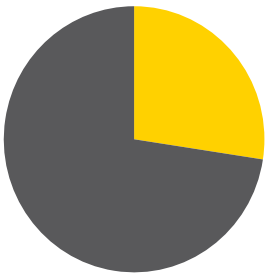
3X HIGHER

Over the course of the project, aircraft measurements have revealed Permian emissions are **2-3 times higher** than what the Environmental Protection Agency estimates in their inventory of greenhouse gas emissions.

FLARING INSIGHTS

8 Total surveys

1,320 Emission sources detected



- 362 Malfunctioning Flares
- 958 Other sources (Tanks, vents, valves)

50%

of super emitters come from midstream operations.

Super emitters are sites that produce a disproportionate amount of methane pollution, releasing 10 kilograms of methane an hour or more.

- Gathering and boosting
- Transmission and storage
- Pipelines and compressors

Mobile laboratory measurements indicate low-producing "marginal wells" are responsible for half of the Permian Basin's well pad emissions. More than 75% of these are owned by major corporations.

Key Insights

Midstream operations and flaring are major emission sources.

Early observations confirmed the Permian Basin is the highest-emitting basin in the United States. The amount of gas lost — 3.5% of what companies produce — is 15 times greater than what many leading companies have pledged to achieve.

Satellite observations also confirmed that methane levels in the Permian are higher than any other oil and gas-producing region in the country.

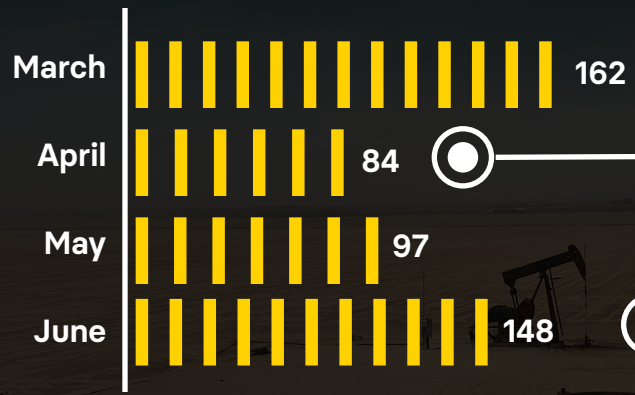
However, by April 2020, once the economic impacts of the COVID-19 pandemic hit, data collected from our network of cell phone towers observed emissions plummeted 60%.

PermianMAP researchers estimate the drop is the result of a decline in new wells coming on line. During more typical price conditions, wells are developed at such a rapid rate that the pipelines, compressor stations, and processing plants can't handle the influx of new gas production because operators haven't made arrangements needed to move produced gas downstream. This results in more intentional and unintentional releases of gas.

Our research shows that flaring is also a significant source of methane pollution. We conducted several different aerial surveys of over 3,000 flares and consistently found that about 10% were either malfunctioning, or completely unlit — venting methane directly into the atmosphere. A drop in the overall amount of flaring, therefore, significantly reduced emissions across the basin.

These observations are highly valuable for understanding the root cause of emissions and informing actions to permanently reduce them. They confirm it is critical that the rate of well development does not exceed the capacity of midstream infrastructure. In addition to eliminating the practice of routine flaring , aligning upstream and midstream development should permanently improve the emissions performance. These findings are available in the journal Atmospheric Chemistry and Physics.

2020 Permian methane emissions (metric tons per hour)
Detected via aircraft and cell phone tower network



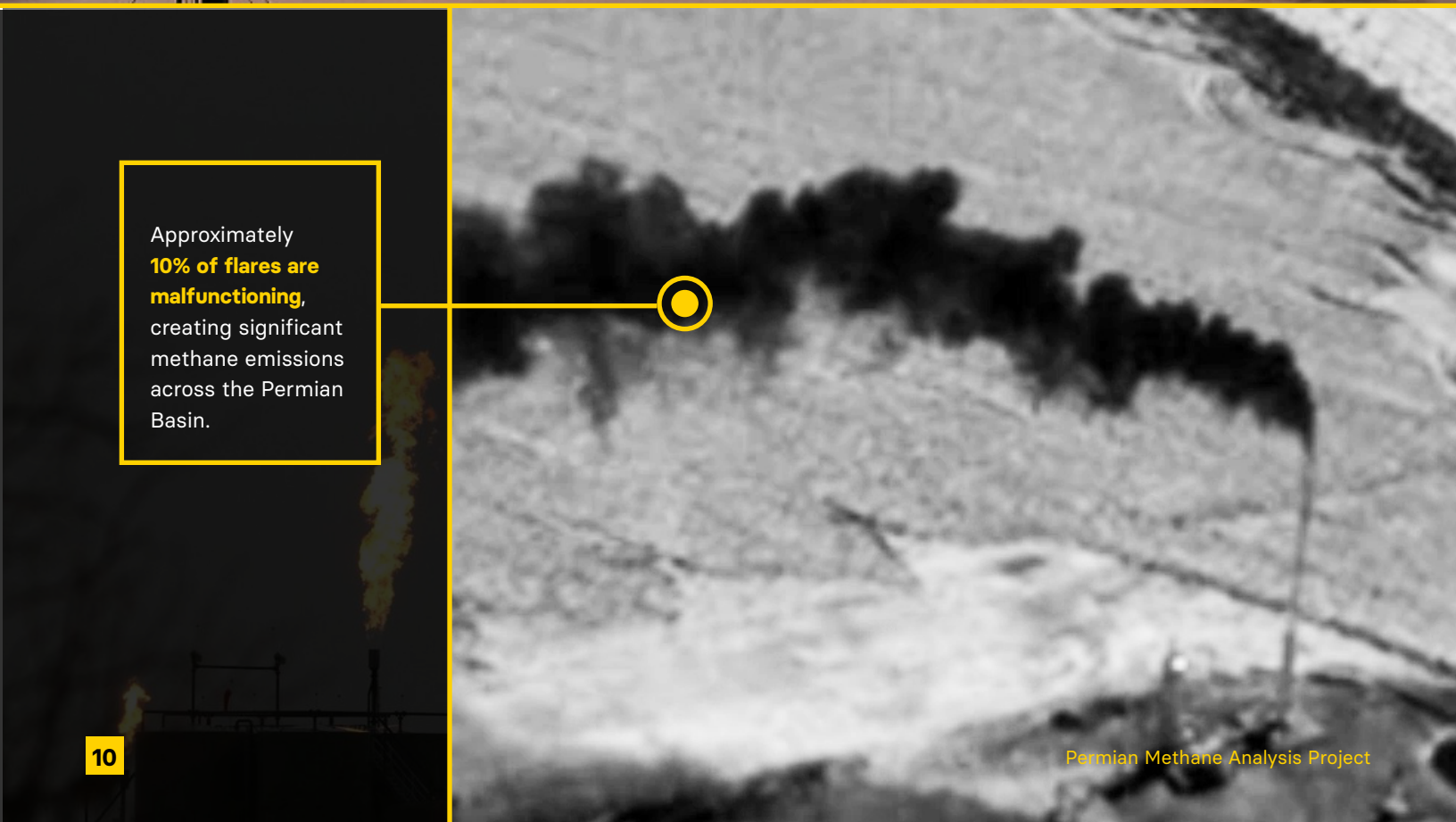
When pandemic first hits, emissions fall by 60%, while production declines 10%.

By summer emissions return to pre-pandemic levels

> **"I knew we would find a lot of pollution, but I had no idea flaring emissions would be this bad."**

David Lyon
Senior Scientist
Environmental Defense Fund

Approximately **10% of flares are malfunctioning**, creating significant methane emissions across the Permian Basin.



Super emitters persist basin-wide and many go unreported.

Throughout the course of the project, we found recurring evidence of super emitters in both the midstream and upstream sectors. Super emitters account for a small number of unique sites, but make up the majority of the region's emissions. Nearly every single one of the 130 flights conducted by Scientific Aviation and Carbon Mapper detected a high-emitting facility.

On Sept. 23, 2020, we detected the largest super emitter of the project at a midstream facility in Midland County, Texas. It emitted 12 metric tons of methane into the air each hour. We notified the operator immediately and emissions were stabilized within about 24 hours. Satellite data reveal the facility had at least a dozen large emission events dating back to July 2020, indicating persistent malfunctions over the course of several months.

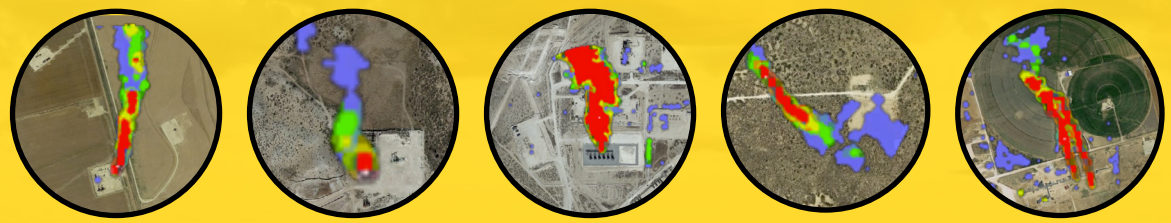
Under state and federal regulations, operators are not required to report abnormal methane events to the state — so many of these episodes are not reflected in public databases.

From what little has been reported to the state, we know this incident produced at least 15 tons of smog-forming volatile organic compounds. The carcinogen benzene was emitted at 7 times the legal level. This does not reflect all emissions that may have occurred. Satellite analyses, which found consistent emissions for months, suggest total emissions from this event to be on the order of 16,000 tons of methane, over a thousand times larger than the reported value.

This stark example of rampant, unreported emissions suggest the improved oversight and more stringent reporting requirements could help keep track of and prevent these ongoing emission problems.

Examples of super emitters from upstream and midstream facilities

Plumes detected and enhanced by Carbon Mapper



Tank | Well pad | Compressor | Pipeline | Processing

How marginal well data gets collected

The research team used a method developed by the Environmental Protection Agency to measure site-level emissions from well pads and tank batteries, all accessible from public roads. By parking their mobile laboratory downwind of sites for ~30 minutes, researchers quantified total emissions of methane and volatile organic compounds and hazardous air pollutants like benzene. Additionally, they surveyed sites from the fence line with an infrared camera so they could see large emission sources.

Low-producers can be high-polluters.

In addition to our aerial surveys and network of tower-based methane monitors, the atmospheric science mobile lab, operated by researchers with the University of Wyoming allowed us to get more granular emissions data from specific sites within the Permian Basin – including "marginal wells", or wells that produce less than 15 barrels of oil or natural gas equivalent a day. The Permian Basin includes tens of thousands of older, low production wells drilled as early as the 1930s.

Site level measurements at marginal wells as part of this campaign were included in a national synthesis study to find several critical insights:

- On average, marginal wells are losing approximately 10% of their gas — several times more than their high-volume counterparts.
- Cumulatively, these wells account for about half of total observable well-pad emissions in the Permian Basin.

These results are in line with similar observations collected by the same research team in 2018. That study, published in ***Environmental Science and Technology***, along with a **number of others** also concluded that on aggregate, low-producing wells had more emissions than their high-producing counterparts.

Historically, regulators have often excluded low-producing well sites from complying with methane reduction programs. This research indicates that to be maximally effective, marginal wells should not be excluded from compliance with regulatory programs.

Operator Performance

METHANE INTENSITY OF MAJOR PRODUCERS IN THE STUDY REGIONS

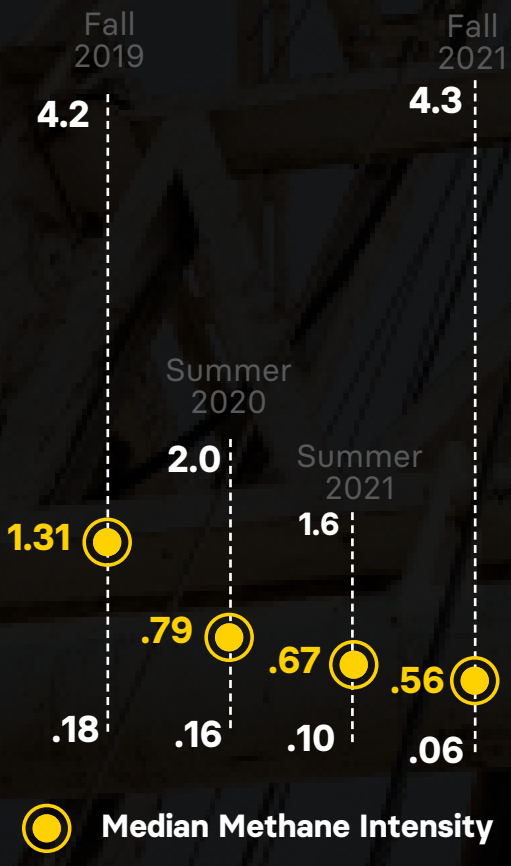
Average % of gas lost from super-emitting sites during aerial campaigns

0% 2.7%

LOW	MEDIUM	HIGH
.1% - .7%	.7% - 1.4%	1.4% - 2.7%
Chevron	ConocoPhillips	BP
Coterra	Diamondback	BTA
EOG	Occidental	Devon
Exxon	Shell	Endeavor
Pioneer		Mewborne

CHANGES IN METHANE EMISSION INTENSITY

Four assessments conducted between 2019-2021



We analyzed data from several aerial surveys conducted between 2019 and 2021 to identify emissions profiles of 14 highly producing operators in the Permian. This dataset represents EDF's first public characterization of oil and gas operator emission intensity (methane leakage) using empirical datasets. These results are specific to the Permian Basin and cannot be generalized to assets in other regions. The emission sources detected in this study represent a sizeable fraction of the total emissions profile (nearly 1% of an operator's gas production on average). Numerous smaller emissions sources, especially those present at low production facilities, are not characterized by this data. This analysis only examined emissions from the production sector, emissions from gathering processing and transporting of gas are also significant. For these reasons, the leak rates in our graphics only represent a fraction of total emissions.

Site-level emission rates vary greatly over time. This analysis represents average results from several snapshots in time and does not necessarily reflect long-term performance.

The top figure groups operators according to their average emission intensity assessed over the four campaigns. While this reflects the mean performance, we observed changes within the four campaigns over three years, as seen in the second figure.

These measurements were conducted throughout a period of highly variable activity in the Permian, complicating interpretation of the observations.

Many operators showed a large decrease in emissions intensity after 2019 with smaller reductions across the later campaigns. EDF shared results with operators and the public as the data became available during this time period. In recent years, several producers have incorporated similar aerial monitoring efforts to quickly identify and mitigate large emission sources Nevertheless, some operators showed no changes as well as increases for subsequent campaigns. Almost all operators' emissions intensity in the Permian are above the 0.2% threshold commitment set by industry, indicating further action is needed to address emissions in the Permian.

Methane Solutions

Since EDF commenced the PermianMAP measurement campaign, many public and private entities have taken significant steps to curb oil and gas methane emissions.

State action

The state of New Mexico moved to reduce methane emissions from oil and gas facilities by proposing some of the strongest methane pollution standards in the country. The standards, which were informed with the help of data collected through this campaign, will require comprehensive leak inspections at nearly all production sites.

The state also developed and implemented a ban on routine venting and flaring, becoming one of the first states to do so and setting a powerful national example.

The Texas Railroad Commission, under increasing public scrutiny, has also moved to increase oversight and transparency around flaring. While insufficient to match the state's flaring challenge, the acknowledgment garnered national attention and has helped build momentum toward federal policy to address routine flaring and the methane emissions it drives.

National leadership

In November 2022, the U.S. Environmental Protection Agency proposed to strengthen the nation's current methane regulations. The proposal is aimed at reducing methane from many of the nation's new and existing oil and gas facilities – including midstream operations. EPA is tacking comment on the proposal which is expected to be finalized.

PermianMAP data has helped inform the EPA's development of strong proposed methane regulations, and underscores the importance of addressing smaller, leak-prone wells and routine flaring in the agency's final rule.

Global commitments

At the United Nations' global climate conference (COP26), more than 100 countries representing 70% of the global economy signed on to a global methane pledge, agreeing to reduce 30% of global methane emissions by 2030.

Company response

In Nov. 2020, the Oil and Gas Methane Partnership – a consortium of more than 80 companies with assets on five continents – required its members to participate in a comprehensive measurement-based methane reporting framework that standardizes rigorous and transparent emissions accounting practices.

EDF's science in the Permian continues to be a powerful proof point for industry engagement.

Companies increasingly understand the need for enhanced leak detection and the direct measurement of methane emissions and many have supported the state, national and global efforts to regulate methane emissions.