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Measuring Methane:

A Groundbreaking Effort to Quantify Methane Emissions from the Oil and Gas Industry

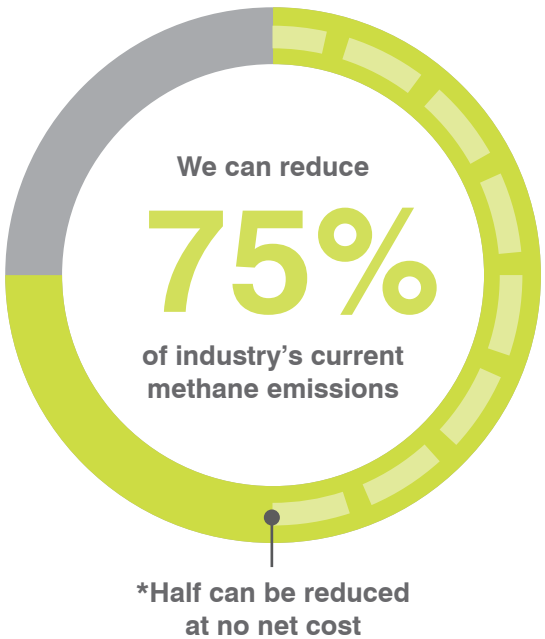
Coordinated by Environmental Defense Fund (EDF) and conducted by more than 140 researchers from 40 institutions, this five-year set of studies of the U.S. oil and gas industry has set a new standard for measuring and mapping methane emissions worldwide.

Methane emerges as one of industry's greatest risks

Methane is a short-lived greenhouse gas that traps at least 80 times more heat than carbon dioxide over 20 years after its release. Consequently, 25 percent of today's warming is driven by methane emissions from human activities.

Tackling climate change requires both rapid reductions of emissions of carbon dioxide, a long-lived climate pollutant, as well as methane and other short-lived climate pollutants. The world's oil and gas industry, which accounts for about one-third of all human-caused methane emissions, represents a critical opportunity for quick and cost-effective emissions reductions.

Government and company action is critical to achieving the significant emissions reductions currently possible. In fact, the International Energy Agency estimates it is feasible to cut global oil and gas methane emissions by 75 percent—and that up to two thirds of those reductions can be achieved at zero net cost.



**According to the International Energy Agency*

Despite dramatic growth in shale development, the scale of U.S. oil and gas industry methane emissions has remained highly uncertain. Until recently, the U.S. Environmental Protection Agency's (EPA) annual estimates of methane emissions from oil and gas were based primarily on data collected in the early 1990s, pre-dating industry's increased use of horizontal drilling and hydraulic fracturing.

Since 2010, the EPA estimates have varied by a factor of two, based on differing assumptions about emissions from key activities associated with hydraulically fractured well sites and from other sources.

Large data gaps prevented concerned scientists, policy makers, citizens and even some industry experts from understanding the climatic implications of increasing natural gas production and use.

Research Objectives:

Establishing a reliable benchmark for methane emissions from the U.S. oil and gas industry

In 2012, Environmental Defense Fund (EDF) initiated the largest, collaborative methane research project to date: a five-year series of studies that scrutinized methane emissions from the oil and gas supply chain in the United States. Our goal was to provide a clear picture of the scale and scope of methane emissions sources and identify the largest opportunities for reductions.

We organized more than 140 independent experts from 40 different research institutions to lead measurement campaigns. More than 50 oil and gas companies from across the supply chain also provided site access and technical input.

Studies were funded largely by philanthropic donors with individual companies providing additional funding to some academic researchers. Consistent with EDF policy, funds received and used by EDF came from philanthropic sources.

Key Objectives

- Fill data gaps and advance the knowledge of U.S. oil and gas industry methane emissions
- Deploy a wide variety of data collection methods to reduce uncertainty
- Examine emissions from each segment of the supply chain

Key Research Principles

Our research was guided by five core principles:

- Projects were led by academic scientists
- Multiple methods were used to quantify emissions when possible
- Research was reviewed by independent scientific experts
- Data was publicly released
- Results were published in peer-reviewed journals

Results and Publications

Since the first study published in 2013, this research effort has:

- Resulted in 35 peer-reviewed published papers
- Informed state and federal methane policies
- Catalyzed EDF's work with companies to develop and test innovative technologies to reduce emissions
- Inspired an additional global research effort under the auspices of UN Environment

Key Research Findings

- Methane emissions are significant across the whole supply chain; production of oil and gas accounts for largest share
- Inventories systematically underestimate overall emissions
- Emissions from unpredictable, widespread sources are responsible for much, but not all, of the discrepancy

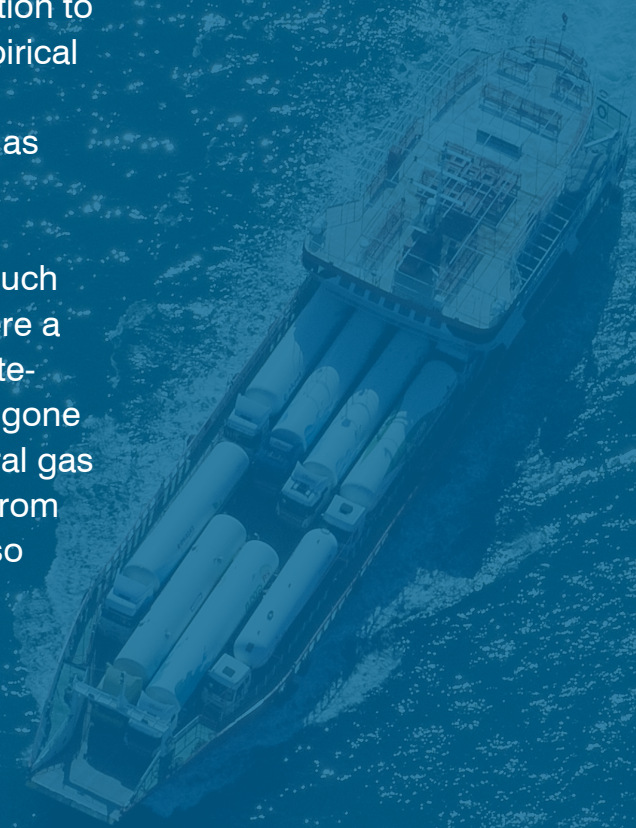
Major contributions to the improved understanding of oil and gas methane emissions also came from a large community of researchers who worked independently of the EDF-coordinated studies.

1

Methane is **emitted** across the supply chain

Field measurements confirmed substantial emissions occur at each segment of oil and gas development, from production to transport to delivery. In the U.S., studies comparing empirical data from recent research to previous EPA Greenhouse Gas Inventory estimates suggest some segments, such as processing, had been overestimated.

In contrast, production and gathering emissions were much higher than reported. In particular, gathering stations were a major source of overlooked emissions. For well pads, site-level measurements indicate significant emissions have gone unreported. Upstream emissions are not limited to natural gas wells or hydraulically fractured wells; in fact, emissions from conventional and unconventional oil-producing wells also appear to be high.



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Inventories **underestimate** overall emissions

There are two general approaches used to estimate oil and gas methane emissions:

Bottom-Up

The bottom-up approach typically used in inventories to estimate regional emissions relies on multiplying activity data (e.g., number of wells) by emission factors (e.g., average emissions per well). This approach, when used in isolation from other methods, can bias the emissions estimates low.

This occurs because oil and gas activity data often have high uncertainty, especially counts of equipment.

It is difficult to accurately quantify total emissions at a given site based only on equipment-level measurements as sources may be overlooked, unsafe to measure, or exceed the maximum emission rate of the measurement technique.

Developing emissions factors that are representative of the total population also requires the use of stratified sampling strategies to accurately account for high-emitting sources. Quantifying total site-level emissions immediately downwind of sites can correct for these effects.

Top-Down

A top-down approach uses methane concentration data collected across an entire basin from surface, aircraft, tower, or satellite observations in combination with atmospheric transport models to estimate site or regional emissions. These techniques have developed rapidly and are effective at both quantifying overall emissions as well as attributing emissions to thermogenic versus biogenic (cattle, landfills, wetlands, etc.) sources. This can be done through the use of hydrocarbon ratios or isotopic signatures. Top-down methods are effective for estimating regional emissions, but they are not effective at pinpointing emissions sources.

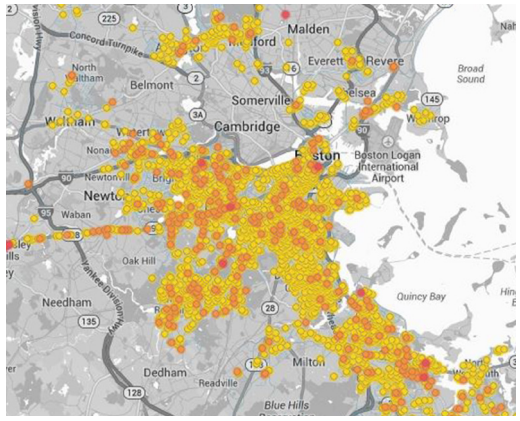
Methane Leak Rate Impacts

- A 2.3% methane leak rate is enough to erode much of the climate advantage gas has over coal
- The volume of lost gas is enough to heat 10 million American homes for a year
- This lost gas is valued at more than $2 billion

3

Emissions are driven by **routine and abnormal** events

Researchers have now characterized emissions from the most common sources and facilities throughout the supply chain and consistently found the existence of heavy-tailed distributions. Observed across a wide range of equipment type and field practice, these distributions are characterized by the outsized influence of a minority of sources on total emissions. On one hand, most sources in a given population usually recorded lower emissions, indicating that companies can effectively control emissions with available technology. However, a significant portion of methane emissions was attributed to “super emitters”—a random assortment of facilities that, sometimes due to mechanical failure, sometimes due to operator error, can send large quantities of methane into the atmosphere. These super emitters are largely absent from emission inventories.



> “The takeaway is clear. Operators need to be **vigilant** in monitoring for leaks. And we need **strong methane policies** to ensure all operators are doing so—not just the leading companies that have implemented leak detection and repair programs voluntarily.”

Matt Watson, EDF Vice President, Energy

Taking Methane Research Global

EDF's initial oil and gas methane studies focused on well-to-meter emissions in the United States, but the issues addressed in this work extend beyond its borders. Recent research conducted in Alberta, Canada corroborates key U.S. findings: measured emissions are higher than reported emissions and a small share of overlooked emitters drive most of the discrepancy.

Several efforts are underway to advance methane research globally. EDF's affiliate MethaneSAT LLC plans to launch a purpose-built satellite (MethaneSAT) to measure and map emissions worldwide to enhance our understanding of the global methane challenge.

EDF, the Oil and Gas Climate Initiative companies, and the UN Environment's Climate and Clean Air Coalition are also collaborating on a set of new peer-reviewed methane studies in key locations across the globe, which will complement the data collected by MethaneSAT.

EDF Coordinated Methane Studies: List of Papers

Scientists have published 35 peer-reviewed papers related to EDF-coordinated U.S. oil and gas methane emissions research. The list below includes the publication date and brief description. Links to all papers can be found at **edf.org/climate/methane-studies.**

1. December 2013: UT Production study
2. May 2014: NOAA DJ Basin Flyover
3. November 2014: HARC/EPA Fence-line study
4. December 2014 UT Pneumatics Study
5. December 2014 UT Liquid Unloadings Study
6. January 2015: Harvard Boston Urban Methane Study
7. February 2015: CSU Transmission and Storage study, Measurement paper
8. February 2015: CSU Gathering and Processing study, Measurement paper
9. March 2015: WSU Local Distribution study
10. May 2015: CSU Gathering and Processing study, Methods paper
11. July 2015: CSU Transmission and Storage study, National results paper
12. August 2015: CSU Gathering and Processing study, National results paper
13. July 2015: Barnett Campaign (13-24): Overview
14. NOAA led Top-down study
15. Bottom-up inventory - EDF
16. Functional super-emitter study - EDF
17. Michigan airborne study
18. WVU compressor study
19. Princeton near-field study
20. Purdue aircraft study
21. Aerodyne mobile study
22. University of Houston mobile study
23. Picarro mobile flux study
24. University of Cincinnati tracer apportionment
25. December 2015: Barnett Synthesis
26. March 2016: Abandoned & Orphaned Wells
27. April 2016: Helicopter survey
28. August 2016: Indianapolis study
29. December 2016: Pump-to-wheels measurement study
30. December 2016: High flow sampler paper
31. January 2017: Barnett component paper
32. March 2017: Local distribution pipeline leak mapping
33. July 2017: Emissions Variability in the Eagle Ford Basin
34. November 2017: Pump-to-wheels modeling paper
35. June 2018: Synthesis of U.S. methane measurements - EDF

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edf.org/climate/methane-studies