U.S. House Committee on Energy and Commerce
Subcommittee on Environment, Manufacturing, and Critical Materials
"Protecting Clean American Energy Production and Jobs by Stopping EPA's Overreach"
[January 10, 2024]

1. Letter to Chair Johnson and Ranking Member Tonko from the Portland Cement Association, January 10, 2023, submitted by the Majority.
2. Letter to Administrator Regan by Chairs Rodgers and Johnson, June 9, 2023, submitted by the Majority.
3. Letter to Administrator Regan by Chairs Rodgers and Johnson, November 7, 2023, submitted by the Majority.
4. Letter to Chair Johnson and Ranking Member Tonko from the Center for Methane Emissions Solutions, January 10, 2024, submitted by the Majority.
5. Report from the American Association for the Advancement of Science entitled, "Inefficient and Unlit Natural Gas Flares Both Emit Large Quantities of Methane" submitted by Rep. Barragan.
6. Letter to Administrator Regan from the Congressional Hispanic Caucus, December 22, 2021, submitted by Rep. Barragan.

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Portland Cement Association
200 Massachusetts Ave NW, Suite 200
Washington D.C., 20001
202.408.9494 Fax: 202.408.0877
www.cement.org

January 10, 2023

The Honorable Bill Johnson
Subcommittee on Environment,
Manufacturing, & Critical Materials
Energy & Commerce Committee
Washington, DC 20150

The Honorable Paul Tonko
Subcommittee on Environment,
Manufacturing, & Critical Materials
Energy & Commerce Committee
Washington, DC 20150

Dear Chairman Johnson and Ranking Member Tonko:

The Portland Cement Association (PCA)[1] appreciates you holding the hearing titled, *Protecting Clean American Energy Production And Jobs By Stopping EPA's Overreach.* This hearing is important to examine potential harm from decreasing domestic natural gas supplies. We encourage pragmatic energy policies that balance environmental protections with the energy supplies necessary for economic growth.

This hearing is essential, as an opportunity to share our progress and challenges with Congress, as the cement industry decarbonizes. We hope that you use this hearing to evaluate future federal permitting and regulatory reform along with the investments needed to reduce manufacturing emissions. We also encourage you to hold future hearings on industrial decarbonization. Additionally, as the Committee considers public policies for decarbonization, it should consider the availability of the materials, its resilience, and its ability to protect life.

Portland cement is the fundamental ingredient in concrete. Cement and concrete products are used to build highways, bridges, runways, water & sewage pipes, high-rise buildings, dams, homes, floors, sidewalks, and driveways. The Portland Cement Association promotes safety, sustainability, and innovation in all aspects of construction, fosters continuous improvement in cement manufacturing and distribution, and promotes economic growth and sound infrastructure investment. Our members represent the majority of cement production capacity in the United States and serve nearly every congressional district.

PCA's members represent the majority of cement production capacity in the United States and serve nearly every congressional district. The cement and concrete industry contribute over $100 billion to the U.S. economy and employs over 600,000 people.

Cement – the principal ingredient in concrete – makes civilization possible. The mixture of portland cement, aggregate, and water makes the building material concrete. Concrete is essential to the modern world. It is used in the pipes and facilities that deliver clean water, to build the ports essential to world trade, to construct mass transit systems connecting people, and in the buildings we work and live in.

Cement is manufactured through an energy-intensive process, utilizing traditional fossil and alternative fuels. The process uses a tightly controlled chemical combination of calcium, silica, aluminum, iron, and other minor ingredients. These chemicals are commonly derived from limestone, chalk, or marl, combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These materials are heated to high temperatures, 2700°F or more, until they liquefy and become clinker. The amount of energy to create one ton of clinker is about 4 million British Thermal Units. Once cooled, gypsum is added to the clinker, and the product is ground into the fine powder that becomes portland cement, the main ingredient in concrete.

The cement industry is decreasing the carbon intensity of its operations and products, is fully committed to decarbonization, and remains focused on improving the energy efficiency of cement plants. For us to become more energy efficient and achieve our decarbonization goals it will require greater access to reliable and affordable energy alongside major improvement to the numerous permitting hurdles our members face.

A key tool of reducing greenhouse gas emissions as advanced carbon management technologies deploy is fuel switching from coal and petroleum coke to natural gas. Natural gas has half the CO_2 emissions (53.06 kg/mm BTU) compared to those of coal (103.69 kg/mm BTU) or petroleum coke (102.41 kg/mm BTU). Over the last decade, as domestic supplies have increased, so has the ability for the cement industry to shift to this fuel. In 2016, cement kilns were utilizing about 10% of their fuels as natural gas. For 2022, it increased to 27.8%. While many cement plants have been able to increase their natural gas use, many do not have access to natural gas in sufficient quantities to transition to the fuel. Federal and state permitting, and other regulatory roadblocks, curtail natural gas access in many regions of the country. Further, recent Environmental Protection Agency actions on methane from natural gas production could harm shifts to cleaner fuels from coal through price increases and supply decreases.

We encourage the Committee to use this hearing to review the impacts to consumers in the industrial sector. We support federal policies that balance environmental protections with economic growth, particularly as the industry shifts to cleaner technologies. We look forward to working with the Committee on legislation and agency oversight as it considers its next steps. If you have any further questions, please contact me at soneill@cement.org or 202.719.1974.

Sincerely,

Sean O’Neill
Senior Vice President, Government Affairs
Portland Cement Association

CATHY McMORRIS RODGERS,
WASHINGTON
CHAIR

FRANK PALLONE, JR., NEW JERSEY,
RANKING MEMBER

ONE HUNDRED EIGHTEENTH CONGRESS

Congress of the United States
House of Representatives
COMMITTEE ON ENERGY AND COMMERCE

2125 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6115

Majority (202) 225-3641
Minority (202) 225-2927

June 9, 2023

The Honorable Michael S. Regan
Administrator
U.S. Environmental Protection Agency
Mail Code 1101A
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Dear Administrator Regan:

We write regarding the U.S. Environmental Protection Agency's (EPA) proposals for new methane regulations under Section 111 of the Clean Air Act (CAA) and the agency's implementation of the Methane Emissions Reduction Program under Section 60113 of the Inflation Reduction Act of 2022 (IRA). The EPA's regulatory proposal for methane creates substantial legal and regulatory uncertainty, which discourages energy production and increases energy prices. The EPA is also planning to add to the regulatory burden with a new tax on methane emissions. As the Congressional Budget Office determined, a tax on methane emissions will increase operational costs, reduce energy production, and increase the price of natural gas.[1]

On November 2, 2021, EPA proposed three separate actions to regulate methane emissions from new and existing oil and gas well sites, compressor stations, processing plants, and transmission and storage facilities.[2] This proposal would dramatically expand EPA's regulatory reach, and it would undercut rules issued under the prior administration that removed regulatory duplication and would have saved millions of dollars each year.[3] The EPA's proposal violates statutory requirements under CAA Section 111 that require, as a predicate to establishing regulations for new sources, a finding that methane emissions from a source significantly contributes to air pollution that endangers public health or welfare. The EPA's proposal also imposes improper requirements on States to issue additional methane regulations for existing sources under CAA Section 111(d).

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[1] See https://www.cbo.gov/publication/58444#:~:text=30%20Section%2060113%20of%20the,emissions%20affects%20outcomes%20as%20well.

[2] See "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," 86 Fed. Reg. 63110 (November 15, 2021).

[3] See "Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Review" 85 Fed. Reg. 57018 (September 14, 2020).

Energy facilities subject to EPA's aggressive regulatory proposals must also plan for compliance with EPA's new Methane Emissions Reduction Program, under which EPA will impose and collect a tax on the reported metric tons of methane emissions that exceed certain thresholds, based on the type of facility, and the amount of natural gas sent to sale. There are several aspects of the methane tax that are undefined in statute, and since there was no hearing, committee report, or debate in Congress, there are significant questions about how the methane taxes and regulations will interact with each other.

While the CAA contains exemptions for regulatory compliance, and when there is a lack of pipeline infrastructure available, it is unclear how EPA will calculate the tax and which operators will be forced to comply. There are also questions about how emissions are reported, whether EPA is coordinating with States, and when EPA will enforce compliance with new taxes and regulations.

To assist with our review of EPA's authorities for methane taxes and regulations under the CAA, we ask that you provide responses to the questions and requested documentation below, no later than June 23, 2023.

1. What is the status and timeline of the proposed regulations under subsection (b) and (d) of Section 111 of the CAA?

2. What is the status and timeline of EPA's implementation of the Methane Emissions and Waste Production Incentive Program?

3. How will the EPA calculate the methane tax?

4. Many of the provisions in the methane tax are based on excess emissions related to natural gas sales.
    a. Since the chemical composition and properties of natural gas differ regionally and is not continuously monitored, how will the EPA require operators to calculate the mass of natural gas sales?
    b. Will operators be challenged by EPA's office of enforcement and compliance or subject to audits?

5. The EPA requires reporting from facilities above an emissions threshold of 25,000 metric tons of CO_2e under Subpart W of 40 C.F.R. Part 98. Subpart W is an approximate emissions estimating tool that wasn't designed for tax collection purposes.
    a. How does the EPA intend to revise the requirements for emissions reporting under Subpart W? If so, what is the timeline for those revisions?
    b. How will the EPA provide guidance to small operators regarding the calculation of the 25,000 metric ton threshold to avoid unnecessary regulatory burdens or audits by EPA enforcement?

6. How will the EPA enforce compliance with methane taxes and regulations?
    a. How soon after finalizing the Methane Emission Reduction Program does the EPA intend to begin enforcement?

   b. Will the EPA penalize operators for non-compliance?
   c. Will the EPA use the methane tax to initiate enforcement actions?

7. How does the EPA interpret the statutory exemptions to the methane tax?
   a. Will EPA notify operators that they are exempt from the methane tax?
   b. The EPA is required to exempt methane emissions "caused by unreasonable delay…in environmental permitting of gathering or transmission infrastructure necessary for offtake." How will the EPA make such determinations?
   c. The EPA is required to exempt operators of facilities "subject to and in compliance with methane emissions requirements pursuant to subsections (b) and (d) of section 111…" Please describe the steps that the EPA is taking to harmonize the new taxes and regulations for methane.

8. Please describe how the EPA is coordinating with States on its implementation of the methane tax.
   a. For example, existing source regulations may be predominantly implemented by States under 40 CFR Part 60 Subpart OOOOc. How is the EPA planning to assure that the required exemptions will be available to operators?

9. Please describe how the EPA is coordinating with relevant stakeholders on its implementation of the methane tax.

10. Please provide an accounting of all financial assistance provided, or proposed to be provided, and the type (*e.g.* grants, rebates, contracts, loans, or other activities) under the Methane Emissions Reduction Program.

11. Please describe any technical assistance provided by the EPA to the States or regulated owner or operators of oil and natural gas facilities.
    a. Please explain how the EPA will avoid using technical assistance to owners and operators or oil and natural gas facilities to initiate enforcement actions.

12. Please describe any Executive Orders that may apply to the Methane Emissions Reduction Program or new methane regulations.

13. Will the EPA utilize the Social Cost of Carbon, the Social Cost of Methane, or other tools or models to estimate environmental costs related to climate change to implement the Methane Emissions Reduction Program? Will the EPA utilize such tools or models to develop new regulations for methane emissions under Section 111 of the CAA?

14. On April 21, 2023, President Biden signed Executive Order 14096, "Revitalizing Our Nation's Commitment to Environmental Justice for All," requiring a "whole-of-government" approach to environmental justice.
    a. Does this Executive Order apply to EPA, and if so, how does EPA plan to comply with the Executive Order regarding the Methane Emissions Reduction program and new regulations for methane emissions under Section 111 of the CAA?

15. Will the EPA incorporate "equity benefits," a term used in the May 5, 2023, proposed rule for natural gas pipeline leak detection and repair issued by the Pipeline and Hazardous Materials Safety Administration, in the methane tax and/or the new regulations for methane emissions under Section 111 of the CAA?
    a. If so, please describe the EPA's statutory authority and methodology for estimating "equity benefits" for use in agency rulemaking.

If you have any questions about this request, please contact Brandon Mooney, Elise Krekorian, or Mary Martin with the Majority staff at (202) 225-3641.

Sincerely,

Cathy McMorris Rodgers
Chair
Committee on Energy and Commerce

Bill Johnson
Chair
Subcommittee on Environment, Manufacturing, and Critical Materials

CATHY McMORRIS RODGERS, WASHINGTON
CHAIR

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2125 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6115
Majority (202) 225-3641
Minority (202) 225-2927

November 7, 2023

The Honorable Michael S. Regan
Administrator
U.S. Environmental Protection Agency
Mail Code 1101A
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Dear Administrator Regan:

Thank you for your August 25, 2023, response to our June 9, 2023, letter regarding the U.S. Environmental Protection Agency's (EPA) proposals for new methane regulations under Section 111 of the Clean Air Act (CAA) and the agency's implementation of the Methane Emissions Reduction Program under Section 60113 of the Inflation Reduction Act of 2022 (IRA). However, questions and concerns remain about the scope and timeline of the EPA's proposed and intended regulatory actions and the heavy burden it will impose on American families.

As you may know, within the next year, the EPA is planning to finalize multiple connected regulatory actions that will increase costs and reduce the production of American energy. Energy prices are projected to rise for American families because of new methane regulations, expanded emissions monitoring and reporting requirements, and a new tax on methane. As we noted in our letter, the EPA's expanded regulatory burden creates substantial legal and regulatory uncertainty, and the Congressional Budget Office (CBO) determined that a tax on methane emissions will increase operational costs, reduce energy production, and increase the price of natural gas.

The scope, timeline, and legal durability of the EPA's regulatory actions are unclear, and several of the questions in our June 2023 letter remain unanswered. What is known is that thousands of American jobs and billions of dollars in local economic development could be impacted by the EPA's actions. Global supply chains remain disrupted, and record inflation has increased prices for equipment and services across the energy sector. If the EPA's scope and compliance timelines do not account for these realities, it could force energy producers to shut in existing production and lay off workers. We are concerned that small businesses and independent energy producers, who are significant contributors to local economies, could suffer the most.

To continue our review of the EPA's authorities for methane taxes and regulations under the CAA, we ask that you provide responses to the questions and requested documentation below, no later than November 22, 2023.

1. Please provide an update on the status and timeline of the proposed regulations under Section 111 (b) and (d) of the CAA.

2. Please provide an update on the status and timeline or the EPA's plans to expand reporting requirements Subpart W of 40 C.F.R. Part 98.

3. Please provide an update on the status and timeline on the EPA's enforcement of the methane tax under the Methane Emissions and Waste Productive Incentive Program.

4. The EPA's planned methane regulations, reporting requirements, and taxes are integrally connected. How does the EPA expect energy producers to plan for compliance with the new methane tax on January 1, 2024, given that the EPA has not finalized the methane regulations and reporting requirements?

5. How does the EPA interpret the statutory exemptions to the methane tax?

6. Please explain how the EPA has complied with the Small Business Regulatory Enforcement Fairness Act (SBREFA) with respect to these various methane proposals.

7. How is the EPA accounting for supply chain disruptions and inflationary cost increases?

8. Does the EPA anticipate that new methane regulations will increase prices and reduce the availability of necessary emissions control equipment, such as pneumatics, monitoring devices, and storage vessels?

    a. What types of equipment are most difficult to obtain and what are the causes of the supply chain disruptions?

    b. How much of the equipment used for methane emissions control and monitoring is domestically produced, and how much is imported?

    c. Which countries does the U.S. rely on for imported methane emissions control and monitoring equipment?

9. Did the EPA review the operator survey of supply chain delays for equipment needed for the EPA Proposed New Source Performance Standards (NSPS) OOOOb Methane Rule?[1]

[1] *See* 2023 Industry Trades NSPS OOOOb Supply Chain Survey, available here: https://www.reginfo.gov/public/do/viewEO12866Meeting?viewRule=true&rin=2060-AV16&meetingId=226273&acronym=2060-EPA/OAR

a. Please summarize EPA's response to the concerns raised in the survey and describe how EPA is incorporating data that indicates backorder times for components necessary for compliance could exceed 24 months.

If you have any questions about this request, please contact Brandon Mooney or Mary Martin with the Majority staff at (202) 225-3641.

Sincerely,

Cathy McMorris Rodgers
Chair
Committee on Energy and Commerce

Bill Johnson
Chair
Subcommittee on Environment, Manufacturing, and Critical Materials

CENTER FOR METHANE EMISSIONS SOLUTIONS

January 10th, 2024

Dear Chairman Johnson and Ranking Member Tonko,

On behalf of the Center for Methane Emissions Solutions (CMES), and its members, I am writing regarding the Subcommittee's hearing on January 10th, 2024, entitled "Protecting American Clean Energy and Jobs By Stopping EPA's Overreach. As the Committee considers next steps, I hope you will consider the points we raise in the enclosed letter.

CMES is a national business coalition that represents the views of companies in the methane mitigation industry across the United States. The methane mitigation industry is a robust and growing American industry. More than 130 companies have headquarters in the U.S., and there are more than 570 methane mitigation facilities located across the country, in 46 states, including New Mexico.

Our members commend the Committee for considering the appropriate role of government in monitoring and regulating methane emissions. We agree wholeheartedly that policymakers should weigh the vital role the oil and gas industry have in our nation's economy, providing thousands of quality jobs and value to communities. We also feel that the increasing level of methane emissions that have been created as a result, can and should be addressed, especially since methane is a highly potent greenhouse gas, over 80 times more potent than carbon in the first 20 years after it is released into the atmosphere.

In addition to the real environmental costs associated with these emissions, there is also a tremendous economic cost. Methane is the primary component of natural gas. Oil and gas operations lose millions dollars-worth of product each year due to methane emission from inefficiencies at oil and gas well sites including faulty equipment and venting practices. If those issues were addressed, it would mean more product could be brought to market and more revenue for companies and for the state. Moreover, cutting methane waste can also help ensure a fair return for royalty owners.

Fortunately, this is a problem with a clear solution. Responding to this market and environmental challenge, our member companies have developed a range of effective, innovative, and low-cost services and technologies that reduce wasteful methane emissions. But you don't have to take our word for it. In their March 2020 report entitled "Global methane emissions from oil and gas", the International Energy Agency found that "While natural gas prices today are relatively low, we estimate that around one-third of our latest estimate of methane emissions from oil and gas operations could still be avoided at no net cost." These results reflect our experience in other states, like Colorado and New Mexico, that have imposed proposals like the one under consideration in Louisiana.

As a result, the federal government need not make a difficult choice between protecting public health and supporting the economy. It is our view, that the rule under consideration takes important steps toward reaching this balance, and that is why our organization writes in support.

CMES and its members support EPA's proposal because we have seen, first-hand, that the development of innovative technologies means that producers throughout the country will have flexibility in identifying low-cost, highly efficient products for their compliance strategy that best fits their business model. Further, these companies provide sustainable, high-paying jobs, thereby supporting the nations economy.

The sum of these factors leads our organization to strongly support EPA's proposal. As the Energy and Commerce Committee continues its work, we would welcome the opportunity to be a resource and are readily available to meet to discuss further.

Isaac Brown

Executive Director

Center for Methane Emissions Solutions

METHANE EMISSIONS

Inefficient and unlit natural gas flares both emit large quantities of methane

Genevieve Plant[1]*, Eric A. Kort[1]*, Adam R. Brandt[2], Yuanlei Chen[2], Graham Fordice[1], Alan M. Gorchov Negron[1], Stefan Schwietzke[3], Mackenzie Smith[4], Daniel Zavala-Araiza[3,5]

Flaring is widely used by the fossil fuel industry to dispose of natural gas. Industry and governments generally assume that flares remain lit and destroy methane, the predominant component of natural gas, with 98% efficiency. Neither assumption, however, is based on real-world observations. We calculate flare efficiency using airborne sampling across three basins responsible for >80% of US flaring and combine these observations with unlit flare prevalence surveys. We find that both unlit flares and inefficient combustion contribute comparably to ineffective methane destruction, with flares effectively destroying only 91.1% (90.2, 91.8; 95% confidence interval) of methane. This represents a fivefold increase in methane emissions above present assumptions and constitutes 4 to 10% of total US oil and gas methane emissions, highlighting a previously underappreciated methane source and mitigation opportunity.

In oil and gas (O&G) production and processing, natural gas—most commonly, associated natural gas (a by-product of oil extraction)—is disposed of through flares for a variety of safety, infrastructure, regulatory, or economic reasons (*1*, *2*). Ideally, the combustion in a flare serves to convert the mostly hydrocarbon gas to carbon dioxide (CO_2) and water (*1*). The primary component of natural gas is typically methane (CH_4), the most important short-lived greenhouse gas owing to its high radiative forcing and global warming potential (*3*), relatively short atmospheric lifetime of 9 to 10 years (*4*, *5*), and contribution to formation of tropospheric ozone (*6*, *7*). The use of flares aims to reduce the climate and health impacts of the disposal of this waste gas. Global flaring activity is captured in the Visible Infrared Imaging Radiometer Suite (VIIRS) Nightfire dataset, where satellite-based nighttime imagery in five spectral bands is used to calculate the temperature, radiant heat, and source area of individual flares (*8*–*10*). From these measurements, flare gas volumes are inferred (*11*–*13*). Using these data, the World Bank estimates that 142 billion cubic meters (bcm) of gas was flared globally in 2020, with the United States having flared 11.8 bcm (*14*). The US consistently ranks among the top five flaring nations in the world (*14*), with >80% of gas volumes flared in the US occurring within three regions: the Permian Basin, the Bakken Formation in the Williston Basin, and the Eagle Ford Shale in the Western Gulf Basin (hereafter referred to as the Permian, the Bakken, and the Eagle Ford; Fig. 1A). These three regions, in aggregate, drive national flaring trends (Fig. 1B) and are the primary observational focus of measurements presented herein, collected as part of the Flaring & Fossil Fuels: Uncovering Emissions & Losses (F^3UEL) project (Fig. 1).

In 2018, Alvarez *et al.* presented a synthesis study considering field measurements made over the previous decade. They concluded that considerable upward revisions of CH_4 emissions estimates were needed for a variety of segments within the O&G sector (*15*). However, given a lack of real-world observations, estimates of flaring emissions were not reevaluated. Estimates of flare-related emissions are generally based on the dual assumptions that flares operate continuously and that 98% of the CH_4 in the flare gas is destroyed through combustion (*16*), a value based on limited US Environmental Protection Agency controlled studies conducted in the 1980s (*17*, *18*). Neither assumption is supported by measurements of real-world flare operations.

Although VIIRS provides global flare volume information for flares large enough to be viewed from space, this product does not evaluate flare performance. The operation of individual flares in response to specific environmental and gas composition variables has been evaluated in laboratory and testing facility studies (*19*–*25*), however, only a handful of in situ measurements to characterize performance (i.e., efficiency) have been made of real-world flares (*26*–*30*). A smaller subset of these studies estimate flaring efficiency in terms of CH_4 removal. An early work based on remote sensing of three flares found combustion efficiencies of >99% on average (*28*), whereas more recent airborne-based studies in the US have found mixed results. Caulton *et al.* sampled 10 flares in North Dakota and Pennsylvania, with a sampling bias toward the largest and brightest flares, and found that all were >99% efficient (*29*). Gvakharia *et al.* measured 37 flares in the Bakken and found that their efficiencies followed a skewed distribution with a median efficiency of 97% (mean: 95.2%), which, if representative of flare performance for the entire basin, would more than double the CH_4 flare emissions from the region (*30*). The limited statistics of these previous studies undermines the ability to extrapolate to larger scales, and, as such, this emission source has not received much attention as a methane emissions mitigation opportunity.

In addition to the efficiency of combusting flares, unlit flares (i.e., those that directly vent hydrocarbons to the atmosphere as a result of the flame extinguishing or never being lit) must also be considered. Data about the incidence rates of unlit flares remain incomplete. To date, the largest evaluation of unlit flares in the US is available through the Permian Methane Analysis Project (PermianMAP), an endeavor by the Environmental Defense Fund to quantify and locate CH_4 emissions in the Permian (*31*, *32*). Lyon *et al.* found that, on average, 4.9% of observed flares were unlit (*33*). It is not known, however, whether these statistics are representative of other regions and basins, particularly as the Permian has experienced unprecedented growth that has contributed to markedly high methane emissions (*34*). Also in the Permian, Cusworth *et al.* found that plumes from active and inactive flares accounted for 12.1% of the detected plume emissions captured in their aerial imaging study (*35*). In Canada, an airborne survey reported by Tyner and Johnson found that unlit flares accounted for 13% of the total CH_4 emissions quantified in their 2019 survey in northern British Columbia (*36*). These surveys highlight the important role unlit flares play in CH_4 emissions from the O&G sector, however, we do not presently know the relative importance to methane emissions of unlit flares compared with inefficient combustion. Knowledge of the full climate impact of flaring could help determine efficient and effective mitigation efforts, guiding efforts to address issues with combustion efficiency as well as with unlit flare prevalence.

As part of the F^3UEL project, we quantified the performance of flares across three regions responsible for the bulk of flaring in the US, namely the Permian, Eagle Ford, and Bakken (Fig. 1A). Using an aircraft-based sampling approach over 12 research flights in 2020 and 2021, we directly measured methane, carbon dioxide, nitric oxide (NO), and nitrogen dioxide (NO_2) in flare combustion plumes, from which we quantified flare performance through calculation of the CH_4 destruction removal efficiency (DRE) for each plume intercept. The assessment of nitrogen oxides, or NOx (NO + NO_2), emissions and air quality implications will be the subject of forthcoming work. Consistent with previous airborne flare

[1]Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI, USA. [2]Department of Energy Science and Engineering, Stanford University, Stanford, CA, USA. [3]Environmental Defense Fund, Reguliersgracht 79, Amsterdam, Netherlands. [4]Scientific Aviation, Boulder, CO, USA. [5]Institute for Marine and Atmospheric Research Utrecht, Utrecht University, Utrecht, Netherlands.
*Corresponding author. Email: geplant@umich.edu (G.P.); eakort@umich.edu (E.A.K.)

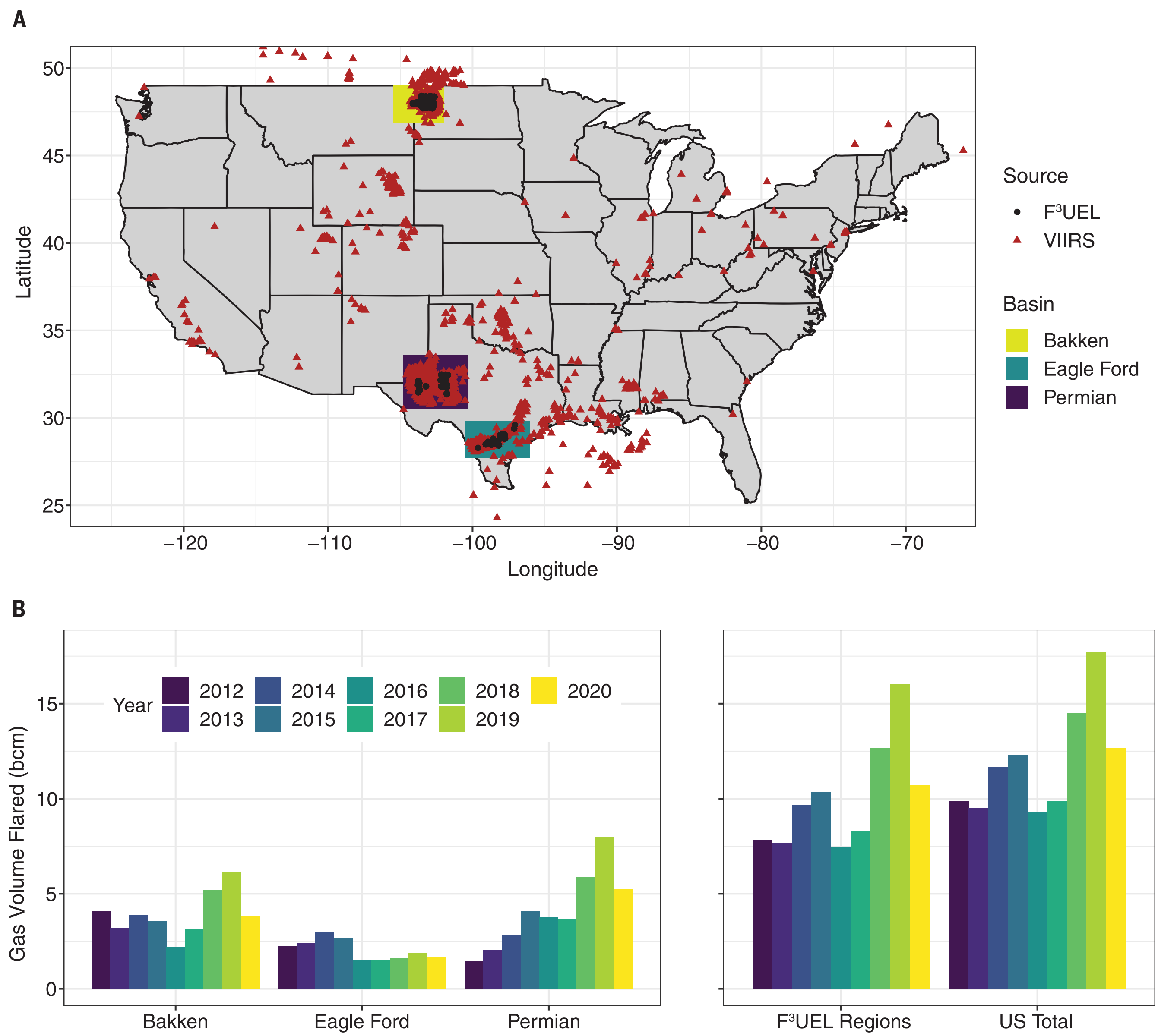

Fig. 1. Flaring activity in the United States. (**A**) Flaring locations in the contiguous US as seen from space (VIIRS, red triangles) for 2020 (*12*) and airborne sampling locations (F[3]UEL, black circles), investigating the regions of the Bakken (yellow), Eagle Ford (green), and Permian (purple) from 25 August 2020 through 4 September 2020 and 28 June 2021 through 15 July 2021. (**B**) Temporal evolution of total gas volumes flared (bcm) in the VIIRS data product in the Bakken, Eagle Ford, and Permian, as delineated by the shaded regions in (A) (*13*). In 2020, VIIRS observed 665, 547, and 1710 flares in the Bakken, Eagle Ford, and Permian, respectively. The three areas in aggregate are the focus of this work (F[3]UEL regions) and represent 80 to 90% of flared volumes in the US. At the national scale, flare volumes represent ~1% of natural gas gross withdrawals and generally track annual trends (fig. S1).

sampling campaigns (*29*, *30*), this method allows for direct measurement of the relative enhancements of the flare combustion plume without ground access to the flaring facility. An example flare-sampling flight track is shown in Fig. 2A, along with the accompanying concentration time series in Fig. 2B (details given in the materials and methods). With the airborne platform, we sampled more than 600 intercepts of flare combustion plumes, representing >300 distinct flares across the three basins (table S1). This represents an order-of-magnitude increase in the amount of data on in situ measurements of real-world flare performance.

Coincident measurements of CO_2 and CH_4 in the flare combustion plume allow for the calculation of CH_4 DRE, characterizing how well the flare's combustion destroys CH_4. DRE is distinct from combustion efficiency (CE)—DRE is the percentage of a specific species (e.g., CH_4) converted to another (e.g., CO_2), whereas CE is the percentage of total hydrocarbons in the gas that is converted to CO_2 (*16*). Following the methodology previously demonstrated in the literature (*29*, *30*), we estimate the DRE of CH_4 for each individual intercept of a flare combustion plume (materials and methods). The distribution of CH_4 DRE (%) values for flare intercepts across the three basins of study is shown in Fig. 3. In reporting and inventory estimates, 98% is a common default value used to quantify the efficiency at which flares convert

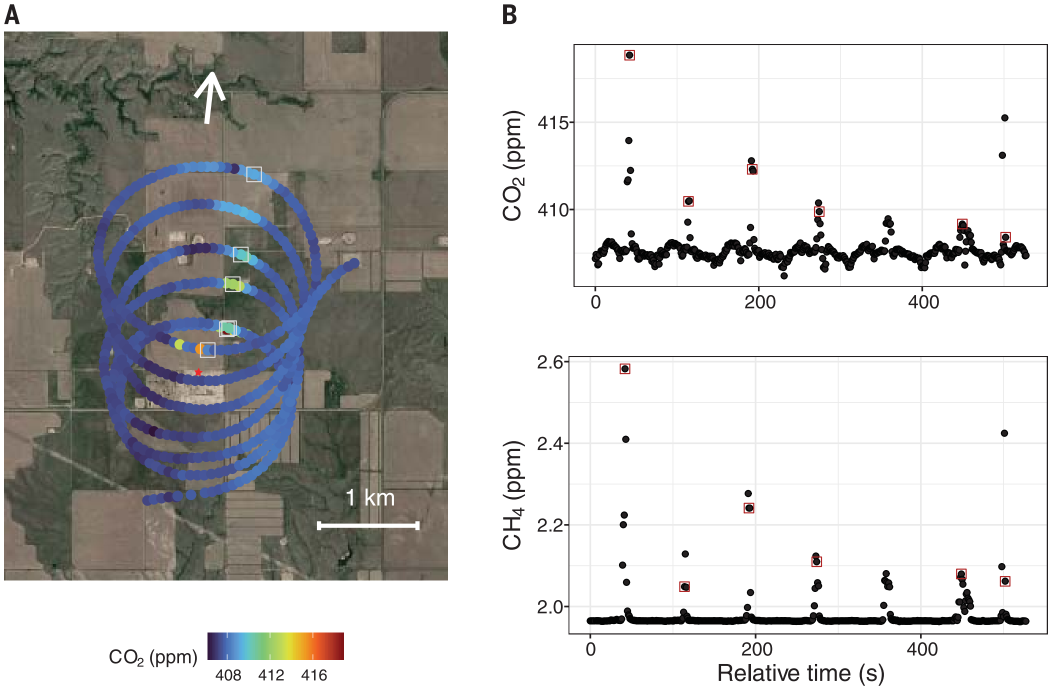

Fig. 2. Airborne flare sampling. (**A**) Flight track from the Bakken on 29 June 2021 colored by the CO_2 signal [parts per million (ppm)]. The white squares indicate the CO_2 peaks attributed to the upwind flare, with the wind direction (measured by the aircraft) indicated by the white arrow. The red star indicates the approximate location of the flare. (**B**) The corresponding time series of CO_2 (ppm) and CH_4 (ppm), with the red squares indicating the location of the combustion plume intercepts identified by the CO_2 peak–finding algorithm (further details in the materials and methods).

Table 1. Basin-level flare effective CH_4 destruction removal efficiency.

Region	Observed flare DRE		Unlit flares (%)	Total effective DRE*	
	Mean (%)	95% CI		Mean (%)	95% CI
Eagle Ford	96.5	95.4, 97.4	4.1†	92.4	91.3, 93.3
Bakken	97.3	96.9, 97.6	3.2	94.1	93.7, 94.4
Permian	91.7	90.5, 92.8	4.9	86.8	85.6, 87.9
Average	95.2	94.3, 95.9	4.1	91.1	90.2, 91.8

*Combines observed unlit flare statistics and DRE of lit flares †Average of unlit flare rate observed in the Bakken (this work) and Permian surveys [Lyon *et al.* (*33*)]

CH_4 in the fuel gas to CO_2 (*1*), and this is shown in Fig. 3 as the dashed vertical line. Similar distributions result when flare intercepts are grouped and attributed to individual flares (fig. S2).

For all basins, the observed DRE values exhibit a skewed distribution, such that the median observed values are close to 98%, however, the effective efficiencies are much lower, with substantial contributions from flares whose DRE can drop as low as 60%. Lognormal distributions, which capture the heavy tail, fit the observed DREs far better than normal distributions (Fig. 3; fit parameters in table S3). This trend is consistent with results from a previous study in the Bakken that observed a similarly skewed DRE distribution among 37 flares (*30*). Investigations into possible drivers of reduced DRE, such as wind speed (measured at the aircraft), flare volume and temperature (VIIRS), and estimated well age and gas/oil ratio (*37*) did not yield compelling explanatory relationships, suggesting that the combination of our airborne sampling and these supplemental datasets cannot explain most of the observed flare CH_4 DRE variability. Improving attribution to flare design, operation, and environmental conditions would require a different study strategy, likely with more information on individual flare infrastructure and operation.

Unlit flares directly venting unburned gas to the atmosphere as a result of the flame being extinguished or never properly ignited have an additional impact on the flaring CH_4 budget. Across three infrared optical gas imaging surveys (onboard a helicopter platform), Lyon *et al.* found that, on average, 4.9% of surveyed flares in the Permian were unlit and venting (*33*). In 2021, we sampled 601 active flares in the Bakken as part of a ground-based infrared imaging survey and found that 3.2% of active flares were unlit (materials and methods and table S6). Owing to a lack of unlit flare observations in the Eagle Ford, in this study we assume the percentage of unlit flares is 4.1%, the average of Bakken and Permian fractions (sensitivity study in material and methods).

To investigate CH_4 emissions from flares at the basin scale, we combined contributions of both inefficient performance and the prevalence of unlit flares into a total effective DRE (Table 1). We expanded our observed DRE estimates to the basin level by randomly resampling (with replacement) the observed DRE distributions and applying those efficiencies to the population of flares seen in VIIRS within each basin (delineated by the yellow, green, and purple regions shown in Fig. 1A), the results of which are shown in Table 1. We used a randomized approach, as we detected no relationship between observed DRE and flare size or temperature as quantified in the VIIRS product (see fig. S3). Additionally, we found that sampled flares represent the range of flare temperatures and sizes as seen by VIIRS (see fig. S4). From a bootstrap resampling (with replacement) of our observations, we inferred the uncertainty of our basin-average estimates, deriving 95% confidence intervals (CI). Unlit flares are assumed to have an efficiency of 0% (i.e., no combustion) and therefore directly reduce the effective DRE at the basin level by the unlit flare fraction (4.9%, Permian; 3.2%, Bakken; 4.1%, Eagle Ford).

The inefficiency of combusting flares in combination with the rate of unlit flares results in effective flare efficiencies that are considerably lower than 98% across all three basins. The standard value of 98% falls outside the confidence intervals for our basin-average DRE for lit flares. This indicates that flaring activities are a much larger part of the CH_4 O&G footprint than previously estimated. In addition, the relative contribution of both poorly combusting and unlit flares to total CH_4 flaring emissions is similar.

The average observed DRE across the study is 95.2%, and the average total effective DRE after accounting for unlit flares is 91.1%. Using flare volumes estimated from VIIRS for these regions (3.8, 1.6, and 5.2 bcm for the Bakken, Eagle Ford, and Permian, respectively, for 2020) (*12*, *13*), along with the basin-specific unlit flare fraction and average gas composition from the Greenhouse Gas Reporting Program (see fig. S5), we estimate a flaring CH_4 emissions rate from lit flares in these three basins of 0.27 (0.14, 0.38; 95% CI) Tg CH_4/year. Accounting for the presence of unlit flares increases that estimate to 0.49 (0.26, 0.72; 95% CI) Tg CH_4/year for these high-flaring areas. These emissions estimates are considerably larger (~5×) than if we assume 98% DRE for all flares quantified by VIIRS and no occurrences of unlit flares (0.10 Tg CH_4/year).

Flaring in the Bakken, Eagle Ford, and Permian represents the vast majority of activity in the US, ~84% (*12*, *13*). If we assume that the average effective DRE and a gas composition of 80% CH_4 is representative of the remaining flares, US CH_4 flaring emissions total 0.60 (0.31, 0.87) Tg CH_4/year, again five times larger than current assumptions would suggest (0.12 Tg CH_4/year), and a total emission magnitude comparable with notable O&G areas such as the Four Corners region (Colorado and New Mexico, US) at 0.54 Tg CH_4/year (± 0.20; 1σ) (*38*). The difference in US flare CH_4 emissions based on the observed effective DRE and 98%, 0.48 Tg CH_4/year, represents a substantial underaccounting of CH_4 emissions from flares. If measures were taken to ensure that US flares operated at 98% efficiency and remained lit, as current accounting assumes, this would be equivalent to removing 2.9 million cars from the road each year these mitigation measures were in place. This calculation uses a 100-year CH_4 global warming potential (GWP) of 28 and an annual emission of a typical passenger vehicle of 4.6 metric tons of CO_2 (*39*). Using a 20-year GWP of 84 (*40*) increases this mitigation measure's impact to the equivalent of removing 8.8 million cars. Our estimate for flaring emissions in the US represents 4 to 10% of total CH_4 emissions inventoried by the US Environmental Protection Agency for the O&G sector [8.4 Tg CH_4/year for 2020 in table 3-2 of (*41*)].

We do not know whether these US-based observations are globally representative. Flaring in other regions with differing regulations and oversight may perform better or worse. Nevertheless, our observationally derived performance characteristics are an improvement over simplified assumptions of 98% with no basis in real-world observations. Recently, the International Energy Agency (IEA) revised their estimate of global methane emission from flares to the assumption that flares operate at 92% efficiency, although the genesis of this value remains opaque (*42*). This assumed efficiency is similar to our US average effective CH_4 DRE of 91.1%. Using this updated efficiency assumption, the IEA estimated that flares were responsible for releasing 8 Tg (8 million tons) of CH_4 in 2020 (*42*), which would be on par with the world's methane ultra-emitters (*43*), equaling 8 to 11% of total global oil gas emissions (*44*). This highlights the need for more measurements of flare performance around the globe and represents a heretofore unrealized—or at least greatly underestimated—large source of methane emissions with known mitigation options. In the US, we find that both inefficient combustion and unlit flares contribute to substantial methane emissions greatly exceeding standard estimates for flares. As a result, mitigation efforts that address either combustion

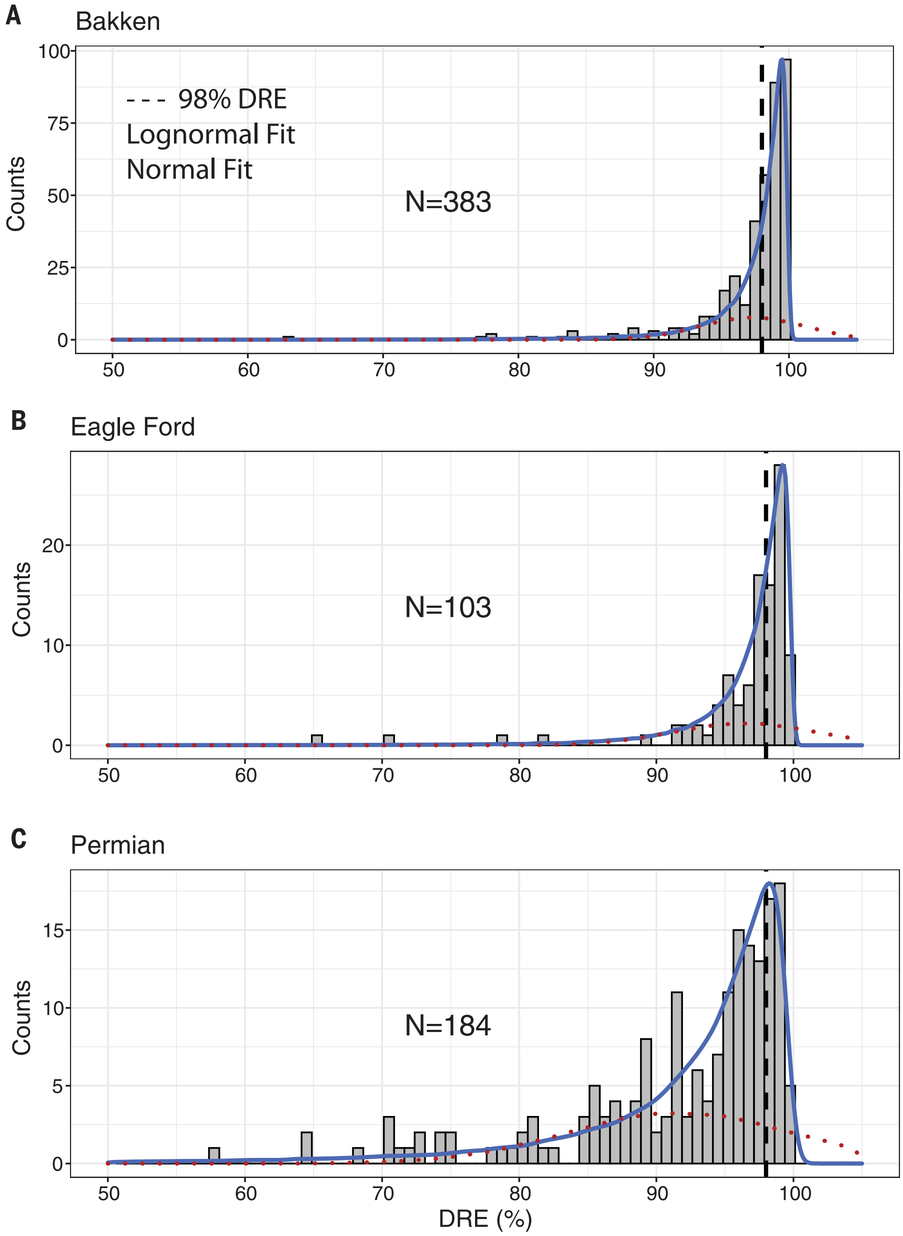

Fig. 3. Performance of active flares. Observed CH_4 DRE distributions of individual intercepts of lit flares for the (**A**) Bakken, (**B**) Eagle Ford, and (**C**) Permian. Normal (red dotted line) and lognormal (blue solid line) fits to the distributions are shown as normalized to the mean and maximum counts, respectively, to overlap with the observed data.

efficiency or unlit flares (such as operational practices on flare maintenance), in addition to reducing the usage of flares altogether (with alternatives such as reinjection or small-scale gas capture technology), would provide considerable methane emission benefits. Because flaring has long been treated as effective, there is little to no assessment of repair and maintenance costs, particularly for the issue of unlit flares. In principle, addressing unlit flares presents a simple and cost-effective CH_4 mitigation opportunity. Further investigation into the cause of flare malfunction could further inform mitigation measures and cost.

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SUPPLEMENTARY MATERIALS

science.org/doi/10.1126/science.abq0385
Materials and Methods
Figs. S1 to S10
Tables S1 to S7
References (*47*–*60*)

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Inefficient and unlit natural gas flares both emit large quantities of methane

Genevieve Plant, Eric A. Kort, Adam R. Brandt, Yuanlei Chen, Graham Fordice, Alan M. Gorchov Negron, Stefan Schwietzke, Mackenzie Smith, and Daniel Zavala-Araiza

Science **377** (6614), . DOI: 10.1126/science.abq0385

Fueling global warming
Flaring, the process of burning natural gas escaping from oil and gas wells, is primarily intended to combust the powerful greenhouse gas methane to minimize its emission. But is flaring as effective as is claimed? Plant *et al*. used airborne sampling to measure flare efficiency in three major gas production regions in the United States and found that methane emissions are five times higher than currently thought (see the Perspective by Duren and Gordon). Therefore, flaring is often not as efficient as presumed—or methane plumes simply are not combusted at all. —HJS

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NANETTE DIAZ BARRAGÁN
44TH DISTRICT, CALIFORNIA
FACEBOOK.COM/CONGRESSWOMANBARRAGAN
TWITTER: @REPBARRAGAN

COMMITTEE ON ENERGY AND COMMERCE

Congress of the United States
House of Representatives
Washington, DC 20515

WASHINGTON OFFICE:
2246 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-8220

DISTRICT OFFICES:
302 W. FIFTH STREET, SUITE 201
SAN PEDRO, CA 90731
(310) 831-1799

701 E. CARSON STREET
CARSON, CA 90745

8650 CALIFORNIA AVENUE
SOUTH GATE, CA 90280

December 22, 2021

The Honorable Michael S. Regan
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvannia Avenue, NW, Mail Stop 1301A
Washington, DC 20460

Dear Administrator Regan,

We write to express our appreciation for the Environmental Protection Agency's (EPA) historic action to combat methane emissions in the agency's recent announcement to strengthen regulations on new and modified sources, and to expand safeguards to existing sources of methane from oil and gas production.[1] We celebrate the much-needed progress EPA is making on methane emissions through this proposal, including necessary protections to zero-out emissions from intentionally polluting equipment like pneumatic controllers.

We also want to raise up the need for the rule to be expanded in two key ways:

- Smaller leak prone wells should be covered with regular inspections under the rule; and
- The wasteful practice of flaring should be addressed more vigorously before the rule is finalized by eliminating routine flaring as leading states have done.

These improvements must be addressed in a final rule to ensure EPA is protecting frontline communities (often communities of color and low-income communities) from pollution, safeguarding public health, holding oil and gas companies accountable, and acting on climate.

As you know, methane is a major contributor to the global climate crisis, as a short-lived climate pollutant that has approximately 80 times the warming potential of carbon dioxide over the first 20 years after its release. Just as importantly, establishing a strong rule for methane will also reduce health-harming co-pollutants, including Volatile Organic Compounds (VOCs) that contribute to ozone, as well as toxic and hazardous chemicals like benzene. The reduction of these co-pollutants will be key to reducing localized air pollution, and the associated negative health impacts that often disproportionately impact communities of color who live near oil and gas development and production sites. For example, 1.81 million Latinos live within a half mile radius of an oil and gas well[2].

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[1] https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-proposes-new-source-performance
[2] https://www.catf.us/wp-content/uploads/2016/09/CATF_Pub_LatinoCommunitiesAtRisk.pdf

Smaller, leak prone wells number in the hundreds of thousands across the country and generate just a trickle of usable product, but are large and disproportionate emitters of methane. Nationwide, more than 7 million people live nearby one of these wells, including nearly half a million children and nearly 2 million people of color[3]. These communities bear the brunt of the environmental, economic, and public health impacts resulting from leaks. While EPA has recognized in the proposal that a “low production” exemption is not appropriate, under the current proposal operators that calculate lower potential emissions (less than 3 tons per year of methane) could still escape regular leak monitoring. This is problematic because these smaller, leak prone wells can release more methane or natural gas into the air than they produce. Also, large leaks can occur at smaller well sites.[4] EPA must address this issue by enacting comprehensive requirements for frequent leak inspections, without exceptions for smaller wells.

Flaring is another wasteful and avoidable practice that is rampant in the oil and gas production sector. When companies rush to extract oil, some forgo investments necessary to capture and sell gas and instead burn it as a waste product, emitting a host of climate and health-harming pollutants, which can exacerbate public health disparities in environmental justice communities. In fact, one study[5] found that pregnant women exposed to excessive amounts of flaring pollution can lead to premature births and reduced birth weight. Further, studies have shown that Latino, Black, and indigenous communities are disproportionately exposed to flaring and its associated health risks,[6] including the development and exacerbation of asthma, cardiopulmonary problems, and cardiovascular mortality. Wasting this gas is an urgent problem, one made even more apparent as we enter a winter with higher natural gas prices and potential shortages. Leading operators have virtually eliminated flaring across all their operations and some states have already moved to eliminate flaring, except in emergency situations. EPA should follow the lead taken in the states and move to end routine flaring.

There is no time to waste in curbing methane pollution and tackling the climate crisis. Our children’s health, the safety of those living in oil and gas communities, and the future of the planet all hang in the balance. We must tackle this growing crisis head on, before it is too late. We look forward to your response and to continuing to work together to address this important issue.

Sincerely,

Nanette Diaz Barragan
Member of Congress
Chair, CHC Climate Task Force

Raul Ruiz, M.D.
Member of Congress

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[3] Data from Environmental Defense Fund’s “Proximity to Environmental Stressors GIS Assessment Tool”

[4] https://www.tandfonline.com/doi/full/10.1080/10962247.2020.1808115

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Teresa Leger Fernandez
Member of Congress

Raúl Grijalva
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