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EPA METHANE EMISSION CONTROLS

Obama vs Trump vs Biden: What Needs to Be Fixed and What Should Be Left Alone

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Abstract

EPA Methane Emission Controls, Obama vs Trump vs Biden:
What Needs to Be Fixed and What Should Be Left Alone

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On 13 August 2020, the U.S. Environmental Protection Agency (EPA) promulgated its final rule amending the New Source Performance Standards (NSPS) for the Oil and Natural Gas Sector. Both adherents and detractors of President Donald J. Trump saw the new rule as contributing to the President's deregulatory agenda, taking an important step toward American dominance in fossil fuels (desirable or not), and winning yet another battle in the war on the environmental protection legacy of President Barack Obama. This simple story line is compelling, but when the details are examined, it is found that the changes were in some ways more important, and in other ways less important than advertised by supporters and opponents. Moreover, some of the changes have damaged positions Trump championed, while others have the potential to substantially improve the environmental performance of the oil and gas industry. Most importantly, some major sources of methane emissions have been inadequately dealt with across both administrations. Therefore the Biden administration EPA, in re-examining NSPS, should take care to discard the mistakes made by the Trump administration, retain the improvements, and move forward on a number of new fronts. Topics explored include redundancy of methane and volatile organic compound leak detection, regulation of older and low production facilities, abandoned wells, pneumatic controllers, oil storage tanks, routine flaring, malfunctioning and unlit flares, gathering pipelines, and EPA certification of new methane emission detection technology.

All results and any errors in this report are the responsibility of the author.

Table of Contents

1. Status of Selected U.S. EPA Methane and Volatile Organic Compound Emission Controls

		2016 (Obama)	2020 (Trump)	2021-2025 (Biden)
		Superseded	Current	Recommended
1	Volatile Organic Compounds	YES	YES	√
2	Methane	YES	NO	√
3	New Facilities (Sept 2015 +)	YES	YES	√
4	Path to Regulation of Old Facilities	YES	NO	√
5	Low Production Well Sites	YES	NO	√
6	Offshore Facilities	NO	NO	√
7	Abandoned Wells	NO	NO	Major Sites
8	Production & Processing			
a	High Bleed Pneumatics	YES	YES	√
b	Intermittent Bleed Pneumatics	NO	NO	√
c	Tanks	YES	YES	√
d	Other P&P Infrastructure	YES	YES	√
e	Routine Flaring	NO	NO	√
f	Unlit Flares	NO	NO	√
g	Gathering Pipelines	NO	NO	√
9	Transmission & Storage	YES	NO	√
10	LNG Facilities	NO	NO	√
11	Local Distribution Systems	NO	NO	??
12	Alt Means of Emission Limitation	DIFFICULT	IMPROVED	√

Table 1. Status of selected U.S. EPA methane and volatile organic compound emission controls, 40 CFR 60 Subpart OOOOa. YES = regulation in force; NO = regulation never promulgated or withdrawn; √ = action should be considered; ?? = study recommended. Green tint = regulation effective; yellow tint = regulation partially effective; red tint = regulation ineffective. The 2020 version of the Alternative Means of Emission Limitation is untested. 2016 Status: 81 Federal Register 35898-35942 (2016). 2020 Status: 85 Federal Register 57438-57460 (2020).

2. Background

Natural gas has many roles in the energy economy of the United States. It provides 32% of primary energy, evenly distributed among electric power generation, industrial use, and residential + commercial consumption [LLNL, 2020]. Natural gas is also the premier low-cost medium of seasonal energy storage at national scale. Each year more than 5% of total U.S. marketed gas production, equivalent to 500 TWh, is shifted from summer production to winter consumption.

The main constituent of natural gas is methane, a powerful greenhouse gas [Kleinberg, 2020]. U.S. natural gas and petroleum systems emit an estimated 13 million metric tons of methane each year, see Table 2. The Environmental Protection Agency U.S. Greenhouse Gas Emissions and Sinks inventory (EPA GHGI) [EPA, 2017], right-hand column, is the product of considerable, serious effort over many years, but is based on studies of the average behavior of individual component types. Therefore it tends to miss what researchers have come to understand are some of the dominant contributions to methane emissions: abnormal process conditions [Zavala-Araiza, et al., 2017]. The 2018 survey by Alvarez et al. [2018], center column, though far less detailed than the EPA inventory, is generally considered to be more accurate. The Alvarez data compilation is informed by both aircraft- and ground-based facility-level field studies, which are more likely to represent actual emissions.

	Methane Emissions, 2015 (million metric tons per year)	
Industry Segment	Alvarez et al.	EPA GHGI
Production	7.6	3.5
Gathering	2.6	2.3
Processing	0.72	0.44
Transmission & Storage	1.8	1.4
Local Distribution	(0.44)	0.44
Total	13	8.1

Table 2. Methane emissions from the U.S. oil and natural gas supply chain. Alvarez et al. did not provide an independent estimate of emissions from local distribution systems and used the EPA GHGI figure without modification. Data: [Alvarez et al., 2018] and [EPA, 2017]

Although the regulation of emissions of air pollutants has a long history [Carlson & Burtraw, 2019], these regulations originally pertained primarily to sizable industrial installations such as refineries and chemical plants. The importance of emissions from oil and gas production infrastructure was recognized in 1993 when the U.S. Environmental Protection Agency instituted its voluntary GasSTAR program [Melvin et al., 2016]. Legal strictures on emissions from crude oil and natural gas production, processing, and transmission systems originated with the promulgation in 2012 of the New Source Performance Standards of 40 CFR 60 Subpart OOOO, which regulated emissions of volatile organic compounds. This was followed in 2016 by 40 CFR 60 Subpart OOOOa, which regulated emissions of greenhouse gases, including specifically methane. Subparts OOOO and OOOOa imposed similar, though not identical, limits on natural gas emissions [Kentucky, 2016]; the measures in OOOO limiting VOC emissions also reduce methane emissions as a co-benefit.

The U.S. Environmental Protection Agency tracks about 250 distinct sources of methane emissions in petroleum and natural gas production, transmission, and distribution systems [EPA, 2020b, Additional Information Methodology Annexes]. Of these, only a fraction are subject to regulatory controls prescribed by the Standards of Performance for New Stationary Sources (40 CFR 60) and detailed in Control Techniques Guidelines for the Oil and Natural Gas Industry [EPA, 2016b], which documents reasonably available control technology (RACT) [Babst Calland, 2020]. While regulated infrastructure is among the largest emission sources, potentially significant sources have not been adequately assessed and might be inadequately regulated for environmental protection. As pointed out in Table 1 and the text below, these include offshore facilities, intermittent bleed pneumatic controllers, oil storage tanks, malfunctioning and unlit flares, gas gathering pipelines, liquefied natural gas facilities, and local distribution systems.

Overall, the results following the promulgation of OOOO and OOOOa have been disappointing. In 2016, the Obama administration pledged to reduce methane emissions from the oil and gas sector by 40-45% by 2025 [White House, 2016]. The methane emission intensity shown in Figure 1 is the ratio of methane emissions from regulated segments of the crude oil and natural gas exploration, production, processing, and transmission and storage segments [EPA, 2020b, Additional Information Methodology Annexes] to total U.S. dry gas production [EIA, 2021]. The intensity decreased by a factor of 1.8 between 2006 and 2018, but this period coincided with an increase of dry gas production by a factor of 1.7, as shown in the figure.

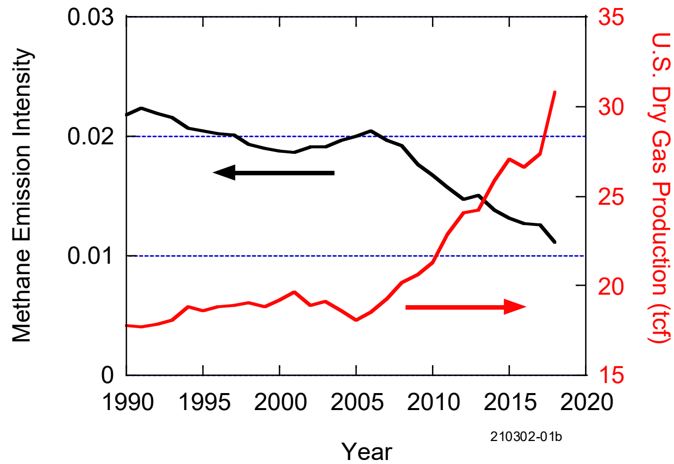

Figure 1. Methane emission intensity from emission factor estimates of OOOO and OOOOa regulated segments, 1990-2018. Data: [EPA, 2020b, Additional Information Methodology Annexes; EIA, 2021].

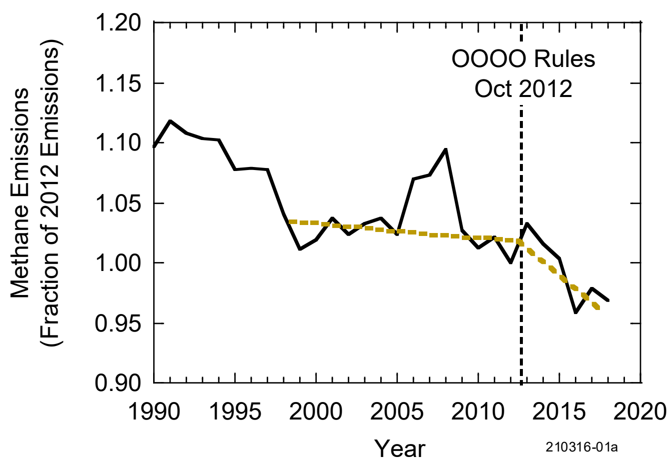

Figure 2. Methane emissions, from emission factor estimates of OOOO and OOOOa regulated segments, 1990-2018, normalized to emissions in 2012. Data: [EPA, 2020b, Additional Information Methodology Annexes].

Figure 2 is a more detailed view of the same data. Methane emissions, normalized to emissions in 2012, are shown. Here the effect of methane emissions regulations is more clear. Emissions declined by only about 5% in the eight years following the promulgation of rules meant to control the emission of natural gas.

Clearly, the imposition of natural gas emission controls starting in 2012 did little to reduce methane emissions from oil and gas infrastructure. Note that the 2012 regulations only applied to new sources, i.e. those for which construction, modification, or reconstruction commenced after 23 August 2011. Therefore either (1) new sources contribute only a very small part of the total methane load attributed to oil and gas infrastructure, and/or (2) the regulations are ineffective.

3. Trump Administration Amendments

On 13 August 2020, the U.S. Environmental Protection Agency (EPA) promulgated its final rule amending the 2012 and 2016 new source performance standards (NSPS) for the oil and natural gas industry, 40 CFR 60 Subpart OOOO and Subpart OOOOa [EPA, 2020a]. Policy amendments deregulated methane emissions in the production and processing segments and deregulated both methane and volatile organic compound emissions in the transmission and storage segment, see Figure 3. Technical amendments reduced inspection and reporting requirements and simplified the process of certifying new emission detection technology. Low producing wells were exempted from regulation, and the path to regulation of methane emissions from facilities constructed prior to September 2015 was blocked. Appendix I provides a guide to relevant documents. A timeline of regulatory actions is presented in Appendix II.

The Trump-era amendments were explicitly promulgated to encourage oil and natural gas production in the United States, as an element of the policy of "energy dominance" [EPA, 2019b]. However, it would appear that the primary goal of the revised rule, the deregulation of methane and other greenhouse gas (GHG) emissions, will among other things compromise the competitiveness of U.S. natural gas exports on world markets [Stern, 2020; WSJ, 2020]. The European Union has put nations exporting fossil fuels to Europe on notice: "As the largest importer of oil and gas, the EU has the leverage to promote energy-related methane emission reductions globally." [European Commission, 2020]. The International Energy Agency has reinforced this message: "IEA calls on companies, governments and regulators to take urgent action to cut methane emissions from oil and gas sector." [IEA, 2021a]

However, the actual environmental damage that will likely result from the 2020 rule changes, while real, is not necessarily profound. The contention of the EPA that detection of methane and volatile organic compounds (VOC) is redundant is supported, at least for presently approved methods as commonly implemented [Kleinberg & Pomerantz, 2019]. Moreover, the 2020 rule incorporates some changes that, if retained in a revised regulation, can potentially have the effect of materially reducing emissions of volatile organic compounds (VOC) and methane, while reducing costs to regulated entities.

In this report, I discuss some principal features of the 2020 rule-making, highlight provisions that should be restored to 2016 standards, and argue that a few important 2020 provisions should be retained. Finally, I point to several regulatory shortcomings that need resolution or further study. The principal conclusions of this study are summarized in Table 1.

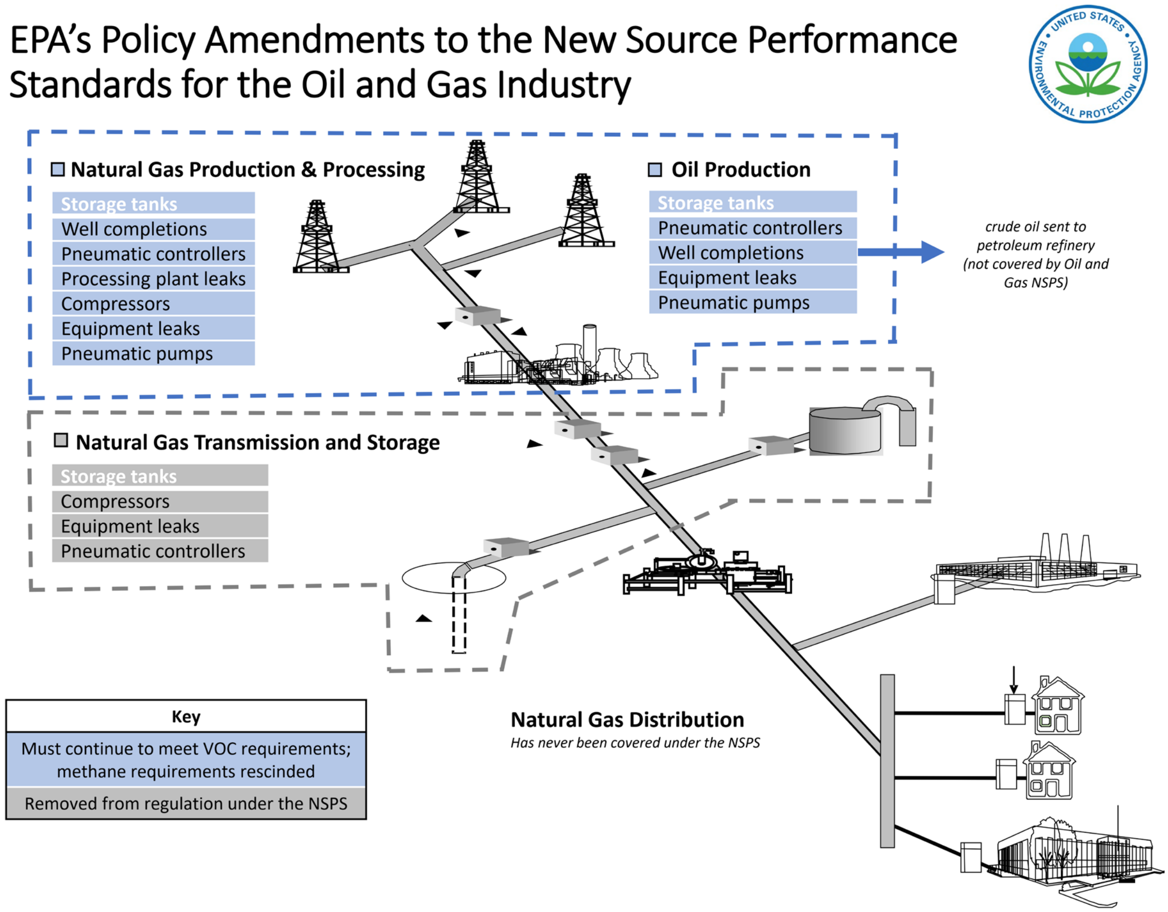

Figure 3. Scope of EPA New Source Performance Standards following Policy Amendments promulgated in August 2020. [EPA, 2020d]

4. Redundancy of Methane and Volatile Organic Compound Leak Detection

In its 2020 final rule, EPA removed the methane leak detection requirements of the NSPS, relying on its unchanged rule limiting volatile organic compound emissions to limit methane emissions as a co-benefit. EPA advanced both legal and technical justifications for deregulation. The legal issues are beyond the scope of this work. Suffice it to say here that the legal arguments set forth by EPA are controversial [Carey, et al., 2019; Webb, 2019; Agri & Kleinberg, 2021].

The technical justification for this proposal comes from the perceived redundancy of methane and VOC detection methods. As stated by EPA,

> "For the production and processing segments, the proposal would rescind emissions limits for methane but would keep emissions limits for VOCs. The proposal notes that the controls to reduce VOC emissions also reduce methane at the same time, so separate methane limitations for these segments of the industry are redundant." [EPA, 2019a]

Note that 20% of natural gas produced in the United States is devoid of volatile organic compounds; see Appendix III for details. In view of this, the validity of the statement that methane controls and VOC controls are redundant was tested [Kleinberg & Pomerantz, 2019]; it was found that

- For leak detection technologies *currently approved* by EPA, the statement is *valid*.
- For *newly developed* technologies that have the potential to significantly reduce the cost of compliance for regulated entities, the statement is *invalid*.

The currently approved leak detection sensors are a sniffer (40 CFR 60 Appendix A-7, Method 21), and an infrared camera (73 Federal Register 78199-78219), both of which, by code, must be sensitive to methane and the higher hydrocarbons defined as volatile organic compounds (40 CFR 51.100(s)).

While methane deregulation may not have an immediate impact on leak detection in production and processing segments, it inhibits the deployment of new, more effective and efficient methods. For example, aircraft- and satellite-borne sensors detect methane but are insensitive to volatile organic compounds as defined in 40 CFR 51.100(s) [Kleinberg & Pomerantz, 2019]. The use of such methods today is entirely voluntary and does not excuse operators from complying with rules compelling the use of presently approved methods, which are much more tedious and miss some of the largest emission sources.

5. Regulation of Older Facilities

The New Source Performance Standards (NSPS) promulgated in 2016 applied to a limited list of crude oil and natural gas facilities for which construction, modification or reconstruction commenced after September 18, 2015. Once it promulgated the revised New Source Performance Standards in 2016, the EPA was legally required to extend regulation of methane emissions to facilities constructed prior to September 2015 (Clean Air Act Sec. 111(d); 42 USC 7411(d)). However, it failed to do so before turning over the reins of government to the following administration. By deregulating methane in the oil and gas industry, the Trump administration eliminated the possibility of regulating methane emissions from older facilities. Reregulating methane emissions from new facilities would reanimate this mandate, as explained elsewhere [Agri & Kleinberg, 2021].

It is believed in some circles that older production and processing facilities do not contribute substantially to methane emissions. Well production declines with age, suggesting that methane emissions from associated facilities decline, too. This is only partially true, as shown in Table 3, which presents the results of a 2019 aerial survey of 32,500 wells in the New Mexico sector of the Permian Basin. Sites less than six years old and sites 6-10 years old displayed a comparable incidence of high-volume leaks. Older sites showed a lower, but hardly insignificant incidence of large leaks. Moreover, there are a large number of older sites, so emissions from this category are significant.

Age of Well Sites	0-5 years	6-10 years	>10 years
Detected Emitters > 20 kg CH_4/h	63	56	78
Wells Surveyed (approx)	5200	4400	22,900

Table 3. Incidence of high leak rates at facilities in various age ranges. Data: Kairos Aerospace, 2019.

6. Regulation of Low Production Facilities

While the 2016 NSPS specified that all new facilities were subject to regulation [EPA, 2016a, page 35856], the 2020 NSPS withdrew regulation from well sites producing less than 15 barrels of oil equivalent (boe) per day [EPA, 2020c, page 57400], a change supported by many industry groups [IPAA, et al., 2019]. A production rate of 15 boe per day is equivalent to 90,000 standard cubic feet of natural gas per day. A well site is defined as a collection of individual wells and related facilities, see 40 CFR 60.5410a(k) and 40 CFR 60.5430a.

Fugitive and vented emissions can depend on throughput, time, or event count, or a combination of these [Heydarzadeh, et al., 2020]. Therefore, low reported gas production is not necessarily correlated with negligible methane emissions, see Figure 4. Another study found that methane intensity (emission rate divided by gas production) of new high-producing wells was very much smaller than old low-producing wells. The causes were plausibly hypothesized as due to inadequate maintenance of old equipment and emission sources whose rates are independent of throughput [Omara, et al., 2016].

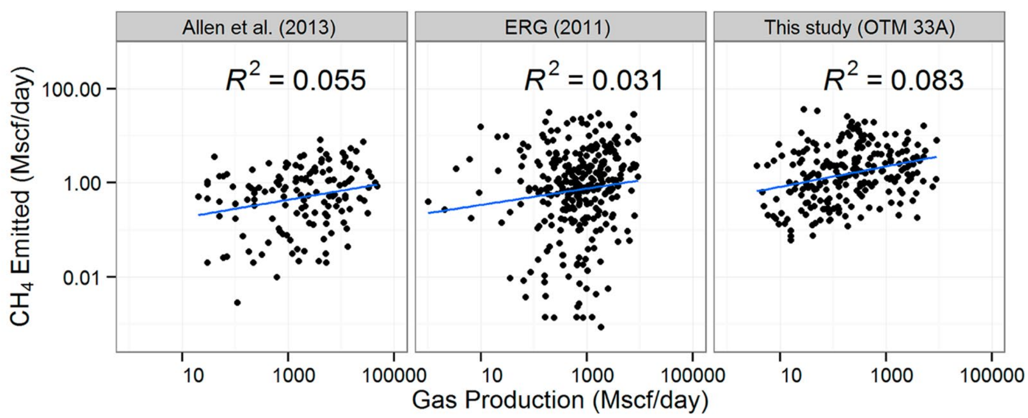

Figure 4. Methane emissions are very poorly correlated with reported gas production rates. [Brantley, et al., 2014]

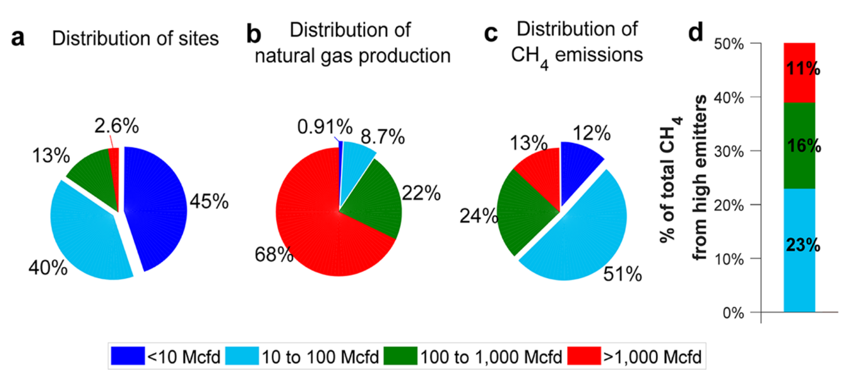

Figure 5. Distribution of U.S. production sites, gas production, and methane emissions. (a) Distribution of natural gas production sites in 2015 (n = 498,000). (b) Distribution of natural gas production (total = 83 Bcf/d). (c) Distribution of estimated methane emissions. (d) Methane emissions from high-emitting (>7.2 kg/h) sites. None of the sites producing <10 Mcfd was estimated to be a high emitter. [Omara et al., 2018]

Figure 5 illustrates some results of a study showing that sites producing less than 100,000 scf/d (equivalent to 17 boe/d) account for (a) 85% of sites, (b) 9.6% of natural gas production, and (c) 63% of methane emissions [Omara et al., 2018]. Equally importantly, (d) 23% of total methane emissions come from well sites producing less than 100,000 scf/d but emitting at a rate exceeding 7.2 kg/h, which is in the range of aircraft detectability [Duren, et al., 2019]. To put it another way, 23% of well site methane emissions come from readily detectable sources at low production sites.

The National Energy Technology Laboratory has commissioned another study of this question [NETL, 2019], with a report expected in September 2021 [GovTribe, 2021].

7. Abandoned Wells

On 27 January 2021 President Biden signed Executive Order 14008 (86 Federal Register 7619). Section 217 calls for plugging methane leaks in existing and abandoned wells and other oilfield infrastructure. Although it appears to be presented primarily as a stimulus to employment, significant environmental benefits can be realized if the program is implemented intelligently.

The EPA estimates there are 3.2 million abandoned oil and gas wells in the United States, accounting for annual methane emissions of 281,000 metric tons [EPA, 2020b], which is not insignificant compared to other sources of methane in the oil and natural gas segments. As is generally the case, a disproportionate share of total emissions derives from a relatively small number of super-emitters. For abandoned wells in Pennsylvania and West Virginia, the largest observed emission rates are typically around 3 t/y ~ 0.3 kg/h per well [Kang et al., 2019; Riddick et al., 2019]. The cost of sealing wells varies; the average cost is $37,000 per well [Kang et al., 2019].

It is estimated that abandoned wells can be remediated for $67 to $170 per ton of CO_2-equivalent avoided [Raimi et al., 2020], which is not a particularly efficient use of remediation resources, but less expensive than widely-discussed solutions such as direct air capture of carbon dioxide. Maximizing efficiency depends on finding and remediating the largest emitters. A methane emission rate of 0.3 kg/h is less than the sensitivity of the best currently available aircraft remote sensing systems [Fox et al., 2019]. Moreover, the number and locations of wells drilled before the second half of the twentieth century can be very uncertain [Riddick, et al., 2019]. Therefore, target selection strategies need to be informed by geology [Kang, et al., 2016].

8. Pneumatic Controllers

The oil and gas industry relies on automated controls to ensure the safety and efficiency of its operations. For example, valves are used to maintain tank pressures or liquid levels within design limits. In remote locations electric power may not be available, so valves and similar devices are actuated by a readily available source of energy: the pressure of produced gas, which is primarily methane and volatile organic compounds. These pneumatic controllers vent ("bleed") gas continuously, or intermittently when the valve is actuated.

In the New Source Performance Standards (NSPS) OOOO (2012) and OOOOa (2016), overly prescriptive rules led to numerous unintended and undesirable outcomes. For example, in the 2012 OOOO rule, renewed in the 2016 OOOOa rule and left unchanged in the 2020 rule, high-bleed pneumatic valves were restricted:

> 40 CFR 60.5390(c)(1) Each pneumatic controller affected facility constructed, modified or reconstructed on or after October 15, 2013, at a location between the wellhead and a natural gas processing plant or the point of custody transfer to an oil pipeline must have a bleed rate less than or equal to 6 standard cubic feet per hour.

Along with voluntary retirements, this rule resulted in a large decrease in the number of high-bleed (> 6 scf/h = 0.11 kg/h)) pneumatic valves deployed at U.S. oil and gas facilities. Generally speaking, high-bleed valves have been replaced by intermittent bleed pneumatic valves. However, the reported performance of intermittent valves varies widely [Allen et al., 2015; Methane Guiding Principles, 2019a], possibly in part because the emission reporting can be unreliable [Simpson, 2014]. A recent report by midsized gas producer EQT points out that emissions from intermittent bleed controllers are better estimated from the rate of *water* production of gas wells, which varies considerably over the life of a well [EQT, 2020].

Using current methodology, EPA estimates that intermittent bleed valves are an important fraction of methane emissions from upstream facilities; see Figure 6 for emissions from valves associated with natural gas production wells. According to the EPA Greenhouse Gas Inventory, eliminating all natural gas actuated pneumatic valves would reduce methane emissions from natural gas and petroleum systems by 1.75 million tons, which is fully 25% of the 7.05 million tons of methane emitted from all upstream oil and gas operations, see Table 4.

Replacements that do not emit natural gas include electrically or mechanically actuated valves, or pneumatic controllers actuated with compressed air [Methane Guiding Principles, 2019a]. Compressed air systems may be only suitable for larger installations [EPA, 2006a; CCAC, 2017a]. If commercially available and economically viable solutions do not exist to solve the pneumatic controller problem, the academic and private sectors should be incentivized to develop them.

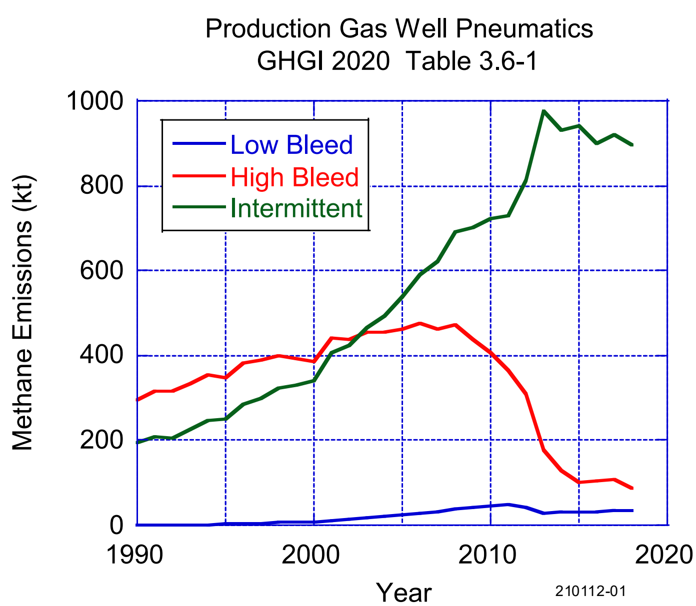

Figure 6. Methane emissions from pneumatic valves associated with production gas wells. U.S. Inventory of Greenhouse Gas Emissions and Sinks [EPA, 2020b Data Tables]

	Petroleum Systems	Natural Gas Systems	Upstream Oil & Gas Totals
Pneumatic Controllers	734,824 (a)	1,016,357 (c)	1,751,000
Total Emissions	1,449,000 (b)	5,598,000 (d)	7,047,000

Table 4. Methane emissions (metric tons) from U.S. upstream petroleum and natural gas systems, 2018 [EPA, 2020b: (a) Table 3-50; (b) Table 3-38; (c) Table 3-70; (d) Table 3-58]

9. Tanks

Tanks are among the elements of infrastructure to be inspected in the production and processing segments. A few times a year they are surveyed with one of the two approved methods that satisfy the OOOOa requirements for leak detection and repair. However, the main sources of natural gas emissions from tanks are not leaking components but pressure relief valves operating intermittently, normally and abnormally, and open inspection hatches [Lyon et al., 2016; Rutherford et al., 2020]. Some two million tons of methane are lost to the atmosphere each year in the United States from tanks, see Figure 7. Vapor recovery units (VRUs) can be used to collect this gas for injection into the reservoir, a sales line, or a flare [EPA, 2006b; EPA, 2009], but in practice VRUs are only practical at larger facilities. There appear to be few other options [CCAC, 2017b]. This issue requires further study.

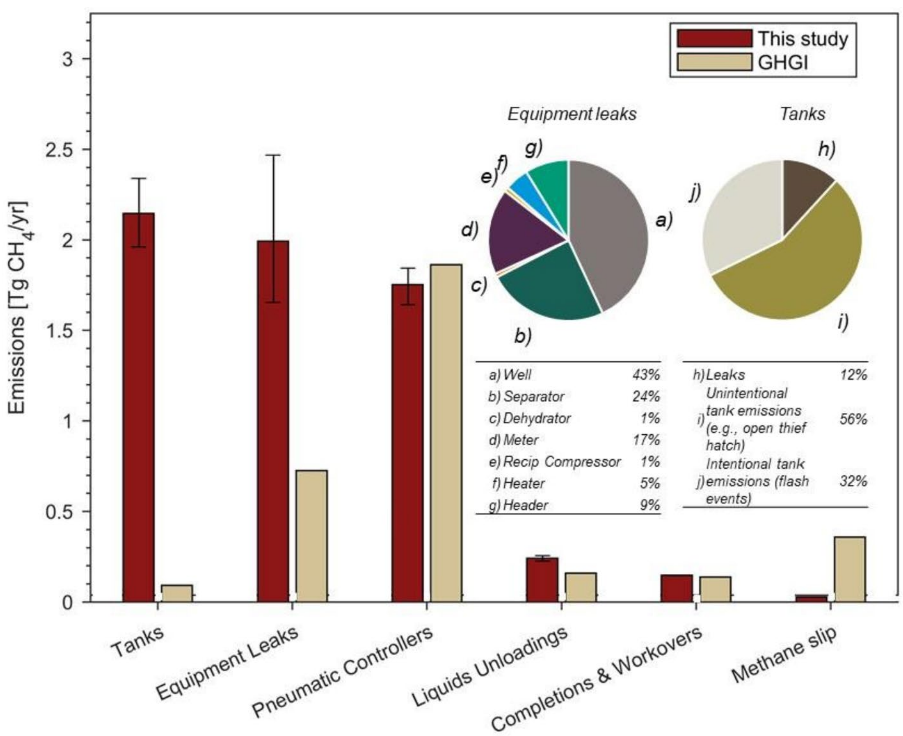

Figure 7. Estimated methane emissions from components of oil and natural gas production, which total 6.3 Tg/y = 6.3 million metric tons per year. [Rutherford, et al., 2020].

10. Routine Flaring

Safe oilfield operations require flares, which ideally operate only in limited circumstances. On the other hand, routine flaring constitutes the destruction of a potentially valuable resource, natural gas, to economically produce another resource, crude oil. Courts have ruled that routine flaring is contrary to state interest [Supreme Court, 1899; Prindle, 1981]. Nonetheless, large scale routine flaring persists in Texas and elsewhere. Figure 8 partitions flaring in the Texas portion of the Permian Basin into routine and event-driven categories; recent routine flaring has ranged from about 130 MMscf/d to about 200 MMscf/d, enough to supply the needs of 600,000 to 1,000,000 residential customers.

Some major producers have made specific pledges to end routine flaring [Pioneer, 2020; Shell, 2020]. The Methane Guiding Principles organization designates routine flaring as a last resort after a plethora of other approaches have been found unfeasible [Methane Guiding Principles, 2019b]. It now appears that a ban on routine flaring may be more widely acceptable to the industry. According to a recent press report, "The Texas Methane & Flaring Coalition, made up of trade groups, oil majors and production companies, said in a statement it supported eliminating routine flaring in the oil field by 2030. Although the group didn't lay out details on how its members will cut their emissions, it's a significant policy change for the industry in the biggest oil-producing state." [E&E News, 2021].

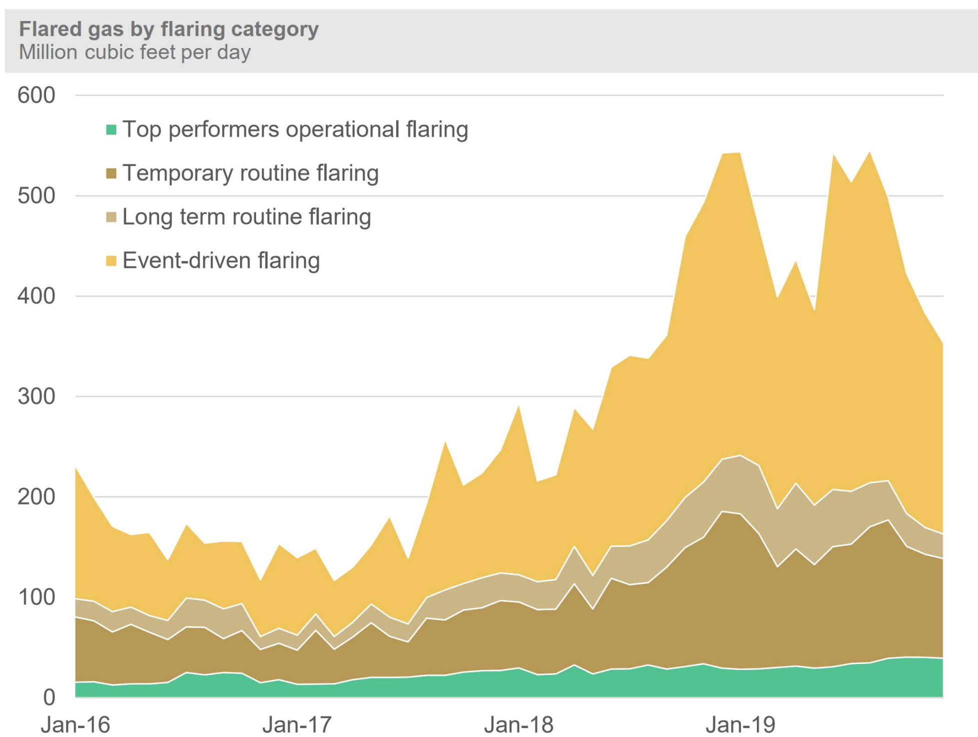

Figure 8. Routine vs event-driven flaring in the Texas portion of the Permian Basin, 2016-2020. [Rystad, 2021].

An emerging solution to the problem of routine flaring is the use of flare gas as fuel for small geographically dispersed power generation. Remarkably, one equipment supplier has installed a gigawatt of electric generation capacity fueled by field gas that would otherwise be flared [World Oil, 2020]. The power can be used to electrify oilfield operations or to power data centers [JPT, 2020]. This may be an attractive solution in remote fields where gas takeaway is impractical.

Bans on routine flaring can be counter-productive. In one notorious case, a nationwide ban on flaring in Turkmenistan resulted in a very large and persistent methane vent, resulting in far greater environmental damage [Calel & Mahdavi, 2020]. Even if such instances of environmental vandalism are rare, they illustrate the need for global surveillance to locate and remediate the very largest methane emitters. Fortunately, national technical means with this capability now exist [ESA, 2021; IEA, 2021b].

11. Malfunctioning and Unlit Flares

Flare Status	Functioning	Malfunctioning	Unlit	Total
EDF	75,000	30,000	200,000	305,000
EPA	80,000			80,000

Table 5. Methane emissions from flaring, metric tons per year, Permian Basin, 2020. [Data: EDF, 2021]

EPA estimates oilfield flares combust waste gas with an efficiency of 98% [EPA, Undated]; 2% of the gas sent to the flare escapes uncombusted to the atmosphere. However, aerial surveys in North Dakota have found weighted average efficiencies to be 95% [Gvakharia, et al., 2017], implying a greenhouse gas footprint considerably in excess of EPA estimates [Kleinberg, 2019].

It has been found that methane emissions from Permian Basin flares alone amount to more than 300,000 tons per year, almost four times larger than the EPA estimate, see Table 5. Excess emissions are due to unlit and malfunctioning flares, comprising 5% and 6%, respectively, of flares in use [EDF, 2021]. Remarkably, a substantial fraction of flares found to be malfunctioning or unlit on one survey were found to have problems on subsequent surveys. It has been independently estimated that 10-20% of total methane emissions in the Permian Basin are due to malfunctioning and unlit flares [Duren, et al., 2020]. Unlit oilfield flares are some of the largest point sources of methane emissions on earth [Bloomberg, 2019].

Flare operation is regulated by 40 CFR 60.18, which specifies that there be a pilot light that is on and monitored, an upper limit on exit velocity of flared gas, and a lower limit on gas heating value. These provisions are meant to ensure that the flare ignites and will not self-extinguish. However, there is no rule stipulating that the flare be actually lit. As the ultimate safety system to prevent system overpressures, flares can never be simply shut off. However, simple combustion sensors can be used to trigger remedial action or notify operators of fault conditions.

12. Gathering Pipelines

Gas gathering pipelines transport gas from production to processing sites. Thus they are notionally part of what EPA considers the production and processing segments. Although gathering system compressors are regulated in NSPS rules, gathering system pipelines and storage volumes have never been regulated by the EPA. The Pipeline and Hazardous Materials Safety Administration (PHMSA) has primary responsibility for the regulation of pipelines in the United States (49 USC 601). The agency's priority has been on safety, as is appropriate, but environmental concerns have been largely neglected [Webb, 2015a].

Aircraft surveys have found that gathering pipeline leaks are responsible for 30% of large (> 30 kg/h) methane emissions in the Permian Basin of southeast New Mexico [Berman et al., 2019; Berman & Deiker, 2020]. This is evidence that failure to regulate this infrastructure class is a significant gap in greenhouse gas control measures.

The Consolidated Appropriations Act of 2021, Division R, effective 27 December 2020, gave the Pipeline and Hazardous Materials Safety Administration the responsibility for leak detection and repair of pipelines "to meet the need for gas pipeline safety . . . and to protect the environment." However, the new law does little to limit methane emissions from oilfield gas gathering pipelines.

> 49 USC 60102 (q) Gas Pipeline Leak Detection and Repair.—
> (1) IN GENERAL.—Not later than 1 year after the date of enactment of this subsection, the Secretary shall promulgate final regulations that require operators of regulated gathering lines . . . to conduct leak detection and repair programs—
>> (A) to meet the need for gas pipeline safety, as determined by the Secretary; and
>> (B) to protect the environment.

The regulated gathering lines specified in the law are defined by PHMSA [2021]:

> when a gas gathering pipeline is close enough to a number of homes or to areas/buildings where people congregate, that an accident on the pipeline could impact them.

Thus PHMSA has not given itself the authority to protect the environment by mandating comprehensive leak detection surveys outside of areas where the safety of people can be affected.

13. Transmission & Storage

The European Space Agency recently announced the discovery of enormous vents along the routes of natural gas transmission pipelines in Russia and the United States. Some of these vents were as large as 290 tons per hour. At least some of these events have been confirmed as associated with planned maintenance of high-pressure gas transmission pipelines [ESA, 2021].

In announcing the deregulation of methane and VOC emissions from the transmission and storage segment, see Figure 3, EPA wrote (85 Federal Register 57049):

> The EPA agrees with commenters that if an appropriate assessment of the emissions from the transmission and storage segment concludes that emissions from this segment contribute significantly to the endangerment to public health or welfare, we would need to propose a separate rulemaking for the regulation of emissions from sources in this segment. However, the EPA is not, at this time, assessing whether the emissions from the transmission and storage segment contribute significantly to the endangerment to public health or welfare.

Table 2 data suggest that deregulation of the transmission and storage sectors was ill-advised, as this segment is responsible for 14% [Alvarez, et al., 2018] or 17% [EPA, 2017] of methane emissions from oil and gas systems. PHMSA regulation of methane emissions from pipelines in the transmission sector is discussed elsewhere [Blanton et al., 2021].

14. Liquefied Natural Gas Facilities

Division R of the Consolidated Appropriations Act of 2021 also directs PHMSA to update current regulations for liquefied natural gas facilities. However, there is nothing in Sections 110 and 111 about environmental issues, so it appears that LNG is still unregulated with respect to the climate effects of methane emissions. Measurements of methane emissions at LNG facilities are scarce, so the dimensions of the problem are not well understood.

15. Local Distribution

A number of surveys of methane leaks from urban distribution systems have been performed in recent years [see e.g. Jackson, 2014; Hendrick, 2016; von Fischer, 2017, Plant, 2019]. However, it cannot be said that methane emissions from local distribution systems have been thoroughly assessed. These systems comprise some two million miles of pipe divided among 1500 systems and are very diverse in their age and characteristics. Alvarez, et al. [2018] declined to provide an independent estimate of total annual emissions.

While local distribution systems are effectively regulated for safety, regulating for climate effect is more challenging. Methane emissions that are individually too small to constitute safety hazards may, in aggregate, be climate-significant. Moreover, common compensation structures perversely disincentivize leak detection and repair [Webb, 2015b]. However, under existing law, PHMSA could revise its regulations to mandate prompt repair of climate-significant leaks.

16. Alternative Means of Emission Limitation

One of the principal means of reducing emissions of methane and VOC is leak detection and repair (LDAR) in natural gas infrastructure. Fugitive emissions from leaks are considerably underestimated by EPA, see Figure 7.

The 2012 OOOO and 2016 OOOOa rules were extraordinarily prescriptive with respect to LDAR. They required inspection of a specified list of components at high sensitivity (0.03 kg/h) [Brandt, et al., 2018]. Two and only two means to satisfy leak detection requirements were accepted: Method 21 (40 CFR 60 Appendix A-7) and optical gas imaging (73 Federal Register 78199-78219). These methods are inefficient, and often miss the largest sources of emissions [Tyner & Johnson, 2020]. In theory, new technology could be accepted as valid means of leak detection, via rules for alternative means of emission limitation (AMEL). However, the AMEL rules themselves were so onerous that no application for acceptance of new technology had been submitted to EPA, let alone allowed.

Despite this highly restrictive regulatory environment, a plethora of methane leak detection technologies have been introduced and deployed in the years since 2016. This activity has been driven by the realization in academic, technology, oil and gas industry, and environmental advocacy communities that methane emissions are a leading cause of climate change, and methane emission mitigation from the oil and gas industry was easier, less disruptive, and had a bigger short term impact than carbon dioxide mitigation.

Using new technologies, a substantial number of large-scale field studies of oilfield methane emissions have been and are being conducted, even though the methods used in these studies cannot be used to satisfy OOOOa requirements for routine inspections. The studies uniformly have shown that facility-level measurements, even when 100 to 1000 times less sensitive than OOOOa mandates, are highly efficient and effective in mitigating methane emissions [see e.g. Sridharan, et al., 2020; Berman & Deiker, 2020; Tyner & Johnson, 2020]. Not only are these methods out of compliance with OOOOa, but they could not in principle be validated by the AMEL procedure.

	2016 Rule	**2020 Rule**
Regulated Pollutants	VOC & Methane	VOC
Applicants for Approval of New Technology	Only Owners or Operators of Facilities	Inventors, Manufacturers, Anyone
Validity	Single Facility	Multiple/Universal
Validation	12 Month On Site Comparison to Old Tech	Field Tests, Test Centers & Modeling, Accounting for Seasonal Variations
Criterion for Approval	Emission Reduction at Each Facility	Emission Reduction Where New Technique is Used

Table 6. Status of US EPA rules for alternative means of emission limitation (AMEL), 40 CFR 60.5398a. Green tint denotes provisions the author deems desirable, red tint denotes provisions the author deems undesirable. 2016 Status: 81 Federal Register 35906-35907. 2020 Status: 85 Federal Register 57443.

In the wake of the 2018 and 2019 notices of proposed rulemaking, academic, technology, environmental advocacy, and industry communities spoke in unison in favor of liberalization of OOOOa and AMEL rules to permit efficient and effective technologies to be used for routine LDAR. EPA responded with a liberalized rule which incorporated many of the suggestions of the diverse group of stakeholders.[1]

The changes to the Code of Federal Regulations are summarized in Table 6 and described in detail in Appendix IV. Unfortunately, the Federal Register commentary (85 Federal Register 57421-57424; 85 Federal Register 57429-57431) appears to be considerably more restrictive than the rule itself as published in the Code of Federal Regulations (40 CFR 60.5398a). In order to encourage innovation, clarity is required. This is particularly true in the case of aerial and satellite surveillance, to which the 2016 AMEL rule provided no path. EPA needs to be very clear that the overarching objective of greenhouse gas control is to reduce emissions at company, basin, national, or even global scale. The previous requirement of single-site approvals poses insurmountable barriers to some of the most promising approaches. Therefore I strongly recommend that most of the 2020 AMEL rules codified in 40 CFR 60.5398a be retained and that the Federal Register commentary be aligned with it.

17. Conclusions

- The 2020 amendments to the New Source Performance Standards have effects both more and less important than proponents and opponents have claimed. In the production and processing

[1] A compilation of significant public submissions in Docket EPA–HQ–OAR–2017–0483 pertaining to AMEL is available from the author upon request.

segments, the new rules will have little or no immediate effect on the scale of methane emissions. In the long term, the new rules will tend to inhibit the widespread deployment of new techniques which can deliver better environmental outcomes at lower cost to regulated entities. They also have sent a clear signal to importing blocs, such as the European Union, that global environmental protection is not a priority of the United States as an exporter of fossil fuels.

- Older and low production facilities cannot be neglected in methane emission control regulation. Both populations (which overlap) are responsible for substantial fractions of total upstream methane emissions. Gathering pipelines, which are not regulated by EPA and inadequately regulated by PHMSA, have been found to be the origin of many of the largest leaks associated with the production and processing segments.

- Some very important sources of vented methane have been inadequately mitigated by both Obama- and Trump-era EPA, and by industry. These include routine emissions associated with normal and abnormal operations of pneumatic controllers and tanks, and malfunctioning and unlit flares, which collectively account for roughly a third of the methane emitted by the entire U.S. oil and gas industry.

- The transmission and storage segment is responsible for 14-17% of emissions of the oil and gas industry. Therefore regulation of this segment should be restored and strengthened. Emissions from liquefied natural gas facilities have not been assessed by field measurements. Given the recent growth of this industry sector, these measurements should be given high priority.

- Distribution systems, which are very widespread and diverse, need to be more fully assessed.

- Newly promulgated rules that encourage the development and use of advanced means of methane emission detection are critical to the effort to reduce these emissions and should be retained in any new regulations.

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References

Agri, P. and Kleinberg, R.L., 2021. Response of a Regulatory Agency to Public Submissions: The Case of Methane Emission Deregulation, in preparation.

Allen, D.T., et al., 2015. Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers, Environmental Science & Technology 49, 633−640. https://pubs.acs.org/doi/10.1021/es5040156

Alvarez, R.A., et al., 2018. Assessment of methane emissions from the U.S. oil and gas supply chain, Science 10.1126/science.aar7204 https://science.sciencemag.org/content/361/6398/186

Babst Calland, 2020. EPA Finalizes Revisions to Oil and Natural Gas New Source Performance Standards, 20 August 2020. http://www.babstcalland.com/news-article/epa-finalizes-revisions-to-oil-and-natural-gas-new-source-performance-standards/

Berman, E.S.F., et al, 2019. Basin-wide, High-resolution, Quantified Methane Emissions Survey of the New Mexico Permian Gives Novel View of Methane Emissions from Oil and Gas Operations – and Suggests Emission Reduction Strategies, Poster GC51M-0964, American Geophysical Union Fall Meeting 2019.

Berman, E.S.F., Deiker, S., 2020. Source-attributable, quantitative results from a basin-wide survey of New Mexico Permian methane emissions, MIT A+B Applied Energy Symposium #280. 13-14 August 2020 https://www.youtube.com/watch?v=ySDjZdHMYBA
http://kairosaerospace.com/wp-content/uploads/2021/02/Source-Attributable-Quantitative-Results-from-a-Basin-Wide-Airborne-Survey-of-Methane-Emissions.mp4

Blanton, E.M., Lott, M.C., Smith, K., 2021. Investing in the US Natural Gas Pipeline System to Support Net-Zero Targets, Columbia University Center on Global Energy Policy, 22 April 2021 https://www.energypolicy.columbia.edu/research/report/investing-us-natural-gas-pipeline-system-support-net-zero-targets

Bloomberg, 2019. Snuffed-Out Flares Are Biggest Methane Offender, Satellites Show, Updated September 26, 2019 https://www.bloomberg.com/news/articles/2019-09-25/gas-flare-hiccups-are-biggest-methane-offender-satellites-show

Brandt, A.R., et al., 2015. Energy Intensity and Greenhouse Gas Emissions from Crude Oil Production in the Bakken Formation: Input Data and Analysis Methods, Argonne National Laboratory, September 2015. https://greet.es.anl.gov/publication-bakken-oil

Brandt, A.R., et al., 2018. Assessment of LDAR technology options, ONE Future Methane & Climate Strategies Event, 15 May 2018. http://onefuture.us/wp-content/uploads/2018/05/Stanford_Brandt_LDAR_2018.pdf

Brantley, H.L., et al., 2014. Assessment of Methane Emissions from Oil and Gas Production Pads using Mobile Measurements, Environmental Science & Technology, 48, 14508−14515 https://pubs-acs-org.ezproxy.cul.columbia.edu/doi/pdf/10.1021/es503070q

Calel, R., Mahdavi, P., 2020. Opinion: The unintended consequences of antiflaring policies—and measures for mitigation. Proceedings of the National Academy of Sciences, 117 (23) 12503-12507. 9 June 2020. https://www.pnas.org/content/117/23/12503

Carey, I., et al., 2019. Re: Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Review, 84 Fed. Reg. 50,244 (Proposed Sept. 24, 2019). Docket ID: EPA-HQ-OAR-2017-0757, 25 November 2019. https://www.regulations.gov/search/comment?filter=EPA-HQ-OAR-2017-0757-1830

Carlson, A., Burtraw, D., 2019. Lessons from the Clean Air Act. Cambridge University Press. https://doi.org/10.1017/9781108377195

CCAC, 2017a. Oil and Gas Methane Partnership Technical Guidance Document Number 1: Natural Gas Driven Pneumatic Controllers and Pumps, March 2017. https://www.ccacoalition.org/en/resources/technical-guidance-document-number-1-natural-gas-driven-pneumatic-controllers-and-pumps

CCAC, 2017b. Oil and Gas Methane Partnership Technical Guidance Document Number 6: Unstabilized Hydrocarbon Liquid Storage Tanks, March 2017. https://www.ccacoalition.org/en/resources/technical-guidance-document-number-6-unstabilized-hydrocarbon-liquid-storage-tanks

Duren, R.M., et al., 2019. California's methane super-emitters, Nature, 575, 180-185. https://www.nature.com/articles/s41586-019-1720-3

Duren, R.M., et al., 2020. Methane point-source emissions from oil, gas, and coal operations, A125-05, American Geophysical Union Fall Meeting, December 2020.

EDF, 2021. PermianMAP, Flaring, Aerial Survey Results, Environmental Defense Fund, Accessed 31 January 2021 https://www.permianmap.org/flaring-emissions/

E&E News, Big Oil does U-turn on gas flaring, 11 February 2021. https://www.eenews.net/energywire/2021/02/11/stories/1063724919

EIA, 2021. U.S. Dry Natural Gas Production, 1930-2020, Energy Information Agency. https://www.eia.gov/dnav/ng/hist/n9070us2a.htm

EPA, Undated. Air Pollution Control Technology Fact Sheet. EPA-452F-03-019. https://www3.epa.gov/ttncatc1/dir1/fflare.pdf

EPA, 2006a. Options For Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry. https://www.epa.gov/sites/production/files/2016-06/documents/ll_pneumatics.pdf

EPA, 2006b. Installing Vapor Recovery Units on Storage Tanks. https://www.epa.gov/sites/production/files/2016-06/documents/ll_final_vap.pdf

EPA, 2009. Installing Vapor Recovery Units. https://www.epa.gov/sites/production/files/2017-07/documents/05_vru_billings_2009.pdf

EPA, 2016a. Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources, 81 Federal Register 35824-35942 (3 June 2016)

EPA, 2016b. Control Techniques Guidelines for the Oil and Natural Gas Industry, U.S. Environmental Protection Agency EPA-453/B-16-001
https://www.epa.gov/sites/production/files/2016-10/documents/2016-ctg-oil-and-gas.pdf

EPA, 2017. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2015. U.S. Environmental Protection Agency
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

EPA, 2019a. Fact Sheet: EPA Proposes Policy Amendments to the 2014 and 2016 New Source Performance Standards for the Oil and Natural Gas Industry, U.S. Environmental Protection Agency (28 August 2019).
https://www.epa.gov/sites/production/files/2019-08/documents/fact_sheet._proposed_amendments_to_nsps_for_oil_and_natural_gas_industry.8.28.19.pdf

EPA, 2019b. News Release: What They Are Saying About EPA's New Methane Proposal, U.S. Environmental Protection Agency (29 August 2019)
https://www.epa.gov/newsreleases/what-they-are-saying-about-epas-new-methane-proposal

EPA, 2020a. EPA Issues Final Policy and Technical Amendments to the New Source Performance Standards for the Oil and Natural Gas Industry. U.S. Environmental Protection Agency (13 August 2020).
https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-issues-final-policy-and-technical

EPA, 2020b. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018. U.S. Environmental Protection Agency (2020)
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
Additional Information: https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2018-ghg
Methodology Annex 3.6: https://www.epa.gov/sites/production/files/2020-02/2020_ghgi_natural_gas_systems_annex36_tables.xlsx Tab 3.6-1

EPA, 2020c. Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration, 85 Federal Register 57398-57460 (15 September 2020)
https://www.federalregister.gov/documents/2020/09/15/2020-18115/oil-and-natural-gas-sector-emission-standards-for-new-reconstructed-and-modified-sources

EPA, 2020d. EPA's Policy Amendments to the New Source Performance Standards for the Oil and Gas Industry, U.S. Environmental Protection Agency, August 2020.
https://www.epa.gov/sites/production/files/2020-08/documents/epas_policy_amendments_to_the_new_source_performance_standards_for_the_oil_and_gas_industry.pdf

EPA, 2020e. EPA Issues Final Policy Amendments to the 2012 and 2016 New Source Performance Standards for the Oil and Natural Gas Industry: Fact Sheet (13 August 2020)
https://www.epa.gov/sites/production/files/2020-08/documents/og_policy_amendments.fact_sheet._final_8.13.2020_.pdf

EQT, 2020. Quantifying Intermittent Bleed Device Emissions by Activation Count. EPA Stakeholder Webinar (Nov. 2020): Natural Gas & Petroleum Systems in the GHG Inventory
https://www.epa.gov/ghgemissions/stakeholder-webinar-nov-2020-natural-gas-petroleum-systems-ghg-inventory

ESA, 2021. Monitoring methane emissions from gas pipelines, European Space Agency, 4 March 2021.
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Monitoring_methane_emissions_from_gas_pipelines

European Commission, 2020. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy to reduce methane emissions, COM(2020) 663 final, 14 October 2020
https://ec.europa.eu/energy/sites/ener/files/eu_methane_strategy.pdf

Fox, T.A., et al., 2019. A review of close-range and screening technologies for mitigating fugitive methane emissions in upstream oil and gas, Environmental Research Letters 14, 053002;
https://iopscience.iop.org/article/10.1088/1748-9326/ab0cc3
Erratum: Environmental Research Letters 14, 069601
https://iopscience.iop.org/article/10.1088/1748-9326/ab20f1

GovTribe, 2021. Cooperative Agreement DEFE0031702. Updated 27 January 2021.
https://govtribe.com/award/federal-grant-award/cooperative-agreement-defe0031702

Gvakharia, A. et al., 2017. "Methane, Black Carbon, and Ethane Emissions from Natural Gas Flares in the Bakken Shale, North Dakota", Environmental Science & Technology 51, 5317−5325
DOI: 10.1021/acs.est.6b05183
https://pubs.acs.org/doi/10.1021/acs.est.6b05183

Heydarzadeh, Z., et al., 2020. Comprehensive Study of Major Methane Emissions Sources from Natural Gas System and Their Dependency to Throughput, Energy Proceedings Volume 08: Proceedings of Applied Energy Symposium: MIT A+B, United States, 2020
http://www.energy-proceedings.org/comprehensive-study-of-major-methane-emissions-sources-from-natural-gas-system-and-their-dependency-to-throughput/

Hendrick, M.F., et al., 2016. Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments. Environmental Pollution, 213, 710-716.
http://dx.doi.org/10.1016/j.envpol.2016.01.094

IEA, 2021a. Press Release: IEA calls on companies, governments and regulators to take urgent action to cut methane emissions from oil and gas sector, 18 January 2021.
https://www.iea.org/news/iea-calls-on-companies-governments-and-regulators-to-take-urgent-action-to-cut-methane-emissions-from-oil-and-gas-sector

IEA, 2021b. Improving methane data: Focus on the role of satellites, January 2021. https://www.iea.org/reports/methane-tracker-2021/improving-methane-data-focus-on-the-role-of-satellites

IPAA et al., 2019. Re: Environmental Protection Agency's Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Review at 84 Federal Register 50,244 (September 24, 2019) https://www.regulations.gov/document/EPA-HQ-OAR-2017-0757-2077

Jackson, R.B, et al., 2014. Natural Gas Pipeline Leaks Across Washington, DC, Environmental Science & Technology, 48, 2051-2058
https://pubs.acs.org/doi/pdf/10.1021/es404474x

JPT, 2020. Innovators Seek To Transform Flaring Into Money and Power, Journal of Petroleum Technology, 29 February 2020. https://jpt.spe.org/innovators-seek-transform-flaring-money-and-power

Kang, M., et al., 2016. Identification and characterization of high methane-emitting abandoned oil and gas wells, Proceedings of the National Academy of Sciences, 113, 13636–13641
https://www.pnas.org/content/113/48/13636
Erratum: Proceedings of the National Academy of Sciences, 114, E6025
https://www.pnas.org/content/114/29/E6025

Kang, M., et al., 2019. Reducing methane emissions from abandoned oil and gas wells: Strategies and costs, Energy Policy 132, 594–601
https://doi.org/10.1016/j.enpol.2019.05.045

Kentucky, 2016. Compliance Guide: Standards of Performance for Crude Oil and Natural Gas Production, Transmission and Distribution (40 CFR 60, Subpart OOOO) and Crude Oil and Natural Gas Facilities for which Construction, Modification, or Reconstruction Commenced After September 18, 2015 (40 CFR 60, SUBPART OOOOa), State of Kentucky Division of Compliance Assistance, August 2016
https://eec.ky.gov/Environmental-Protection/Compliance-Assistance/DCA%20Resource%20Document%20Library/CrudeOilandNaturalGasTransmissionDistribution.pdf

Kleinberg, R.L., 2019. Greenhouse Gas Footprint of Oilfield Flares Accounting for Realistic Flare Gas Composition and Distribution of Flare Efficiencies, Earth and Space Science Open Archive, 27 June 2019.
https://doi.org/10.1002/essoar.10501340.1

Kleinberg, R.L., Pomerantz, A.E., 2019. Rescinding Limits on Methane Emissions: Impact on Technological Innovation Re: Docket ID No. EPA-HQ-OAR-2017-0757; EPA 'Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration; Proposed Rule'; 84 FR 50244 (24 September 2019), 25 November 2019.
https://www.regulations.gov/document?D=EPA-HQ-OAR-2017-0757-2195

Kleinberg, R.L., 2020. The Global Warming Potential Misrepresents the Physics of Global Warming Thereby Misleading Policy Makers, EarthArXiv, 25 October 2020.
https://eartharxiv.org/repository/view/1686/

LII, 2021. 40 CFR Subpart OOOOa - Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced After September 18, 2015. Cornell Law School Legal Information Institute, Electronic Code of Federal Regulations, Accessed 18 January 2021. https://www.law.cornell.edu/cfr/text/40/part-60/subpart-OOOOa

LLNL, 2020. Energy Flow Charts: Estimated U.S. Energy Consumption in 2019, Lawrence Livermore National Laboratory, LLNL-MI-410527, March 2020. https://flowcharts.llnl.gov/

Lyon, D.R., et al., 2016. Aerial Surveys of Elevated Hydrocarbon Emissions from Oil and Gas Production Sites, Environmental Science & Technology, 50, 4877−4886 https://pubs.acs.org/doi/10.1021/acs.est.6b00705

Melvin, A.M., et al., 2016. Climate Benefits of U.S. EPA Programs and Policies That Reduced Methane Emissions 1993−2013, Environmental Science & Technology, 50, 6873−6881 https://pubs.acs.org/doi/10.1021/acs.est.6b00367

Methane Guiding Principles, 2019a. Reducing Methane Emissions: Best Practice Guide, Pneumatic Devices, November 2019. https://methaneguidingprinciples.org/wp-content/uploads/2019/11/Reducing-Methane-Emissions-Pneumatic-Devices-Guide.pdf

Methane Guiding Principles, 2019b. Reducing Methane Emissions: Best Practice Guide, Flaring, November 2019. https://methaneguidingprinciples.org/wp-content/uploads/2019/11/Reducing-Methane-Emissions-Flaring-Guide.pdf

National Archives, 2021. Title 40 Chapter I Subchapter C Part 60 Subpart OOOOa - Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced After September 18, 2015. National Archives, Electronic Code of Federal Regulations as of 14 January 2021. https://ecfr.federalregister.gov/current/title-40/chapter-I/subchapter-C/part-60#subpart-OOOOa

NETL, 2019. Quantification of Methane Emissions from Marginal (Small Producing) Oil and Gas Wells, DE-FE0031702, 1 November 2019 https://netl.doe.gov/node/9373

NYSDEC, 2011. New York State Department of Environmental Conservation. Revised Draft Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program. Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs. NYSDEC September 7, 2011. Table 5.30. http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf

Omara, M., et al., 2016. Methane Emissions from Conventional and Unconventional Natural Gas Production Sites in the Marcellus Shale Basin, Environmental Science & Technology 50, 2099−2107. https://pubs.acs.org/doi/10.1021/acs.est.5b05503

Omara, M., et al., 2018. Methane Emissions from Natural Gas Production Sites in the United States: Data Synthesis and National Estimate, Environmental Science & Technology 52, 12915−12925 https://pubs.acs.org/doi/10.1021/acs.est.8b03535

PADEP, 2018. DEP Office of Oil and Gas Management, Oil & Gas Well Production Report, January - December 2018
http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?%2fOil_Gas%2fOil_Gas_Well_Production

PHMSA, 2021. Fact Sheet: Gathering Pipelines. Accessed 13 February 2021.
https://primis.phmsa.dot.gov/comm/factsheets/fsgatheringpipelines.htm

Pioneer Natural Resources, 2020 Sustainability Report.
https://www.pxd.com/sites/default/files/reports/2020-sustainability-report-final.pdf

Plant, G., et al., 2019. Large fugitive methane emissions from urban centers along the U.S. East Coast. Geophysical Research Letters, 46, 8500–8507. https://doi.org/10.1029/2019GL082635

Prindle, D.F., 1981. The Texas Railroad Commission and the Elimination of the Flaring of Natural Gas, 1930-1949. The Southwestern Historical Quarterly, 84(3), 293-308, January 1981.
https://www.jstor.org/stable/30238689

Raimi, D., et al., 2020. Green Stimulus for Oil and Gas Workers: Considering a Major Federal Effort to Plug Orphaned and Abandoned Wells, Columbia University Center on Global Energy Policy, July 2020.
https://www.energypolicy.columbia.edu/sites/default/files/file-uploads/OrphanWells_CGEP-Report_071620.pdf

Riddick, S.N., et al., 2019. Measuring methane emissions from abandoned and active oil and gas wells in West Virginia, Science of the Total Environment 651, 1849–1856.
https://doi.org/10.1016/j.scitotenv.2018.10.082

Rutherford, J.S., et al., 2020. Closing the gap: Explaining persistent underestimation by US oil and natural gas production-segment methane inventories, EarthArXiv, 11 November 2020.
https://eartharxiv.org/repository/view/1793/

Rystad, 2021. Permian Basin Flaring Outlook, Condensed Report, January 2021.
http://blogs.edf.org/energyexchange/files/2021/01/20210120-Permian-flaring-report.pdf

Shell, 2020. Shell and BP Recommend the Railroad Commission of Texas (RRC) to Consider Eliminating Routine Flaring in Texas. https://www.shell.us/energy-and-innovation/shale-gas-and-oil/shell-and-bp-recommend-the-railroad-commission-of-texas--rrc--to.html

Simpson, D.A., 2014. Pneumatic Controllers in Upstream Oil and Gas. Oil & Gas Facilities, 3(5), 83-96. Society of Petroleum Engineers Paper 172505. https://doi.org/10.2118/172505-PA

Sridharan, S., et al., 2020. Long Term, Periodic Aerial Surveys Cost Effectively Mitigate Methane Emissions, Society of Petroleum Engineers Paper SPE 201312.
https://onepetro.org/SPEATCE/proceedings-abstract/20ATCE/3-20ATCE/D031S034R004/449845

Stern, J., 2020. Methane Emissions from Natural Gas and LNG Imports: an increasingly urgent issue for the future of gas in Europe. Oxford Institute for Energy Studies, OIES Paper: NG 165, November 2020.
https://www.oxfordenergy.org/publications/methane-emissions-from-natural-gas-and-lng-imports-an-increasingly-urgent-issue-for-the-future-of-gas-in-europe/

Supreme Court of the United States, 1899. Ohio Oil Co. v. Indiana No. 1, 177 US 190
https://www.loc.gov/item/usrep177190/

Tyner, D.R., Johnson, M., 2020. Quantitative Assessment of Airborne LiDAR Technology for Methane Source Measurement and Comparison with Parallel Tracer Release and OGI Camera Survey Data, GC093-05, American Geophysical Union Fall Meeting, December 2020.

von Fischer, J.C., et al., 2017. Rapid, Vehicle-Based Identification of Location and Magnitude of Urban Natural Gas Pipeline Leaks, Environmental Science & Technology, 51, 4091−4099
https://pubs.acs.org/doi/10.1021/acs.est.6b06095

Webb, R.M., 2015a. Safety First, Environment Last: Improving Regulation of Gas Pipeline Leaks, Kay Bailey Hutchison Center Research Paper No. 2015-14, September 2015
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2671847

Webb, R.M., 2015b. Lost but not forgotten: The hidden environmental costs of compensating pipelines for natural gas losses, Kay Bailey Hutchison Center Research Paper No. 2015-01, April 2015
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2597846

Webb, R.M., 2019. Re: EPA's Proposed Revisions to the New Source Performance Standards for the Oil and Natural Gas Sector (Docket ID EPA-HQ-OAR-2017-0757), 22 November 2019.
https://www.regulations.gov/search/comment?filter=EPA-HQ-OAR-2017-0757-1122

White House, 2016. Leaders' Statement on a North American Climate, Clean Energy, and Environment Partnership, The White House Office of the Press Secretary, 29 June 2016.
https://obamawhitehouse.archives.gov/the-press-office/2016/06/29/leaders-statement-north-american-climate-clean-energy-and-environment

World Oil, 2020. Aggreko passes 1 GW milestone in flare gas to power generation projects. World Oil, 21 October 2020.
https://www.worldoil.com//news/2020/10/21/aggreko-passes-1gw-milestone-in-flare-gas-to-power-generation-projects

WSJ, 2020. France's Engie Backs Out of U.S. LNG Deal, 3 November 2020.
https://www.wsj.com/articles/frances-engie-backs-out-of-u-s-lng-deal-11604435609

Zavala-Araiza, D., et al, 2017. Super-emitters in natural gas infrastructure are caused by abnormal process conditions, Nature Communications, 8:14012, DOI: 10.1038/ncomms14012
https://www.nature.com/articles/ncomms14012

Appendix I: EPA Policy and Technical Amendments to New Source Performance Standards

	Policy Amendments	Technical Amendments
Summary	[EPA, 2020a]	
Docket (www.regulations.gov)	EPA–HQ–OAR–2017–0757	EPA–HQ–OAR–2017–0483
Federal Register	85 Fed Reg 57018-57072	85 Fed Reg 57398-57460
Effective Date	14 September 2020	16 November 2020
Code of Federal Regulations	[LII, 2021; National Archives, 2021]	

Table A.1. 2020 amendments to 40 CFR 60 OOOO (2012) and 40 CFR 60 OOOOa (2016) New Source Performance Standards for the oil and natural gas industry.

Appendix II: Timetable of Regulatory Actions

Action	OOOO	OOOOa	Technical Amendments	Policy Amendments
Proposed Rule Signed			11 Sept 2018	28 Aug 2019
Proposed Rule Federal Register	23 Aug 2011	18 Sept 2015	15 Oct 2018	24 Sept 2019
Comment Deadline	30 Nov 2011 (extended)	17 Nov 2015	17 Dec 2018	25 Nov 2019
Final Rule Announced			13 Aug 2020	13 Aug 2020
Final Rule Federal Register	16 Aug 2012	3 June 2016	15 Sept 2020	14 Sept 2020
Effective Date	15 Oct 2012	2 August 2016	16 Nov 2020	14 Sept 2020

Appendix III: Definition of Volatile Organic Compound; Composition of Natural Gas Produced in the United States

Definitions of volatile organic compounds (VOC) vary by purpose. For EPA air quality programs, including NSPS, volatile organic compounds are defined in 40 CFR 51.100(s) as being photochemically reactive in the atmosphere. VOC includes propane, butane, and pentane, which are often found in natural gas as produced at the wellhead. The definition specifically excludes the most important constituents of natural gas, methane and ethane.

About 20% of the gas produced in the United States is associated gas from oil wells. This gas has a substantial fraction of VOC. An extreme but important example is gas from the Bakken formation of North Dakota, the molar (approximately equal to volumetric) composition of which is, on average, 49% methane, 21% ethane, and 25% VOC [Brandt, 2015]. Non-hydrocarbon gases account for the balance. For this class of natural gas, any method that detects VOC for the purposes of leak detection and repair, thereby reducing VOC emissions, will result in a concomitant reduction of methane emissions as a co-benefit.

At the other extreme, and even more important, are natural gas resources that are almost completely devoid of volatile organic compounds. A prominent example is the Marcellus shale of northeastern Pennsylvania. In 2018, Susquehanna, Bradford, Tioga, Wyoming, Lycoming, and Sullivan counties produced 3.4 trillion cubic feet of gas, 9% of total U.S. dry gas production [PADEP, 2018]. In Bradford County, in the heart of this region, the VOC content of field gas averages less than 0.1% [NYSDEC, 2011]. Therefore, there is 1000 times more methane than VOC in Bradford County fugitive gas. Another example is found in the Haynesville shale, which accounted for another 9% of total 2018 U.S. dry gas production. Gas produced from Haynesville shale has VOC content averaging 0.3% by volume. In other words, there is 300 times more methane than VOC in gas escaping from Haynesville infrastructure. The VOC content of coal bed methane is negligible; this resource accounts for more than 3% of U.S. gas production. Thus, more than 20% of total U.S. gas production has little or no VOC content. For these classes of gases, a method that detects only VOC without detecting methane will fail to prevent emissions.

Appendix IV: Revised Text Pertaining to Alternative Means of Emission Limitation, 40 CFR 60.5398a

Original: 81 Federal Register 35906-35907 (3 June 2016) (normal and ~~red strikeout~~ fonts)
Revision: 85 Federal Register 57443 (15 September 2020) (normal and <u>red underlined</u> fonts)
Author Annotations: Yellow highlights

§ 60.5398a What are the alternative means of emission limitations for ~~GHG and~~ VOC from well completions, reciprocating compressors, the collection of fugitive emissions ~~component~~<u>components</u> at a well site and the collection of fugitive emissions components at a compressor station?

> I support the reinstatement of methane and other GHG emission controls here and elsewhere in this regulation.

(a) If, in the Administrator's judgment, an alternative means of emission limitation will achieve a reduction in ~~GHG (in the form of a limitation on emission of methane) and~~ VOC emissions at least equivalent to the reduction in ~~GHG and~~ VOC emissions achieved under <u>§</u> 60.5375a, <u>§</u> 60.5385a, <u>andor §</u> 60.5397a, the Administrator will publish, in the Federal Register, a notice permitting the use of that alternative means for the purpose of compliance with <u>§</u> 60.5375a, <u>§</u> 60.5385a, ~~and~~<u>or §</u> 60.5397a.

> This liberalizes the AMEL rule by specifying that it can apply to <u>any</u> of (1) well affected facilities, (2) reciprocating compressor affected facilities, or (3) an affected facility which is the collection of fugitive emissions components at a well site and an affected facility which is the collection of fugitive emissions components at a compressor station. In the 2016 rule, the new technology had to apply to <u>all</u> these situations.

~~The notice may condition permission on requirements related to the operation and maintenance of the alternative means.~~ <u>The authority to approve an alternative means of emission limitation is retained by the Administrator and shall not be delegated to States under section 111(c) of the Clean Air Act (CAA).</u>

> This reserves to EPA the sole right to approve new technology.

(b) Any notice under paragraph (a) of this section must be published only after notice and an opportunity for a public hearing.

~~(c) The Administrator will consider applications under this section from either owners or operators of affected facilities.~~

> "Any person" is now allowed to apply for the certification of new LDAR technology, in compliance with the Clean Air Act. This is a major improvement.

~~(d)~~

(c) Determination of equivalence to the design, equipment, work practice, or operational requirements of this section will be evaluated by the following guidelines:

> ~~(1) The applicant must collect, verify and submit test data, covering a period of at least 12 months to demonstrate the equivalence of the alternative means of emission limitation.~~
>
> (1)The applicant must provide information that is sufficient for demonstrating the alternative means of emission limitation achieves emission reductions that are at least equivalent to the emission reductions that would be achieved by complying with the relevant standards.
>
> > This provision eliminates the requirement of 12 months of testing. The unmodified and unexplained word "equivalence", which has been a stumbling block, is replaced by "emission reductions that are at least equivalent". I believe this is a substantial improvement.
>
> At a minimum, the application must include the following information:
>
> > (i) Details of the specific equipment or components that would be included in the alternative.
> > (ii) A description of the ~~technology or process.~~
> > ~~(ii)~~alternative work practice, including, as appropriate, the monitoring method, monitoring instrument ~~and~~or measurement technology~~ or process.~~
> > ~~(iii) A description of performance based procedures (*i.e.,* method) and~~, and the data quality indicators for precision and bias~~;~~.
> > (iii) The method detection limit of the technology~~ or process.~~
> > ~~(iv) For affected facilities under § 60.5397a, the action criteria and level at which a fugitive emission exists.~~
> > ~~(v~~, technique, or process and a description of the procedures used to determine the method detection limit. At a minimum, the applicant must collect, verify, and submit field data encompassing seasonal variations to support the determination of the method detection limit. The field data may be supplemented with modeling analyses, controlled test site data, or other documentation.

The motivation for this provision is explained at 85 FR 57422, where the existence of the Methane Emissions Technology Evaluation Center (METEC) is acknowledged and its methodology critiqued. Overall, this is responsive to commenters and an improvement over the previously mandated procedure, which excluded modeling analyses and controlled test site data.

(iv) Any initial and ongoing quality assurance/quality control measures.
(vi) necessary for maintaining the technology, technique, or process, and the timeframes for conducting such measures. ongoing quality assurance/quality control.
(vii) Field data verifying viability and detection capabilities of the technology or process.
(viii)
(v) Frequency of measurements.
(ix) For continuous monitoring techniques, the minimum data availability.

I believe this to be the first recognition of continuous monitoring as a potentially valid LDAR method.

(vi) Any restrictions for using the technology, technique, or process.
(xi) Operation and maintenance procedures and other provisions necessary to ensure reduction in methane and VOC emissions at least equivalent to the reduction in methane and VOC emissions achieved under § 60.5397a.
(xii)
(vii) Initial and continuous compliance procedures, including recordkeeping and reporting., if the compliance procedures are different than those specified in this subpart.

(2) For each determination of equivalency requested, the emission reduction achieved by the design, equipment, work practice or operational requirements shall be demonstrated.

(2) (3) For each affected facility For each technology, technique, or process for which a determination of equivalency is requested, the application must provide a demonstration that the emission reduction achieved by the alternative means of emission limitation shall be demonstrated. is at least equivalent to the emission reduction that would be achieved by complying with the relevant standards in this subpart.

The focus has shifted from facility to technology. This is an important improvement.

(4) Each owner or operator applying for a determination of equivalence to a work practice standard shall commit in writing to work practice(s) that provide for emission reductions equal to or greater than the emission reductions achieved by the required work practice.

(e) After notice and opportunity for public hearing, the Administrator will determine the equivalence of a means of emission limitation and will publish the determination in the FEDERAL REGISTER.

~~(f) An application submitted under this section will be evaluated as set forth in paragraphs (f)(1) and (2) of this section.~~

~~(1) The Administrator will compare the demonstrated emission reduction for the alternative means of emission limitation to the demonstrated emission reduction for the design, equipment, work practice or operational requirements and, if applicable, will consider the commitment in paragraph (d) of this section.~~
~~(2) The Administrator may condition the approval of the alternative means of emission limitation on requirements that may be necessary to ensure operation and maintenance to achieve the same emissions reduction as the design, equipment, work practice or operational requirements, (g)~~

(d) Any ~~equivalent~~alternative means of emission limitations approved under this section shall constitute a required work practice, equipment, design, or operational standard within the meaning of section 111(h)(1) of the CAA.

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Kleinberg, Robert. 2021. *EPA Methane Emission Controls, Obama vs Trump vs Biden: What Needs to Be Fixed and What Should Be Left Alone,* (Boston University Institute for Sustainable Energy, Boston, MA, USA). Available at bu.edu/ise and http://dx.doi.org/10.2139/ssrn.3810337.