U.S. Department of Transportation

Pipeline and Hazardous Materials
Safety Administration
Washington, DC 20590

Draft Environmental Assessment

[Docket No. PHMSA-2021-0039]

Pipeline Safety: Leak Detection and Repair

Proposed Rule

Office of Pipeline Safety

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Table of Contents

List of Tables

List of Figures

Executive Summary

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is proposing regulatory amendments that implement Congressional mandates in the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020 (PIPES Act of 2020) to reduce emissions of methane and other flammable, toxic, and corrosive gases[1] from new and existing gas transmission, distribution, and 49 CFR part 192-regulated gathering (Types A, B, and C) pipelines and other gas pipeline facilities, including liquefied natural gas (LNG) facilities and underground natural gas storage facilities (UNGSFs). Among the proposed amendments for part 192-regulated gas pipelines are strengthened leakage survey and patrolling requirements; performance standards for advanced leak detection programs; leak grading and repair criteria and mandatory repair timelines; and requirements for mitigation of emissions from blowdowns and pressure relief device design, configuration, and maintenance. The rulemaking also proposes enhanced reporting requirements for operators of all gas pipeline facilities within DOT's jurisdiction, including LNG facilities and UNGSFs.

The purpose of this draft Environmental Assessment (DEA) is to comply with the requirements of the National Environmental Policy Act (NEPA), 42 U.S.C. 4321 *et seq.*, and NEPA implementing regulations at 40 CFR parts 1500-1508 and in accordance with DOT Order 5610.1C by providing PHMSA's analysis of the potential consequences of the proposed rule on the human and natural environment. PHMSA will review and respond to any comments submitted in response to this DEA and proposed FONSI. The accompanying Preliminary Regulatory Impact Analysis (PRIA) complements the analysis presented in this DEA by analyzing the environmental and safety benefits expected to result from the proposed rule (PHMSA, 2023).

Overall, the proposed rule is expected to benefit the physical environment, human health, and public safety by decreasing the quantity and consequences of gas releases from regulated gas gathering, transmission, and distribution pipelines and other gas pipeline facilities. Specifically, PHMSA estimates that the proposed rule would reduce methane emissions (see Table ES-1 for estimated reductions) over the 15-year analysis period.

Table ES-1: Changes in methane emissions (Metric Ton CH_4)

Year	Gathering[1]	Transmission[1]	Distribution[1]		Total emissions[1, 2]	
			Lamb *et al.* (2015)	Weller *et al.* (2020)	Low	High
2024	-52,300	-1,300	-42,280	-115,300	-95,900	-168,900
2025	-79,000	-1,900	-82,470	-229,900	-163,300	-310,800
2026	-106,000	-2,500	-135,400	-423,500	-243,800	-532,000
2027	-133,400	-3,100	-179,300	-588,400	-315,800	-724,900

[1] Much of the discussion in the NPRM and in this Preliminary Regulatory Impact Assessment is focused on methane emissions from natural gas pipeline facilities, as those facilities constitute the great majority of gas pipeline facilities subject to parts 191 and 192. However, PHMSA parts 191 and 192 requirements are not limited to natural gas pipelines; rather, they also apply to pipeline facilities transporting other gases which are flammable, toxic, or corrosive — releases of which may entail significant public safety or environmental consequences (including potential contributions to climate change) in their own right. See §§ 191.3 and 192.3 (definitions of "gas" for the purposes of parts 191 and 192, respectively).

Table ES-1: Changes in methane emissions (Metric Ton CH_4)						
Year	**Gathering**[1]	**Transmission**[1]	**Distribution**[1]		**Total emissions**[1, 2]	
			Lamb *et al.* (2015)	**Weller *et al.* (2020)**	**Low**	**High**
2028	-161,300	-3,700	-206,400	-699,400	-371,300	-864,300
2029	-189,500	-4,300	-223,100	-770,700	-416,900	-964,500
2030	-218,100	-4,900	-237,500	-817,200	-460,500	-1,040,200
2031	-247,100	-5,600	-251,600	-863,800	-504,200	-1,116,400
2032	-276,500	-6,200	-265,300	-910,600	-547,900	-1,193,300
2033	-306,300	-6,800	-278,600	-957,600	-591,700	-1,270,800
2034	-336,500	-7,500	-291,500	-1,005,000	-635,500	-1,348,900
2035	-367,200	-8,100	-304,200	-1,052,000	-679,500	-1,427,700
2036	-398,300	-8,800	-316,700	-1,100,000	-723,800	-1,507,300
2037	-429,800	-9,500	-329,000	-1,148,000	-768,300	-1,587,600
2038	-461,800	-10,100	-341,200	-1,197,000	-813,100	-1,668,700

The estimates do not include additional emission reductions expected from mitigating releases of natural gas during venting and blowdown of part 192-regulated gathering, transmission, and distribution pipelines and other pipeline facilities.

[1] Negative values represent reduced methane emissions under the proposed rule. Total emissions reflect the range of estimated distribution emissions. The low estimate reflects distribution costs based on Lamb et al. (2015) whereas the high estimate reflects distribution costs based on Weller et al. (2020).

[2] Total may not sum up due to independent rounding.

Source: PHMSA analysis

PHMSA also expects that by providing for more timely detection and repair of leaks, the proposed rulemaking would enhance protection of public safety and the environment. Leaks on any gas pipeline facility can degrade into more serious integrity failures (such as ruptures and other incidents) posing significant risks for public safety and the environment if not repaired in a timely manner. For gas gathering lines conveying unprocessed natural gas, the risks to public safety and the environment from infrequent (or non-existent) leak survey requirements are particularly acute as any leaks releasing volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) such as benzene, and corrosive materials entrained with the unprocessed natural gas can expedite degradation of pipeline integrity. In addition, detecting and repairing leaks from gas gathering lines may also have human health benefits by reducing emissions of VOCs and HAPs contained in unprocessed gas. As discussed at greater length in EPA (2022b), VOC emissions are a precursor to ozone and ambient ozone is associated with adverse health effects, including respiratory morbidity, asthma attacks, hospital and emergency department visits, lost school days, and premature respiratory mortality. HAPs associated with natural gas production include several substances that are known or suspected carcinogens, including but not limited to benzene, formaldehyde, toluene, xylenes, ethylbenzene.

By reducing contributing drivers of climate change and reducing public safety and health risks associated with leaks from gas pipeline facilities, the proposed rule is also expected to further the environmental justice goals described in Executive Order 14008, Tackling the Climate Crisis at Home and Abroad (86 FR 7619, February 1, 2021) to address the disproportionately high and adverse human health, environmental, climate-related, economic, and other impacts on disadvantaged communities.

While the proposed rule is not expected to affect the construction of gas pipeline facilities and the associated impacts, it may result in additional excavations to investigate leak indications or to perform certain leak repairs that operators may otherwise have deferred. Excavation work can have adverse impacts on water and air quality, and PHMSA expects that these activities would have localized, temporary, and relatively minor environmental effects, relative to the more significant cumulative climate impacts or safety risks resulting from gas pipeline leaks.

1 Determination of Need

1.1 Background

Federal leak detection and repair standards for gas pipelines have remained largely unchanged since the 1970s. Since that time, advances in leak detection technology and the growing understanding of the contribution of methane—the primary component of natural gas and a powerful greenhouse gas—to climate change, as well as recent incidents attributable to inadequate leak survey practices, have pointed to the need to update those standards. The general leak repair requirements in §192.703(c) and distribution line leakage survey requirements in §192.723 were established on August 19, 1970 (35 FR 13257), and leakage survey requirements for gas transmission lines were promulgated five years later, on May 9, 1975 (40 FR 20279). These provisions lack sufficiently robust and enforceable standards for the performance of leakage surveys and repair of leaks discovered, especially for leaks that pipeline operators consider "non-hazardous" to safety based on the leak rate, location, and other factors.

This proposed rulemaking addresses a negative externality in gas transportation wherein the cost of emissions of methane and other gases associated with leaks from gas pipeline facilities are borne not by pipeline operators responsible for detecting and repairing leaks, but by society as a whole. Gas pipeline and other facility contributions to methane emissions have been well documented. For example, the U.S. Environmental Protection Agency (EPA) estimates that gas sources regulated by PHMSA emitted approximately 0.9 million metric tons (MMTon) of methane in 2020, based on the Greenhouse Gas Inventory (EPA, 2022a; EPA, 2022d). EIA, 2022Market forces alone have proven insufficient to fully incentivize distribution pipeline operators to detect and repair natural gas leaks. Studies have found underinvestment in cost-effective methane reduction strategies relative to the cost of the lost gas—*i.e.*, leak mitigation measures whose cost is below the value of the gas that would be contained by executing them are not being implemented—particularly when also considering the social cost of methane (Hausman & Muehlenbachs, 2018; Hausman & Raimi, 2019). In part, this is because cost-of-service regulations often incorporate allowances for "just and reasonable" amount of lost and unaccounted for (LAUF) gas, with that cost passed through to customers. Although some states have adopted regulatory incentives to reduce LAUF gas, such losses are still considered part of "normal" operations and factored into operating costs. While some States have adopted such regulatory incentives, many have not, and it is not clear when or if they may take action on this issue. Further, the economic incentives for operators that bear the cost of lost gas are to reduce leaks only to the point where the marginal cost of leak detection and mitigation equals the value of lost gas. Further, even if companies were incentivized to avoid losses through higher operating costs and lower net revenue, they would not internalize the external costs of climate change impacts of methane emissions, which are roughly 10 times greater than natural gas market prices.[2] Thus, curtailing methane emissions as needed from a societal perspective is not

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[2] As detailed in the PRIA (section 5.2), PHMSA uses estimates of the social cost of methane (SC-CH_4) to estimate the climate benefits from reducing methane emissions. The SC-CH_4 represents the monetary value of the net harm to society associated with a marginal change in methane emissions in a given year. In principle, the SC-CH_4 includes the value of all climate change impacts (both negative and positive),

achievable through the existing market mechanisms alone. The proposed rule does not change those market mechanisms or incentives. Instead, the rule addresses the negative externality by requiring operators to perform leak surveys and repair leaks.

Natural gas production is projected to increase by 24 percent between 2021 and 2050, according to the Energy Information Administration (EIA, 2022). Exports, particularly liquefied natural gas (LNG), are projected to account for much of the growth in production, due to strong global demand and the continued expansion of LNG export capacity. Since methane emissions are in part driven by natural gas throughput (Cooper *et al.*, 2021), putting in place measures to ensure that leaks are found and promptly fixed will be critical for meeting future energy needs in an environmentally responsible manner. In Section 113 of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020 (PIPES Act of 2020; Pub. L. 116-260), Congress recognized these weaknesses and the need for more stringent regulation by mandating that PHMSA establish performance standards for leak detection and repair programs and require that gas pipeline operators implement such programs.

The section below highlights the current environmental impacts of gas leaks and methane emissions that exist currently, without the assistance of proposed advanced leak detection equipment and procedures. The Notice of Proposed Rule Making (NPRM) published in the Federal Register (FR) provides additional information on the policy background and need for this rulemaking, as well as a section-by-section discussion of the rule provisions.

1.2 Gas Leaks and Methane Emissions

1.2.1 Methane Emissions

The Environmental Protection Agency's (EPA) Greenhouse Gas Inventory (GHGI) provides the federal government's official estimates of U.S. GHG emissions, including methane from natural gas pipeline systems.[3] The latest inventory covers the period of 1990-2020 (EPA, 2021c; EPA, 2022d). The inventory incorporates emissions reported by major GHG sources to the GHG Reporting Program (GHGRP) and estimates derived using emission factors and activity data (EPA, 2021a; EPA, 2022a). The most recent GHGI estimates for the natural gas system are based on emission factors from various sources, including EPA & Gas Research Institute (GRI) (1996) and Lamb *et al.* (2015).[4]

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including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The average SC-CH4 at a 3 percent discount is $1,500 per metric tonne CH_4 in 2020, which is approximately 13 times the market price of natural gas in 2020, based on projected Henry Hub spot prices from the Energy Information Administration's Annual Energy Outlook 2021 (U.S. Energy Information Administration, 2021).

3 As discussed in section II.C of the NPRM, some studies criticize the EPA's GHGI estimates as under-reporting methane emissions. To the extent that the criticism levelled in those studies is warranted and the GHGI estimates are lower than actual emissions, PHMSA submits that this rulemaking can be expected to result in larger avoided GHG emissions benefits.

4 See tables 3.6-6 and 3.6-17 of Annex 36 of the 2021 GHGI for the source and methodology of each methane emissions factor (EPA, 2021a; EPA, 2022a).

Table 1 summarizes methane emission estimates for natural gas segments of the Oil and Gas sector. Estimates relevant to sources regulated by PHMSA include 0.14 million metric tons (MMTon) of methane for gathering pipeline leaks and blowdowns, 0.22 MMTon for transmission pipelines (including both leaks and venting), and 0.55 MMTon from distribution systems, including 0.20 MMTon from distribution pipeline leaks. Only a fraction of gas gathering pipeline emissions is expected to come from PHMSA-regulated lines in scope of this proposed rule since regulated gathering lines account for only 23 percent of the total mileage of gas gathering lines in the United States.[5]

Methane emissions from natural gas pipeline infrastructure occur due to unintentional leaks throughout the pipeline infrastructure; intentional venting, such as when a pipeline is blown down for repairs or maintenance; or accidents such as when a pipeline ruptures. The vast majority of methane emissions from gas distribution systems are caused by leaks and ruptures from pipeline facilities. Approximately half of net methane emissions from natural gas distribution systems in the GHGI stem from pipeline leaks and mishaps (*e.g.*, excavation damage and other incidents). Leaks from customer meters, meter stations, and regulator stations comprise most of the remaining emissions. While the net methane emissions from natural gas pipelines are small relative to that of the natural gas industry overall, the leak detection and repair standards required by the PIPES Act of 2020 and proposed in this NPRM could meaningfully decrease emissions from PHMSA-regulated sources and reduce total emissions.

In addition, as discussed later in this document and in sections 3.5 and 6.1 of the PRIA, PHMSA in this proposed rule is also codifying the self-implementing provisions of the PIPES Act of 2020, including requirements that operators mitigate vented and other emissions from gas pipeline facilities. The self-implementing provisions, which are part of the baseline for the proposed rule, help further reduce the environmental and safety impacts of gas pipelines.

Table 1: Inventoried methane emissions from natural gas systems in 2020

Natural gas industry segment and source	Net emissions (MMTon CH_4)
Exploration	**0.01**
Production	**3.55**
Onshore production	1.97
Offshore production[6]	0.04
Gathering and boosting	1.54
Pipeline leaks[1]	0.13
Pipeline blowdowns[1]	0.01
All other gathering and boosting sources	1.40
Processing	**0.49**
Transmission and storage	**1.62**
Compression	1.38
Pipeline leaks[2]	<0.01

5 In 2020, PHMSA regulated 11,368 miles of onshore gas gathering lines, compared to a total of 438,971 miles of gathering lines in the GHGI (EPA, 2021c; EPA, 2022a; EPA, 2022d). The 2021 Expansion of Gas Gathering Regulation (86 FR 63266, November 15, 2021) added an estimated 90,863 miles of Type C gathering lines to the regulated universe and brought the PHMSA-regulated share to approximately 23 percent of the GHGI total mileage.

6 “Boosting” infrastructure on gas gathering pipelines is analogous to compression on gas transmission pipelines.

Table 1: Inventoried methane emissions from natural gas systems in 2020	
Natural gas industry segment and source	Net emissions (MMTon CH_4)
Pipeline venting	0.22
LNG storage and import/export terminals	0.02
Distribution	**0.55**
Pipeline leaks	0.20
Meter/regulator	0.04
Customer meters	0.24
Routine maintenance (pressure relief, blowdown)	0.00
Mishaps/dig-ins	0.07
Total[3]	**6.23**

[1] Pipeline leaks and blowdowns estimated based on 438,971 miles of gathering lines.
[2] Estimated emissions from pipeline leaks were 3.3 kt CH4 in 2020, *i.e.*, greater than zero but less than the 0.01 MMTon CH_4 data resolution of this table.
[3] Total may not add up due to independent rounding.
Source: EPA, 2022a; EPA, 2022d

Further, some researchers have suggested that the GHGI understates the amount of methane emitted by the natural gas industry and, in particular, methane emissions from pipeline segments. For example, a study by Alvarez *et al.* (2018), estimated methane emissions that were approximately 60 percent higher than the corresponding GHGI estimates for the year 2015 (and also significantly higher than those in EPA's GHGI for the year 2020), with the largest difference observed for the production segment. They attributed the differences to EPA's inventory methods failing to account for significant releases during abnormal operating conditions. A survey of the Permian oil and gas production area by Chen *et al.* (2022) showed emission rates for gathering line leaks that were two orders of magnitude larger than estimates derived from the GHGI and PHMSA data (1,452 vs 11.4 metric tons CH_4/leak-year).[7] Weller *et al.* (2020) focused specifically on the natural gas distribution segment and estimated emissions that were five times larger than those in the 2017 GHGI (0.69 MMTon vs. 0.14 MMTon).[8] Weller *et al.* (2020) attributed the differences to a larger number of leaks and better characterization of the upper tail of the skewed distribution of emission rates.

1.2.2 Overview of Regulated Gas Pipelines

As of 2020, there were 339,544 miles of regulated gas gathering and gas transmission pipelines and 1.33 million miles of gas distribution mains. The vast majority of these lines transported natural gas. In 2020, practically no gathering pipeline, and less than 0.1 percent and 0.2 percent of gas transmission and distribution mains, respectively, transported other gas commodities, including propane, synthetic gas, nitrogen, and landfill gas (PHMSA, 2021a; 2021b).

Age and pipe material have been shown to affect the leak rates of gas pipelines. As shown in Table 2, plastic pipe accounted for the largest and fastest growing share of the total mileage of gas distribution mains in 2020. Despite the progressive replacement of older "leak-prone" cast

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7 Section 6.2 in the PRIA presents alternative estimates for gathering lines derived from field surveys in the Permian Basin oil and gas production area.

8 Emissions obtained by Weller *et al.* (2020) are also greater than the more recent GHGI estimates of pipeline leaks summarized in Table 1 for calendar year 2020: 0.20 MMTon CH_4.

iron and bare steel distribution mains with plastic lines over the last decades, cast iron and unprotected steel still accounted for nearly half of EPA's GHGI estimate for distribution mains (EPA, 2021a) given the much higher emission rates of these lines (40 and 30 times larger) when compared to plastic. As shown in Table 3, which summarizes emission factors from selected studies, Weller *et al.* (2020) estimated leak incidence rates for plastic pipelines that, while lower than for other materials (0.43 leaks per mile vs. 1.00 leak per mile for cast iron) were larger than those assumed by EPA based on EPA & GRI (1996) or Lamb *et al.* (2015). Weller *et al.* (2020) also found that leak incidence of all material types increases with age.

Table 2: Mileage of gas distribution mains by material (miles)

Pipe Material	2015	2020	Average annual change, 2015-2020
Bare Steel, Unprotected	39,652	30,183	-1,894
Coated Steel, Unprotected	20,090	18,003	-417
Bare Steel, Protected	11,835	10,268	-313
Coated Steel, Protected	467,941	460,604	-1,467
Plastic	706,395	787,507	16,222
Cast Iron	27,765	19,989	-1,555
Ductile Iron	575	476	-20
Copper	17	8	-2
Reconditioned Cast Iron	21	34	3
All Others	1,277	1,299	5
Total	**1,275,566**	**1,328,372**	**10,561**

Data include all gas commodities.
Source: Gas Distribution Annual Report. Part B: System Description (6/1/21 data release)

Table 3: Gas distribution system methane emission factors from selected studies.

Pipe Material	EPA & GRI (1996)		Lamb *et al.* (2015)		Weller *et al.* (2020)	
	Leak incidence (leak/mile)	Emissions rate (g/min-leak)	Leak incidence (leak/mile)	Emissions rate (g/min-leak)	Leak incidence (leak/mile)	Emissions rate (g/min-leak)
Bare (unprotected) steel	1.82	1.91	2.51	0.77	0.51	2.24
Cast iron	N/A	3.57	2.88	0.90	1.00	1.72
Coated (protected) steel	0.14	0.76	0.11	1.21	0.61	2.00
Plastic	0.18	1.88	0.05	0.33	0.43	2.03
Total (all materials)	0.35	N/A	0.23	N/A	0.51	N/A

N/A: Value not available.
Source: Adapted from Table 1 and Table 2 in Weller et al. (2020)

All distribution pipelines and approximately 97 percent of gathering and transmission pipelines are located onshore. For onshore gathering and transmission pipelines, the pipeline safety regulations at 49 CFR 192.5 use class locations to provide a graded approach to ensuring safety margins and standards commensurate with the potential consequences of pipeline incidents. This is because while all leaks can have potential environmental impacts, pipeline locations determine the direct safety risk that leaks represent to people and property. The class locations are defined based on the population density near a pipeline, with Class 1 indicating rural areas with very few buildings and Class 4 indicating locations where buildings with 4 or more stories above ground are prevalent. Table 4 summarizes the distribution of gathering and transmission lines by location.

Table 4: Mileage of gas gathering and gas transmission lines by location in 2020 (miles)				
Location	**Class[1]**	**Gathering[2]**	**Transmission**	**Total**
Offshore	N/A	5,907	2,854	8,761
Onshore	1	90,863	234,178	325,041
	2	6,999	30,259	37,258
	3	4,357	33,775	38,131
	4	13	866	879
Total		**108,138**	**301,933**	**410,071**

N/A: Not applicable

[1] Class locations are defined at § 192.5. A Class 1 location is an offshore area or any class location unit with 10 or fewer buildings intended for human occupancy within the class location unit. A Class 2 location is any class location unit with more than 10 but fewer than 46 buildings intended for human occupancy within the class location unit. A Class 3 location is any class location unit with 46 or more buildings intended for human occupancy or an area where the pipeline lies within 100 yards of either a building or a small, well-defined outside area that is occupied by 20 or more persons on at least 5 days a week for 10 weeks in any 12-month period within the class location unit, and a Class 4 location is any class location unit where buildings with 4 or more stories above ground are prevalent.

[2] Onshore mileage includes Type A, Type B, and Type C part 192-regulated gathering. Type A gathering lines are those made of metallic pipe and a maximum allowable operating pressure (MAOP) more than 20 percent of the specified minimum yield strength (SMYS), or non-metallic pipe with MAOP more than 125 psig. Type B gathering lines are those made of metallic pipe with MAOP less than 20 percent of SMYS, or non-metallic pipe with MAOP less than 125 psig. Type C gathering lines are those in Class 1 locations that have outer diameters of 8.625 inches or greater and operate at higher stress levels or pressures.

Source: Gas Transmission and Gathering Annual Report, 2020. Part L: Miles of Pipe by Class Location (6/1/21 data release)

1.2.3 Reported Leaks from Gas Pipeline Systems

Operators report to PHMSA the number of leaks eliminated (*i.e.*, repaired) each year as part of their Transmission and Gathering Annual Report and their Gas Distribution Annual Report.

Gas gathering and gas transmission operators reported an average of 1,640 leaks eliminated each year during the period of 2015-2020. The majority of leaks repaired on gathering and transmission pipelines (Figure 1) were due to the reporting categories of “corrosion” (including external corrosion, internal corrosion, and stress corrosion cracking), “manufacturing,” "construction," and "equipment". [9,10] PHMSA notes that the reported values in this section for the number of leaks detected, as well as the number of leaks repaired, likely undercount actual values for gas distribution, transmission, and part 192-regulated gathering pipelines because, inter alia: (1) part 191 reporting requirements for those gas pipeline facilities do not require the reporting of leaks that can be eliminated by routine maintenance such as lubrication, tightening, or adjustment, and (2) Types C and R gathering pipelines — which comprise most gas gathering pipelines regulated pursuant to part 191 — have not historically been subject to any part 191 reporting requirements.

Distribution operators reported an average of 124,242 leaks eliminated or repaired each year during that same period (Figure 2); an average of 107,231 leaks involved causes other than excavation damage. These leaks included an average of 42,553 leaks per year (Figure 3) that operators determined presented an existing or probable hazard to persons or property that required immediate repair or continuous action until the conditions are no longer hazardous.[11] This category corresponds to "hazardous leaks" that must be repaired pursuant to §192.703(c), and to grade 1 leaks in the NPRM. As such, the annual reports only cover a small subset of all existing gas distribution leaks. Importantly, any insight that can be derived from the annual reports would not account for the full set of leaks targeted by the proposed leak detection and repair provisions under the proposed rule, or the proposed expanded scope of "hazardous" leaks to be reported to PHMSA to go beyond leaks hazardous to public safety to also include leaks hazardous to the environment.[12]

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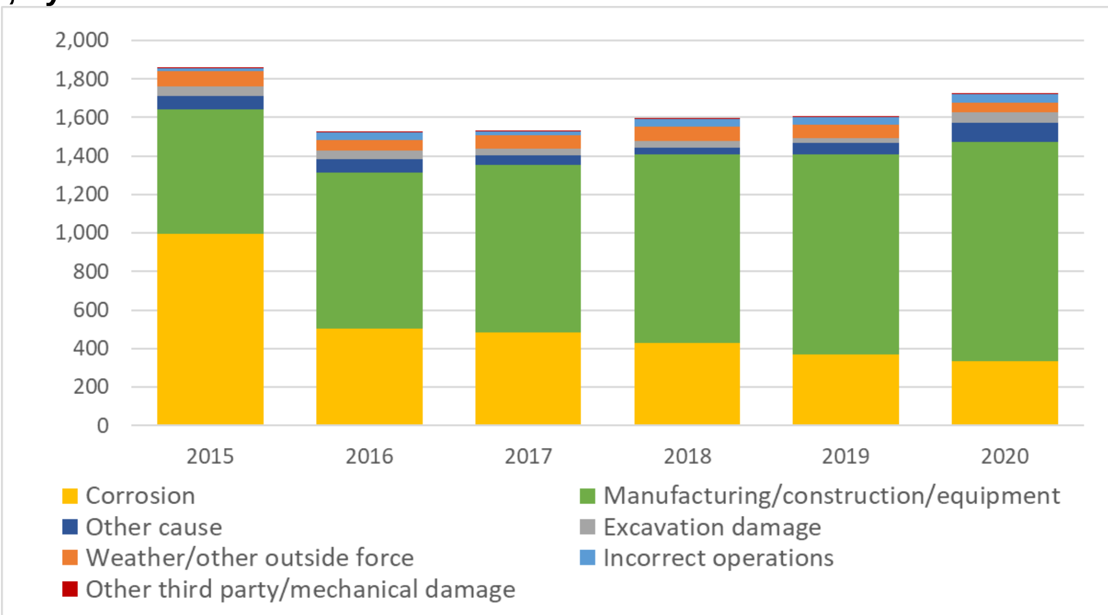
9 The instructions for the Gas Gathering and Transmission Annual Report describe these categories as follows:
Manufacturing: includes releases or failures caused by a defect or anomaly introduced during the process of manufacturing the pipe, including seam defects and defects in the pipe body or pipe girth weld.
Construction: includes releases or failures caused by a dent, gouge, excessive stress, or some other defect or anomaly introduced during the process of constructing, installing, or fabricating pipe (or welds which are an integral part of pipe), including welding or other activities performed at the facility.
Equipment: includes releases from or failures of items other than pipe or welds, and includes releases or failures resulting from: malfunction of control/relief equipment including valves, regulators, or other instrumentation; compressors or compressor-related equipment; various types of connectors, connections, and appurtenances; the body of equipment, vessel plate, or other material (including those caused by: construction-, installation-, or fabrication-related and original manufacturing-related defects or anomalies; and low temperature embrittlement); and, all other equipment-related releases or failures.

10 For additional details, see Part M of Form OMB 2137-0522, "Annual Report: Natural Gas and Other Gas Transmission and Gathering Pipeline System."

11 This category corresponds to "hazardous leaks" that must be repaired pursuant to § 192.703(c), and to grade 1 leaks in the NPRM.

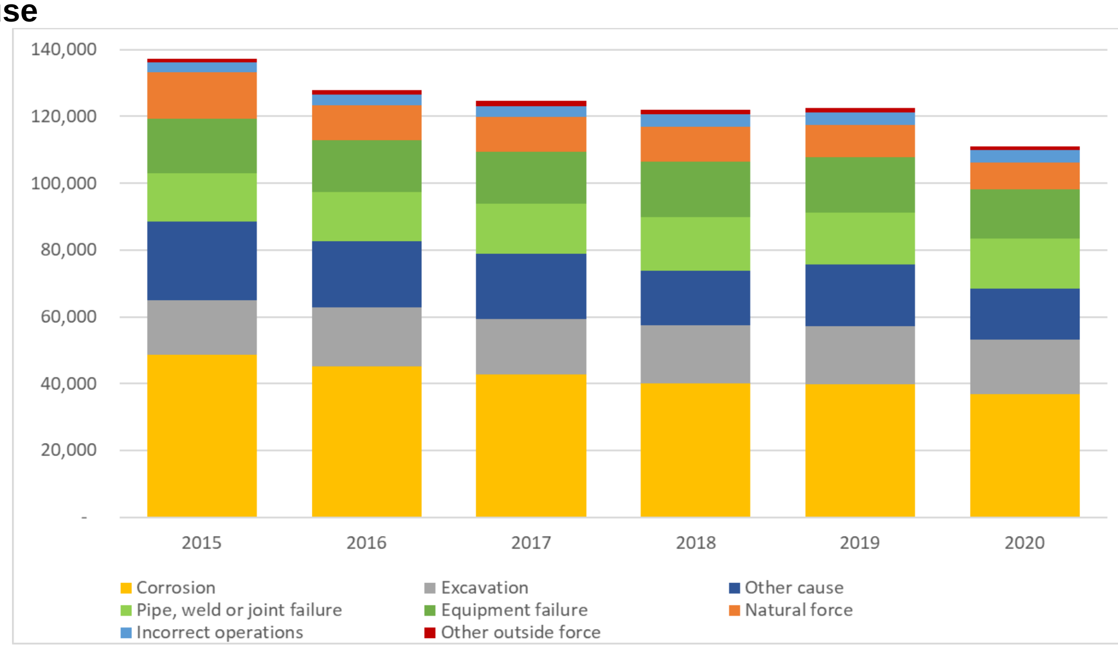
12 As detailed in the NPRM, PHMSA proposes to change Form F7100.1-1 and its instructions to collect data on leaks detected and repaired by grade in the annual reporting period; the number (by grade) of unrepaired leaks at the conclusion of the annual reporting period; and the estimated aggregate and average per-leak emissions from leaks on an operator's system over the annual reporting period. PHMSA also proposes to revise miscellaneous sections of those annual reports and their instructions to remove statements expressing or suggesting a distinction between hazardous leaks, other leaks, or other gas releases allegedly too small to merit reporting.

Figure 1: Total gathering and transmission leaks eliminated or repaired in 2015-2020, by cause



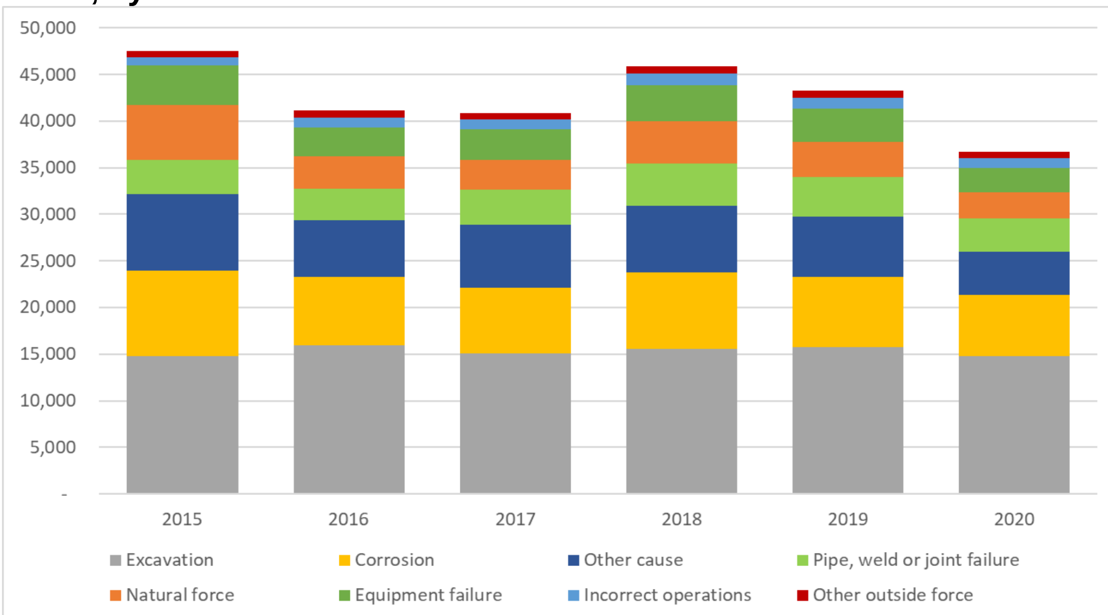
Source: Gas Transmission and Gathering Annual Report (6/1/21 data release).

Figure 2: Total distribution main leaks eliminated or repaired in 2015-2020, by cause



Source: Gas Distribution Annual Report (6/1/21 data release).

Figure 3: Number of distribution mains hazardous leaks eliminated or repaired in 2015-2020, by cause



Source: Gas Distribution Annual Report (6/1/21 data release).

Operators of LNG facilities and UNGSFs report to PHMSA each year on the characteristics and operational status of their facilities.[13] For LNG facilities, the reported information includes the number of leaks resulting in a release detected and repaired, by location and cause. Figure 4 shows the total leaks in 2015-2020 by location within the LNG facility. The vast majority of the leaks originated from plant piping and equipment. Of those leaks, most were attributed to "equipment failure" (*e.g.*, 36 out of the 46 leaks reported in 2020 as originating from plant piping and equipment were caused by equipment failure). Annual reporting by UNGSFs started in 2017, with operators required to report the number of wells with casing, wellhead, or tubing leaks as well as the number of wells undergoing certain repairs and other maintenance activities. In total in 2020, UNGSF operators reported a total of 56 well leaks, out of a total of 13,984 injection and/or withdrawal wells.

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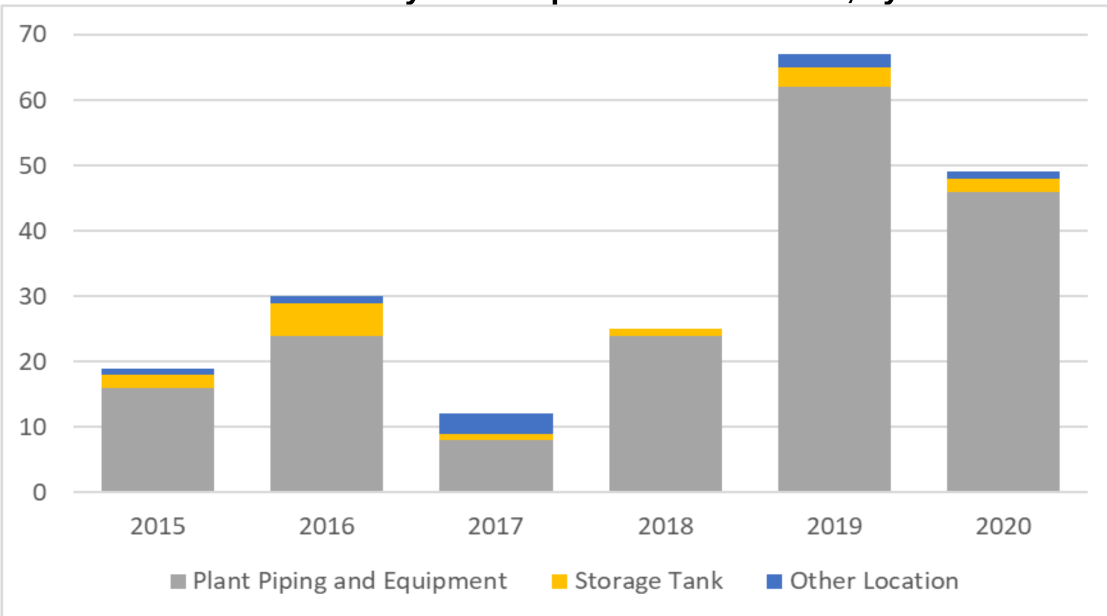
13 Similar to gas distribution, transmission, and gathering pipelines, the values historically reported to PHMSA regarding the number of leaks identified and repaired on LNG facilities and UNGSFs are likely lower than the actual number of leaks because part 191 reporting requirements for facilities do not require the reporting of leaks that can be eliminated by routine maintenance such as lubrication, tightening, or adjustment.

Figure 4: Number of LNG facility leaks repaired in 2015-2020, by location



Source: Liquefied Natural Gas Facilities Annual Report (8/1/2022 data release).

2 Alternatives

2.1 Proposed Action (Proposed Rule)

2.1.1 Proposed Changes to Requirements Applicable to Regulated Gas Pipelines and Other Gas Facilities

PHMSA proposes to establish performance standards for an Advanced Leak Detection Program (ALDP), grading and repair standards for pipeline leaks, enhanced leakage survey and repair requirements, and other requirements designed to minimize methane emissions from gas pipeline systems. The proposed rule would apply to all regulated gas gathering, gas transmission, gas distribution pipelines and other gas pipeline facilities, offshore or onshore, that transport natural gas or other gas commodities subject to 49 CFR part 192.

In addition, PHMSA is proposing changes to codify the self-implementing provisions of the PIPES Act of 2020. For example, this rule would add requirements that operators must mitigate vented and other emissions from gas pipeline facilities (including part 192-regulated pipelines, underground storage facilities, and part 193-regulated LNG facilities) (§§192.9, 192.12, 192.605, 192.770, 193.2503, 193.2523 and 193.2605).

Table 5 summarizes the proposed rule changes. At the top of the table are general requirements applicable to all regulated pipelines, including LNG facilities and UNGSFs,[14] such as performance criteria for advanced leak detection (ALD) technologies and practices used to conduct leak surveys.[15] The table then highlights proposed changes to requirements specific to gas gathering and gas transmission pipelines, and to requirements specific to gas distribution lines. Note that this table provides only a high-level summary of the changes. The NPRM provides the actual text of the proposed changes, as well as a section-by-section discussion of the rule provisions.

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14 The Pipeline Safety Regulations define an LNG facility as a "pipeline facility that is used for liquefying natural gas or synthetic gas or transferring, storing, or vaporizing liquefied natural gas" (§193.2007).The Pipeline Safety Regulations define an UNGSF as "a gas pipeline facility that stores natural gas underground incidental to the transportation of natural gas, including (1) (i) A depleted hydrocarbon reservoir; (ii) An aquifer reservoir; or (iii) A solution-mined salt cavern. (2) In addition to the reservoir or cavern, a UNGSF includes injection, withdrawal, monitoring, and observation wells; wellbores and downhole components; wellheads and associated wellhead piping; wing-valve assemblies that isolate the wellhead from connected piping beyond the wing-valve assemblies; and any other equipment, facility, right-of-way, or building used in the underground storage of natural gas." (§192.3)

15 PHMSA sees an ALDP as a complementary set of mutually-reinforcing technologies and procedures (including analytics) that the operator uses to detect all leaks. As proposed, the ALDP requirements include four main elements: (1) leak detection equipment employing commercially available advanced technology, (2) leak detection procedures, (3) prescribed leakage surveys, and (4) program evaluation.

Table 5: Summary of principal proposed changes for gas pipelines		
Industry Segment	**Topic**	**Changes**
General	191.19: Large-volume release reports and 191.23: Reporting safety-related conditions	• Adds a requirement to report large-volume releases, defined as releases greater than 1 million cubic foot (MMcf), to PHMSA. (Note that this requirement applies to releases from pipelines as well as other gas facilities, including underground storage and LNG facilities). • Excepts large-volume releases as defined in proposed §191.3 from the requirement to submit a safety-related condition report pursuant to §191.23, thereby leaving reportable safety-related conditions unchanged. • Amends §191.23(a)(9) to explicitly limit that safety-related condition reporting requirement to imminent hazards to public safety.
	191.3: Definitions	• Defines, for the purposes of all subparts of part 192 other than IM requirements in §192.12(d) and subparts O and P, a "leak or hazardous leak" as any release of gas from a pipeline that is uncontrolled at the time of discovery and is an existing, probable, or future hazard to persons (including operating personnel), property, or the environment, or any uncontrolled release of gas from a pipeline that is detectable via equipment, sight, sound, smell, or touch.
	192.553 and 192.557: Uprating	• Revises the general requirements for uprating to clarify that any hazardous leaks detected during the uprating process on gas transmission, distribution, offshore gathering, and Type A gathering lines must be repaired prior to further increasing the pressure of the pipeline. • Adds a requirement to conduct a leak test and make any needed repair prior to uprating a pipeline to operate at an MAOP producing a hoop stress less than 30 percent of SMYS, or that is made of plastic, cast iron, or ductile iron.
	192.760: Leak grading and repair (also 192.703(c)-(d), 192.709, and 192.763)	• Requires operators to develop procedures for grading and repairing leaks. (192.760(a)) • Defines criteria for grading leaks from gathering, transmission, and distribution pipes into grades 1, 2, and 3. Grade 1 leaks are existing or probable hazards to persons or property, or existing hazards to the environment. Grade 2 leaks represent a probable future hazard to safety or the environment, but not current or imminent hazards like grade 1 leaks. Grade 3 leaks do not meet the grades 1 or 2 criteria. (192.760(b) and (c)) • Specifies deadlines for repairing leaks, ranging from immediate repair to 5 years depending on the leak grade and ongoing evaluation measures. (192.760(b) and (c)) • Requires post-repair evaluation. (192.760(e)) • Operators may submit requests for "no objection" to extend repair deadline for grade 3 leaks. (192.760(h)) • Requires documentation of the leaks, repairs, and post-repair evaluation. (192.760(i))

Table 5: Summary of principal proposed changes for gas pipelines		
Industry Segment	**Topic**	**Changes**
	192.763: Advanced leak detection systems	• Specifies performance standards for detection equipment and methods, including minimum sensitivity. • Outlines elements of the ALD program, including equipment, procedures, frequency of leakage surveys, and evaluation and improvement. • Specifies requirements for operators to request alternative performance standards for certain gathering and transmission lines. • Requires that operators conduct an analysis to select the tools, procedures and analysis methodology appropriate to their conditions.
	192.769: Leakage survey practices	• Requires that leakage survey, analysis, and grading be conducted only by adequately qualified individuals.
	192.773: Maintenance of pressure relief devices and adjustment of configuration	• Requires operators to have written operation and maintenance (O&M) procedures for assessment of the proper function of pressure relief devices. • Requires operators to assess and either repair or replace malfunctioning pressure relief devices. • Identifies specific action operators have to take on operation of a malfunctioning pressure relief device. • Requires that operators maintain records documenting the proper operation and any remediation/replacement of pressure relief devices for the service life of their facilities.
Gathering and transmission	191.17: Annual reports	• Changes the gas transmission and regulated gathering annual report form (Form F7100.2-1) to collect data on leaks detected and repaired by grade during the annual reporting period.
	191.29: National Pipeline Mapping System (NPMS)	• Adds NPMS reporting requirements for regulated gas gathering lines (Type A, Type B, and Type C), onshore or offshore, by deleting the current exemption for these systems.
	192.9: Requirements applicable to gathering lines	• Revises the list of requirements applicable to Type B and Type C gathering lines and to offshore gas gathering pipelines. In particular, the revisions expand the scope of leak survey and repair requirements to all Type C gathering pipelines in accordance with 192.703(c)-(d), 192.709, and 192.760.
	192.199: Design and configuration of pressure relief and limiting valves	• Requires that all new, replaced, relocated, or otherwise changed overpressure protection devices be designed and configured to minimize unnecessary releases of gas to the atmosphere
	192.605: Procedural manual for operations, maintenance, and emergencies	• Extends the requirements for procedural manuals to Type B and Type C gathering lines. • Incorporates the self-executing mandate at section 114 of the PIPES Act of 2020 that the maintenance and operating procedures must include procedures for each of the elimination of leaks and for minimizing releases of gas from pipelines, as well as the remediation or replacement of pipelines known to leak based on their material, design, or past maintenance and operating history
	192.705: Patrolling	• Increases the minimum frequency of visual right-of-way patrols on gas transmission lines and on part 192-regulated Type A gas gathering pipelines to 12 times per calendar year, with the interval not exceeding 45 days between patrols.

Table 5: Summary of principal proposed changes for gas pipelines		
Industry Segment	**Topic**	**Changes**
		• Requires patrols for Type B and Type C gathering lines at frequencies identical to the patrol requirements for as transmission and Type A gathering pipelines.
	192.706: Leakage surveys	• Revises the survey frequencies accordingly: non-HCA pipelines once per calendar year, not to exceed every 15 months; Class 1, Class 2, and Class 3 pipelines in HCAs twice each calendar year not to exceed every 7 ½ months; and Class 4 pipelines in HCAs four times each calendar year not to exceed 4 ½ months. • Shortens the minimum frequency for leakage surveys in HCA and moderate consequence area (MCA) pipelines. • Requires more frequent surveys for all valves, flanges, tie-ins with valves and flanges, in-line inspection (ILI) launcher and receiver facilities, and pipe with a known leak or incident history. • Requires that leak detection surveys be conducted with equipment meeting ALD performance standards in 192.763. • Allows for an exemption from the equipment requirements if operators obtain authorization from PHMSA.
	192.770: Minimizing emissions from blowdowns	• Requires that operator implement practices that minimize the amount of gas released to the atmosphere during blowdown, and O&M procedures to verify the proper functioning of equipment that may release gas.
Distribution	191.11: Distribution annual reports	• Changes Form F7100.1-1 to collect data on leaks detected and repaired by grade in the annual reporting period and the number (by grade) of unrepaired leaks at the conclusion of the annual reporting period. • Changes the form to include estimated aggregate gas emissions from leaks by grade and other emissions categorized by source category over the annual reporting period.
	192.605: Procedural manual for operations, maintenance, and emergencies	• Incorporates the self-executing mandate at Section 114 of the PIPES Act of 2020 that the maintenance and operating procedures must include procedures for eliminating leaks and minimizing releases of gas from pipelines, as well as the remediation or replacement of pipelines known to leak based on their material, design, or past maintenance and operating history.
	192.723: Leakage surveys	• Revises the survey frequencies for different lines according to location (inside or outside business districts), pipe material and corrosion protection, and leak or accident history. • Increases the frequency of leakage surveys outside business districts. • Adds requirements to conduct leakage surveys when freezing or other environmental conditions may allow gas migration into nearby buildings, or after extreme weather events or land movement. • Requires that leak detection surveys be conducted with equipment meeting ALD performance standards in 192.763.
LNG facilities	193.2503: Operating procedures and 193.2605: Maintenance procedures	• Incorporates the self-implementing mandate that requires operators update their procedures to provide for the elimination of leaks and minimize release of gas from pipeline facilities by requiring LNG facilities to have and follow written procedures for normal and abnormal operations and for maintenance.

Table 5: Summary of principal proposed changes for gas pipelines		
Industry Segment	**Topic**	**Changes**
	193.2523: Minimizing emissions from blowdowns and boiloff	• Requires LNG facilities to mitigate methane emissions from non-emergency, vented releases such as blowdowns and tank boiloff
	193.2624 Leakage Surveys	• Requires operators of LNG facilities to perform periodic methane leakage surveys on methane or LNG-containing components and equipment at least four times each calendar year, with a maximum interval between surveys not to exceed 4 ½ months. • Specifies minimum performance standards for leak detection equipment.
UNGSFs	191.12(c): Procedural manual	• Requires UNGSFs to update their procedures to provide for the elimination of leaks and minimize release of natural gas from pipeline facilities.

2.1.2 Other Proposed Rule Changes

Certain additional proposed rule changes define terms, clarify existing requirements and practices, or revise text to ensure consistency across sections and therefore are not anticipated to result in incremental costs (or benefits). These additional rule changes, which are not detailed in this report, include:

- **Sections 192.507, 192.509, and 192.513: Test requirements**. PHMSA proposes to remove the qualifier “potentially” modifying “hazardous leak” in recognition of the certainty of environmental harms from any released gas.
- **Section 192.617: Investigation of failures**. PHMSA proposes to define the term “failure” for the purposes of existing requirements to investigate the causes of failures and incidents to clarify that these requirements apply to leaks. This change is consistent with existing industry standards and with PHMSA’s core hazardous materials safety mission.
- **Section 192.629: Purging of pipelines**. PHMSA proposes to clarify that the provisions governing the purging of gas from gas transmission, distribution, offshore gathering and Type A gathering pipelines remain focused on addressing risks to public safety.
- **Section 192.769: Qualification of leakage survey, investigation, and grading personnel.** PHMSA proposes to clarify training and qualification requirements for personnel that conduct leakage surveys, investigation, and leak grading on gas transmission, distribution, offshore gathering, and Types A gathering pipelines. Specifically, §192.769 clarifies that surveying, investigating, and grading leaks are covered tasks under subpart N and therefore personnel conducting these activities must be qualified and have documented work history or training.

2.2 No Action Alternative (Alternative 1)

PHMSA assessed keeping the requirements in 49 CFR unchanged. This alternative, however, would fail to fulfill the mandate Congress placed on PHMSA in Section 114 of the PIPES Act of

2020. The analysis of the proposed rule uses this alternative as the baseline against which PHMSA assesses environmental impacts.

2.3 Other Alternatives Considered

2.3.1 Alternative 2: Adjusted Leak Detection Survey Intervals for Plastic Distribution Mains

PHMSA assessed an alternative that would leave survey intervals for plastic pipes outside of business districts unchanged (5 years). PHMSA considered this alternative based on the differences in leak incidence for plastic pipes across studies (refer to discussion in section 3.2.3 of the PRIA) and the associated uncertainty on whether more frequent surveys of relatively new plastic pipes would provide the benefits estimated for the proposed rule. As summarized in section 6.6 of the PRIA, this alternative has lower costs, but also much lower benefits than the proposed rule, relative to the baseline. Based on studies that show plastic pipes as representing significant sources of methane leaks, PHMSA did not propose this alternative.

2.3.2 Alternative 3: Annual Surveys of All Distribution Mains

PHMSA also assessed an alternative that would require annual surveys for all distribution mains. While this alternative goes the farthest in fulfilling the PIPES Act of 2020 mandate, it results in much larger incremental costs for operators relative to the baseline, as summarized in section 6.6 of the PRIA. PHMSA did not propose this alternative.

2.3.3 Alternative 4: Leak Detection and Repair Requirements at Gas Transmission Pipeline Compressor Stations and Gas Gathering Pipeline Boosting Stations

EPA's current and proposed Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources in the Oil and Natural Gas Sector (49 CFR part 60, subparts OOOOa, OOOOb [NSPS] and OOOOc [EG]) apply to compressor stations on gas transmission pipelines and gas gathering pipelines, among other sources. The regulations set requirements for methane emissions monitoring, repair, and maintenance of certain pipeline facilities and their appurtenances.

Given EPA requirements, PHMSA is proposing to exempt gas transmission and gas gathering compressor stations subject to methane emissions standards (at current 40 CFR part 60, subpart OOOOa regulations, proposed subpart OOOOb updates and proposed subpart OOOOc methane emissions guidelines (as implemented through EPA-approved State plans with standards at least as stringent as EPA's emission guidelines in subpart OOOOc or implemented through a Federal plan), as well as any subsequent methane emissions standards at 40 CFR part 60) from each of its requirements pertaining to leak repair (§192.703(c)), leakage survey and patrol (§§ 192.705 and 192.706), leak grading and repair (§192.760), advanced leak detection program (ALDP) (§192.763) and qualification of leak detection personnel (§192.769). In proposing these exemptions, PHMSA considered that EPA's regime at 40 CFR part 60 for monitoring fugitive methane emissions from gas transmission compression stations and gas gathering and boosting (G&B) compressor stations provides public safety and environmental protection comparable to PHMSA's proposal. Although PHMSA assessed an alternative where no such exemption would be provided, PHMSA did not propose that alternative to avoid duplicative regulation of those facilities.

3 Affected Environment and Environmental Consequences

PHMSA evaluated the environments that may be affected by this proposed rule and the consequences that actions to implement the rule requirements could have on these affected environments. Because of the national scope of the regulation, this evaluation is not focused on specific areas, but instead considers the general environmental, social, and economic setting of gas facilities subject to the proposed rule. Further, this proposed rule is not expected to affect permitting for, or location of, gas facilities and therefore is not expected to have material impacts on land use. As discussed below, the categories of potential impacts most relevant to this analysis are those resulting from measures taken to reduce natural gas leaks and associated methane emissions, including most notably climate change and public safety, as well as the impacts of activities operators may implement to comply with the requirements, such as air quality, noise, and other impacts associated with leak surveys and repairs (e.g., additional miles driven by survey vehicles and crews, excavation to repair leaks, and indirect impacts from the production of methane detection equipment).

3.1 Climate Change

3.1.1 Impacts from Avoided Emissions

PHMSA anticipates the principal effect of the proposed rule to be a reduction of methane emissions through more timely discovery and repair of gas leaks from gathering, transmission, and distribution pipelines and other gas pipeline facilities. Methane is more than 25 times as potent as carbon dioxide at trapping heat in the atmosphere. Human emissions of methane are responsible for about one third of the warming due to well-mixed greenhouse gases (Intergovernmental Panel on Climate Change, 2021). Methane is also an important precursor to the formation of tropospheric (*i.e.*, ground-level) ozone. Ground-level ozone, itself a greenhouse gas, is a regulated air pollutant responsible for harmful effects on human health and damages to crops and vegetation (EPA, 2020). Natural gas is composed of 79 to 93 percent methane depending on the production region and processing stage; EPA estimates that natural gas is 87.0 percent methane before processing (in gathering pipelines), whereas natural gas transmitted and distributed is 93.4 percent methane (EPA, 2021a; EPA, 2022a). Methane also represents roughly 50 percent of landfill gas (before further processing; EPA, undated-a) and, depending on the gasification source, 0 to 5 percent of synthetic gas (U.S. Department of Energy National Energy Technology Laboratory, n.d.).

Table 6 summarizes the range of methane emissions that PHMSA estimates would be avoided over the 15-year analysis period through the implementation of the proposed rule. Section 5.1 in the PRIA describes the approach PHMSA used to estimate changes in methane emissions.

For transmission and gathering pipelines, PHMSA estimated the reductions in methane emissions associated with accelerating the repairs of leaks through the timelier discovery of leaks, and the improved effectiveness of leak detection and repair practices under the proposed rule compared to the baseline. EPA estimated a methane emission factor of 288.5 kg/mile for gas gathering pipeline leaks and 10.9 kg/mile for gas transmission and storage pipeline leaks in the GHGI (EPA, 2021c; EPA, 2022d).

For distribution pipelines, PHMSA estimated reductions in methane emissions associated with more effective and timelier detection of gas leaks, followed by the timelier repairs of these leaks. As detailed in section 3.3 of the PRIA, available studies provide differing estimates of leak incidence and emissions rates across pipe material. PHMSA used values from Lamb *et al.* (2015) and Weller *et al.* (2020) to estimate ranges of the number of leaks present across the distribution system and the methane emissions associated with these leaks.[16] The range of estimates for the distribution segment reflect differences in emission factors across studies; this range gets carried forward when estimating total avoided emissions across industry segments.

PHMSA understands its estimates for avoided methane emissions may understate actual emissions for several reasons, including the use of emission factors from the EPA GHGI. Studies have shown much higher fugitive emissions than estimated in the GHGI (Alvarez *et al.*, 2018; Brandt *et al.*, 2014; Lyon *et al.*, 2021; Zavala-Araiza *et al.*, 2017). See Section II.C of the NPRM for further discussion.

Table 6: Changes in methane emissions (Metric Ton CH4)

Year	Gathering	Transmission	Distribution		Total emissions[1]	
			Lamb *et al.* (2015)	Weller *et al.* (2020)	Low[2]	High[2]
2024	-52,300	-1,300	-42,280	-115,300	-95,900	-168,900
2025	-79,000	-1,900	-82,470	-229,900	-163,300	-310,800
2026	-106,000	-2,500	-135,400	-423,500	-243,800	-532,000
2027	-133,400	-3,100	-179,300	-588,400	-315,800	-724,900
2028	-161,300	-3,700	-206,400	-699,400	-371,300	-864,300
2029	-189,500	-4,300	-223,100	-770,700	-416,900	-964,500
2030	-218,100	-4,900	-237,500	-817,200	-460,500	-1,040,200
2031	-247,100	-5,600	-251,600	-863,800	-504,200	-1,116,400
2032	-276,500	-6,200	-265,300	-910,600	-547,900	-1,193,300
2033	-306,300	-6,800	-278,600	-957,600	-591,700	-1,270,800
2034	-336,500	-7,500	-291,500	-1,005,000	-635,500	-1,348,900
2035	-367,200	-8,100	-304,200	-1,052,000	-679,500	-1,427,700
2036	-398,300	-8,800	-316,700	-1,100,000	-723,800	-1,507,300
2037	-429,800	-9,500	-329,000	-1,148,000	-768,300	-1,587,600
2038	-461,800	-10,100	-341,200	-1,197,000	-813,100	-1,668,700

Negative values represent reduced methane emissions under the proposed rule.
[1] Total may not add up due to independent rounding.
[2] The low estimate reflects distribution emissions based on Lamb *et al.* (2015) whereas the high estimate reflects distribution emissions based on Weller *et al.* (2020).
Source: PHMSA analysis

As noted in the PRIA, measures mandated by Section 114 of the PIPES Act of 2020 to reduce intentional venting of natural gas during scheduled repairs are expected to be implemented in the

16 Weller *et al.* (2020) found much greater incidence of leaks in plastic and coated steel mains (nearly 9 times and 6 times greater, respectively), and much smaller incidence in bare steel and cast iron mains (approximately one fifth and one third, respectively) than Lamb *et al.* (2015). Emission rates in Weller *et al.* (2020) are consistently higher across all material types, by as much as six times higher for plastic mains. The Weller *et al.* (2020) emission rates are more comparable to those in EPA & GRI (1996).

baseline and therefore PHMSA did not attribute the reductions to the proposed rule even though these measures are expected to also reduce methane emissions. For example, eliminating all existing methane emissions from blowdown of gathering, transmission, and distribution pipelines and LNG facilities and UNGSFs could reduce an additional 246,601 metric tons CH_4 per year (Table 7).

Table 7: Estimated blowdown emissions in 2020 (Metric Ton CH_4)

Industry Segment	CH_4 Emissions
Gathering and boosting	9,390
Transmission[3]	221,278
Distribution	2,093
LNG storage blowdown	13,840
UNGSF blowdown	N/A[1]
Total	**246,601**

[1] The GHGI does not separate out UNGSF blowdown emissions from venting and other emissions sources.
Source: U.S. EPA (2022d)

For the purposes of this DEA, PHMSA estimated the potential reductions in blowdown emissions expected from implementing measures to reduce blowdown and intentional venting of natural gas by pipeline operators. The analysis focuses on operators that are not currently implementing these measures, based on participation in EPA's voluntary Natural Gas STAR program. The experience of existing operators in the Natural Gas STAR program suggests that mitigation measures may help reduce emissions by 43.4 percent for gathering and boosting[17] and transmission pipelines, and by 8.2 percent for distribution pipelines.[18] PHMSA further assumed that incremental reductions would come from operators not already voluntarily participating in EPA's Natural Gas STAR program. PHMSA first calculated unit blowdown emission factors on a per pipeline mile basis, and then multiplied the pipeline mileage for operators not already part of the Natural Gas STAR program by this emission factor and the percent reductions above. These emissions reductions estimates are expected to be achieved incrementally as a result of the self-implementing provisions of the PIPES Act of 2020. These estimates consider the number of activities requiring blowdown, existing blowdown practices, and mitigation practices chosen by operators. Table 8 presents the avoided blowdown emissions by segment assuming the average percentage reductions are achieved in each year of the analysis period. Avoided blowdown methane emissions increase over time as a result of increasing pipeline mileage.

Table 8: Changes in blowdown methane emissions (Metric Ton CH_4)

Year	Gathering[1]	Transmission[1]	Distribution[1]	Total[1]
2024	-2	-96,857	-104	-96,963
2025	-3	-97,587	-105	-97,694
2026	-3	-98,321	-106	-98,429
2027	-3	-99,059	-107	-99,169
2028	-3	-99,828	-108	-99,939

[17] Due to lack of available data, PHMSA is unable to estimate emissions reductions for the gathering segment and therefore applies the transmission emissions reduction estimate to this segment as well.

[18] Percent reductions reflect blowdown emission reductions achieved by Southern California Gas Company, 2020, Pacific Gas and Electric Company, 2020, and Pacific Gas and Electric Company, 2022

Table 8: Changes in blowdown methane emissions (Metric Ton CH_4)				
Year	Gathering[1]	Transmission[1]	Distribution[1]	Total[1]
2029	-3	-100,647	-109	-100,759
2030	-3	-101,469	-110	-101,583
2031	-3	-102,293	-112	-102,408
2032	-3	-103,121	-113	-103,237
2033	-3	-103,949	-114	-104,066
2034	-4	-104,777	-115	-104,895
2035	-4	-105,619	-116	-105,739
2036	-8	-106,470	-117	-106,592
2037	-4	-107,327	-119	-107,449
2038	-4	-108,188	-120	-108,312

[1] Negative values represent reduced methane emissions.
Source: PHMSA analysis

In assessing avoided blowdown methane emissions, PHMSA considered emissions from natural gas pipelines only due to limited information regarding the costs and effectiveness of blowdown mitigation measures at LNG facilities and UNGSFs. Additional reductions from LNG facilities and UNGSFs are expected to result from implementing blowdown mitigation practices. For example, if blowdown mitigation practices are capable of reducing emissions from LNG storage by half, the additional methane emission reductions would be approximately 7 metric tons CH_4 per year.

As discussed in the NPRM, other proposed rule provisions would also contribute additional methane emission reductions but did not quantify those changes in this analysis due to data limitations. For example, PHMSA expects methane emission reductions from:

- Investigation of failure (§192.617), which complements the leak grading and repair requirements by providing operators, PHMSA, and State regulators with information needed in developing proactive initiatives to avoid future pipeline failures and associated methane emissions.
- Pressure relief valve design, configuration, and maintenance requirements (§192.773), which require operators to assess and either repair or replace malfunctioning pressure relief devices, such as devices that are releasing gas below the set pressure ranges. Pressure relief devices are a notable source of methane emissions. Since 2010, operators have submitted 103 incident reports to PHMSA for releases from pressure relief devices on gas transmission and regulated gas gathering pipelines, reporting an average release volume of 12.6 million cubic feet from each event.
- Methane leakage surveys of LNG facilities (§193.2624), which require that operators remedy leaks and other conditions discovered during the surveys. Equipment leaks and other fugitive methane emissions are the second largest methane emissions source from LNG storage facilities and the largest methane emissions source from LNG export terminals.

3.1.2 Impacts from Leakage Surveys and Changes in Operational Practices

As described in the NPRM, there are various approaches for conducting leakage surveys. Survey along the pipeline right-of-way (ROW) with handheld leak detection equipment (*i.e.*, walking survey) is the most common method for instrumented leakage surveys on gas pipelines. These surveys may use a flame ionization detector (FID) or other gas detector to sample gas above a buried pipeline, inside underground structures, and possibly in the soil. Similar equipment used in walking surveys can be mounted on cars and trucks to allow more efficient surveying of pipelines with adequate road access. Some vehicle-based solutions combine highly sensitive gas detectors, anemometers, GPS sensors, other sensors, and advanced analytics to enable estimates of the size and point of origin of a plume of gas as the vehicle drives through it. These leak indications (and gaps in the survey coverage) are then assessed by personnel with handheld equipment. Driving surveys may be best suited to densely populated areas where pipelines follow roadways. In rural areas with gas transmission and gas gathering pipelines, it can be more effective to use aerial surveys or continuous monitoring technology because pipeline ROWs may be difficult to traverse on the ground or safely access with traditional equipment. Aerial sensing involves gas detection equipment mounted on fixed wing or rotary wing aircraft, unmanned aerial systems, or satellites. Other aerial platforms may use direct sampling, laser-based methane detectors, LIDAR, optical gas imaging, or other methods that detect methane gas concentrations along a pipeline ROW or at aboveground facilities. Finally, continuous monitoring involves using stationary gas detectors, including in-home methane detectors, that emit audible alerts and communicate with operator personnel or a control center.

The proposed rule is performance-based and does not require operators to use specific survey equipment or methods. Operators may continue to use their existing equipment and practices where they meet the proposed requirements. However, PHMSA recognizes that pipeline operators may nonetheless acquire and deploy new equipment to detect natural gas leaks to comply with the proposed performance standards and conduct their leakage surveys more efficiently. While the manufacture of gas detectors and their various components (*e.g.*, semiconductors and other electronic components, batteries, filters, fuel cylinders) could result in indirect environmental impacts, PHMSA does not have a way to quantify these impacts, and they are likely to be small and are subject to applicable environmental controls. Some operators may increasingly rely on mobile survey methods, using vehicle- or aerial-based platforms, to conduct more frequent leakage surveys efficiently. This practice could increase the number of vehicle miles driven or flown and the associated transportation emissions. It is possible to limit these emissions through use of fuel-efficient vehicles or by combining leakage surveys with existing O&M practices. Overall, PHMSA expects emissions and other environmental impacts of leakage surveys to be small when compared to the methane emissions detected and avoided as a result of the surveys. For example, EPA estimates that the average passenger vehicle emits about 404 grams of CO_2 per mile driven (EPA, 2018). A vehicle driving along a distribution main three times, as is the practice for some mobile surveys, would emit less than 0.01 to 0.7 percent of the average greenhouse gas emissions detected on the distribution main being surveyed, depending on the pipe material and assumed leak rate.[19]

Finally, the requirement that operators maintain certain pressure relief devices (§192.773) has the potential to release methane to the atmosphere; a very small volume of gas trapped between the

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19 Each pipeline mile surveyed may result in 1.212 kg CO_2 in vehicle tailpipe emissions, based on three passes. This is compared to annual emission factors for distribution mains ranging between approximately 182 and 21,300 kg CO_{2e} per mile, depending on the pipe material (1 kg CH_4 is equivalent to 21 kg CO_2). See section 3.3 in the PRIA for details on distribution main emission factors.

isolation valve and the relief seat may be released when testing or removing a mechanical relief device. These releases are small when compared to the release that may occur with an improperly functioning pressure relief device.

3.2 Other Environmental Impacts

The proposed rule is not expected to have other direct, material adverse environmental impacts, *i.e.*, to directly affect water quality, waste generation, or land use.

The proposed rule is expected to accelerate or prompt the repair of additional leaks in cases where operators would otherwise have delayed or forgone repairing the leaks. PHMSA recognizes that this may increase the number of excavations that may be necessary to investigate leak indications and perform certain repairs. PHMSA expects any increased excavations that may occur to be temporary and generally limited to the existing pipeline right-of-way. Nonetheless, excavation for any purpose, including pipeline maintenance activities, can result in increased erosion and higher sediment loads in runoff to receiving waters. Stream siltation can negatively impact fish, especially fish reproduction; benthic organisms; and aquatic vegetation. However, these impacts can be mitigated by implementing common best management practices that minimize the time bare soil is exposed and capture or filter the sediment mobilized at excavation sites. Further, most impacts from siltation result from prolonged sediment loadings to streams. Repair activities required by this rule could require the use of heavy equipment, which can emit air pollution due to diesel combustion, including particulate matter, oxides of nitrogen, hydrocarbons, carbon monoxide, and other hazardous air pollutants and air toxics. These pollutants contribute to and aggravate asthma, emphysema, heart and lung disease and a range of other health effects (EPA, undated-b). Overall, these activities would have localized, temporary, and relatively minor environmental effects relative the risks to public safety and environmental resources resulting from gas pipeline leaks, incidents or climate change that leaks and incidents contribute to.

Repair and accompanying excavation activities also cause noise impacts and disrupt activities in the vicinity of the pipeline right of way. Noise impacts can cause stress in human populations and may disrupt wildlife feeding and breeding behaviors. Finally, excavation and the use of heavy equipment can impact agriculture, aesthetic enjoyment, and recreational activities. Excavation work can also result in temporary road closures, which can present a need for detours that can result in minor increases in vehicle miles traveled. Each of these impacts would be localized to the nearby vicinity of the pipeline right of way and temporary in nature.

3.3 Public Health and Safety

PHMSA expects the final rule to improve public health and safety because the measures are intended to result in earlier detection and repairs of gas leaks and other releases, reducing the risk to life or property.

3.3.1 Identification of Safety Conditions through Enhanced Leak Detection

Operators report to PHMSA the number of leaks eliminated (*i.e.*, repaired) each year. As summarized in section 1.2.3, gas gathering and gas transmission operators reported an average of 1,640 leaks each year during the period of 2015-2020. The majority of leaks from gathering and transmission pipelines (Figure 1) were due to corrosion (including external corrosion, internal corrosion, and stress corrosion cracking), and to failure associated with pipeline manufacturing, construction, or equipment. Distribution operators reported an average of 124,242 leaks eliminated or repaired each year during that same period (Figure 2); an average of 107,231 leaks involved causes other than excavation damage. These leaks included an average of 42,553 leaks per year (Figure 3) that operators determined presented an existing or probable hazard to persons or property that required immediate repair or continuous action until the conditions were no longer hazardous.

These data do not indicate the ways these leaks were first identified, *e.g.*, whether operators discovered them as a result of a scheduled survey or following a gas odor call from the public. However, it is reasonable to assume that more frequent and effective leak surveys would help detect leaks of all types, including leaks that present a risk to life or property, and monitoring and repair requirements would help reduce the risk to life or property that may develop over time with some leaks. Several studies have demonstrated that leak surveys using ALD methods are an effective way of identifying leaks up-to-then unknown to pipeline operators (Lamb *et al.*, 2015; Weller *et al.*, 2020; Zimmerle *et al.*, 2020). In addition, a National Transportation Safety Board (NTSB) investigation into a gas distribution incident that occurred on February 23, 2018 revealed how weaknesses in leak detection procedures can result in failures to detect hazardous leaks under certain circumstances (NTSB, 2018).

Past incident reports lend further support to expectations that more frequent and effective leak surveys may yield safety benefits. PHMSA reviewed a total of 1,344 gas gathering and transmission incidents and 1,258 gas distribution incidents reported by pipeline operators during the period of 2010 through 2020. These data include only reportable incidents[20] and therefore represent only a small subset of all gas releases from pipelines and other gas facilities.

Most of the incidents reported for gathering and transmission systems (1,261) were from transmission pipelines, including over 500 leaks.[21] Equipment failure, corrosion and material failure of pipe or weld accounted for almost two thirds of incidents (792). Since these causes are conditions that may develop over time, they may be most amenable to being discovered during leak surveys. Part 192-regulated gathering lines (Type A or B)[22] had 83 gas incidents, including 69 leaks. Seventy-one incidents were due to causes that may develop gradually and be detected during a leak survey. Incident descriptions do not consistently describe incident circumstances, but the data do indicate how the incident was first discovered. For 61 leak incidents, discovery occurred through an air patrol (31 incidents) or a ground patrol by the operator or its contractor (29 incidents). Several incident descriptions noted that patrols or instrumented surveys led to the discovery of leaks, for example by noticing bubbles in the vicinity of a transmission pipeline. For two incidents, the incident description specifically mentioned a line having been patrolled or

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20 Following §191.3, a reportable pipeline incident is an event with one or more of the following consequences: (i) A death, or personal injury necessitating in-patient hospitalization; (ii) Estimated property damage of $122,000 or more, including loss to the operator and others, or both, but excluding the cost of gas lost; (iii) Unintentional estimated gas loss of three million cubic feet or more; or an event that is significant in the judgment of the operator, even though it did not meet other applicability criteria.

21 Other types of incidents include mechanical puncture, rupture, and other.

22 Incidents from regulated Type C gathering lines did not need to be reported during the data period.

surveyed prior to the incident. One incident was identified during a "30-day leak follow-up inspection" of the same pipeline segment. In the other incident, the leak was discovered on a line that had been recently patrolled, which led the operator to conclude along with visual evidence on the ground that the leak occurred more recently (the description did not provide the elapsed time since the patrol). In another incident, a second separate leak was discovered by company personnel patrolling the pipeline as part of follow-up on a first leak.

Similarly, distribution operators attributed incidents reported to PHMSA to one of four release types (leaks, mechanical punctures, ruptures, and "other"). Overall, pipeline leaks accounted for 31 percent of all release types (377 incidents). Excavation damage and other outside force damage were by far the most common causes of distribution incidents, accounting for almost two thirds of reported incidents. While more frequent or better leak surveys may not help prevent these types of incidents, they may be helpful in cases where damage is minimal and undiscovered until later when a leak or hazardous conditions develop. Corrosion, equipment failure, and material failure of pipe or weld accounted for 14 percent of all incidents. These pipeline conditions develop over time and may be the most amenable to detection through periodic leak surveys. Of the leak incidents, the most common causes were "other" (35 percent), which encompassed a wide variety of incident circumstances. Most were sudden and may not be preventable through more frequent or better leak surveys. Out of a total of 377 leak incidents, 55 were attributed to natural forces (*e.g.*, lightning or heavy rain), which could be detected by extreme weather-related leak surveys. Leaks leading to reportable incidents were most often discovered via notification from emergency responder (54 percent), local operating personnel (21 percent), and notification from the public (16 percent), but there were least 16 incidents for which the incident narrative specifically mentioned that the incident was discovered during a scheduled leak survey by operator or contractor personnel.[23]

3.3.2 Potential Prevention of Safety Conditions

There is no way to definitively ascertain how many more leaks hazardous to life or property may be discovered through more frequent, and more effective, pipeline surveys and repaired as a result of the proposed rule. In the PRIA, PHMSA estimated the changes in the mileage of pipelines surveyed each year under the proposed rule and the additional leaks discovered during these surveys.

For distribution pipelines, assuming uniform leak incidence rates per pipe material and a constant share of leaks classified in each grade based on the current definitions, PHMSA estimated that approximately 17,700 to 25,100 more leaks per year may be discovered through more frequent surveys and more effective survey methods. This estimate is based on the annual average incremental number of leaks detected under the proposed rule, as compared to the baseline, and the assumption that 40 percent of all leaks are categorized in grades 1 or 2, following the baseline definitions. PHMSA estimated the increase to be largest in the early years of the analysis period as operators transition to shorter survey intervals.

Repairing these leaks earlier may help avoid deaths, injuries, evacuations, and property and environmental damages. Table 9 summarizes PHMSA data on reported pipeline incidents by

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[23] Incident narratives generally did not provide details on survey or maintenance practices.

industry segment and release type during the period of 2010-2020. Incidents categorized as leaks tended to release smaller quantities of gas, on average, than those categorized as mechanical puncture or rupture. However, they were still significant both individually and in total, given their frequency. Incidents caused by leaks accounted for the largest aggregate volume of gas released in gathering incidents. For transmission pipelines, leaks were second only to incidents due to rupture, whereas for distribution pipelines, leaks were second to incidents due to mechanical puncture. The average damage costs reported to PHMSA due to a leak was $373,000 to $395,000 per incident. The average cost in Table 9 accounts only for costs directly incurred by operators and does not include other costs to society. The total social costs of these incidents can be much larger, particularly where fatalities and injuries are involved. The severity of harm to human safety and property depends principally on the type of pipeline, the leak amount, and the leak location. Population density and proximity to buildings and other structures are critical factors. As summarized in Table 9, injuries or fatalities occurred in approximately a quarter of the reported distribution incidents. While injuries and fatalities were less frequent for gathering and transmission incidents, they were reported for 31 incidents during the 11-year period. For example, the 140 fatalities due to gas pipeline incidents between 2010 and 2020 have social costs estimated at $1.6 billion.[24] Including the 647 non-fatal injuries associated with the incidents and assuming that each injury was serious brings the total value of injuries and fatalities to $2.4 billion.[25]

[24] Calculated using DOT's Value of a Statistical Life of $11.6 million in 2020 (U.S. Department of Transportation, n.d.).

[25] Injuries were monetized using DOT's recommended disutility factor for serious injuries (Maximum Abbreviated Injury Scale (MAIS) 3 = 0.105) times the VSL estimate. Department of Transportation, 2021

Table 9: Damages and costs from reported gas pipeline incidents in 2010-2020

Industry Segment	Release type	Total number of incidents	Number of incidents with injuries or fatalities	Number of Fatalities	Number of Injuries	Average volume of gas released (Mcf)[1]	Total Volume of Gas Released (Mcf)	Average cost (2020$)[2]	Value of Injuries and Fatalities (2020$)[3]
Gathering	Leak	69	1	0	1	4,861	320,803	$395,190	$1,218,000
	Mechanical puncture	2	0	0	0	12,680	12,680	$3,079,639	$0
	Rupture	5	0	0	0	26,830	134,148	$1,686,308	$0
	Other	7	0	0	0	15,067	90,401	$14,466,256	$0
	All types	**83**	**1**	**0**	**1**	**7,154**	**558,031**	**$1,724,370**	**$1,218,000**
Transmission	Leak	500	5	1	7	11,890	5,921,329	$373,076	$20,126,000
	Mechanical puncture	126	6	6	13	11,718	1,476,521	$408,945	$85,434,000
	Rupture	169	8	10	75	52,136	8,811,065	$5,942,098	$207,350,000
	Other	466	11	10	13	15,196	6,914,321	$592,805	$131,834,000
	All types	**1,261**	**30**	**27**	**108**	**18,528**	**23,123,236**	**$1,207,637**	**$444,744,000**
Distribution	Leak	377	98	28	182	1,355	444,437	$394,395	$546,476,000
	Mechanical puncture	356	53	15	96	2,150	743,960	$463,367	$290,928,000
	Rupture	55	17	7	19	1,847	97,870	$229,763	$104,342,000
	Other	421	119	63	241	979	326,920	$5,425,612	$1,024,338,000
	All types	**1,209**	**287**	**113**	**538**	**1,520**	**1,613,187**	**$2,121,050**	**$1,966,084,000**

[1] Estimated volume of gas released unintentionally and intentionally (during controlled release or blowdown). The average includes only incidents with non-zero reported volumes released.

[2] Estimated costs of the release, including property damage, repairs, emergency response, value of gas lost, and other costs incurred by operators. The average includes only incidents with non-zero reported costs.

[3] Estimated value of injuries and fatalities based on VSL (U.S. Department of Transportation, n.d.) and DOT's recommended disutility factor for serious injuries (Maximum Abbreviated Injury Scale (MAIS) 3 = 0.105; Department of Transportation, 2021)

Source: PHMSA Pipeline Incident Flagged Files, June 30, 2021

PHMSA also expects safety benefits from expanded NPMS reporting requirements for gathering lines, although these benefits are difficult to quantify. The requirement to submit data to the NPMS would help operators develop and maintain adequate maps and records of their systems. Pipeline safety stakeholders — including the public, emergency responders, excavators, and elected officials — can use the NPMS to view the locations of pipelines and related infrastructure, identify the names and contact information of pipeline operators, and understand other attributes of pipelines such as commodities transported and diameter. For example, emergency responders often use the NPMS to identify pipelines in the vicinity of reported leaks and to contact relevant operators. NPMS data can also make it easier for third parties such as other operators, researchers, or the public to report leaks, ruptures, and other unsafe conditions to the appropriate operator.

3.3.3 Public Health

PHMSA also expects additional human health benefits from reducing emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) contained in unprocessed natural gas, particularly unprocessed natural gas in gathering lines.[26] As discussed at greater length in EPA (2022b), VOC emissions are precursor to ozone, and to a lesser extent fine particulates ($PM_{2.5}$). Both ambient ozone and $PM_{2.5}$ are associated with adverse health effects, including respiratory morbidity, asthma attacks, hospital and emergency department visits, lost school days, and premature respiratory mortality (U.S. EPA, 2019; 2020, 2022c). HAPs contained in unprocessed natural gas includes several substances, including but not limited to benzene, formaldehyde, toluene, xylenes, and ethylbenzene, that are known or suspected carcinogens or have other adverse health effects (U.S. EPA, 2022b).

Benzene is a known human carcinogen (causing leukemia) and chronic inhalation has been associated with several adverse noncancer health effects including arrested development of blood cells, anemia, leukopenia, thrombocytopenia, and aplastic anemia (Agency for Toxic Substances and Disease Registry [ATSDR], 2007a; U.S. EPA, 2012). Acute exposure to benzene vapors has been reported to cause respiratory effects such as nasal irritation, mucous membrane irritation, dyspnea, and sore throat.

Formaldehyde is classified by the National Toxicology Program (NTP) as known to be a human carcinogen based on sufficient evidence of cancer from studies in humans supporting data on mechanisms of carcinogenesis (NTP, 2021). Formaldehyde inhalation exposure causes a range of noncancer health effects including irritation of the nose, eyes, and throat in humans and animals. Repeated exposures cause respiratory tract irritation, chronic bronchitis and nasal epithelial lesions such as metaplasia and loss of cilia in humans, whereas there is evidence that formaldehyde may increase the risk of asthma and chronic bronchitis in children (ATSDR, 1999; U.S. EPA, 2000b).

Toluene has been shown to affect the central nervous system under acute and chronic exposures with low or moderate levels of toluene exposure by inhalation causing fatigue, sleepiness,

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26 While VOCs and HAPs have mostly been documented in unprocessed natural gas transported in gathering lines, some studies suggest that they are also present within the transmission, storage and distribution segments (Michanowicz *et al.*, 2022; Nordgaard *et al.*, 2022).

headaches, and nausea (U.S. EPA, 2005a; 2005b). Chronic inhalation exposure of humans to toluene also causes irritation of the upper respiratory tract, eye irritation, dizziness, headaches, and difficulty with sleep. Human studies have also reported developmental effects from toluene exposure, such as central nervous system dysfunction, attention deficits, and minor craniofacial and limb anomalies, in the children of women who abused toluene during pregnancy. A substantial database examining the effects of toluene in subchronic and chronic occupationally exposed humans exists. The weight of evidence from these studies indicates neurological effects (*i.e.*, impaired color vision, impaired hearing, decreased performance in neurobehavioral analysis, changes in motor and sensory nerve conduction velocity, headache, and dizziness) as the most sensitive endpoint.

Short-term inhalation of mixed xylenes in humans may cause irritation of the nose and throat, nausea, vomiting, gastric irritation, mild transient eye irritation, and neurological effects (U.S. EPA, 2000c). Other reported effects include labored breathing, heart palpitation, impaired function of the lungs, and possible effects in the liver and kidneys (ATSDR, 2007b). Long-term inhalation exposure to xylenes in humans has been associated with a number of effects in the nervous system including headaches, dizziness, fatigue, tremors, and impaired motor coordination (ATSDR, 2007b). The EPA has classified mixed xylenes in Category D, not classifiable with respect to human carcinogenicity (U.S. EPA, 2000c).

Acute (short-term) exposure to ethylbenzene results in respiratory effects such as throat irritation and chest constriction, and irritation of the eyes, and neurological effects such as dizziness. Chronic (long-term) exposure to ethylbenzene may cause eye and lung irritation, with possible adverse effects on the blood (U.S. EPA, 2000a). EPA has classified ethylbenzene as a Group D, not classifiable as to human carcinogenicity. However, on the basis of chronic inhalation bioassay in mice and rats conducted by NTP, the International Agency for Research on Cancer (IARC) classified ethylbenzene as Group 2B, possibly carcinogenic to humans (ATSDR, 2010).

PHMSA found no national estimate of VOC and HAP emissions released from gas pipelines. Emissions rates vary according to the production region, emissions sources (*e.g.*, well head, condensate tanks, engine exhausts), and other factors (Lebel *et al.*, 2022; Michanowicz *et al.*, 2022; Nordgaard *et al.*, 2022). EPA (2022b) estimated that reducing fugitive methane emissions from well sites and gathering and boosting stations also reduced associated emissions of VOCs and HAPs, with each short ton of methane avoided corresponding to 0.28 short ton VOC and 0.01 short ton HAP avoided.

PHMSA did not quantify the magnitude of these benefits in this analysis but notes that the impacts of these pollutants accrue at different spatial scales. HAP emissions associated with unprocessed natural gas increase exposure to carcinogens and other toxic pollutants primarily near the emission source, and therefore a detailed analysis would need to account for the location of the gathering lines relative to exposed populations. VOC emissions are precursors to secondary formation of $PM_{2.5}$ and ozone on a broader regional scale, requiring air quality modeling to assess changes in ambient concentrations.

Methane is also a precursor to global background concentrations of ozone and reducing methane emissions is therefore expected to also reduce global background ozone concentrations that contribute to the incidence of ozone-related health effects (U.S. Global Change Research

Program, 2018). Due to data limitations regarding the location, magnitude, and duration of exposure and the quantitative relationship between exposure and incidence of health effects, PHMSA did not quantify these benefits. PHMSA requests data and comments on the potential human health benefits from reducing emissions of VOCs and hazardous air pollutants HAPs resulting from the proposed rule, including information that would better enable quantification and monetization of the potential public health effects.

3.4 Environmental Justice

Executive Order 12898 (59 FR 7629, February 11, 1994) requires that, to the greatest extent practicable and permitted by law, each Federal agency must make the achievement of environmental justice (EJ) part of its mission. Executive Order 12898 provides that each Federal agency must conduct its programs, policies, and activities that substantially affect human health or the environment in a manner that ensures such programs, policies, and activities do not have the effect of (1) excluding persons (including populations) from participation in, or (2) denying persons (including populations) the benefits of, or (3) subjecting persons (including populations) to discrimination under such programs, policies, and activities because of their race, color, or national origin.

Executive Order 14008 (86 FR 7619, February 1, 2021) expands on the policy objectives established in Executive Order 12898 and directs federal agencies to develop programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts.

The Executive Order titled "Revitalizing Our Nation's Commitment to Environmental Justice for All" (April 21, 2023),[27] further supplements Executive Orders 12898 and 14008 and sets forth the Administration policy to "advance environmental justice for all by implementing and enforcing the Nation's environmental and civil rights laws, preventing pollution, addressing climate change and its effects, and working to clean up legacy pollution that is harming human health and the environment."[28]

To meet the objectives of the foregoing Executive Orders, and consistent with DOT guidance on considering EJ in the development of regulatory actions, PHMSA assessed whether the benefits of the proposed rule may be differentially distributed among population subgroups in the affected areas. As noted above, the proposed rule is not expected to affect permitting for, or location of, gas facilities so the assessment considers whether the measures taken by operators to reduce natural gas leaks and associated methane emissions may exacerbate or mitigate EJ concerns. The proposed rule is expected to reduce methane emissions that contribute to climate change. The climate change impacts of methane emissions extend far beyond their sources and

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27 Executive Order number and Federal Register citation forthcoming.

28 White House, "Executive Order on Revitalizing Our Nation's Commitment to Environmental Justice for All" (April 21, 2023), https://www.whitehouse.gov/briefing-room/presidential-actions/2023/04/21/executive-order-on-revitalizing-our-nations-commitment-to-environmental-justice-for-all/#:~:text=We%20must%20advance%20environmental%20justice,human%20health%20and%20the%20environment

affect communities that do not necessarily live close to the pipelines. Numerous studies and scientific assessments have demonstrated that low income or predominantly non-White communities and other groups that historically have been disproportionally affected by environmental stressors, also face disproportionate risks from climate change (Intergovernmental Panel on Climate Change, 2014; EPA, 2021b; U.S. Global Change Research Program, 2018). Some communities of color, specifically populations defined jointly by ethnic/racial characteristics and geographic location, may be uniquely vulnerable to climate change health impacts in the U.S. These communities live in areas where the impacts of climate change (*e.g.*, extreme temperatures, flooding) may be the greatest, and they tend to have limited adaptive capacities and are more dependent on climate-sensitive resources such as local water and food supplies or have less access to social and information resources. In particular, the 2016 scientific assessment on the *Impacts of Climate Change on Human Health* found with high confidence that vulnerabilities are place- and time-specific, lifestages and ages are linked to immediate and future health impacts, and social determinants of health are linked to greater extent and severity of climate change-related health impacts (U.S. Global Change Research Program, 2016).

Additionally, to the extent that historically marginalized and overburdened communities are in proximity to leaking regulated natural gas gathering, transmission, and distribution lines, they would benefit from more timely discovery and repairs of leaking pipes and lower risk of accidents and other consequences. For example, a study by Emanuel *et al.* (2021) has showed a positive correlation between county-level density of natural gas gathering and transmission pipelines and an index of social vulnerability that accounts for demographic (*e.g.*, racial composition, age distribution) and socioeconomic factors. Their analysis suggests that environmental, health, and other burdens associated with the gas pipeline infrastructure are shouldered disproportionately by communities that have a limited economic capacity to carry such loads. As such, these communities may receive environmental, health, and safety benefits from detecting and repairing leaks from gas facilities.

Recent studies focused on distribution systems also show inequitable distribution of gas leaks according to socioeconomic factors. A study by Weller *et al.* (2022) of distribution systems in 13 metropolitan areas showed patterns of increasing leak densities in areas with increasing percent people of color and decreasing median household income, even after controlling for differences in housing age. In another study, Luna and Nicholas (2022) used high-resolution leak data from Home Energy Efficiency Team (HEET) to assess the degree to which gas main and service leaks and repairs are differentially distributed across communities in Massachusetts. The authors looked at the population-weighted mean exposure to gas leaks in the distribution systems of six utilities, as well as the distribution of leak grade and leak age at the time of repairs. They found inequities in the geographic distribution of leaks, as well as in how quickly they have been repaired. People of color, limited English speaking households, lower income persons, renters, and adults with lower levels of education lived in neighborhoods or areas with higher leak densities, even when controlling for housing density, and slower repair times. Luna and Nicholas (2022) concluded that these inequities reveal a procedural inequity in how leaks are being addressed, with differences not explained by differences in infrastructure age across residential neighborhoods. They also noted that Class 3 “non-hazardous” leaks were the ones most associated with inequities as utilities have discretion on the timing of repairs.

These studies highlight the potential equity and environmental justice benefits of setting more explicit leak detection and repair requirements, particularly for leaks that utilities may classify as non-hazardous.

4 Proposed Finding of No Significant Impact

Based on the analysis summarized in this DEA and accompanying NPRM, PHMSA proposes to find that the proposed rule would not result in a significant detrimental impact on the human environment. The proposed rule is expected to have an overall positive environmental impact by reducing the occurrence, magnitude, and consequences of gas releases and associated methane emissions from gathering, transmission and distribution pipelines. PHMSA welcomes comments on the environmental or safety impacts of the proposed rule and this DEA generally.

5 Agencies and Persons Consulted

Public involvement is a critical aspect of the NEPA process. PHMSA held a public meeting on May 5 and 6, 2021 during which stakeholder groups and members of the public had the opportunity to share and discuss perspectives on improving gas pipeline leak detection and repair (86 FR 18117, April 7, 2021). The meeting examined the sources of methane emissions from natural gas pipeline systems, current regulatory requirements for managing fugitive and vented emissions, industry leak detection and repair practices, and the use of advanced technologies and practices to reduce methane emissions from gas pipeline systems. PHMSA heard from a range of perspectives. For example, the Environmental Defense Fund (EDF) presented a set of recommended elements for an ALD system. Industry representatives[29] noted some of the limitations of currently available leak detection technologies. Several stakeholders emphasized the importance of flexibility in PHMSA's promulgation of ALD standards, recommending that PHMSA assess the suite of leak detection technologies that are currently commercially available and introduce requirements that promote continued development of advanced technologies. The NPRM summarizes the input PHMSA received during the meeting. Meeting material and comments are available in the docket.[30]

PHMSA met with EPA at various stages of the development of this proposed rule to discuss the available data and separate efforts by EPA to limit methane leaks from the natural gas infrastructure. These efforts include both voluntary programs and regulatory efforts. Voluntary programs include Methane Challenge, and Natural Gas STAR. The regulatory programs include proposed amendments to the New Source Performance Standards for the Oil and Gas Industry (40 CFR part 60), which apply to natural gas facilities such as compression stations and associated components, such as compressors, turbines, and pneumatic controllers. PHMSA staff also attended the EPA methane Detection Technology Workshop on August 23-24, 2021.[31,32,33,34]

PHMSA also met with representatives of industry (*e.g.*, pipeline operators and consultants, leak detection equipment vendors), environmental groups, government agencies/municipalities, and other stakeholders (*e.g.*, National Association of Pipeline Safety Representatives (NAPSR), Gas

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29 The American Gas Association (AGA), American Petroleum Institute, American Public Gas Association, and Interstate Natural Gas Association of America jointly submitted comments.

30 https://www.regulations.gov/docket/PHMSA-2021-0039

31 Recordings are available at the meeting webpage at: https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-methane-detection-technology-workshop#:~:text=Natural%20Gas%20Industry-,EPA%20Methane%20Detection%20Technology%20Workshop%20%2D%2D%20August%2023%20and%2024,oil%20and%20natural%20gas%20industry.

32 See "Attachment 1: Summary Report Methane Detection Technology Workshop" of "Background Technical Support Document for the Proposed New Source Performance Standards (NSPS) and Emissions Guidelines (EG)" at https://www.regulations.gov/ Docket ID No. EPA–HQ–OAR–2021–0317-0166.

33 See "EPA's Methane Detection Technology Virtual Workshop. August 23-24, 2021. Audio", "Transcripts", and "Presentations" at https://www.regulations.gov/ Docket ID No. EPA–HQ–OAR–2021–0317-0183, EPA-HQ-OAR-2021-0317-0181, and EPA-HQ-OAR-2021-0317-0182 respectively.

34 See "Controlling Air Pollution from the Oil and Natural Gas industry. EPA Methane Detection Technology Workshop. August 23 and 24, 2021" https://www.regulations.gov/ Docket ID No. EPA–HQ–OAR–2021–0317-0183

Piping Technology Committee (GPTC)) to get additional input to inform the development of the proposed requirements.

PHMSA received input from the Gas Pipeline Advisory Committee (GPAC). The GPAC is a statutorily mandated advisory committee that advises PHMSA on proposed safety standards, risk assessments, and safety policies for natural gas pipelines and hazardous liquid pipelines. The Pipeline Advisory Committees (PACs) were established under the Federal Advisory Committee Act (Pub. L. 92-463, 5 U.S.C. App. 1-16) and the Federal Pipeline Safety Laws. Each committee consists of 15 members, with membership divided among the Federal and State agencies, the regulated industry, and the public. The PACs advise PHMSA on the technical feasibility, practicability, and cost-effectiveness of each proposed pipeline safety standard.

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7 References

Agency for Toxic Substances and Disease Registry. (1999). *Toxicological Profile for Formaldehyde*. Retrieved from https://www.atsdr.cdc.gov/ToxProfiles/tp111.pdf

Agency for Toxic Substances and Disease Registry. (2007a). *Toxicological Profile for Benzene*. Retrieved from https://www.atsdr.cdc.gov/ToxProfiles/tp3.pdf

Agency for Toxic Substances and Disease Registry. (2007b). *Toxicological Profile for Xylene*. Retrieved from https://www.atsdr.cdc.gov/ToxProfiles/tp71.pdf

Agency for Toxic Substances and Disease Registry. (2010). *Toxicological Profile for Ethylbenzene*. Retrieved from https://www.atsdr.cdc.gov/ToxProfiles/tp110.pdf

Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science, 361*(6398), 186-188. doi:10.1126/science.aar7204

Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Pétron, G., Jordaan, S. M., . . . Harriss, R. (2014). Methane Leaks from North American Natural Gas Systems. *Science, 343*(6172), 733-735. doi:doi:10.1126/science.1247045

Chen, Y., Sherwin, E. D., Berman, E. S. F., Jones, B. B., Gordon, M. P., Wetherley, E. B., . . . Brandt, A. R. (2022). Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey. *Environmental Science & Technology, 56*(7), 4317-4323. doi:10.1021/acs.est.1c06458

Cooper, J., Balcombe, P., & Hawkes, A. (2021). The quantification of methane emissions and assessment of emissions data for the largest natural gas supply chains. *Journal of Cleaner Production, 320*, 128856. doi:https://doi.org/10.1016/j.jclepro.2021.128856

Department of Transportation. (2021). *Departmental Guidance: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses*. Retrieved from https://www.transportation.gov/sites/dot.gov/files/2021-03/DOT%20VSL%20Guidance%20-%202021%20Update.pdf

Emanuel, R. E., Caretta, M. A., Rivers III, L., & Vasudevan, P. (2021). Natural Gas Gathering and Transmission Pipelines and Social Vulnerability in the United States. *GeoHealth, 5*(6). doi:https://doi.org/10.1029/2021GH000442

Energy Information Administration. (2022). *Annual Energy Outlook 2022*. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2022_Narrative.pdf

Hausman, C., & Muehlenbachs, L. (2018). *Price Regulation and Environmental Externalities: Evidence from Methane Leaks*. Retrieved from https://www.nber.org/system/files/working_papers/w22261/w22261.pdf

Hausman, C., & Raimi, D. (2019). *Plugging the leaks: Why existing financial incentives aren't enough to reduce methane*. Retrieved from https://kleinmanenergy.upenn.edu/wp-content/uploads/2020/08/Plugging-the-Leaks-1.pdf

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Retrieved from https://www.ipcc.ch/report/ar5/wg2/

Intergovernmental Panel on Climate Change. (2021). *Climate Change 2021: The Physical Science Basis*. Retrieved from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Lamb, B. K., Edburg, S. L., Ferrara, T. W., Howard, T., Harrison, M. R., Kolb, C. E., . . . Whetstone, J. R. (2015). Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States. *Environmental Science & Technology, 49*(8), 5161-5169. doi:10.1021/es505116p

Lebel, E. D., Michanowicz, D. R., Bilsback, K. R., Hill, L. A. L., Goldman, J. S. W., Domen, J. K., . . . Shonkoff, S. B. C. (2022). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology, 56*(22), 15828-15838. doi:10.1021/acs.est.2c02581

Luna, M., & Nicholas, D. (2022). An environmental justice analysis of distribution-level natural gas leaks in Massachusetts, USA. *Energy Policy, 162*, 112778. doi:https://doi.org/10.1016/j.enpol.2022.112778

Lyon, D. R., Hmiel, B., Gautam, R., Omara, M., Roberts, K. A., Barkley, Z. R., . . . Hamburg, S. P. (2021). Concurrent variation in oil and gas methane emissions and oil price during the COVID-19 pandemic. *Atmos. Chem. Phys., 21*(9), 6605-6626. doi:10.5194/acp-21-6605-2021

Michanowicz, D. R., Dayalu, A., Nordgaard, C. L., Buonocore, J. J., Fairchild, M. W., Ackley, R., . . . Spengler, J. D. (2022). Home is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User. *Environmental Science & Technology, 56*(14), 10258-10268. doi:10.1021/acs.est.1c08298

National Toxicology Program. (2021). *Formaldehyde Profile*. Retrieved from https://ntp.niehs.nih.gov/ntp/roc/content/profiles/formaldehyde.pdf

National Transportation Safety Board. (2018). *Investigation: Atmos Energy Corporation Natural Gas-Fueled Explosion* (Accident Number PLD18FR002). Retrieved from https://www.ntsb.gov/investigations/Pages/PLD18FR002.aspx

Nordgaard, C. L., Jaeger, J. M., Goldman, J. S. W., Shonkoff, S. B. C., & Michanowicz, D. R. (2022). Hazardous air pollutants in transmission pipeline natural gas: an analytic assessment. *Environmental Research Letters, 17*(10), 104032. doi:10.1088/1748-9326/ac9295

Pacific Gas and Electric Company. (2020). *2020 Gas Safety Plan*. Retrieved from https://www.pge.com/pge_global/common/pdfs/safety/gas-safety/safety-initiatives/pipeline-safety/2020GasSafetyReport.pdf

Pacific Gas and Electric Company. (2022). *2022 Gas Safety Plan*. Retrieved from https://www.pge.com/pge_global/common/pdfs/safety/gas-safety/safety-initiatives/pipeline-safety/2022GasSafetyReport.pdf

Pipeline and Hazardous Materials Safety Administration. (2021a). *Gas Distribution Annual Data*. Retrieved from: https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids

Pipeline and Hazardous Materials Safety Administration. (2021b). *Gas Transmission and Gathering Annual Data*. Retrieved from: https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids

Pipeline and Hazardous Materials Safety Administration. (2023). *Preliminary Regulatory Impact Analysis: Leak Detection and Repair Proposed Rule*. Retrieved from

Southern California Gas Company. (2020). *2020 SB 1371: Compliance Plan*. Retrieved from https://www.socalgas.com/sites/default/files/2020_Final_SCG_SB1371_Compliance_Plan_sm.pdf

U.S Environmental Protection Agency. (2012). *Health Effects Notebook for Hazardous Air Pollutants: Benzene*. Retrieved from https://www.epa.gov/sites/default/files/2016-09/documents/benzene.pdf

U.S. Department of Energy National Energy Technology Laboratory. (n.d.). Range of Syngas Compositions Across Different Gasifier Type, and Feedstock Produced by the Gasification of Coal Feedstocks. Retrieved from https://netl.doe.gov/sites/default/files/netl-file/Range-of-syngas-Comp.pdf

U.S. Department of Transportation. (n.d.). *Departmental Guidance on Valuation of a Statistical Life in Economic Analysis*. Retrieved from https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

U.S. Energy Information Administration. (2021). *Annual Energy Outlook 2021: Reference Case*. Retrieved from https://www.eia.gov/outlooks/aeo/tables_ref.php

U.S. Environmental Protection Agency. (2000a). *Health Effects Notebook for Hazardous Air Pollutants: Ethylbenzene*. Retrieved from https://www.epa.gov/sites/default/files/2016-09/documents/ethylbenzene.pdf

U.S. Environmental Protection Agency. (2000b). *Health Effects Notebook for Hazardous Air Pollutants: Formaldehyde*. Retrieved from https://www.epa.gov/sites/default/files/2016-09/documents/formaldehyde.pdf

U.S. Environmental Protection Agency. (2000c). *Health Effects Notebook for Hazardous Air Pollutants: Xylenes (Mixed Isomers)*. Retrieved from https://www.epa.gov/sites/default/files/2016-09/documents/xylenes.pdf

U.S. Environmental Protection Agency. (2005a). *Chemical Assessment Summary: Toluene*. Retrieved from https://iris.epa.gov/static/pdfs/0118_summary.pdf

U.S. Environmental Protection Agency. (2005b). *Toxicological review of Toluene*. (EPA/635/R-05/004). Retrieved from https://iris.epa.gov/static/pdfs/0118tr.pdf

U.S. Environmental Protection Agency. (2018). *Greenhouse Gas Emissions from a Typical Passenger Vehicle*. (EPA-420-F-18-008). Retrieved from https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

U.S. Environmental Protection Agency. (2019). *Integrated Science Assessment (ISA) for Particulate Matter*. (EPA/600/R-19/188). Retrieved from https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=539935

U.S. Environmental Protection Agency. (2020). *Integrated Science Assessment (ISA) for Ozone and Related Photochemical Oxidants* (EPA/600/R-20/012). Retrieved from https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=348522

U.S. Environmental Protection Agency. (2021a). *2021 GHG Inventory Public Review: Annex 3.6 - Methodology for Estimating CH4, CO2, and N2O Emissions from Natural Gas Systems*. Retrieved from https://www.epa.gov/ghgemissions/stakeholder-process-natural-gas-and-petroleum-systems-1990-2019-inventory

U.S. Environmental Protection Agency. (2021b). *Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts* (EPA 430-R-21-003). Retrieved from https://www.epa.gov/cira/social-vulnerability-report

U.S. Environmental Protection Agency. (2021c). *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2019*. (EPA 430-R-21-005). Retrieved from https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf

U.S. Environmental Protection Agency. (2022a). *2022 GHG Inventory Public Review: Annex 3.6 - Methodology for Estimating CH4, CO2, and N2O Emissions from Natural Gas Systems*. Retrieved from https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2020-ghg

U.S. Environmental Protection Agency. (2022b). *Regulatory Impact Analysis of the Supplemental Proposal for the Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review*.

U.S. Environmental Protection Agency. (2022c). *Supplement to the 2019 Integrated Science Assessment for Particulate Matter*. (EPA/600/R-22/028).

U.S. Environmental Protection Agency. (2022d). *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2020*. (EPA 430-R-21-005). Retrieved from https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf

U.S. Environmental Protection Agency. (undated-a). Basic Information about Landfill Gas. Retrieved from https://www.epa.gov/lmop/basic-information-about-landfill-gas

U.S. Environmental Protection Agency. (undated-b). Learn About Impacts of Diesel Exhaust and the Diesel Emissions Reduction Act (DERA). Retrieved from https://www.epa.gov/dera/learn-about-impacts-diesel-exhaust-and-diesel-emissions-reduction-act-dera

U.S. Environmental Protection Agency, & Gas Research Institute. (1996). *Methane Emissions from the Natural Gas Industry*. Retrieved from https://www.epa.gov/natural-gas-star-program/methane-emissions-natural-gas-industry

U.S. Global Change Research Program. (2016). *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. Retrieved from https://health2016.globalchange.gov/downloads

U.S. Global Change Research Program. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Retrieved from nca2018.globalchange.gov

Weller, Z. D., Hamburg, S. P., & von Fischer, J. C. (2020). A National Estimate of Methane Leakage from Pipeline Mains in Natural Gas Local Distribution Systems. *Environmental Science & Technology, 54*(14), 8958-8967. doi:10.1021/acs.est.0c00437

Weller, Z. D., Im, S., Palacios, V., Stuchiner, E., & von Fischer, J. C. (2022). Environmental Injustices of Leaks from Urban Natural Gas Distribution Systems: Patterns among and within 13 U.S. Metro Areas. *Environmental Science & Technology*. doi:10.1021/acs.est.2c00097

Zavala-Araiza, D., Alvarez, R. A., Lyon, D. R., Allen, D. T., Marchese, A. J., Zimmerle, D. J., & Hamburg, S. P. (2017). Super-emitters in natural gas infrastructure are caused by abnormal process conditions. *Nature Communications, 8*(1), 14012. doi:10.1038/ncomms14012

Zimmerle, D., Vaughn, T., Bell, C., Bennett, K., Deshmukh, P., & Thoma, E. (2020). Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. *Environmental Science & Technology, 54*(18), 11506-11514. doi:10.1021/acs.est.0c01285