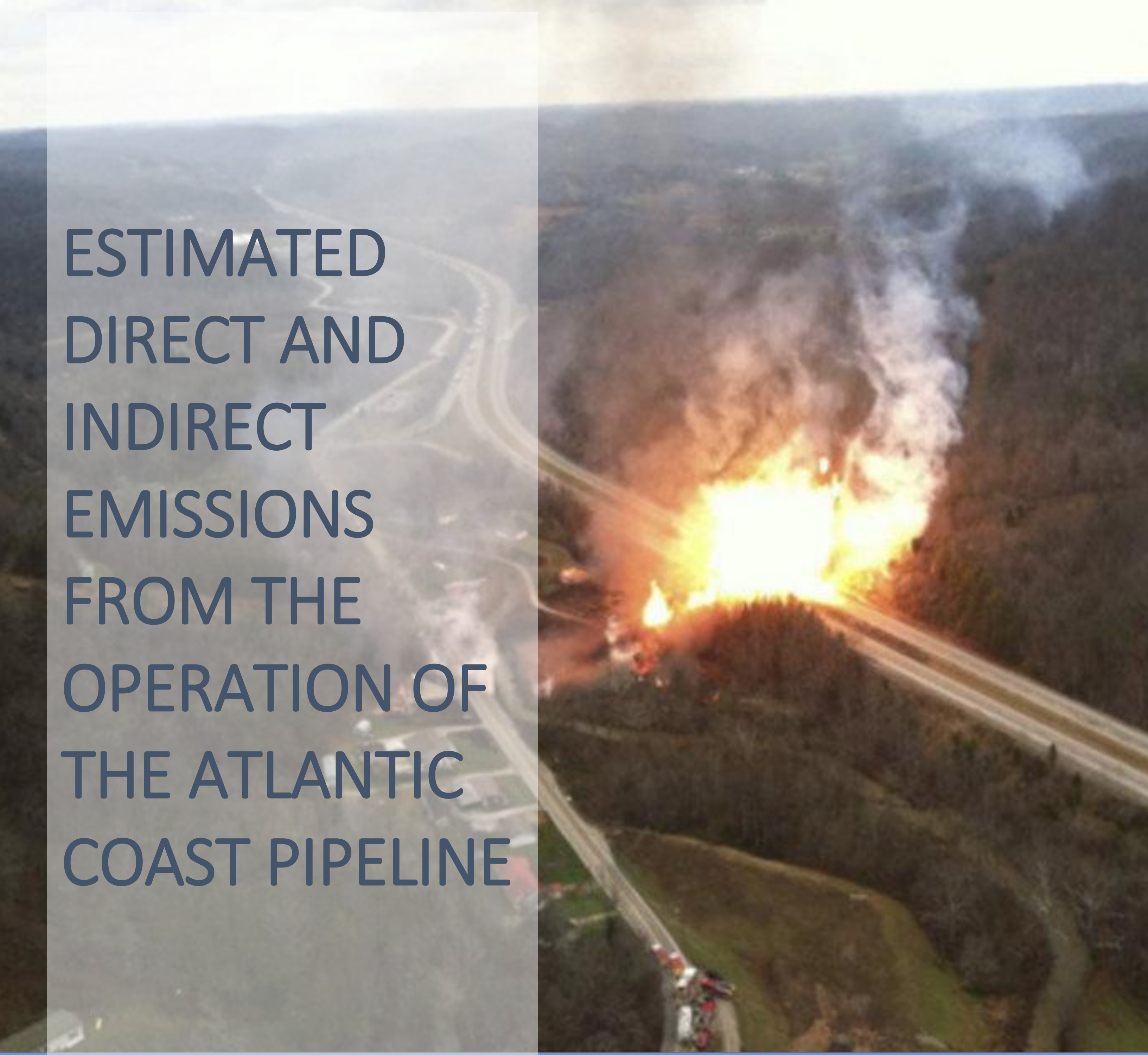

ESTIMATED DIRECT AND INDIRECT EMISSIONS FROM THE OPERATION OF THE ATLANTIC COAST PIPELINE

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CLEAN WATER FOR NORTH CAROLINA

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Executive Summary

The proposed Atlantic Coast Pipeline (ACP) would be a 600-mile natural gas transmission line that would carry natural gas from the Marcellus shale fracking operations in West Virginia, Pennsylvania and Ohio. It would pass through West Virginia, Virginia, and North Carolina, ending in Robeson County. There is speculation that the pipeline's builders, Duke Energy, Dominion Energy and Southern Company, plan to extend the ACP into South Carolina and closer to export terminals. Methane is the main component of natural gas and directly contributes to climate change as a very potent greenhouse gas. This report aims to estimate how much methane would be emitted directly and indirectly form the operation of the ACP and the resulting climate forcing. The results of our calculations show that **fugitive emissions from the supply chain of the Atlantic Coast Pipeline could increase the climate forcing by over 13% from current U.S. EPA estimates of methane emissions from U.S. natural gas infrastructure.**

Background

The Atlantic Coast Pipeline

The proposed Atlantic Coast Pipeline (ACP) is a 42-inch natural gas transmission pipeline that would run 600 miles between West Virginia, Virginia and North Carolina. First announced in 2014 by Dominion Energy, Inc. with an original estimated cost of $5.1 billion, the ACP would transport 1.5 BCF (billion cubic feet) of gas per day.

In 2017 the Federal Energy Regulatory Commission (FERC) issued the Final Environmental Impact Statement (FEIS) for the project, an 866-page document that purported to assess the potential environmental impacts that could result from the construction and operation of the ACP. In the FEIS, FERC proposes recommendations on geology, soils, groundwater, surface water, wetlands, vegetation, wildlife, fisheries, land use, recreation, socioeconomics, cultural resources, air quality, noise, and safety.[1]

However, advocates concerned about impacts of fossil fuel development, misleading economic projections, adverse impacts to water quality and Environmental Justice, criticized the EIS extensively on all of these issues, saying that the pipeline could not be constructed without extensive adverse impacts that could not be avoided.

The FEIS also includes a section on climate change that is only three and a half pages long. The section states that average temperatures have risen and will continue to rise in the US, that greenhouse gases are one of the reasons behind climate change, and that fugitive emissions of methane from pipelines are common in natural gas systems. Although FERC acknowledged that fugitive methane emissions from the Atlantic Coast Pipeline have the potential to contribute to climate change, a climate assessment that would measure the extent of methane emissions and their effects was not required for the project.

In December, 2018, construction of the ACP was voluntarily stopped as a result of permits being vacated by 4th Circuit Court decisions, including the Fish and Wildlife Service's Incidental Take Statement and the overarching Biological Opinion, as wells as a Forest Service permit to cross the Appalachian Trail.[1] Construction of the ACP was first targeted to finish in late 2019 and to cost $5.1 billion, but as construction has been halted for nearly a year, the ACP's completion is not expected until at least 2021 and projected to cost over $7.5 billion.[2]

Another key argument raised against the ACP is the lack of need for the pipeline. Dominion's reasoning behind the proposed construction of the Atlantic Coast Pipeline was that demand for natural gas to generate power in North Carolina and Virginia was expected to grow 6.3% every year between 2014 and 2035. However, a 2019 report shows that natural gas demand trends has shifted dramatically since the project was first proposed. Models show that natural gas consumption will not, in fact, increase as it was presumed by the ACP's builders, and that demand for natural gas in Virginia and

North Carolina will be further eroded in the next decade by efficiency and renewable energy sources.[2]

Introduction

Methane and climate change

Methane (CH_4) is a greenhouse gas that directly contributes to climate change. Although methane's lifetime in the atmosphere is shorter than that of carbon dioxide (CO_2), it is more efficient at trapping radiation than CO_2. With a Global Warming Potential (GWP) of 86 in a 20-year time frame, CH_4 is 86 times more potent at trapping heat in the atmosphere than CO_2.[3] Even though CH_4 lasts only about 12.4 years in the atmosphere, after that period it breaks down into other greenhouse gases such as CO_2 and water vapor, extending methane's impact on the climate.[4]

Methane effects the atmosphere for a shorter period than CO_2, but in that period, the effect is far more substantial. **The acknowledgment of the 20-year impact of CH_4 is critical, as that is closer to the window of opportunity we have to slow down climate change.**[5] According to the 2017 IPCC report, the next 12 years (10 years from 2019) are decisive to keep world temperatures from increasing more than the 1.5 to 2°C that would result in melting the world's permafrost, releasing significant quantities of stored CO_2 and CH_4, making climate change irreversibly devastating.[6] Figure 1 shows the impacts warming the atmosphere by 1.5°C and 2°C would have on the planet.

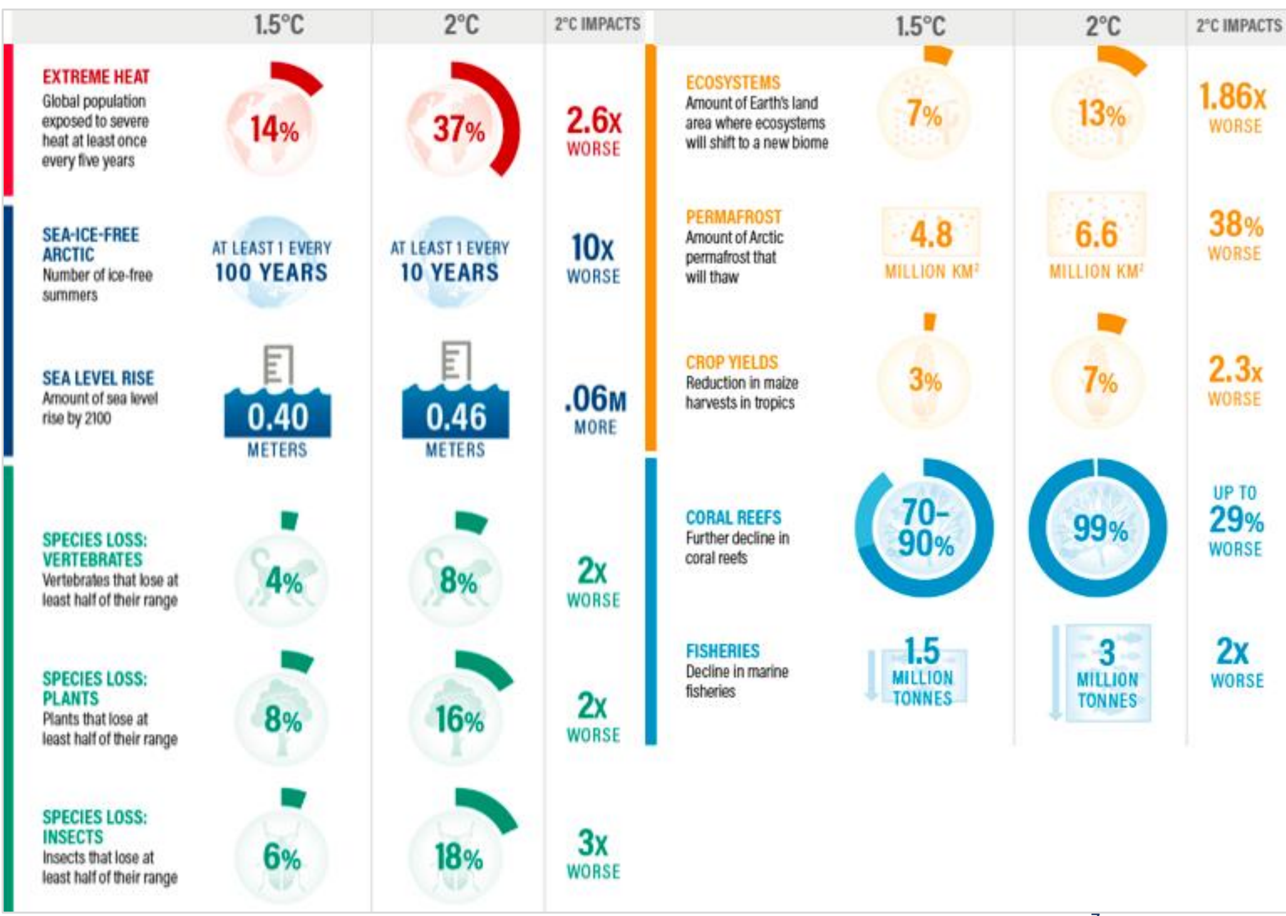

Fig 1. Comparison of impacts from 1.5°C and 2°C atmospheric warming. (Kelly Levin, 2018) [7]

Methane emissions to the atmosphere have increased substantially in recent decades. A 2016 study using satellite retrievals and surface observations of atmospheric methane reported that “U.S. methane emissions have increased by more than 30% over the 2002-2014 period”. The same study suggests that this increase accounts for 30-60% of the global growth of atmospheric methane in the past decade. Several scientific reports estimate higher U.S. methane emissions than the EPA (Fig 2).[8]

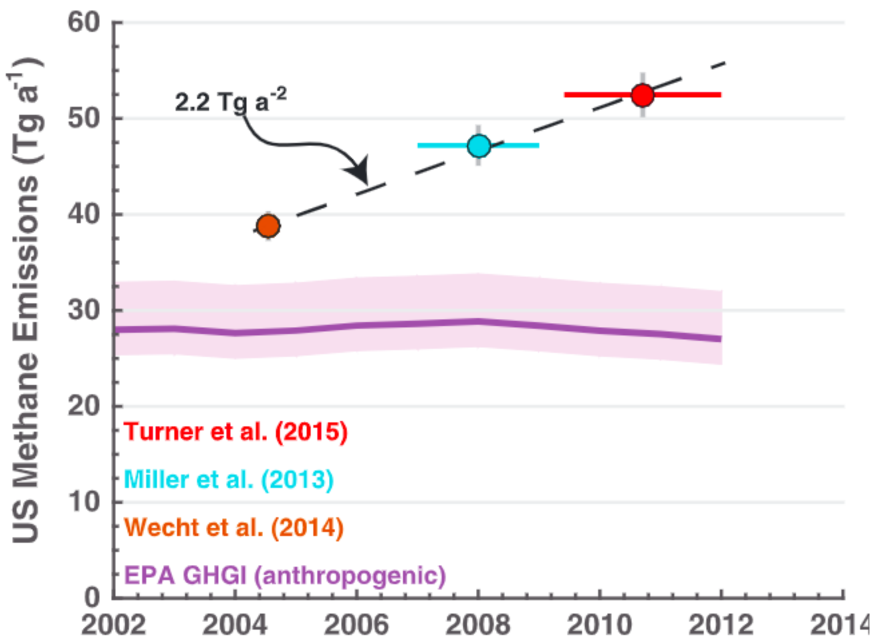

Fig 2. 2002-2014 trend in U.S. methane emissions from three studies compared to U.S. EPA emissions estimates. (Turner et al., 2016) [8]

Limiting global warming to 1.5°C will require drastic emission cuts. Scientists agree that we need to reach net-zero greenhouse gas emissions by 2050 to achieve this goal. Net-zero emissions mean adopting energy efficiency measures, switching to renewable energy, reducing energy demand, improving the efficiency of food production, and removing CO_2 from the atmosphere.[3, 7]

Natural gas

Approximately 50-65% of total CH_4 emissions to the atmosphere come from human activities, the most significant contributor being the energy industry sector. Natural gas and petroleum systems are the largest sources of CH_4 emissions in the United States.[9] Methane is the main component of natural gas, about 93.9% by volume,[10] and is leaked during fracking, a process that extracts natural gas from wells.

CH4 also leaks to the atmosphere along the natural gas supply chain. Gas leaks from the processing plants that remove impurities, from compressor stations that pressurize pipelines to keep gas flowing, from pipeline accidents and leaks, and from storage facilities. In 2012, the EPA reported that methane leaked from pipes "accounted for more than 13 million metric tons of CO_2 equivalent emissions", which at the time was more than 10% of total methane emissions from natural gas systems in the US.[11] Emission estimates from the EPA have historically been underestimated. A 2018 report estimated that methane emissions from the U.S. oil and natural gas supply chain are 60% higher than the U.S. EPA inventory estimate.[12] According to the Environmental Defense Fund, the methane leaked from the U.S. oil and gas sector is worth an estimated $2 billion and enough to heat 10 million homes.[13]

Methane leaking from pipelines is of extreme concern. According to a 2015 analysis from the Pipeline Safety Trust, new pipelines are failing "even worse than older pipelines." The report looked at annual average number of incidents per 10,000 miles of onshore gas transmission lines based on decade of installation, and observed that pipelines installed in the 2010s had an incident rate of 6.64 per 10,000 miles**. The incident rate for pipes installed after the 2010s is the highest ever**, even exceeding the rate for pipelines installed before the 1040s (Fig 3).[14]

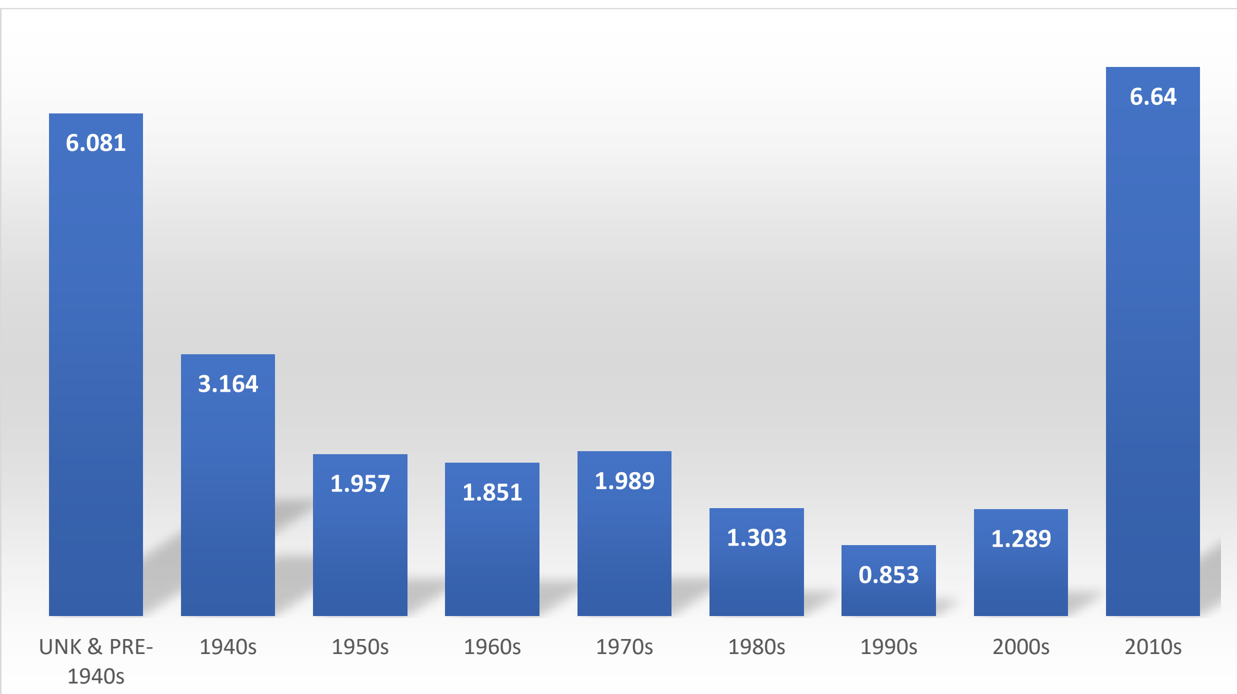

Fig 3. Average number of annual incidents over 2005-2013 per 10,000 miles of onshore gas transmission pipe by decade of pipe installation from Pipeline Safety Trust. [14]

Robert Miller, the chairman of the National Association of Pipeline Safety Representatives, attributes this high number of incidents to poor construction practices. Carl Weiner, the director of the Pipeline Safety Trust, explained that the boom of the oil and gas industry pipeline construction increased so quickly that construction is not being done properly.[14]

Another 2018 study observed that **natural gas pipelines are a significant source of fugitive methane to the atmosphere.** The study detected leaks at every pipeline joint (88 leaks per kilometer of pipe) in the United Kingdom, with a flux of 8.2 British tonnes of CH_4/km/yr. According to this study, the hole required for such leaks to occur can be as small as the size of a computer pixel (0.5 mm).[15]

Methodology

Methane emissions

For methane emissions to the atmosphere from the ACP supply chain, our estimate is based on a study done by Alvarez et al., which estimated methane losses from the U.S. Oil and Natural Gas supply chain by using ground-based and facility-scaled measurements, validated with aircraft observations.[12]

Projected methane emissions due to operation of the Atlantic Coast Pipeline supply chain were estimated for 1) upstream of the pipeline 2) the pipeline itself, and 3) downstream of the pipeline.

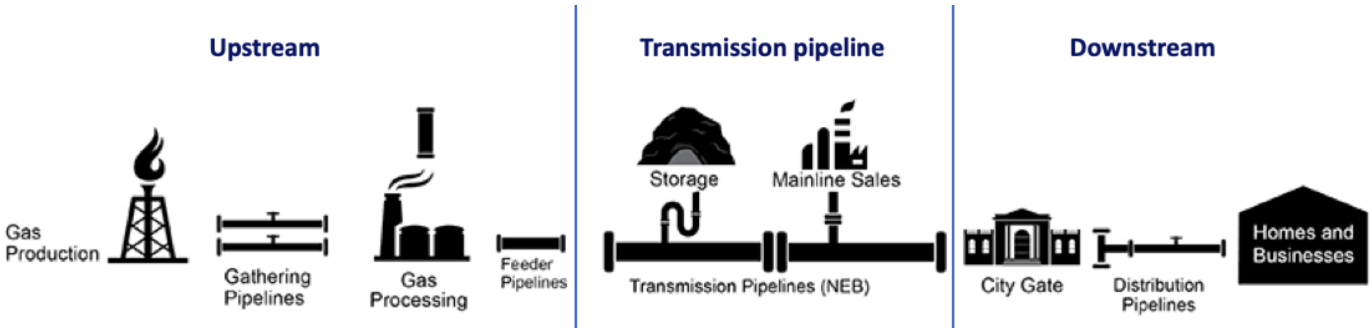

Fig 4. Illustrated sections of the natural Gas supply chain. [15]

Upstream CH4 emissions

Alvarez et al. estimated a loss rate of 2.25% percent of total methane delivered to the “city gates” from the upstream section of the pipeline. The estimated loss rate, which includes emissions from production, and gathering, was applied to the 1.5 BCF that will be transported by the ACP per day.

Pipeline emissions

An estimated loss rate of 0.35% of total methane delivered, lost as fugitive emissions from the transmission pipeline itself,[12] including storage and compressor facilities, was applied to the 1.5 BCF/day transported by the ACP.

Methane emissions from accidents for the pipeline were estimated from the PHMSA Pipeline Failure Database. Incidents that met the following requirements were extracted: the pipeline was constructed after 2010, and it was an onshore natural gas transmission pipeline. The reports provided information on intentional and unintentional releases of methane from 106 accidents, these emissions were summed, and their average emission was calculated. Methane emissions from accidents were then normalized to adjust for the length of the ACP. First, to calculate how many accidents would happen per year in a pipeline the size of the ACP, normalization was done by dividing the rate of accidents in pipelines constructed since 2010 reported by the Pipeline Safety Trust (6.64

accidents) by 10,000 miles (see Fig 3).[14] This number was then multiplied by the number of miles of the ACP (600 miles). The resulting number, 0.39, is an estimate of the number of accidents that would happen in a year along the Atlantic Coast Pipeline; and it was then multiplied by the average methane emission from accidents from onshore transmission lines constructed since 2010.

Total methane emissions for the transmission and storage segment of the Atlantic Coast Pipeline were estimated by adding the calculated CH_4 emissions from the pipeline itself over a period of a year, or 365 days, and the normalized CH_4 emissions from pipeline failures.

Downstream emissions

A loss rate of 0.3% estimated by Alvarez et al. for downstream emissions after the city gates was applied to the 1.5 BCF/day transported by the ACP. Industry and engineers define "city gates" as the point where gas distribution pipelines begin, which are different from gas transmission pipelines which transport natural gas from production sites to distribution networks.

Estimated CH_4 emissions for the supply chain of the Atlantic Coast Pipeline, from production to delivery, were calculated by adding upstream, pipeline, and downstream emissions. These estimated losses total 2.9% of the 1.5 BCF of natural gas that will pass through the transmission pipeline every day. Emissions from anticipated pipeline failures were also added to this total estimate.

Climate assessment

Fugitive emissions

To assess the climate forcing of CH_4 emissions from the Atlantic Coast Pipeline, the estimated methane emissions from the entire natural gas supply chain were multiplied by the Global Warming Potential (GWP). GWP measures how much heat a greenhouse gas will trap in the atmosphere relative to CO_2. In this case, a GWP20 of 86 was used, meaning that over a 20-year horizon, CH_4 will trap heat 86 times more effectively than the same number of moles of CO_2.

Gas combustion

The climate forcing of the 1.5 BCF of gas from the ACP burned to make electricity, home heating and cooling, and industrial processes, assuming that none was lost in the supply chain, was also calculated. "Dry" natural gas is 93.9% methane, this percentage of methane was then multiplied by the GWP20.

Atmospheric assessment

The estimated effect emissions of methane from the Atlantic Coast Pipeline will have on increasing the amount of methane in the atmosphere was calculated by adding the calculated emissions from the supply chain to the current atmospheric concentration of methane.

Atmospheric $CH_{4,}$ as of March 2019 was 1866.4 ppb, or 1866.4 molecules of CH_4 every 1,000,000,000 molecules of air. The total molecules of CH_4 in the atmosphere was calculated using the assumption that there are 1.09x10^44 molecules of air in the atmosphere. The molecules of CH_4 were then transformed to moles using Avogadro's number and then to grams using a molecular weight for CH_4 of 16.04 g/mol. To calculate its CO_2 equivalency the estimated grams were then converted to metric tons and multiplied by the GWP20 of methane. The previously estimated CO_2e from CH_4 fugitive emissions and leaks from the Atlantic Coast Pipeline was then added to this estimate.

The concentration of atmospheric $CO_{2,}$ as of April 2019, was 411.5 ppm, meaning that for every 1,000,000 molecules of air there are 411.5 molecules of CO_2. The total molecules of CO_2 in the atmosphere were calculated using the assumption that there are 1.09x10^44 molecules of air in the atmosphere. Molecules were then converted to moles and then to grams of CO_2 using a molecular weight of 44.01 g/mol of CO_2.

To understand conceptually how localized or distributed the methane would be in the atmosphere, relative to carbon dioxide, the ratio between the rates of diffusion of CH_4 and CO_2 was calculated using Graham's law. This law states that the rate of diffusion of a gas in inversely proportional to the square root of its molecular weight.

Limitations

Data for all calculations performed in this report was obtained from federal databases. As previously mentioned, U.S. methane emissions and natural gas fugitive emissions have been historically been underestimated by the EPA.

The average of methane emissions from pipeline accidents that was used to estimate how much methane would be released annually from the Atlantic Coast Pipeline due to accidents was obtained from reports from the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA). Through a personal communication on July 2019 with Blaine Keener, the PHMSA Director of Operations Systems Division, we learned that the agency requires pipeline operators to submit a report after each incident to the required agency. PHMSA then evaluates each report and adds it to a database. For certain serious incidents, for pipelines that are regulated by the federal government and not a state and that have had major impacts on people or the environment, PHMSA performs a follow-up investigation and posts a more detailed report online as a PDF document. The number of these PDF reports is very small compared to the total number of accidents. In fact, out of the 106 pipeline accidents that met the criteria for this assessment, only one had a PDF report on PHMSA's webpage. The lack of detailed reports and information for pipeline accidents was a limitation encountered during this study and could have affected how accurate the estimate was of methane emissions from annual accidents from the ACP.

Another limitation is that the rate of methane leakage is hotly debated as leaks are difficult to measure, and different scientific studies show widely varying estimates. "Bottom-up" studies that measure leaks in the field are the most precise, but are hard to generalize, as emissions estimates are usually only accurate for the sites where they are taken.

Also, formulas and percentages for the calculations for this study were obtained from a literature review. There is limited recent research on methane emissions from natural gas systems, and most of the scientific papers cited in this report have been done in conjunction with scientists who work in the industry sector, which may result in some reporting bias.

Results

Pipeline accidents

A total of 106 reports from pipeline accidents met the criteria required for this climate assessment. Total methane released from accidents in pipelines constructed after 2010 is estimated to be 1,675,103.4 MCF (thousand cubic feet), with an average of 15802.9 MCF. Emissions from accidents ranged from 165,000 MCF, from a 2018 West Virginia incident in a transmission line owned by Columbia Gas Transmission LLC to 0.2 MCF, from a 2014 Texas incident in a transmission line owned by Katy Storage and Transportation LP. A few accidents also had some casualties. This was the case for a 2014 incident in Texas on a transmission line owned by WTG Gas Transmission Company that killed one person. The list of accidents and their emissions can be seen in Appendix1.

Incidents in natural gas lines due to equipment failures or human accidents are very common across the country. Even the smallest mishap can be quite devastating; as the case of the 2-inch pipeline hit by construction workers in Durham, NC on May 2019. The blast that involved five buildings, killed two people and injured 24 others.

Methane emissions

Estimated methane emissions from the Atlantic Coast Pipeline's supply chain are 15.93 BCF/year, attributed to 12.3 BCF/year CH_4 emissions from the upstream segment, 1.9 BCF/year from the pipeline itself, 0.01 BCF from annual pipeline accidents, and 1.7 BCF/year from downstream emissions (Fig 5).

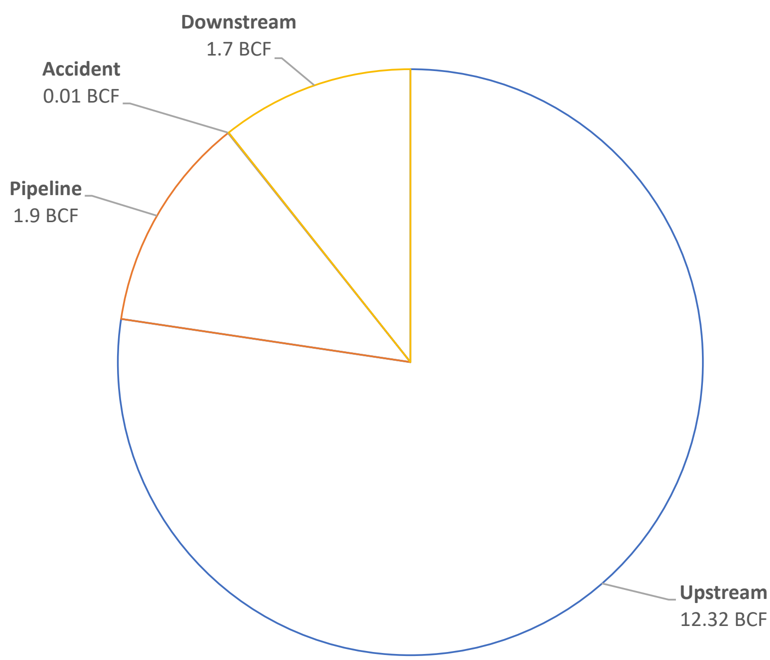

Fig 5. Methane emissions from the total supply chain of the Atlantic Coast Pipeline

Climate assessment

Calculations of Carbon Dioxide Equivalency (CO_2e) estimate that the climate forcing of fugitive emissions from the Atlantic Coast Pipeline is 453.01 BCF of CO_2e over the horizon of 20 years. The estimated climate forcing is attributed to 350.99 BCF of CO_2e from upstream fugitive emissions of methane, 54.6 BCF of CO_2e from the pipeline itself, 0.18 BCF CO_2e from pipeline failures, and 47.2 BCF of CO_2e from downstream fugitive emissions (Table 1).

Section	CH_4 emissions (BCF CH_4/yr)	Climate forcing (BCF of CO_2e)
Upstream	12.32	350.99
Pipeline	1.90	54.59
Accident	0.01	0.18
Downstream	1.70	47.25
Total	**15.93**	**453.01**

Table 1. Climate forcing of methane emissions from the supply chain of the Atlantic Coast Pipeline

This climate forcing estimate is attributed to fugitive emissions from 1.5 BCF per day of natural gas being transported through the Atlantic Coast Pipeline in one year. The EPA reported that the climate forcing of methane emissions from natural gas systems from 2017 was 165.6 MMT (million metric tons) or 3255.8 BCF of CO_2e.[17] **Fugitive emissions from the supply chain of the Atlantic Coast Pipeline would increase the climate forcing for acknowledged U.S. CH4 emissions from natural gas systems by 13.91%.**

Gas combustion for electricity is estimated to have a climate forcing of 40.13 BCF of CO_2e for 1.5 BCF of natural gas, which is 93.9% methane, burned in one day. The climate forcing of natural gas combustion for a year was also estimated to be 14648.27 BCF of CO_2e.

Climate forcing of fugitive emissions of methane from the supply chain of the Atlantic Coast Pipeline was estimated using the EPA Greenhouse Gas Equivalencies Calculator.[18] It is estimated that the 15.93 BCF Ch4 emitted in one year, with a CO2 equivalency of 453.01 BCF, would be equal to the CO2 emissions form 5.9 coal-fired power plants working in a year, or to 2,759,146 homes' energy use for a year. To avoid the full climate forcing of these emissions, 4883 wind turbines must be run for a year; or carbon must be sequestered by 380,998,210 tree seedlings grown for 10 years (Fig 6).

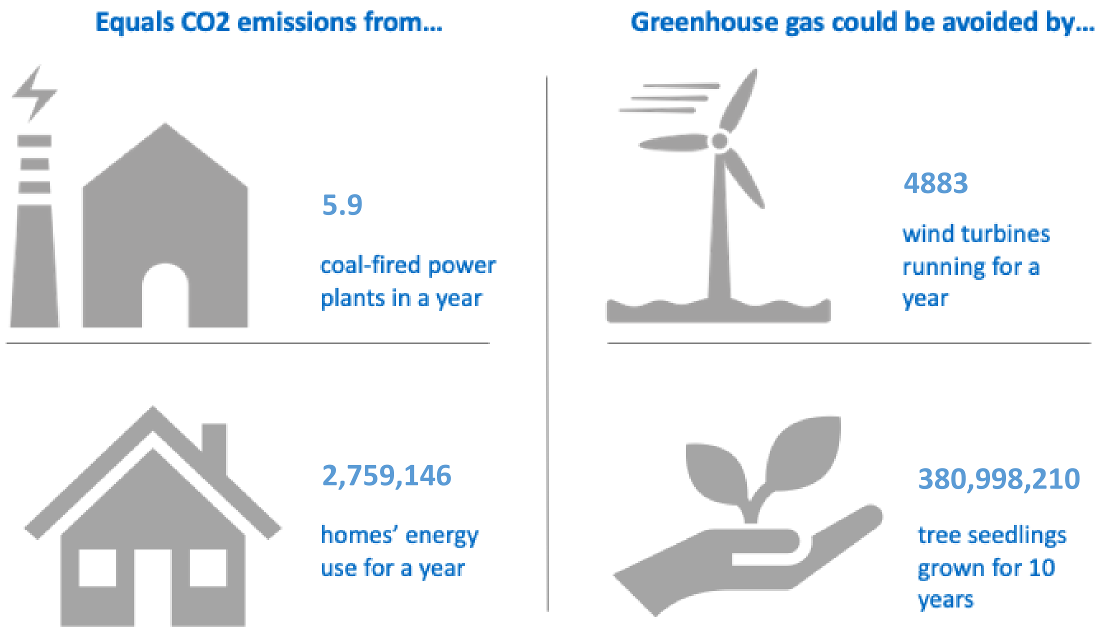

Fig 6. Greenhouse gas equivalencies. [18]

Just for the pipeline itself, CH4 lost as fugitive emissions would be equal to 0.713 coal-fired power plants run in a year, or 332,491 homes' energy use for a year. These greenhouse gas emissions could be prevented by instead running 588 wind turbines or sequestering carbon by growing 45,912,215 tree seedlings for 10 years.

Atmospheric assessment

The climate forcing of the concentration of atmospheric CH_4 as of March 2019 is estimated to be 8310200.588 BCF of CO_2e. Fugitive emissions and methane leaks from the ACP would increase both the atmospheric methane concentration the climate forcing of atmospheric methane by 0.0054% per year. Also, the amount of atmospheric CO_2 as of April 2019 was calculated be 58455472.31 BCF. Current atmospheric concentrations of CH4 and CO2 can be observed in Fig 7 and Fig 8 respectively.

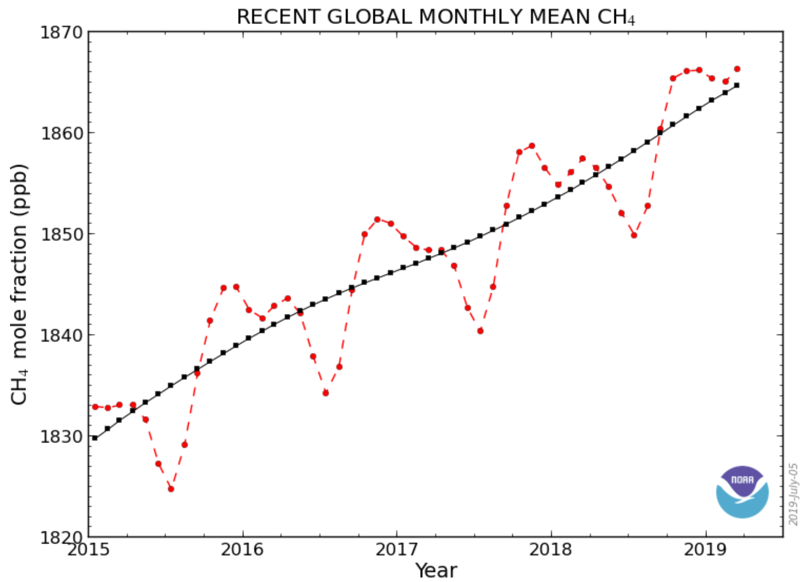

Fig 7. Historical atmospheric concentration of CH4 in parts per billion. (NOAA, 2019) [19]

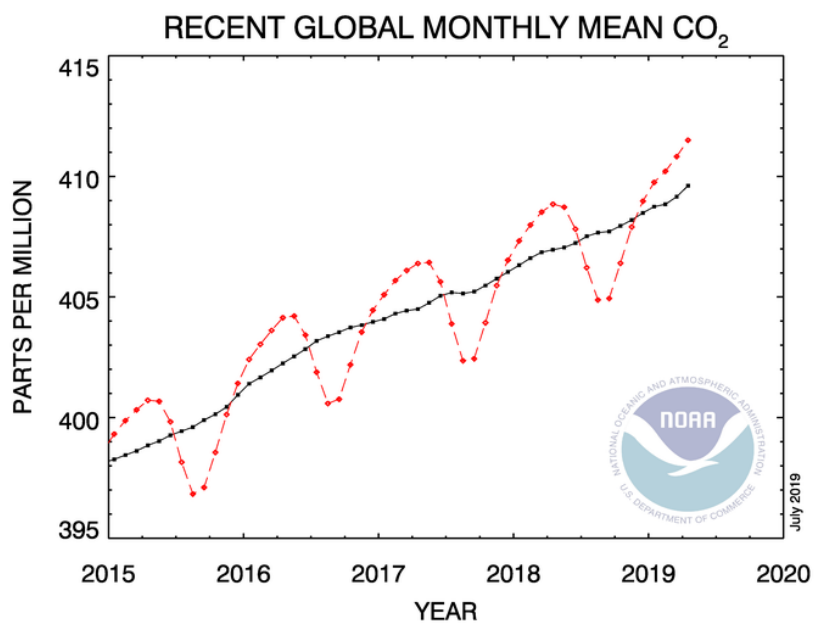

Fig 8. Historical atmospheric concentration of CO2 in parts per million. (NOAA, 2019) [20]

Since the rate of diffusion of methane in the atmosphere is 1.65 as fast as the rate of diffusion of carbon dioxide, **methane emitted from the Atlantic Coast Pipeline supply chain will easily spread out in the atmosphere and have a global effect**.

Discussion

Implications for climate change

Direct and indirect emissions from the **operation of the Atlantic Coast Pipeline would not only accelerate climate warming due to a climate forcing of 453.01 CO_2e annually but also represent a step back in the process of achieving net-zero emissions**--as needed to keep the atmosphere from warming 1.5°C or more. If, in the next 10 years we don't limit the atmosphere's warming to 1.5°C, climate change in the U.S. and around the world will not only contribute to environmental deterioration but also pose a major threat to health.[3] Some of the health threats from climate change include heat waves, the spread of diseases transmitted by insects and other vectors, and intense natural disasters like hurricanes, flooding, wildfires, and droughts.

Actual leakage rates of methane from the natural gas supply chain are likely higher than estimated by agencies or limited studies, due to the difficulty of measuring these emissions. **The estimated 15.93 BCF that will be emitted as fugitive emissions from the Atlantic Coast Pipeline supply chain is likely to be an underestimate**. There are also a significant number of other health risks associated with pipelines. Even small leaks or incidents could cause natural gas pipelines to explode and burn, damaging homes and businesses, and injuries or death. Pipelines also emit gas during blowdowns, which involves complete venting of the gas inside a section of a pipe or compressor stations for repairs. Blowdowns are usually done before inspections or cleaning and release a 90- to 180-foot plume of natural gas into the atmosphere. A typical blowdown could last up to three hours and emit not only methane, but high concentrations of other gases toxic to local residents.

The industry argues that switching to natural gas for electricity and heat generation has a climate advantage, as it produces less carbon dioxide, when burned ,than coal. But methane, which is the main component of natural gas is a very potent greenhouse gas, and often leaks, unburned, to the atmosphere. Though energy companies claim methane is less potent than carbon dioxide because of its relatively short life, when it first enters the atmosphere, CH_4 is 120 times more powerful a greenhouse gas than CO_2, and 86 times more potent over its first 20 years in the atmosphere.[4] Overall, methane has a higher greenhouse gas footprint than carbon dioxide (Fig. 8), and the cumulative effects of CH_4 being emitted to the atmosphere in the next 10 years--the most critical to limit the effects of climate change according to the 2017 IPCC report,[3] ---overwhelm any claimed "advantages" of burning natural gas instead of coal.

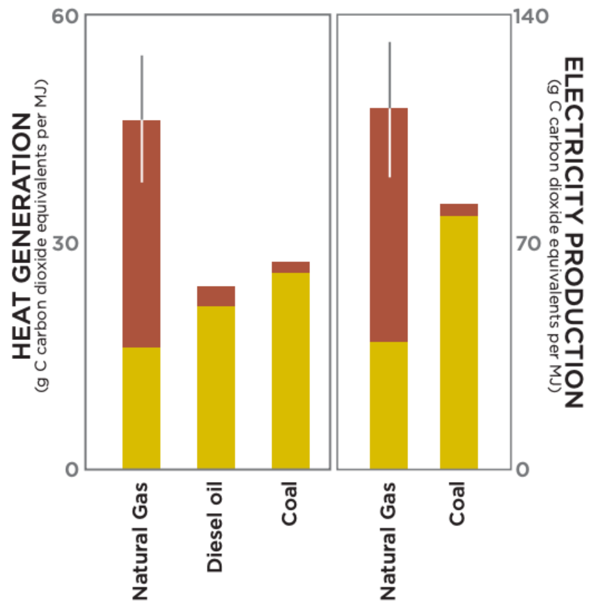

Fig 8. Comparison of the greenhouse gas footprint for using natural gas, diesel oil, and coal for generating primary heat (left) and for using natural gas and coal for generating electricity (right). (Physicians for Social Responsibility, 2017) [4]

There is a critical need to avoid the climate crisis, and **methane's impact on climate needs to be taken into account.** To meet the goal of limiting atmospheric warming and also meet the U.S.' energy need, there must be a transition from fossil fuels such as natural gas to energy-efficiency and carbon-free energy sources.

APPENDIX 1

Methane missions from pipeline accidents along+ onshore transmission lines constructed after 2010, emissions are in MCF (thousand cubic feet).[21]

Year	Name	Installation	Reason	Unintentional	Intentional	Total
2019	Kinder Morgan Tejas Pipeline	2018	LEAK	8802	0	8802
2019	Rocky Mountain Natural Gas Llc	2012	RUPTURE	800	0	800
2019	East Tennessee Natural Gas, Llc (Spectra Energy Partners, Lp)	2016	OTHER	3138	0	3138
2019	Energy Transfer Company	2016	OTHER	8490	0	8490
2019	Enable Gas Transmission, Llc	2016	LEAK	8600	0	8600
2019	Sabal Trail Transmission, Llc (Spectra Energy Partners, Lp)	2016	OTHER	21700	0	21700
2019	Consumers Energy Co	2018	OTHER	8367	1520	9887
2019	Transcontinental Gas Pipe Line Company	2019	LEAK	7.2	36591	36598.2
2019	Midwestern Gas Transmission Co	2018	OTHER	4650	0	4650
2019	Equitrans Midstream Corporation	2015	RUPTURE	17812	0	17812
2019	Consumers Energy Co	2016	OTHER	32564	0	32564
2019	Indiana Gas Co Inc	2014	OTHER	15900	0	15900
2019	Colorado Interstate Gas Co	2013	LEAK	3282	96.1	3378.1
2019	Texas Eastern Transmission, Lp (Spectra Energy Partners, Lp)	2017	LEAK	112.8	41	153.8
2018	Tennessee Gas Pipeline Company	2016	OTHER	4529	0	4529
2018	Consumers Energy Co	2016	LEAK	5264	0	5264
2018	Tennessee Gas Pipeline Company	2015	OTHER	7501	0	7501

2018	Melissa Renewables	2017	MECHANICAL PUNCTURE	49.3	0	49.3
2018	Enable Gas Transmission, Llc	2018	OTHER	4512	0	4512
2018	Sabal Trail Transmission, Llc (Spectra Energy Partners, Lp)	2016	OTHER	26404	0	26404
2018	Transcontinental Gas Pipe Line Company	2017	OTHER	0	185.6	185.6
2018	Northern Natural Gas Co	2018	OTHER	3869	0	3869
2018	Greylock Midstream, Llc	2015	OTHER	3646	0	3646
2018	Columbia Gas Transmission, Llc	2017	LEAK	2200	3300	5500
2018	Arcadia Gas Storage, Llc	2013	OTHER	30000	0	30000
2018	Columbia Gas Transmission, Llc	2017	RUPTURE	165000	0	165000
2018	Kinder Morgan Tejas Pipeline	2012	OTHER	13911	0	13911
2018	Gulf South Pipeline Company, Lp	2018	OTHER	0	398	398
2018	Enterprise Products Operating Llc	2017	OTHER	13200	0	13200
2018	Kinder Morgan Tejas Pipeline	2017	OTHER	3920	0	3920
2018	Rockies Express Pipeline Llc	2014	RUPTURE	23500	0	23500
2018	Tennessee Gas Pipeline Company	2017	OTHER	16280	0	16280
2017	Columbia Gulf Transmission, Llc	2015	OTHER	5229	0	5229
2017	Northern Natural Gas Co	2014	LEAK	3396	0	3396
2017	Cypress Gas Pipeline Company	2016	OTHER	4000	0	4000
2017	Iroquois Gas Corp	2017	OTHER	140	0.1	140.1
2017	Bluestone Pipeline Company Of Pa, Llc	2015	OTHER	10800	0	10800
2017	Tennessee Gas	2015	OTHER	17810.6	18498.8	36309.4

	Pipeline Company					
2017	Consumers Energy Co	2015	OTHER	1417	0	1417
2017	Enable Oklahoma Intrastate Transmission, Llc	2015	LEAK	6400	0	6400
2017	East Tennessee Natural Gas, Llc (Spectra Energy Partners, Lp)	2017	OTHER	9000	0	9000
2017	Oneok Westex Transmission, Llc	2016	OTHER	69217	0	69217
2017	Pacific Gas & Electric Co	2017	LEAK	0.2	2.6	2.9
2017	Tennessee Gas Pipeline Company	2015	OTHER	7456	0	7456
2016	Oneok Westex Transmission, Llc	2016	OTHER	92600	0	92600
2016	Oneok Westex Transmission, Llc	2016	OTHER	12890	0	12890
2016	Consumers Energy Co	2016	OTHER	3680	0	3680
2016	Enterprise Products Operating Llc	2012	LEAK	14000	0	14000
2016	Northern Natural Gas Co	2014	OTHER	9737	0	9737
2016	Kinder Morgan Texas Pipeline Co	2014	OTHER	6107	0	6107
2016	Tennessee Gas Pipeline Company	2013	OTHER	32147	0	32147
2016	Pacific Gas & Electric Co	2014	OTHER	7990	0	7990
2016	Columbia Gas Transmission, Llc	2016	OTHER	3242	1308	4550
2016	Southcross Ccng Transmission Ltd	2016	OTHER	738	0	738
2016	Texas Eastern Transmission, Lp (Spectra Energy Partners, Lp)	2015	OTHER	3800	0	3800
2016	Rockies Express Pipeline Llc	2015	LEAK	911	67902	68813
2015	Tennessee Gas Pipeline Company	2015	OTHER	5780	0	5780
2015	Southern Star Central	2014	OTHER	5510	0	5510

	Gas Pipeline, Inc					
2015	Transcontinental Gas Pipe Line Company	2015	OTHER	6271	0	6271
2015	Consumers Energy Co	2010	OTHER	13500	0	13500
2015	Kinder Morgan Texas Pipeline Co	2014	OTHER	17714	0	17714
2015	Anr Pipeline Co	2015	OTHER	8600	0	8600
2015	Panhandle Eastern Pipeline Co	2014	OTHER	12100	0	12100
2015	Kinder Morgan Texas Pipeline Co	2014	OTHER	10600	0	10600
2015	Enterprise Products Operating Llc	2012	OTHER	6190	0	6190
2015	Consumers Energy Co	2011	OTHER	5800	0	5800
2015	Pacific Gas & Electric Co	2014	OTHER	15175	0	15175
2015	Enable Midstream Partners, Lp	2012	OTHER	4580	0	4580
2015	Southern Natural Gas Co	2014	OTHER	8151	0	8151
2015	Pacific Gas & Electric Co	2014	OTHER	4250	0	4250
2014	Katy Storage & Transportation Lp	2014	OTHER	0.2	0	0.2
2014	Columbia Gulf Transmission, Llc	2013	OTHER	16431	0	16431
2014	Pacific Gas & Electric Co	2014	OTHER	119000	0	119000
2014	Columbia Gulf Transmission, Llc	2013	OTHER	19637	0	19637
2014	Northern Natural Gas Co	2014	OTHER	3990	0	3990
2014	Consumers Energy Co	2010	OTHER	9258	0	9258
2014	Southern Star Central Gas Pipeline, Inc	2013	OTHER	4875	0	4875
2014	Columbia Gas Transmission, Llc	2013	OTHER	8038	0	8038
2014	Northern Natural Gas Co	2014	OTHER	6392	0	6392
2014	Wtg Gas Transmission Company	2013	OTHER	0	906.6	906.6
2014	Mojave Pipeline	2014	LEAK	18725	0	18725

	Operating Company					
2014	Energy Transfer Company	2014	LEAK	1890	3780	5670
2014	Gulf South Pipeline Company, Lp	2014	LEAK	15	90	105
2014	Pacific Gas & Electric Co	2014	LEAK	20	650	670
2014	Wbi Energy Transmission, Inc.	2012	RUPTURE	224	0	224
2014	Texas Gas Transmission, Llc	2012	OTHER	45600	0	45600
2014	Columbia Gas Transmission, Llc	2012	RUPTURE	7200	0	7200
2013	Wbi Energy Transmission, Inc.	2010	OTHER	3609	0	3609
2013	Columbia Gas Transmission Corp	2013	LEAK	1	11909	11910
2013	Columbia Gulf Transmission, Llc	2013	LEAK	3	15560	15563
2013	Tennessee Gas Pipeline Company	2010	OTHER	13000		13000
2013	Pvr Marcellus Gas Gathering, Llc	2012	OTHER	26350	0	26350
2013	Questar Pipeline Company	2012	OTHER	54400	0	54400
2013	Tennessee Gas Pipeline Company	2012	OTHER	22000	0	22000
2012	Acadian Gas Pipeline System	2010	OTHER	0	0.3	0.3
2012	Gulf South Pipeline Company, Lp	2012	LEAK	0	131	131
2011	Colorado Interstate Gas Co	2011	OTHER	1000	181	1181
2011	Transcanada Northern Border Inc	2010	RUPTURE	50555	41938	92493
2011	Devon Gas Services	2010	LEAK	345	0	345
2011	Enogex Llc	2010	OTHER	1773	0	1773
2011	Oneok Gas Transportation, Llc	2010	OTHER	41240	5304	46544
2011	Enogex Llc	2010	OTHER	9909	0	9909
2010	Texas Gas Service Company	2010	OTHER	10	13	23

2010	Centerpoint Energy - Mississippi River Gas Transmission Corp	2010	LEAK	1897	250	2147
2010	Trunkline Gas Co	2010	OTHER	71664	556	72220
2010	Kinder Morgan Texas Pipeline Co	2010	OTHER	1	0	1
					Total	**1675103.5**
					Average	**15802.9**

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