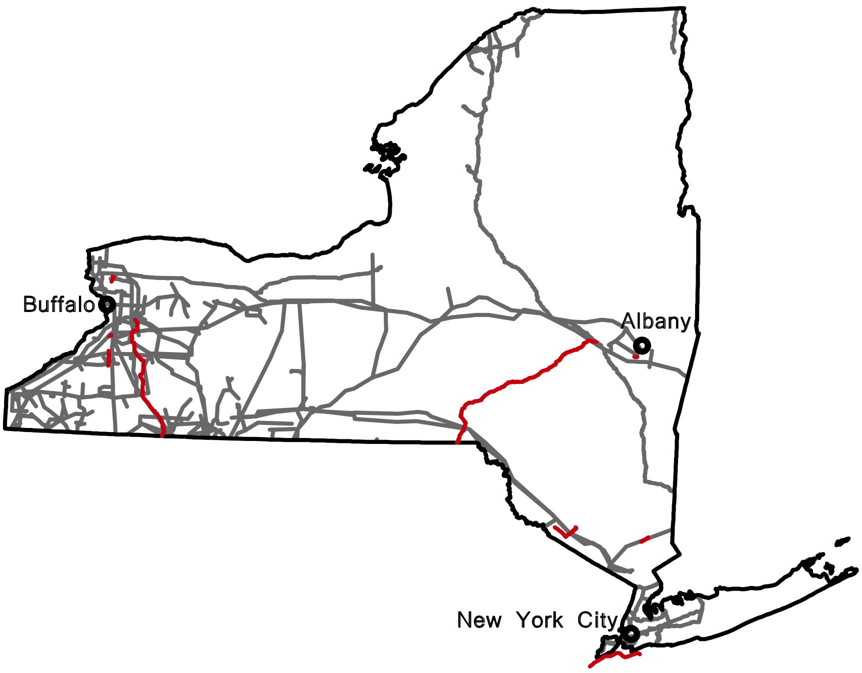
The greenhouse gas impacts of proposed natural gas pipeline buildout in New York



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About PSE Healthy Energy

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Cover image: existing (gray) and proposed (red) pipelines in New York State.

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Executive Summary

New York has set a target to reduce greenhouse gas emissions by 40% from 1990 levels by 2030 [1], yet there are numerous proposals to expand fossil fuel infrastructure across the state. In this analysis, we estimate the potential increase in greenhouse gas emissions from the buildout of ten proposed natural gas pipelines and associated compressor stations in New York State. Our estimates include both fugitive methane emissions from the proposed natural gas infrastructure itself as well as the carbon dioxide (CO_2) and lifecycle methane emissions associated with the increase in natural gas consumption implied by this pipeline buildout. While we do not analyze whether sufficient demand actually exists to justify the addition of these new pipelines, our results indicate that construction of the proposed pipelines and utilization at average rates would undermine the state's greenhouse gas emission reduction efforts.

Proposed natural gas infrastructure in New York State as of late 2017 includes ten pipelines, five compressor stations, five meter and regulator stations, and four compressor station upgrades. These projects currently range in status from proposed to under construction to on hold due to permit denial by the New York Department of Environmental Conservation. Six of the pipelines are meant to deliver natural gas to New York, two to New England or Canada, and two to both New York and out-of-state locations. Our analysis indicates that if these pipelines and compressors are built, in-state fugitive methane emissions from natural gas transmission infrastructure would increase by 8%. If we assume the pipelines meant to deliver natural gas to New York are utilized at the same average rate as existing pipelines—and existing pipelines maintain their current flow rates—the natural gas supplied to New York would increase by 23%. The annual greenhouse gas footprint of this natural gas, inclusive of combustion and lifecycle methane emissions (assuming a methane loss rate of 2.5% of dry gas production[1]), would be 31 million metric tons CO_2-equivalent (CO_2e) on a 20-year timescale and 24 million metric tons on a 100-year timescale—an increase in New York's energy-related greenhouse gas emissions of 12% and 11% respectively, all other sources being held constant.

[1] See full report for a discussion of methane leakage rates.

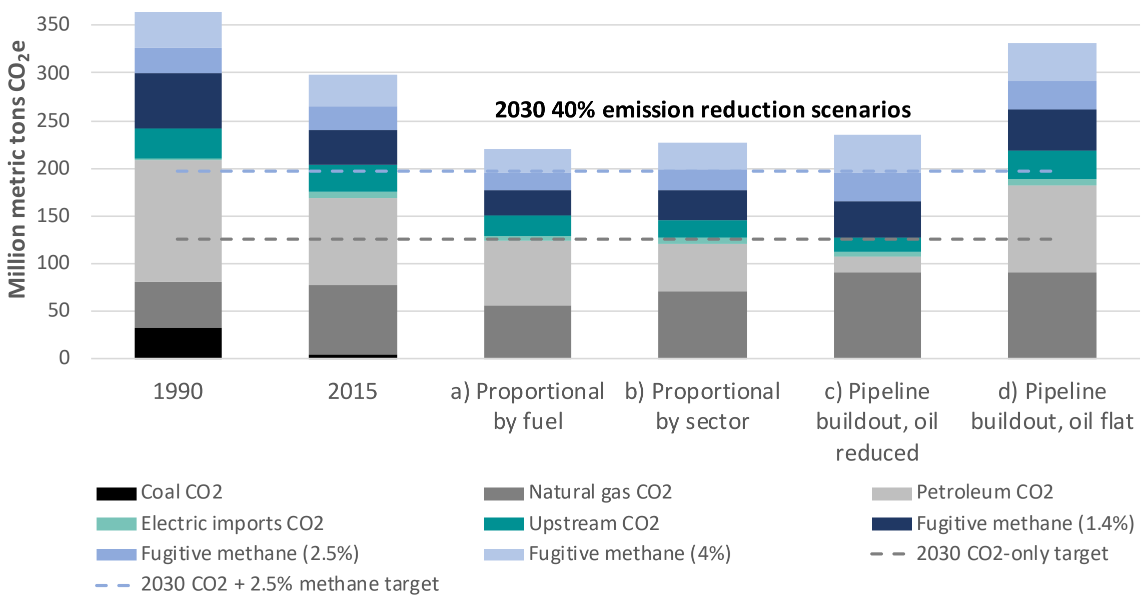

Figure E1: New York's energy-related greenhouse gas emissions in 1990, 2015, and 2030 scenarios. Scenarios include a) proportional emission reductions from oil and gas, b) proportional emission reductions by sector, favoring oil reductions before gas, c) oil cuts required in case of pipeline buildout, and d) oil use flat and pipeline buildout. The 2030 target lines reflect 40% emission reductions from 1990 levels based on CO_2 emissions alone (gray) and inclusive of 2.5% lifecycle methane leakage, using a global warming potential of 87 (blue).

New York could achieve its 40% greenhouse gas reduction target—the equivalent of reducing 2015 emissions by roughly 26-30%—along numerous pathways, although all feasible approaches require reductions in both petroleum and natural gas use. In **Figure E1**, we show the state's energy-related greenhouse gas emissions in 1990, 2015, and in various 2030 scenarios, inclusive of methane leakage at three different rates: a low estimate based on the U.S. Environmental Protection Agency's 2017 Greenhouse Gas Inventory (1.4% of dry production in 2015); a medium estimate of 2.5% reflecting summary estimates from the scientific literature [2, 3]; and a high estimate of 4.0%, in line with the upper range reported elsewhere [3, 4], all using a 20-year global warming potential for methane of 87 [5]. In all 2030 scenarios we assumed that coal use, which has declined rapidly in recent years, falls to zero. These 2030 scenarios include a) proportional emission reductions from petroleum and natural gas to achieve the 40% target; b) proportional emission reductions in each sector (e.g. residential, transportation) prioritizing cuts to oil use before natural gas within each sector; c) petroleum reduction that would be required if proposed pipelines are built and used; and d) flat oil consumption with emissions increasing in accordance with pipeline buildout. Scenarios **a** and **b** present reasonable pathways to achieve 2030 targets. Scenario **c** shows that in order to reduce direct carbon dioxide emissions to 60% of 1990 levels, New York would have to reduce petroleum use by 67% from 2015 levels by 2030 if the proposed pipelines are built and natural gas use increases accordingly, effectively eliminating oil from residential, commercial, and industrial sectors and reducing oil use in transportation by 57%; if a 2.5% methane leakage rate is included in greenhouse gas targets, petroleum use would have to be cut by 83%. If petroleum consumption stays flat as in scenario **d**, New York State's energy-related greenhouse gas emissions would increase by 12% from 2015 levels under pipeline buildout and utilization.

These greenhouse gas emission estimates change based on various assumptions. If the pipelines currently on hold due to permit denial are not built, the implied increase in emissions would fall by over 40%. If we calculate targets using the 100-year global warming potential for methane rather than the 20-year global warming potential, it is only slightly easier to achieve the 2030 target in the case of pipeline buildout—requiring 77% petroleum reductions rather than 83%. However, methane leakage rates across the natural gas lifecycle are highly uncertain. If methane leakage is at the high end of the range examined here—4%—then petroleum use would have to be nearly eliminated by 2030 in order to achieve emission reduction targets if the pipelines are built and used. Assigning responsibility for methane leakage also requires some jurisdictional questions for greenhouse gas inventories. For example, for natural gas transported through New York, should the fugitive methane emissions from that infrastructure be included in New York's greenhouse gas accounting or in the state or country that actually uses the natural gas? And finally, we did not calculate potential demand for the gas to be delivered by these pipelines. If this demand does not exist, then pipelines may be underutilized, resulting in lower overall emissions than estimated here but also potentially inefficient investments.

Under all reasonable assumptions, however, New York needs to reduce its natural gas consumption in order to achieve its 2030 greenhouse gas targets—meaning that building out new pipelines and increasing the natural gas supply to the state would either greatly undermine these emission reduction efforts, or result in inefficient investments in infrastructure that will be greatly underutilized by 2030 if the state succeeds in achieving its climate goals.

Contents

1. Introduction

The State of New York has set a greenhouse gas target of 40% emission reductions from 1990 levels by 2030 [1], but the proposed expansion of fossil fuel infrastructure across the state may undermine the state's ability to achieve this goal. In this analysis, we estimate the implied increase in natural gas use and associated greenhouse gas emissions from the construction of proposed natural gas pipelines and infrastructure across New York, and compare our findings to the state's greenhouse gas targets. We include pipelines that are proposed or approved as well as those that have been denied but are appealing the decision. This study is not meant to estimate the demand for natural gas in New York State, but instead to answer the question: if the proposed natural gas pipelines are built and used at current average rates, can New York achieve its greenhouse gas targets?

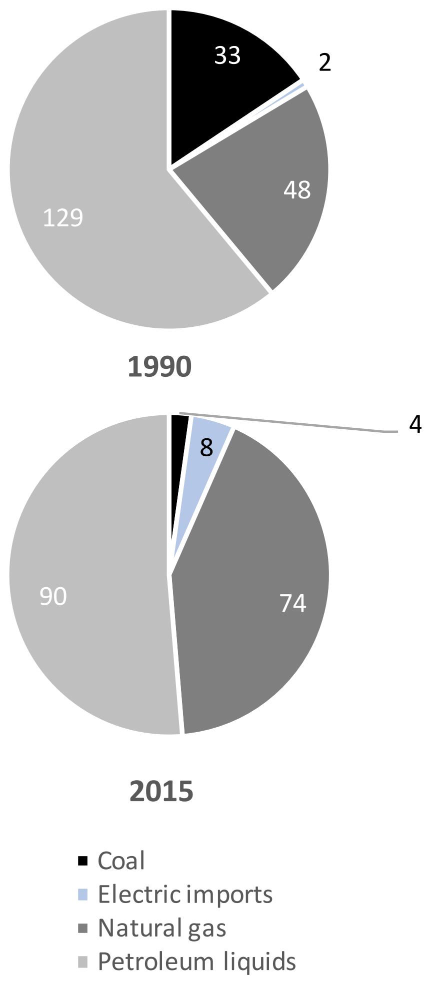

Figure 1.1: Direct energy-related CO_2 emissions by fuel source in 1990 and 2015 [6, 7].

According to the New York State Energy Research and Development Authority (NYSERDA) greenhouse gas inventory, New York State reduced its energy-related greenhouse gas emissions by 13% between 1990 and 2014, implying the need for an additional 31% reduction in greenhouse gas emissions from 2014 levels by 2030 to meet state targets [6]. New York State's direct energy-related carbon dioxide (CO_2) emissions by fuel source in 1990 and 2015 are shown in **Figure 1.1**.[1] Direct CO_2 emissions from natural gas combustion increased by 55% from 1990 to 2015, but some of these increases were offset by an 80% decline in coal-related emissions and a 30% decline in petroleum-related emissions. As of 2015, natural gas was responsible for 44% of New York's in-state energy-related CO_2 emissions, while petroleum products and coal contributed 54% and 2% respectively [7]. In order to cut emissions by nearly a third, New York will therefore need to significantly reduce its consumption of natural gas.

In addition to the combustion-related CO_2 emissions described above, fugitive methane emissions throughout the natural gas system can greatly increase the lifecycle greenhouse gas impacts of natural gas use. Methane from fossil fuel sources is 36 times more potent than CO_2 as a greenhouse gas on a 100-year timescale and 87 times more potent on a 20-year timescale [5]. In the New York State Greenhouse Gas Inventory, NYSERDA estimates that methane leakage from natural gas systems accounts for 1% of New York's total 2014 greenhouse gas emissions from all sectors [6], but relies on outdated global warming potentials and methane leakage data to reach this estimate. The current peer-reviewed literature indicates that the actual methane leakage from natural gas used in New York is likely higher than this estimate but still uncertain, because upstream methane leakage rates are uncertain [2]. In its Greenhouse Gas Inventory, the U.S. Environmental Protection Agency (EPA) provides an upstream methane leakage estimate of approximately 1.4%

[1] We use Energy Information Administration (EIA) values here because they are complete through 2015 [7], while the NYSERDA inventory only has 2014 data [6].

of dry natural gas production (about 1.25% of gross methane withdrawals) [8], while the majority of the scientific literature reports higher rates [2, 3, 9, 10, 11, 12, 13]. At the high end of these estimates, researchers measuring atmospheric concentrations of methane over individual oil and gas fields—such as North Dakota's Bakken Shale and Texas's Eagle Ford Shale plays—have suggested leakage in these specific locations of more than 10% [9]. Even a leakage rate of 1.4%, however, would imply a roughly 40% increase in the greenhouse gas footprint of natural gas use when using methane's 20-year global warming potential and 17% using a 100-year global warming potential. These data further highlight the need to reduce natural gas production, transmission, distribution and consumption to achieve meaningful greenhouse gas emission reductions.

Although New York aims to cut its greenhouse gas emissions, the construction of numerous new natural gas transmission pipelines and compressor stations has been proposed across the state. Six of these pipelines are expected to deliver natural gas to New York, and four more are expected to supply multiple markets in New York and New England and potentially Canada. Four of these pipelines are under construction, three are in planning stages, and three are currently on hold due to permit denials by the New York Department of Environmental Conservation (DEC) but continue to appeal these decisions. In addition to these pipelines, there are five new compressor stations and four compressor station upgrades proposed across New York State, as well as five new meter and regulator stations. In this report, we analyze the potential greenhouse gas emission impacts of this set of planned and under-construction pipelines and infrastructure and analyze what these emissions mean for reaching the New York State greenhouse gas emission reduction targets in 2030.

We estimate the greenhouse gas emission implications of pipeline and compressor station buildout in two broad categories. In the first category, we estimate the fugitive methane emissions associated with the proposed pipeline and compressor station infrastructure across New York State. In the second category, we estimate how much natural gas would likely be delivered to New York via these pipelines (rather than out-of-state) and analyze the lifecycle greenhouse gas emissions from this implied increase in natural gas use, including CO_2 from combustion and fugitive methane from the entire natural gas life cycle. The in-state methane fugitives from transmission infrastructure in the first category are a component of the lifecycle analysis of in-state natural gas in the second category, but methane from infrastructure delivering gas to New England or Canada is considered an additional set of emissions. We then compare the resultant emissions with the state's greenhouse gas targets, assuming the pipelines are used at average utilization rates. As noted, the results are not meant to indicate that the demand for natural gas at these utilization rates exists.

2. Background

New York has set a number of clean energy and greenhouse gas targets for the year 2030, using a baseline year of 1990. Here we give an overview of these targets using a direct CO_2-only lens, then discuss the impact of upstream CO_2 and fugitive methane emissions on these greenhouse gas targets.

2.1 New York's historic CO_2 emissions and greenhouse gas targets

New York has set three broad energy and climate goals for 2030 [1], including:

- 40% greenhouse gas emission reductions from 1990 levels;
- 50% renewable energy in its power sector;
- 600 trillion British thermal unit increase in energy efficiency savings.

According to NYSERDA's greenhouse gas inventory calculations, the state's energy-related carbon dioxide equivalent (CO_2e) emissions declined by 13% between 1990 and 2014, from 213 million metric tons (MMt) to 186 MMt [6].[1] This inventory implies a 2030 target of 128 MMt CO_2e, which is 31% below 2014 levels.

Emissions from natural gas combustion (excluding lifecycle methane emissions), increased from 48 MMt CO_2 in 1990 to 74 MMt CO_2 in 2015 [6, 7]. This growth is shown in **Figure 2.1**, which provides annual direct CO_2e emissions from each major fossil fuel source from 1990-2015. Total direct CO_2 emissions declined due to lower petroleum use and the near elimination of coal by 2015.

From a sectoral standpoint, the historic declines in CO_2 emissions stem primarily from emission reductions in the industrial and electric power sectors and minor emission reductions in the commercial sector, while direct CO_2 emissions have actually increased in the residential and transportation

[1] NYSERDA estimates include 4.6 MMt CO_2e from methane leakage in 1990 and 2.2 MMt CO_2e in 2014 using a global warming potential of 25.

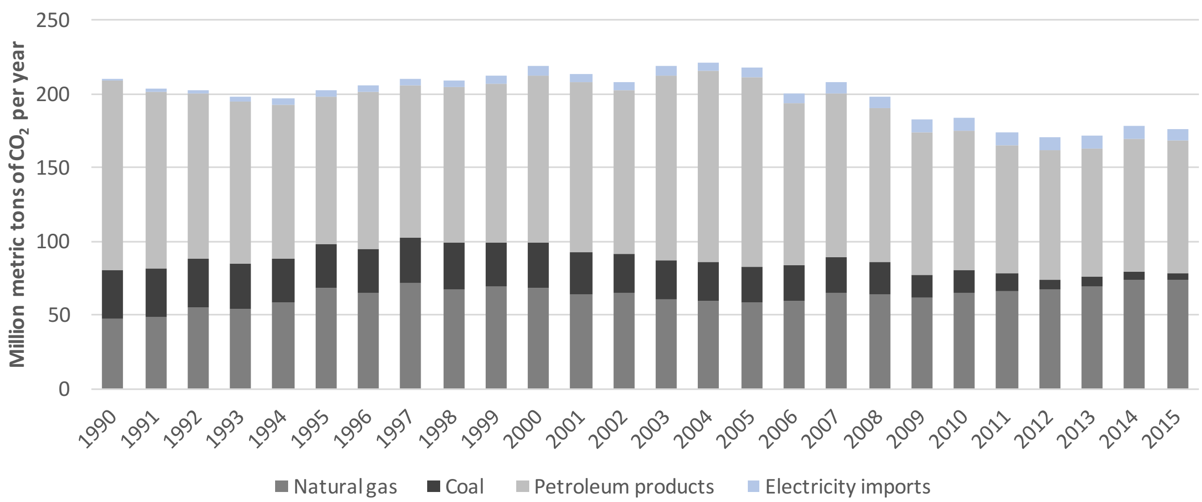

Figure 2.1: Direct energy-related CO_2 emissions in New York State by fuel. Emission sources include coal, petroleum products, natural gas, and electricity imports [6, 7].

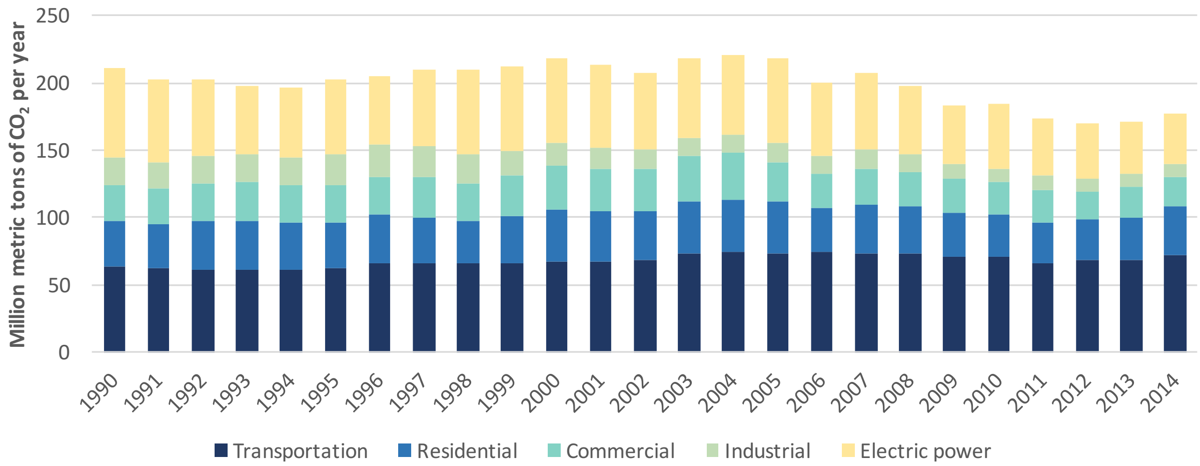

Figure 2.2: Direct energy-related CO_2 emissions in New York State by sector. Sectors include residential, commercial, industrial, transportation and electric power [6, 7].

sectors. Petroleum use overall has fallen primarily due to reductions in oil used for building heating and electricity generation, even as petroleum use has increased in the transportation sector. Sectoral direct CO_2 emission trends are shown in **Figure 2.2**.

2.2 Lifecycle greenhouse gas emissions: fugitive methane and upstream CO_2

Figures 2.1 and **2.2**, however, omit the lifecycle CO_2 and methane emissions associated with fossil fuel production and use. CO_2 emissions are associated with the production and processing of fossil fuels, in large part from energy use, in addition to end-use combustion emissions. Meanwhile, natural gas is primarily composed of methane, a powerful greenhouse gas. Methane is known to leak throughout the entire natural gas fuel lifecycle, including during production, processing, storage, transmission and distribution. Methane leakage is also associated with coal and oil production, but at lower emission rates per unit energy delivered than for natural gas.

Fugitive methane emission rates for natural gas are highly uncertain, and estimates vary by location and by detection method. Numerous factors affect this uncertainty. Leakage rate can vary based on characteristics such as geology, age and material of components, production method, and equipment type, among others. Furthermore, *bottom-up* accounting approaches which measure leakage from individual components typically find much lower leakage rates than *top-down* approaches which measure atmospheric concentrations of methane above production sites [14, 15]. Some of this discrepancy may be due to the presence of super-emitters. Brandt *et al.* suggest that 5% of super-emitting sources across the natural gas systems—from well pads to compressor stations to processing facilities—may be responsible for more than half of fugitive methane emissions [15].

As a result of these uncertainties, estimates of leakage vary significantly. Using a bottom-up approach, the EPA's Greenhouse Gas Inventory for 2017 reports a roughly 1.4% leakage rate as a fraction of dry natural gas production in 2015 (about 1.25% of gross withdrawals),[2] attributing two thirds of this leakage to production, 20% to transmission and storage, and the remainder split between processing and distribution [8]. By dry production, we refer to processed natural gas from which ethane, propane and butane have been removed. These estimates are revised each year: the

[2]Calculated using EPA emission totals and EIA data on dry natural gas production [8, 16].

2017 estimates for 2014, for example, are lower than the 2016 estimates for 2014 [8, 17]. Littlefield *et al.* review ground-based methane measurements to estimate a lifecycle leakage rate of 1.3%-2.2% [18]. Brandt *et al.* find that atmospheric methane measurements across the U.S. suggest that 2011 lifecycle methane emissions from natural gas systems were roughly 1.5 times larger than the 2013 EPA Greenhouse Gas Inventory estimate of 1.5% of gross methane withdrawals on a mass basis, or roughly 1.8% of dry production [2]. This estimate implies a 2011 leakage rate of 2.25% of gross methane withdrawals or 2.5% of dry production. If all excess methane in the atmosphere beyond that included in the EPA's greenhouse gas inventory is attributable to natural gas, Brandt places an upper limit on leakage at 7.1% on an end-use basis, but considers this unlikely because unattributed methane may come from numerous sources. Schwietzke *et al.* estimate a global leakage value of 2.2% of dry production in 2013 [3].

Meanwhile, studies of atmospheric concentrations of methane above individual gas and oil fields have suggested much higher leakage rates from production in specific regions, albeit with significant uncertainty ranges. The EPA estimate of production-related methane leakage is roughly 0.8% of gross withdrawals. The field measurements with much higher leakage rates include 1.3%-19% over the Barnett shale formation [12]; 1.5%-6.3% [19] and 2.8%-17.3% [10] above the Marcellus formation; 2.6%-5.6% above the Denver-Julesburg Basin in Colorado [20]; 6.2%-11.7% above the Uintah Basin in Utah [21]; 9.1% above the Eagle Ford in Texas [9]; and 4.2%-8.4% [22] and 10.1% [9] above the Bakken in North Dakota.

In this study, we consider both the full lifecycle emissions of natural gas use as well as a subset of these emissions from pipeline and compressor station infrastructure. To calculate greenhouse gas emissions, we use a low, medium and high value for potential methane emission rates from the natural gas fuel cycle. We use a baseline methane leakage estimate of 2.5% of dry gas production, in line with estimates by Brandt [2] and Schwietzke [3]. We provide a low estimate based on the EPA's bottom-up greenhouse gas inventory of 1.4% of dry natural gas production [8], and a high estimate of 4%. While some estimates of methane leakage are higher than 4%, these values allow us to reasonably discuss the impact of a range of leakage rates on New York's greenhouse gas emissions and targets.

The EPA's 2017 Greenhouse Gas Inventory estimates that 0.26% of dry natural gas produced leaks from natural gas transmission infrastructure, including pipelines, compressor stations and storage. Using a mix of on-site measurements and Monte Carlo simulations, Zimmerle *et al.* provide a higher estimate of emissions from the transmission and storage sector of 0.28%-0.45%, with nearly a third of these emissions coming from super-emitters [23].[3] Here, we use the Zimmerle *et al.* values for transmission sector emissions due to their inclusion of field measurements and super-emitter emissions which are not fully reflected in the greenhouse gas reporting program data used by the EPA. The specific values used for each component, including low and high estimates, are detailed in the methods section. Significant uncertainty still remains in terms of leakage rates, particularly in regard to super-emitters, but these values are the most detailed current estimates in the scientific literature.

Upstream methane emission are also associated with coal and petroleum production, albeit at lower rates. While this study is not focused on coal and petroleum, we include estimates of these emissions for completeness. A review of 17 studies by Whitaker *et al.* yields a median estimate of methane emissions from the coal lifecycle of 63 grams CO_2e/kilowatt-hour using a global warming potential of 25 [24], which we adjust to reflect more recent consensus estimates of methane's global warming potential [5]. We calculate the upstream methane emissions associated with petroleum

[3] We note that Zimmerle *et al.* compare their findings to the EPA's 2012 Greenhouse Gas Inventory and find lower transmission and storage leakage than the EPA, but the EPA has since revised inventory estimates and the Zimmerle values are now higher.

use using the EPA's Greenhouse Gas Inventory estimates for methane emissions from petroleum production, weighted on an energy basis by the fraction of oil as compared to natural gas produced from oil fields.[4] Using this approach, we find that EPA's methane emission estimates historically implied an increase in CO_2e emissions of 12-14% above direct combustion emissions on a 20-year timeframe and 5% on a 100-year timeframe, but that this rate fell by 2015 to about 7% on a 20-year timeframe, or 3% over 100 years. This bottom-up approach yields lower lifecycle methane emissions than might be suggested by the top-down measurements over certain oil fields described above [9, 22], but due to the much smaller contribution of petroleum-related methane as compared to natural gas-related methane in our upstream calculations, our findings are not greatly sensitive to this assumption.

Upstream CO_2 emissions from fossil fuel production stem in large part from energy used in production and processing and, to a lesser extent, non-combustion CO_2 emissions. When discussing lifecycle CO_2 emissions we assume coal emissions increase direct combustion emissions by 2% [25, 26], natural gas by 13% [27], and petroleum by 19% [26].

2.3 Impact of methane leakage and upstream CO_2 on New York's greenhouse gas emissions and targets

As noted, methane leakage rates are highly uncertain, and this uncertainty increases greatly as we estimate historic emissions back to 1990. In **Figure 2.3**, we plot estimated lifecycle CO_2e along with a range of three natural gas methane leakage rates to illustrate New York's historic energy-related CO_2e emissions. The low leakage rate is calculated from the EPA's 2017 Greenhouse Gas Inventory [8], inclusive of reported methane from across the natural gas industry as well as from oil production, and applied to natural gas and petroleum use accordingly, with adjustments to reflect natural gas production at oil fields. Natural gas leakage rates, according to the inventory, declined from 2.5% to 1.4% of dry production between 1990 and 2015. These methane leakage rates increase the greenhouse gas footprint of natural gas by 79% and 41%, respectively, compared to direct CO_2 emissions and using the 20-year global warming potential for methane.

As noted earlier, the EPA inventory calculates bottom-up methane leakage estimates for natural gas that have been found to be consistently lower than *in situ* and direct atmospheric measurements from scientists in the peer-reviewed literature in recent years. However, there is a dearth of top-down studies of atmospheric methane concentrations to compare to the EPA inventory for the 1990s. As such, throughout this report, we use a moderate and high value of 2.5% and 4% methane leakage to reflect current leakage. We use the ratio of these values to the current EPA estimate (e.g. 2.5/1.4 and 4/1.4) to calculate "moderate" and "high" scaling factors for the years 1990-2013. As such, we provide "medium" and "high" estimates of historic methane leakage by multiplying EPA's historic emission estimates by a factor of 1.8 and 2.9, respectively. Given the lack of atmospheric data until recent years, these values are meant to be illustrative but cannot express historic leakage rates with any certainty.

Figure 2.3 shows that New York's total annual greenhouse gas emissions are significantly higher than direct emissions when lifecycle CO_2 and methane are included, even at the low-end estimates reported in the EPA Greenhouse Gas Inventory. The inventory also reflects a decline in methane leakage rates over the past 25 years; if this reported trend is accurate, the declining leakage rates offset the methane impact of growing natural gas demand in New York. Using EIA values, New York's direct energy-related CO_2 emissions declined by 16% between 1990 and 2015.[5] Inclusion of

[4] The natural gas component was included in the 1.4% EPA leakage we described earlier.
[5] Calculated from EIA emission data [7], but inclusive of import electricity emissions reported by NYSERDA [6].

lifecycle CO_2 emissions and a range of upstream methane emissions yields an estimated decline in energy-related lifecycle greenhouse gas emissions by 17%-20% over the same period. These values are slightly different than NYSERDA's reported numbers. NYSERDA only reports data through 2014, but 2014 and 2015 emissions were similar. If we update the global warming potential for methane used by NYSERDA from 25 to 87, we find an 11% decline in combustion-related CO_2 emissions from 1990-2014 and 14% decline in CO_2 from combustion plus CO_2e from methane emissions over the same period.[6] The discrepancy primarily stems from different values used for 1990 petroleum emissions from transportation.

New York's Clean Energy Standard sets a target of 40% reduction in greenhouse gases below 1990 levels by 2030. If only considering direct CO_2 emissions, New York must cut emissions by 28% from 2015 levels by 2030. If we update the methane global warming potential in NYSERDA's inventory, this target implies a 30% reduction in combined methane and CO_2 from energy-related sources from 2014 levels by 2030. Using the EIA's values and lifecycle methane and CO_2 emissions based on EPA leakage estimates, the implied reduction is 25%.[7] The inclusion of lifecycle methane and CO_2 emissions in the 1990 greenhouse gas baseline calculation, under the assumptions above, has only a moderate impact on the remaining emission reduction percentage required from 2015 levels, but a much greater effect when comparing pathways to achieve these emission reductions.

2.4 Pathways to achieve 2030 emission targets

There are numerous pathways that would allow New York to reduce greenhouse gas emissions to meet its target, but all of the feasible pathways rely on reducing natural gas consumption. Coal use has declined in recent years, accounting for 1.3% of electricity generation and a small amount of industrial use in 2016 [7, 28]. Coal will likely be nearly eliminated by 2030, but the low current

[6] We consider nitrous oxide emissions to be beyond our scope and they are excluded from this analysis. They contribute a small fraction of NYSERDA's energy-related greenhouse gas emissions [6].

[7] If we assume methane leakage is higher than EPA estimates, the reductions required are slightly higher.

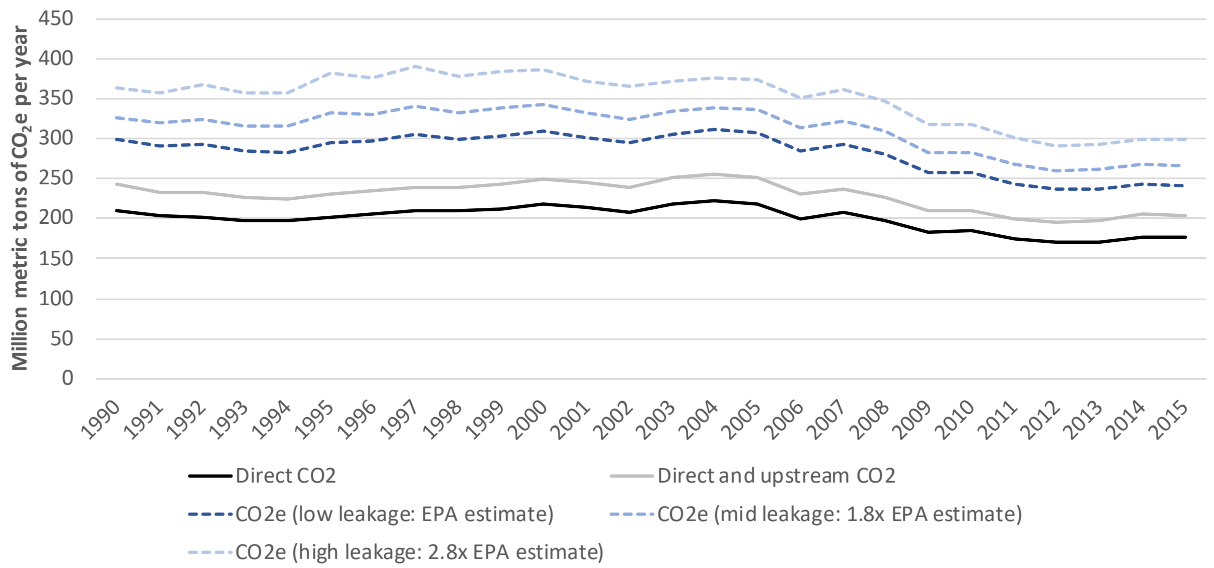

Figure 2.3: Total direct CO_2 emissions in New York State compared to lifecycle CO_2e estimates inclusive of methane leakage. Methane leakage rates shown include 1) annual values reported in the 2017 EPA Greenhouse Gas Inventory [8], 2) 1.8x inventory values for lifecycle methane emissions from natural gas, and 3) 2.9x inventory values. CO_2e for methane calculated using a global warming potential of 87.

level of use means that elimination of coal would reduce current emission levels by only 3%. For the purposes of this analysis, we assume coal use will be phased out entirely in all scenarios, meaning that in order to achieve targets, emissions must be reduced by an additional 22%-27% from combined cuts to natural gas and petroleum (and electricity imports). It would technically be possible for all of the remaining greenhouse gas emission reductions to come from cutting back on oil alone, but the state's 2030 target would only be achieved if petroleum use was cut in half—or even more when accounting for methane leakage. This pathway seems unlikely; while petroleum consumption has fallen significantly since 1990, the transportation sector now accounts for 80% of New York petroleum consumption, and oil use in this sector has actually grown since 1990. Thus, emission reductions will likely require New York to reduce both its oil and natural gas use.

Figure 2.4 shows greenhouse gas emissions for 1990, 2015 and three approaches to reduce greenhouse gas emissions by 40% by 2030. We set the overall target using a 2.5% leakage rate for methane and assuming this rate is constant until 2030, but we also illustrate the impact of higher leakage rates on emission reductions. The three approaches to achieve a 40% reduction in emissions by 2030 include a) equal emission reductions by fuel source; b) all emission reductions allocated to petroleum; and c) a sectoral-based compliance approach wherein each sector reduces emissions by the same proportion but within each sector reductions are achieved by first reducing coal and oil followed by natural gas. For example, in the residential sector, oil-based heating systems would be phased out before natural gas heating systems.

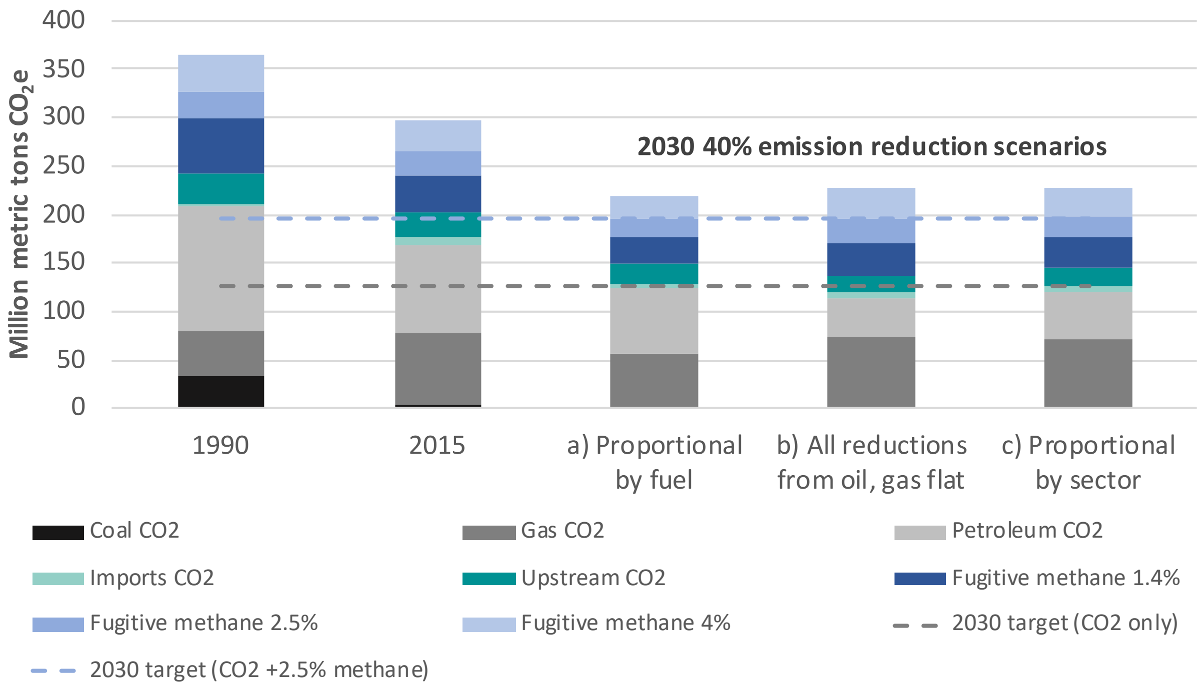

Figure 2.4: CO_2 and methane emissions in 1990 and 2015 compared to 2030 target of 40% emission reductions. Methane leakage reflects 1.4%, 2.5% and 4% for 2015 and 2030; rates are higher for 1990 based on EPA estimates. Upstream CO_2 is shown aggregated for all fuels. The 2030 targets provide an option for a) reducing emissions proportionately from petroleum and gas, b) achieving emission targets through oil reductions alone, and c) reducing each sector by the same proportion, but reducing oil and coal before natural gas within each sector.

These emission reduction scenarios illustrate a number of key points. First, achieving these targets through coal and petroleum reductions alone (scenario **b**) while keeping natural gas flat would require reducing oil use by 55% between 2015 and 2030, which would present a formidable challenge. Emission reductions using the sectoral approach described (scenario **c**) would require at least a 10% reduction in natural gas use and 42% reduction in oil use. However, **Figure 2.4** illustrates that for higher methane leakage rates, this leakage undermines emission reductions, and that this effect is greater in scenarios **b** and **c**, which have higher natural gas use in 2030. As a result, pursuing deeper emission cuts from natural gas may provide a hedge against the risk of greater climate impacts resulting from higher methane leakage. We note, however, that petroleum combustion typically emits more co-pollutants like particulate matter than natural gas, so reducing petroleum use may result in greater health co-benefits, although health-damaging co-pollutants are emitted across production, transmission and combustion for both fossil fuels.

Clearly, multiple pathways would allow New York to achieve emission reduction targets. The two most reasonable pathways (proportional by sector and proportional by fuel) require natural gas emission reductions between 10% and 25% from 2015 levels. Pathways with lower levels of natural gas use help hedge against the climate risks of potentially high methane leakage rates. In the following section, we analyze the implied emissions associated with building out proposed natural gas pipelines in New York State and compare these emissions to the greenhouse gas reduction pathways described above.

3. Methods

To estimate the potential greenhouse gas emission impacts of natural gas transmission infrastructure build-out in New York State, we identified proposed infrastructure and calculate the increase in natural gas use if this infrastructure is used at current average utilization rates. We estimated the greenhouse gas emissions of this usage inclusive of combustion-related direct CO_2 emissions; fugitive methane emissions from gas production, processing, transmission, and distribution; and the subset of fugitive methane emissions specific to the proposed pipeline and compressor station infrastructure. Below we describe in detail our methods for each source of greenhouse gas emissions included in our analysis.

3.1 Methane emissions from pipelines

We developed a list of proposed and permitted pipelines running through New York State by performing data searches in multiple state and federal databases, including data from the Federal Energy Regulatory Commission (FERC) [29, 30], EIA [31], and the New York Department of Environmental Conservation (DEC) [32]. For the purposes of this analysis, we define proposed as any pipeline that has been suggested by an operator but has not yet come online or been cancelled. This list includes interstate and intrastate pipelines, as well as pipelines that both have, and have not, received approval from FERC and DEC. Our analysis also includes pipelines that have been permitted and are currently under construction.

We conducted background research on each pipeline to ensure that it is still in the "proposed" stage—i.e. the project had not been cancelled as determined by a withdrawn application from FERC, or completed as determined through an In-Service Notification filed with FERC or DPS. Using these criteria, our approach resulted in ten proposed pipelines as of April 2017 that will be delivering gas to or are located at least partially within New York State.

We obtained proposed pipeline mileage from the pipeline applications submitted by the operators to FERC. With mileage data we estimated fugitive (unintentional including upsets) and vented (e.g., planned due to routine maintenance) methane emissions from pipelines.[1] While we primarily rely on a study by Zimmerle *et al.* for transmission sector fugitive methane emission factor estimates [23], this study does not provide emission factors for pipeline leakage emissions. We therefore rely on EPA Greenhouse Gas Inventory values for these emission factor estimates. Using the EPA Greenhouse Gas Inventory emission factors, pipeline leakage contributes an estimated 7.7% of transmission and storage sector emissions [8].

3.2 Methane and CO_2 emissions from transmission and storage compressor stations

A list of proposed new compressor station builds and upgrades was compiled by reviewing the FERC documentation associated with each planned pipeline. We also aggregated data for existing transmission and storage compressor stations requiring air permits within New York State from the DEC [34]. The DEC has two categories of air pollution control permits: State facility permits and

[1] Upsets are unexpected and/or emergency situations that arise and need to be dealt with immediately that may cause unexpected releases of methane to the atmosphere [33].

Title V facility permits, which are distinguished based on air pollution severity [35, 36, 37].[2] We manually retrieved permits on the DEC website that met two criteria: (1) a Standard Industrial Classification (SIC) code of 4922, indicating that the facility's primary purpose is natural gas transmission [38]; and (2) an indication in the facility name or description that the site is primarily a natural gas compressor station.[3] In addition, we found two natural gas compressor stations with the SIC code 1311, denoting crude petroleum and natural gas [39].

Some facilities with non-trivial emissions are not required to obtain a DEC air permit. Such facilities are instead required to submit only a registration to the DEC, and are therefore not listed on the DEC website [35, 40]. We conducted a review of documents and maps released by government agencies, natural gas operators, and non-governmental organizations to determine if we were failing to include any compressor stations [41, 42, 43, 44, 45, 46, 47, 48, 49]. We differentiated transmission compressor stations from storage compressor stations using classifications reported on FERC Form 2 by each major gas transmission company [50, 51, 52, 53, 54, 55, 56, 57]. To quantify emissions at each existing compressor station in New York, we used Zimmerle *et al.*'s emission factors for transmission and storage station fugitives, compressor exhaust, pneumatic devices, station venting, and super-emitters [23]. We used DEC permits and FERC submissions to quantify compressor station type (transmission or storage), and the count, horsepower, and type (reciprocating or centrifugal) of all full-time compressors to estimate methane emissions by compressor station. For compressors with make and model but missing horsepower, we assumed average values for horsepower as reported in Zimmerle *et al.* [23].[4] For seven compressors without make and model, we used average U.S. capacities reported in Greenblatt of 1,700 horsepower (hp) for reciprocating gas engines and 6,600 hp for centrifugal gas turbines [58]. For smaller compressor stations not requiring a DEC air permit and with incomplete data, we used the mean emissions from facilities that do not have air permits but for which we do have complete data. We excluded emergency compressors from this analysis because New York regulation requires that they run under 500 hours per year [60]. A permit application to the DEC by the Millennium Pipeline Company for its Eastern System Upgrade quantifies CO_2e emissions from an emergency generator as 0.3% of those from the full-time compressor engines [60]. If accurate, this application suggests emergency generator emissions may be negligible, but we note that minor sources often have higher emission rates than formally reported and this area may warrant additional future research.

To estimate the emissions from pneumatic devices, we used average device counts from Zimmerle *et al.*, including an average of 24 pneumatic devices per transmission compressor station and 85 per storage compressor station [23].

Zimmerle *et al.* estimate that super-emitter facilities are found at a frequency of 1 in 25 compressors at any given time [23]. We do not know which facilities in New York might be super-emitters, and therefore we assigned an equal probability to each station. We increased emission estimates at each site by 200 metric tons/station-year based on Zimmerle *et al.* emission factors [23], to account for the average increase in emissions from super-emitters. Altogether, Zimmerle *et al.* attribute

[2] Title V permits are issued to "facilities that are judged to be major under the department's regulations, or that are subject to New Source Performance Standards (NSPSs), to a standard or other requirements regulating hazardous air pollutants or to federal acid rain program requirements" [37]. State facility permits are issued to facilities that fall outside the criteria of major, but within the criteria for permit requirement [36].

[3] Permit information was retrieved on April 7, 2017.

[4] Each compressor requires a prime mover, also called the compressor driver, which powers the compressor unit. In the U.S. transmission, storage, and distribution systems, the most commonly used prime movers are gas engines, gas turbines, and electric motors [58]. According to both the Interstate Natural Gas Association of America (INGAA) [59] and a U.S. Department of Energy Report [58], gas engines are typically used with reciprocating compressors and gas turbines are typically used with centrifugal compressors, with electric motors less common (<10% of total prime mover capacity in the U.S. [58]) but able to be used with either reciprocating or centrifugal compressors. Zimmerle *et al.* corroborated this by finding that 98% of reciprocating compressors were powered by internal combustion engines [23].

just under 40% of compressor station emissions to super-emitters. This estimate is similar to a Brandt *et al.* estimate that roughly 50% of fugitive methane emissions come from super-emitters across natural gas systems, defining super-emitters as the top 5% of emitters [15]. Super-emitter emission factors warrant additional research to help constrain these estimates.

On-site combustion used to drive compressor station operations also releases direct CO_2 emissions. These annual emissions are reported by the EPA for 18 of New York's existing transmission compressor stations and one storage compressor station [61]. Each station's CO_2 emissions vary by year, but the average value tends to increase with station horsepower. The 18 transmission compressor stations reporting emissions are, on average, over twice the size as measured in horsepower as those stations not reporting emissions, and the storage stations are even smaller by half. To estimate the emissions from the missing compressor stations, we calculated the average rate of CO_2 emissions per unit horsepower over a three-year period from 2014 to 2016, and applied this factor to those stations without data. For the proposed compressor stations, we applied this same emission factor to estimate CO_2, and compare these results to values reported in permitting materials, which also provide a potential emissions estimate [62, 63, 64].

3.3 Methane emissions from meter and regulator stations

We compiled a list of proposed new meter and regulator (M&R) stations by reviewing the FERC documentation associated with each proposed new pipeline. To each new M&R station, we applied methane emission factors from the 2017 EPA Greenhouse Gas Inventory to calculate estimated methane emissions at each facility [8]. We summed estimated emissions over all facilities to estimate statewide emissions from proposed M&R new builds.

3.4 Implied natural gas consumption and CO_2 emissions from proposed pipeline usage

We calculated the implied annual New York natural gas consumption per proposed pipeline based on the pipeline capacity, the average existing pipeline utilization rate, and the estimated flow fraction to be delivered within New York State. This approach is not meant to predict natural gas demand within New York State but instead simply provides an estimate of the increase in natural gas use that could occur in the state if the proposed pipelines are used at similar rates to historic pipelines—that is, the intended natural gas usage implied by the pipeline proposal.

For each proposed pipeline, we estimated the flow fraction to be delivered within New York State by searching FERC and pipeline operator records for the pipeline end location, the geographic service area of firm contracts, and the locations of any tie-ins with existing pipeline networks. We estimated the fraction of natural gas delivered to New York in quartiles (0%, 25%, 50%, 75%, 100%). A value of 100 means a pipeline is expected to deliver all natural gas for consumption within New York State, whereas a value of 0 indicates that the pipeline passes through New York but is expected to deliver all gas out-of-state. Estimates in between these two values indicate varying degrees of consumption in-state, ranging from mostly out-of-state consumption (25%) to mostly in-state consumption (75%). These estimates are not meant to reflect actual natural gas demand either in or outside of New York. In any real-world situation, flow volume and destination could easily change with the year, the weather, or with individual state or utility policies. Pipeline flow in some situations may even change directions. Instead, this calculation is meant to capture the justification for the pipeline's construction, either reported or implied, such as pipeline construction for the purpose of increased distribution to businesses and residences in upstate New York.

We calculated the net inflow capacity for existing pipelines entering New York by subtracting the pipeline capacity exiting the state from the capacity entering the state [65]. Next, we calculated the average utilization rate of these pipelines by dividing New York's average consumption by the net pipeline inflow capacity. We find that the pipeline utilization rate averaged 53% between 2010 and 2015 for delivery to New York State. The U.S. Department of Energy reports a comparable average nationwide capacity utilization rate of 54% for the years 1998-2013 [66]. A 2013 New York Independent System Operator (NYISO) report demonstrates that natural gas pipeline deliveries in New York follow a seasonal pattern in response to increased demand in cooler months and much lower demand in warmer months [67]. We assumed that this average effective utilization rate of 53% would apply to all proposed gas pipelines delivering gas within New York State.

We calculated the implied proposed increase in natural gas use by multiplying the proposed pipeline capacity by the average utilization rate of existing pipelines, and scaling the result to the proportion of gas expected to be delivered in New York State. We provide low and high estimates to establish upper and lower bounds on how much gas is likely to be delivered in state or to pass through to neighboring states.

3.5 Lifecycle greenhouse gas emissions associated with increased natural gas use

We estimated the lifecycle greenhouse gas emissions associated with increased natural gas use implied by the intended usage for these new builds by calculating both direct combustion emissions associated with natural gas as well as methane leakage and upstream CO_2 emissions across the natural gas lifecycle. These lifecycle estimates include energy use and upstream leakage from production and transmission outside of New York as well as within the state. In the discussion section, we address the matter of how to attribute these greenhouse gas emissions (for example, if New York includes lifecycle methane leakage from gas produced in Pennsylvania but consumed in New York, should it be responsible for methane leakage from transmission infrastructure if those pipelines are destined for New England?).

We calculated direct CO_2 emissions from increased natural gas consumption in New York State using an emission factor of 54.8 kg of CO_2 per thousand cubic feet (Mcf) of gas. This factor was derived by dividing EIA-reported natural gas CO_2 emissions [7] by natural gas consumption in New York [16], and is slightly higher than the EIA's nationwide estimate of 53.1 kg CO_2/Mcf [68].

We estimated lifecycle methane emissions using a range of methane leakage estimates as described in **Section 2.2** of this report. For a baseline, we used a leakage rate of 2.5% of dry natural gas production (or 2.25% of gross methane withdrawals) based on estimates from Brandt *et al.*—slightly above but in line with global estimates from Schweitzke *et al.* of 2.2% of dry production. For a low estimate, we used the EPA's 2017 Greenhouse Gas Inventory methane leakage estimate of 1.4% of dry natural gas production. We used a high methane leakage estimate of 4.0%, slightly above Schweitzke *et al.*'s upper global estimate of 3.7% of dry production and considered a reasonable upper range in other studies [4]. As noted in **Section 2.2**, there are methane leakage rates observed in parts of the country that exceed 10% (e.g., Schneising *et al.* [9]). However, these basin-wide methane emission rates have been observed in only limited parts of the country where tight oil dominates the oil/gas ratio, and where gas gathering infrastructure has been limited (e.g., the Bakken Shale Play in North Dakota and the Eagle Ford Play in Texas). We assumed these leakage rates stay flat through 2030, although these rates could change based on changes in gas production methods, efforts to detect and replace leaking components, or other efforts. We attributed lifecycle emissions to each pipeline build by applying the methane loss rate to the implied annual New York natural gas consumption per proposed pipeline. We calculated upstream CO_2 using the emission factors for natural gas described in **Section 2.2**.

We calculated the aggregate greenhouse gas impact of the proposed pipeline buildout by summing the direct CO_2 emissions from increased gas consumption, the lifecycle CO_2 and methane emissions from this gas consumption, and the additional methane and CO_2 emissions from transmission infrastructure located in New York but delivering gas to New England or Canada. We compared these results to the existing CO_2 and methane emissions in New York as well as the state's 2030 targets.

4. Results

The ten proposed pipelines that would run through New York, their status, end points, capacity and estimated gas delivery to New York are presented in **Table 4.1**. Their estimated methane emissions are displayed by pipeline status (on hold, planning stages, and mid-construction) in **Figure 4.1**. Proposed pipelines are mapped in **Figure 4.2**. Six of these pipelines would deliver all of their gas within New York State, including four intrastate and two interstate pipelines. Of these six pipelines, four have firm contracts to provide natural gas to industrial, commercial, and residential customers through local distribution networks [69, 70, 71, 72]. One, the Millennium Valley Lateral Project, has a firm contract to supply the 680 MW CPV Valley Energy Center, a natural gas combined cycle plant under construction in Orange County [73]. We could find no evidence of a firm contract indicating future natural gas use for the final proposed pipeline—the National Fuel Line T2KNY Install, Line TNY Replacement, and Line KNY Abandonment Project [74, 75]. This may be because the project is primarily abandonment and replacement of outdated lines, and net new natural gas capacity would be limited to only 2.6 MMcf/day which is substantially smaller than the planned capacity of all the other proposed pipelines.

Two proposed pipelines, the Tennessee Gas Connecticut Expansion Project and the Algonquin Gas Atlantic Bridge Project, would transport natural gas into New England and/or Canada, with no New York consumption [76, 77].

The final two proposed pipelines, the Constitution & Iroquois Gas Wright Interconnect Project and the National Fuel & Empire Pipeline Inc. Northern Access 2016 Project, have agreements with distribution networks both within and outside of New York State [78, 79]. However, these operators do not specify the allocation of natural gas per individual state. For these two proposed projects, we estimate the percentage of gas remaining in New York in quartiles. The Northern Access 2016 project has contracts with Seneca Resources Corporation providing 72% of piped natural gas to an existing interconnection with TransCanada heading northwest into Canada [79, 80, 81], and transferring the remaining 28% to an existing Tennessee Gas pipeline network running across New York to the east into Massachusetts and New England and to the west into Pennsylvania and eventually into the Midwestern U.S. [44, 79, 81]. Therefore, we estimate New York gas delivery at 25%.

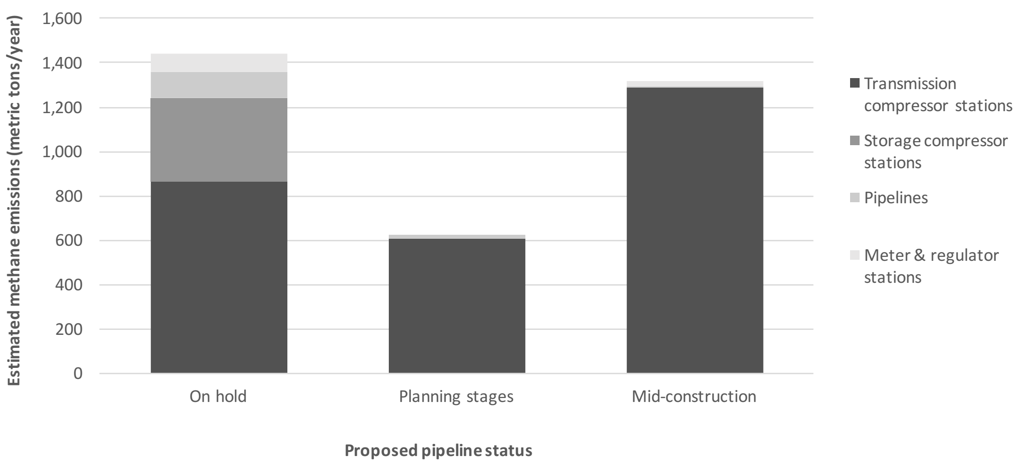

Figure 4.1: Proposed pipeline methane emissions in metric tons per year by pipeline status and emission source.

Table 4.1: **Proposed pipeline projects completely or partially sited in New York State as of mid-2017.**

Company/project	Status	FERC docket no.	Net new capacity (MMcf/d)	Pipeline start point	Pipeline end point	Estimated flow fraction delivered in NY	Implied NY natural gas consumption (MMcf/year)
Dominion New Market Project	Mid-construction	CP14-497	112	Clinton County, PA	Montgomery & Schenectady Counties, NY	100%	21,666
National Fuel Line T2KNY, TNY, and KNY Updates	Mid-construction	CP16-125	3	Erie County, NY	Erie County, NY	100%	503
Tennessee Gas Connecticut Expansion Project	Mid-construction	CP14-529	72	Albany County, NY	Hartford County, NY	0%	0
Transcontinental Gas NY Bay Expansion Project	Mid-construction	CP15-527	115	York County, PA	NY State waters & Richmond County, NY	100%	22,247
Constitution & Iroquois Gas Wright Interconnect Project	On hold	CP13-499; CP13-502	650	Susquehanna County, PA	Schoharie County, NY	75%	94,307
Millennium Valley Lateral Project	On hold	CP16-17	130	Orange County, NY	Orange County, NY	100%	25,149
National Fuel & Empire Pipeline Inc. Northern Access 2016 Project	On hold	CP15-115	497	McKean County, PA	Niagara & Erie Counties, NY	25%	24,036
Algonquin Gas Atlantic Bridge Project	Planning stages	CP16-9	239	Bergen County, NJ & Rockland County, NY	MA, ME & US-CA border	0%	0
Millennium Eastern System Upgrade	Planning stages	CP16-486	223	Steuben County, NY	Rockland County, NY	100%	43,139
Transcontinental Gas Northeast Supply Enhancement	Planning stages	CP17-101	400	York County, PA	Offshore Rockaway Transfer Point, NY	100%	77,380

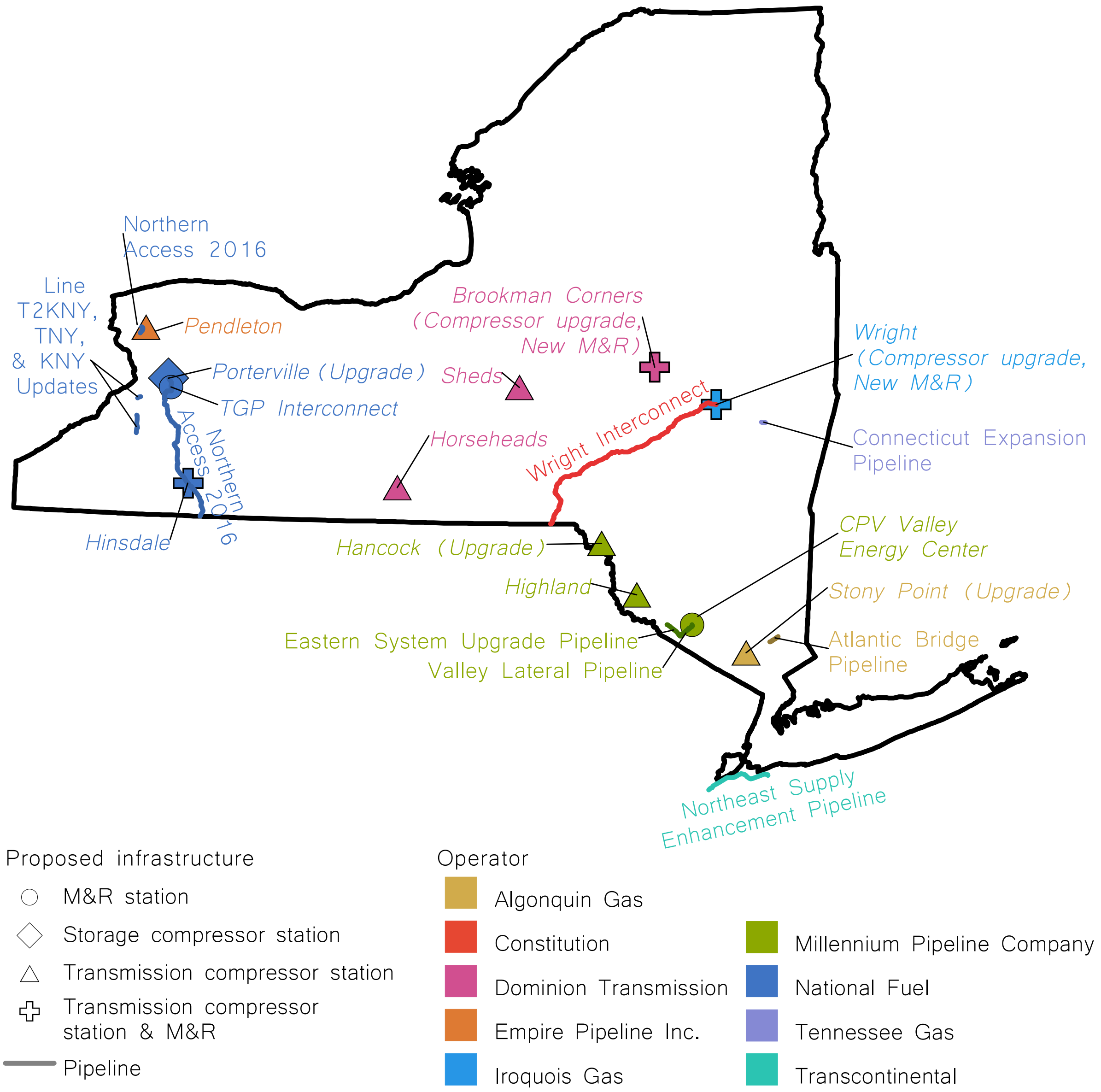

Figure 4.2: Map of proposed natural gas infrastructure in New York. M&R refers to meter and regulator stations. The Borger, Zoar and Utica Compressor Stations, which have pending upgrades but not expansions, are not included.

Similarly, the Constitution Pipeline Company and Iroquois Gas plan for their Wright Interconnect Project to supply gas to customers served by the Iroquois and Tennessee Gas Pipeline Systems [78]. The Iroquois Gas pipeline network runs in both New York and Connecticut [49], and the Tennessee Gas pipeline network runs through at least sixteen states [44], although the target market is listed as "major northeastern markets," primarily New York and secondarily New England [78]. In addition, the Constitution Pipeline is currently being planned as an open access pipeline with at least one current contract of this type, which would allow municipalities or public utilities adjacent to the pipeline route to gain access to the pipeline and provide local connections to residential, commercial, and industrial customers [82, 83]. After evaluating these sources we estimate New York delivery at 75%.

Under the assumption that proposed pipelines are used at the average historic rate of 53% of capacity, and delivery is apportioned to New York as described above, the proposed pipelines imply an increase in natural gas consumption of 308,000 MMcf/year. Compared to New York's

2015 natural gas consumption of 1,353,000 MMcf, this result implies that building all of the proposed pipelines in New York and delivering gas through these pipelines at average utilization rates would increase in-state consumption by 23%. If the pipelines with mixed delivery in New York and New England deliver all gas to New England, the value drops to 14%. If instead all gas from these pipelines is delivered to New York, the value jumps to 30%. The delivery destination of these pipelines could also change over time. If these pipelines are used less or more than average, the increase in natural gas use would be lower or higher accordingly. For example, applying the 53% pipeline utilization rate to the CPV Lateral pipeline would result in a natural gas supply to the 680 MW CPV Valley natural gas combined cycle plant equivalent to a capacity factor of 55%—roughly the same as the 2015 U.S. average usage rate for natural gas combined cycle plants of 56% [84]. However, if New York relies heavily on CPV Valley to replace generation from the retiring Indian Point nuclear power plant, the capacity factor could be much higher; if instead New York rapidly expands its offshore wind generation, perhaps the plant would be used less.

The total combustion-related CO_2 emissions from this implied increase in natural gas use in New York State reach 17 million metric tons/year, an increase in natural gas combustion CO_2 emissions of 23% and of total in-state energy-related CO_2 emissions of about 10% [7]. Two of the pipelines—the Constitution & Iroquois Gas Wright Interconnect Project and the Transcontinental Gas Northeast Supply Enhancement—account for over half (56%) of the estimated CO_2 emissions. The natural gas flowing through the state to New England would likely contribute to increasing CO_2 emissions as well, but out-of-state combustion is beyond our scope.

214 miles of new pipeline are proposed for New York State. Methane emissions in New York State from these proposed pipelines total an estimated 2.3 metric tons per year for fugitive pipeline leak emissions and 130.3 metric tons/year for pipeline venting emissions from routine maintenance or upsets, totaling 132.6 metric tons—an increase of 4.8% compared to the estimated emissions from New York pipelines for 2017. The greenhouse gas footprint of this methane is 11,500 metric tons CO_2e per year over a 20-year frame and 4,800 metric tons CO_2e per year over a 100-year frame. These emissions are proportional to the pipeline mileage, so 81% of this estimate comes from the two proposed pipelines with the greatest length in New York: the Constitution & Iroquois Gas Wright Interconnect Project and the National Fuel & Empire Pipeline Inc. Northern Access 2016 Project [85]. Both of these projects are currently on hold.

4.1 Transmission and storage compressor stations

There are 58 active natural gas compressor stations in New York State, including 39 transmission stations and 19 storage stations. These facilities average 3.3 compressors per station, 68% of which are reciprocating, 26% centrifugal, and 6% electric. Using emission factors from Zimmerle *et al.* for reciprocating and centrifugal compressors [23], and scaling by compressor count, we estimate that together these stations emit 38,500 metric tons of methane per year, including 24,400 metric tons per year from transmission stations (mean 626/median 433 per station), and 14,400 metric tons per year from storage stations (mean 756/median 605 per station). The estimated distribution of emissions from existing and proposed compressor stations in New York is provided in **Figures A.1** and **A.2** in **Appendix A**.

There are five proposed new compressor stations and four existing compressor stations with proposed upgrades. For the five proposed new transmission compressor stations, we calculate a mean of 432 metric tons/year methane emissions per station. This mean value is 31.1% lower than the mean from existing transmission compressor stations because the proposed stations all rely on centrifugal compressors, which have lower transmission station fugitives and exhaust emissions than

Table 4.2: Estimated annual methane emissions per proposed New York compressor station.

Compressor station name	Station type	Proposal type	Affiliated proposed pipeline	NY DEC Permit No.	Town	Estimated methane emissions (metric ton/year)
Brookman Corners	Transmission	Upgrade	Dominion New Market Project	4-2730-00038/00001	Minden	388
Hancock	Transmission	Upgrade	Millennium Eastern System Upgrade	4-1236-00708/00001	Hancock	111
Highland	Transmission	New build	Millennium Eastern System Upgrade	3-4834-00147/00001	Eldred	392
Horseheads	Transmission	New build	Dominion New Market Project	8-0740-00081/00001	Veteran	512
Pendleton	Transmission	New build	National Fuel & Empire Pipeline Inc. Northern Access 2016 Project	9-2932-00111/00001	Pendleton	433
Porterville	Storage	Upgrade	National Fuel & Empire Pipeline Inc. Northern Access 2016 Project	9-1442-00039/00015	Elma	380
Sheds	Transmission	New build	Dominion New Market Project	7-2530-00033/00001	Georgetown	389
Stony Point	Transmission	Upgrade	Algonquin Gas Atlantic Bridge Project	3-3928-00001/00027	Stony Point	106
Wright	Transmission	New build	Constitution & Iroquois Gas Wright Interconnect Project	4-4350-00008/00012	Wright	431

their reciprocating counterparts. These stations also average only two compressors per station. Together, we estimate the proposed compressor stations would emit 2,160 metric tons of methane emissions per year. There are no proposed new storage compressor stations. **Figure 4.3** shows the estimated annual methane emissions by source for existing and proposed compressors, including upgrades. Proposed compressor stations are also mapped in **Figure 4.2**.

There are four proposed upgrades to existing compressor stations, three for transmission and one for storage. Two of these upgrades (Stony Point and Hancock) add or expand a centrifugal compressor, and are estimated to emit a little more than 100 metric tons methane per year each. Porterville is adding two reciprocating compressors and Brookman Corners is adding one centrifugal and two reciprocating compressors, which will add an estimated 380 and 388 metric tons of methane year to each station, respectively. Data for each station are provided in **Table 4.2**.

If all of the proposed new and upgraded compressor facilities are built, their emissions would increase statewide compressor methane emissions by an estimated 8.1%. This value drops to 4.9% if we exclude projects that are currently on hold, and it drops further to 3.3% if we only consider projects that are mid-construction. Five of the proposed new and upgraded compressor stations are associated with pipelines that are expected to deliver all gas to New York State, three are connected to pipelines with partial delivery in New York State, and one (Stony Point) is associated with a pipeline delivering gas out of state.

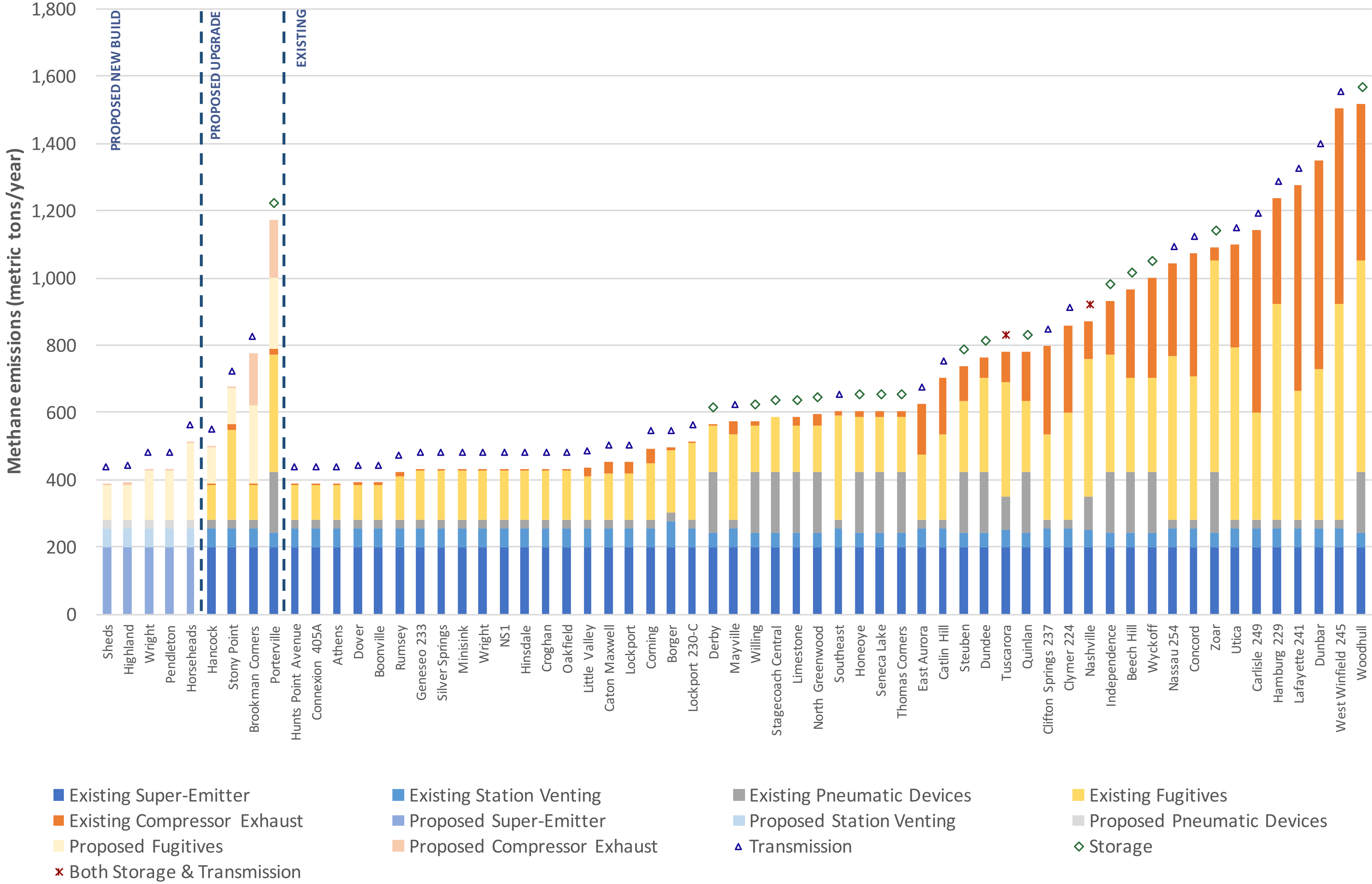

Figure 4.3: Existing and proposed methane emissions in metric tons per year by compressor station and emission category.

Based on both historic reported emissions and average emission factors when data is unavailable, we estimate that New York's compressor stations also emit approximately 1.2 million metric tons of CO_2 per year, with the majority of these emissions from transmission compressor stations as compared to storage compressor stations. The permitting documents for proposed compressor stations and upgrades suggest that these facilities have the potential to emit an additional 500,000 metric tons CO_2 per year. However, based on historic emission factors for these facilities, the permitted values are likely an upper estimate. Applying an average emission factor to the summed horsepower of these facilities suggests an increase in CO_2 emissions of about 240,000 metric tons CO_2 per year, an increase above current compressor CO_2 emissions of around 20%.

4.2 Meter and regulator stations

There are five proposed new M&R stations to be located within New York State for which we have found records. We estimate methane emissions for M&R stations on a facility type basis. The four stations that would transfer natural gas to other transmission companies would emit an estimated 28 metric tons of methane/year based on values from Zimmerle *et al.* [23], while the remaining one station that plans to transfer its natural gas to a private buyer (CPV Valley Energy Center) would emit substantially less at an estimated 0.2 metric tons/year. Data for these stations is given in **Table 4.3**. Proposed M&R stations are also mapped in **Figure 4.2**.

Table 4.3: Estimated methane emissions per proposed New York meter and regulator station.

M&R station name	Type	Affiliated proposed pipeline	Handover company	Town	Estimated methane emissions (metric tons/year)
Brookman Corners	Trans. co. interconnect	Dominion New Market Project	Iroquois Gas Transmission (IGT)	Minden	28.0
Westfall Road	Trans. co. interconnect	Constitution & Iroquois Gas Wright Interconnect Project	n/a, receiving gas from Constitution Pipeline Company, LLC	Wright	28.0
TGP Interconnect	Trans. co. interconnect	National Fuel & Empire Pipeline Northern Access 2016	Tennessee Gas (TGP 200 Line)	Wales	28.0
Hinsdale	Trans. co. interconnect	National Fuel & Empire Pipeline Northern Access 2016	National Fuel (Line X-South)	Hinsdale	28.0
CPV Valley Energy Center	Farm taps & direct sales	Millennium Valley Lateral Project	CPV Valley Energy Center	Wawayanda	0.2

4.3 Aggregate transmission and storage sector emissions

When all the sources of proposed transmission and storage sector infrastructure are combined, transmission compressor stations comprise the vast majority of methane emissions at 81.6%. Proposed storage compressor stations have the next highest emissions at 11.2%, and both pipelines and M&R stations have comparatively low emissions at 3.9% and 3.3%, respectively. The esti-

Table 4.4: Estimated in-state methane emissions from proposed new infrastructure in the natural gas transmission and storage sector in New York State. Total CO_2e calculated using a global warming potential of 87 over a 20-year period and 36 over a 100-year period. Values in parentheses indicate the share of these in-state methane emissions that are associated with natural gas expected to be delivered out of state.

	Estimated annual methane emissions by source (metric tons)					Total CO_2e	
Proposed project	**New pipelines**	**New compressors**	**Compressor upgrades**	**New M&R stations**	**Total**	**Total in CO_2e, 20-year**	**Total in CO_2e, 100-year**
Dominion New Market Project	0	901	388	28	1,317	114,621	47,429
National Fuel Line T2KNY, TNY, and KNY Updates	1	0	0	0	1	81	34
Tennessee Gas Connecticut Expansion Project	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	73 (73)	30 (30)
Transcontinental Gas NY Bay Expansion Project[a]	0	0	0	0	0	0	0
Constitution & Iroquois Gas Wright Interconnect Project	61 (15)	431 (108)	0 (0)	28 (7)	520 (130)	45,256 (11,314)	18,727 (4,682)
National Fuel & Empire Pipeline Northern Access 2016	47 (35)	433 (433)	380 (285)	56 (49)	916 (694)	79,656 (60,351)	32,961 (24,973)
Algonquin Gas Atlantic Bridge Project	2 (2)	0 (0)	106 (106)	0 (0)	108 (108)	9,429 (9,429)	3,902 (3,902)
Millennium Eastern System Upgrade	5	392	111	0	508	44,197	18,288
Millennium Valley Lateral Project	5	0	0	0.2	5	440	182
Transcontinental Gas Northeast Supply Enhancement	11	0	0	0	11	938	388
New York total	133	2,157	985	112	3,387	294,691	121,941

[a]These values are zero because this project is a pipeline upgrade expected to increase gas delivery to New York but for which all upgrades are located in New Jersey or Pennsylvania.

mated emissions per pipeline for each type of transmission and storage infrastructure is shown in **Table 4.4**. Forty-three percent of all the proposed transmission and storage sector methane emissions would come from three projects that are currently on hold due to the denial of required permits by New York regulatory agencies—the Constitution & Iroquois Gas Wright Interconnect, the National Fuel & Empire Pipeline Northern Access 2016, and the CPV Valley Lateral pipelines. Projects that are currently in the planning stages comprise 19% of the estimated future emissions, and projects that are currently mid-construction make up the remaining 39%.

The estimated methane emissions from proposed infrastructure are equivalent to 300,000 metric tons CO_2e over a 20-year timeframe, or 120,000 metric tons over 100 years. Combined with direct CO_2 emissions, the total greenhouse gas impact from this proposed infrastructure in New York State is 540,000 and 360,000 metric tons CO_2e over 20 and 100 years, respectively.

4.4 Lifecycle greenhouse gas emissions from proposed natural gas infrastructure buildout and use

The combined methane and CO_2 emissions from the implied increase in New York natural gas consumption due to the proposed natural gas infrastructure buildout sum to 26 million, 31 million, and 38 million metric tons CO_2e per year at low, medium, and high fugitive methane leakage rates, respectively, if using a 20-year global warming potential. These values come to 22 million, 24 million, and 27 million for low, medium, and high leakage rates, respectively, if using a 100-year global warming potential. Methane, carbon dioxide, and their combined CO_2e estimates over 20- and 100-year time frames are shown in **Table 4.5** for the low, medium, and high leakage rate scenario results.

Proposed pipelines that are currently in the planning stages would comprise 39% of all lifecycle CO_2e emissions. Projects that are now on hold would comprise approximately 46% of CO_2e emissions, while projects that are currently mid-construction would make up the remaining 14%. These data are displayed in **Figure 4.4**. Trends in emission estimates by project status are substantially different when quantifying direct emissions from proposed transmission and storage sector infrastructure (**Figure 4.1**) versus quantifying emissions by lifecycle emissions associated with use of the delivered gas (**Figure 4.4**). For the New York transmission and storage sector alone, emissions are highest for projects currently on hold (43%), closely followed by projects currently under construction (39%), and lowest for projects in their planning stages (19%). The different trends in emissions by status are due to the sources of emissions for each type of estimate. In the transmission and storage sector estimates, emissions are calculated by counts and associated horsepower

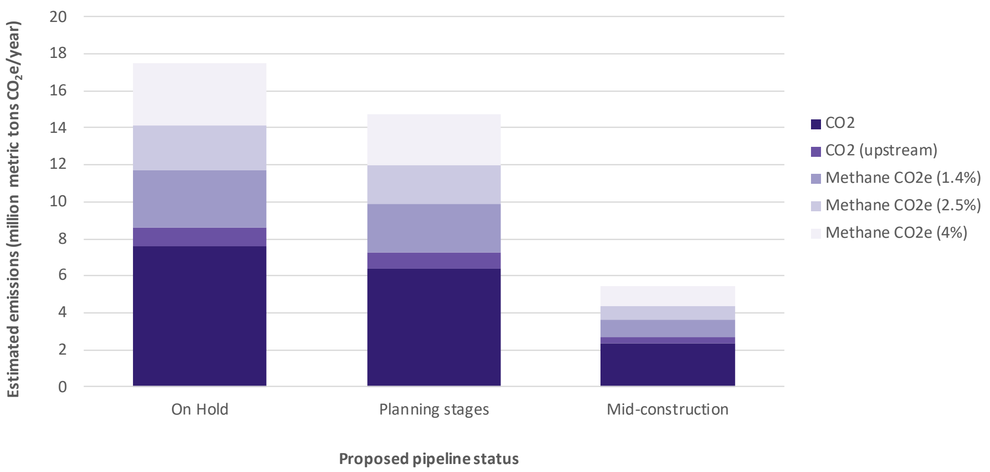

Figure 4.4: Estimated annual proposed pipeline greenhouse gas emissions by pipeline status, using low (1.4%), medium (2.5%) and high (4%) upstream methane leakage rates over a 20-year time frame.

for specific pieces of emitting equipment. Thus, in these estimates emissions are heavily influenced by the very high emissions associated with transmission and storage compressor stations. Lifecycle emissions, on the other hand, include presumed natural gas consumption, which is reasonably assumed to be a function of proposed pipeline capacity. These lifecycle emissions are calculated using estimated leakage rates across the natural gas lifecycle but are not dependent on features of the specific facilities in New York beyond pipeline capacity. In addition, the two pipelines that would provide natural gas entirely outside of New York are excluded completely from the lifecycle emission calculations, while emissions associated with their proposed infrastructure to be located within the state of New York are included in emission calculations for the transmission and storage sector-specific estimates. Even though **Figures 4.1** and **4.4** show differing trends, they both show the considerable emissions that would result from the buildout of the ten proposed projects.

In addition to lifecycle emissions from natural gas consumed in-state, there are also methane emissions from natural gas transmission infrastructure located within New York that are associated with pipelines destined for out-of-state use. These in-state emissions from at least partial out-of-state consumption are associated with four pipelines, two planned new compressor stations, two compressor stations with planned updates, and three proposed new M&R stations, and are included in **Table 4.4**. If we combine lifecycle methane emissions from new New York gas use along with additional in-state emissions from pipelines delivering gas out of state, methane emissions would increase 23% over existing methane emissions from lifecycle New York natural gas use. The scale of estimated methane emissions from proposed pipelines—comprised of in-state emissions from proposed pipelines delivering out-of-state and total lifecycle emissions from proposed pipelines delivering within New York—is compared to 2015 lifecycle emissions from New York gas use in **Figure 4.5**.

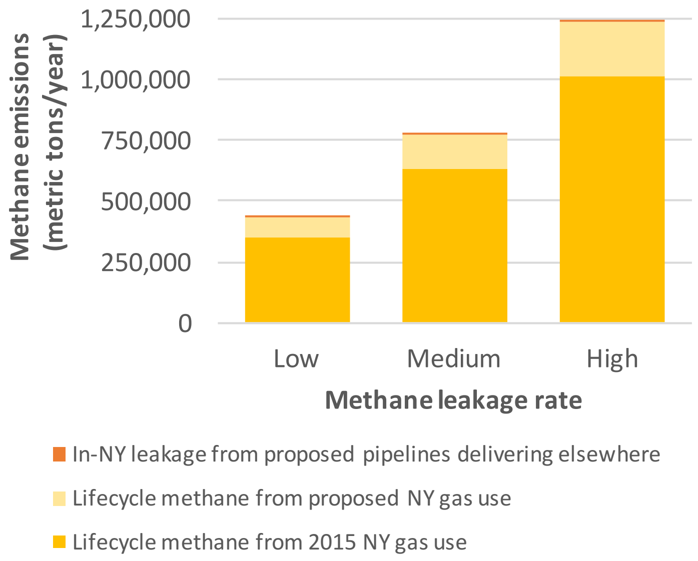

Figure 4.5: Estimated annual lifecycle methane emissions associated with New York State's current and proposed in-state natural gas consumption and in-state infrastructure delivering gas out-of-state. Comparisons of low (1.4%), medium (2.5%) and high (4%) upstream methane leakage rates.

Table 4.5: Estimated lifecycle methane and carbon dioxide emissions resulting from presumed consumption of natural gas delivered to New York via proposed pipelines, inclusive of upstream CO_2 emissions and low, medium, and high methane leakage rates. Values reflect low (1.4%), mid (2.5%) and high (4%) fugitive methane leakage rates, using a global warming potential (GWP) of 87 over a 20-year period and 36 over a 100-year period. Tennessee Gas Connecticut Expansion Project and Algonquin Gas Atlantic Bridge Project excluded due to expected delivery outside of New York State.

Proposed project	**CO_2 emissions**		**Methane emissions**			**Methane and CO_2 emissions (20-year GWP)**			**Methane and CO_2 emissions (100-year GWP)**		
	Direct	**Upstream**									
	million metric tons CO_2/year		metric tons methane/year			million metric tons CO_2e/year			million metric tons CO_2e/year		
Methane leakage rate			low	medium	high	low	medium	high	low	medium	high
Constitution & Iroquois Gas Wright Interconnect Project	5.16	0.69	23,640	42,210	67,540	7.91	9.52	11.72	6.70	7.34	8.28
Dominion New Market Project	1.19	0.16	5,430	9,700	15,520	1.82	2.19	2.69	1.54	1.69	1.90
Millennium Eastern System Upgrade	2.36	0.31	10,810	19,310	30,900	3.62	4.36	5.36	3.06	3.37	3.79
Millennium Valley Lateral Project	1.38	0.18	5,880	10,500	16,800	2.07	2.47	3.02	1.77	1.94	2.16
National Fuel & Empire Pipeline Northern Access 2016	1.32	0.17	6,030	10,760	17,210	2.01	2.43	2.99	1.71	1.88	2.11
National Fuel Line T2KNY, TNY, and KNY Updates	0.03	0.004	130	230	360	0.042	0.051	0.063	0.036	0.039	0.044
Transcontinental Gas NY Bay Expansion Project	1.22	0.16	5,580	9,960	15,930	1.86	2.25	2.77	1.58	1.74	1.95
Transcontinental Gas Northeast Supply Enhancement	4.24	0.56	19,400	34,640	55,420	6.49	7.81	9.62	5.50	6.05	6.79
New York total	16.89	2.24	78,890	137,300	219,680	25.82	31.07	38.24	21.90	24.07	27.04

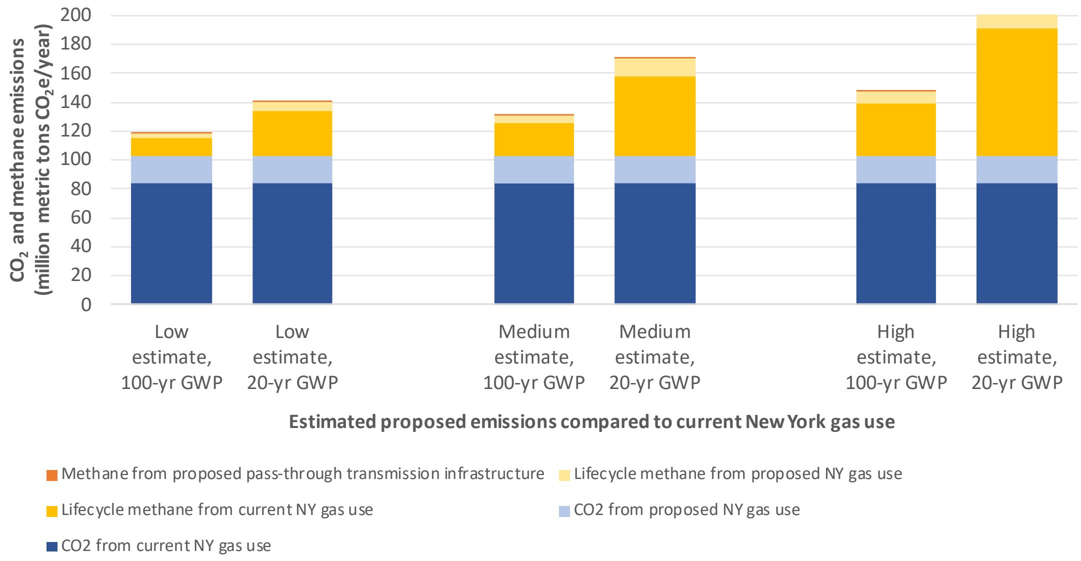

Figure 4.6: CO_2 and methane emissions in New York associated with proposed natural gas infrastructure expansions compared with emissions from current natural gas consumption. Includes CO_2e over a 20- and 100-year time frame, using low (1.4%), medium (2.5%) and high (4%) upstream methane leakage rates.

We also compared existing CO_2 emissions to emissions that would be associated with planned natural gas infrastructure should it be built out. Building all proposed pipelines and delivering increased gas to New York State in these pipelines at average utilization rates would result in an estimated 23% increase in CO_2 emissions from natural gas consumption in New York. If compared to all fossil fuel burning in New York, the proposed pipelines would result in an estimated 10% increase in CO_2 emissions. Greenhouse gas emissions from both methane and CO_2 associated with pipeline buildout using 20-year and 100-year global warming potentials are shown in **Figures** 4.6 and 4.7. **Figure** 4.6 compares proposed emissions to existing greenhouse gas emissions associated with natural gas consumption in New York. **Figure** 4.7 compares proposed emissions to total existing fossil fuel greenhouse gas emissions in New York.

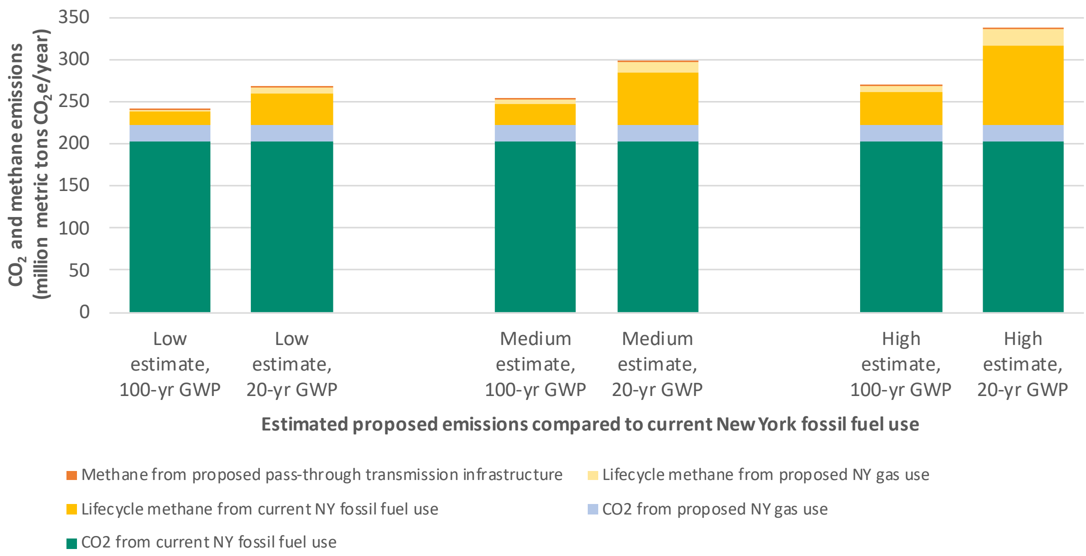

Figure 4.7: CO_2 and methane emissions in New York associated with proposed natural gas infrastructure expansions compared with emissions from all current fossil fuel consumption. Includes CO_2e over a 20- and 100-year time frame, using low (1.4%), medium (2.5%) and high (4%) upstream methane leakage rates.

5. Discussion

The magnitude of greenhouse gas emissions of the proposed pipelines in New York State depends on how many of them are approved and built as well as their rates of use and in-state natural gas demand. The impact of any growth in natural gas use on New York's efforts to reduce statewide greenhouse gases by 2030 also depends on the state's success in reducing emissions from other sources, primarily petroleum. In **Figure** 5.1, we compare New York's 1990 and 2015 energy-related greenhouse gas emissions to 2030 emissions under a number of fuel use scenarios. In all scenarios we assume coal is phased out entirely, leaving an additional 22% to 27% emission reduction requirement for 2030. We set the 2030 target using a 2.5% leakage rate.

In scenarios **a-c**, we provide three strategies by which New York State could achieve greenhouse gas emission reductions as described in the **Section** 2 of this report. These scenarios include (a) proportional emission reductions from current oil and gas emission levels; (b) all reductions from oil; and (c) a sectoral-based approach reducing emissions proportionally by sector but preferentially reducing oil and coal emissions before natural gas emissions in any given sector. Scenarios **d-f** in **Figure** 5.1 illustrate the greenhouse gas emissions under various pipeline buildout scenarios, assuming again that all pipelines are built and utilized at average rates. In the case of full pipeline buildout and utilization (scenario **d**), the State of New York would have to reduce oil consumption by 67% from 2015 levels by 2030 in order to reach emission targets considering CO_2 alone—and reduce it by 83% if we include lifecycle methane leakage of 2.5%. If no significant greenhouse gas efforts are made, such as if petroleum and coal use stay flat as in scenario **e**, the buildout of natural gas would imply an increase in cross-sector energy-related greenhouse gas emissions of 11%, 12% or 13% as compared to 2015 under low, medium and high methane leakage rates, respectively. Finally, in scenario **f**, even if New York successfully cuts petroleum use by the same portion as in scenario **a**, the increase in natural gas use under the case of pipeline buildout and utilization would mean barely 3% overall reduction in greenhouse gases by 2030 under a low methane leakage scenario and an actual increase in emissions under a high leakage scenario.

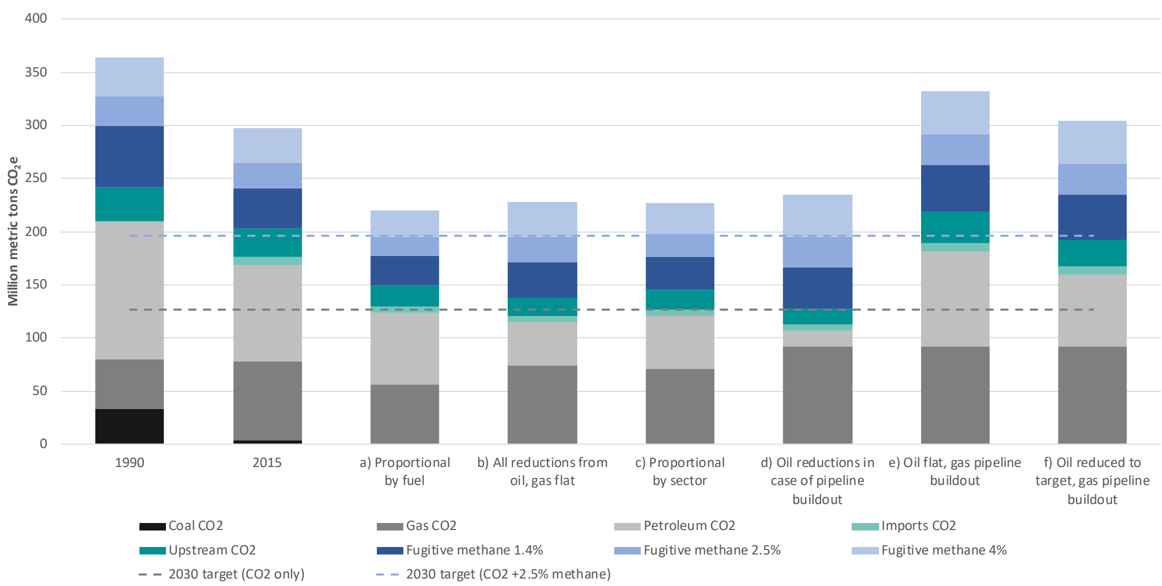

Figure 5.1: Energy-related greenhouse gas emissions in New York in 1990, 2015, and under various 2030 scenarios. Scenarios a-c achieve the 40% target as follows: a) proportional emission reductions from oil and natural gas, b) natural gas flat at 2015 levels, oil reduced, and c) proportional emission reductions by sector. Scenarios d-f reflect pipeline buildout and use with the following levels of oil consumption: d) oil reduced to achieve 2030 target, e) oil flat at 2015 levels, and f) oil reduced 25%. CO_2e for methane is calculated using the 20-year global warming potential of 87.

Under these scenarios, if all proposed natural gas pipelines are built and utilized, the only approach to achieve New York's 2030 greenhouse gas emission reduction target would be to cut oil in the range of 70-100%, reflecting 0-4% upstream methane leakage rates. Even in the case that methane leakage is not included in the target calculation (a leakage rate of 0%), the estimated increase in gas use from pipeline buildout would require a 67% reduction in oil use by 2030—**effectively eliminating oil from residential, commercial and industrial sectors and reducing oil use in transportation by 57%**. Accounting for methane leakage makes achieving the 2030 target an even taller order: the higher the methane leakage rate, the deeper the petroleum reductions required under a pipeline buildout scenario.

These results hold implications for fuel switching activities in New York. In some cases, natural gas growth is promoted as a means of reducing emissions from oil, which emits more CO_2 than natural gas at the point of combustion per unit energy delivered. In New York, such fuel switching would mean using natural gas in lieu of burning fuel oil or petroleum liquids for home heating or for transportation fuel. However, the results above show that an increase in natural gas use from fuel switching would necessitate deep petroleum reductions not only for residential or commercial use but also in transportation, making a target of 40% overall emission reductions significantly more challenging. Fuel switching brings up some additional considerations. Fuel oil to natural gas switching is likely to lower the emissions of health-damaging co-pollutants such as particulate matter at the point of use, albeit not as much as electrifying heating or transportation and powering them with renewable electricity. Both sources are associated with health-harming pollutant emissions across their lifecycle, including production as well as from sources like compressor stations, but fuel oil has higher point-of-use co-pollutant emissions. However, the suggestion that fuel switching from fuel oil to natural gas would provide climate benefits has not been supported in the scientific literature because even low levels of methane leakage erode the climate benefits of lower combustion-related CO_2 emissions from natural gas. Recent research, for example, has found that using natural gas instead of diesel in trucks would take 50-90 years to provide any climate benefit at a well-to-pump natural gas loss rate of 1.65% and 1.2% for compressed and liquefied natural gas, respectively [4]. In New York's residential sector, the average CO_2 emissions from homes that use natural gas is about 20% higher than from homes that use petroleum liquids for heating,[1] a difference that is magnified when lifecycle methane emissions are also included. This difference is likely the result of homes using natural gas not only for heating, like oil users, but also for appliances such as clothes dryers and water heaters. These cases highlight the need to reduce greenhouse gas emissions in homes or transportation by electrifying current oil and gas fuel users, and to expand renewable electricity in New York to power these new electric vehicles or air source heat pump systems. **Reducing oil use by switching to gas will not only fail to offer meaningful emission reductions but could actually result in an increase in greenhouse gas emissions, particularly in the near term.**

The actual greenhouse gas impacts of pipeline buildout in New York depends on numerous factors. If the demand for these pipelines does not exist, their construction would not result in the level of emissions described here, but would instead result in underutilized infrastructure becoming stranded assets. Some of the pipeline infrastructure may be meant to meet peak demand, and as such could be intended for lower usage rates than average.[2] In the other direction, future pipeline utilization rates could be higher than the current average and lead to higher emissions, particularly if summer demand increases. Currently, New York's natural gas use in winter is double the use in summer months, and peak capacity is required to meet winter heating demand. If New York expands its natural gas power generation (which peaks in July in New York), such as with the

[1] Calculated by dividing residential emissions by fuel as reported by the EIA [7] by the number of households using each type of heating fuel as reported by the U.S. Census [86].

[2] If any pipelines are indeed just meant for peak, then concerted efficiency efforts, such as weatherization to reduce heating needs, could mitigate the need to build out this infrastructure.

planned CPV Valley and Cricket Valley plants, then summer pipeline flow rates and average annual utilization rates would increase. The result would be higher natural gas use—and emissions—from the same total pipeline capacity.

If the pipelines currently on hold due to permit denial are not built, the estimated increase in emissions would fall by nearly 40%, from 12% to 7%. Furthermore, we assume that methane leakage rates stay flat in the coming years, but leakage could decrease with tighter environmental regulations or potentially increase with changing production methods. The lifecycle methane emissions from natural gas are, as described, uncertain. Ongoing research will help provide greater constraints on the potential range of fugitive methane leakage rates, however the emission range presented here provides an effective bound for the purpose of this report.

Evaluation of the magnitude of greenhouse gas emissions from these pipeline buildouts within the context of New York State targets also depends on a few additional considerations. One consideration is the use of the 100-year or the 20-year global warming potential for methane. The greenhouse gas impacts of methane are much higher on a shorter time period, such that the implied pipeline buildout greenhouse gas impacts at a 2.5% leakage rate sum to 24 and 31 million metric tons per year on a 100-year and 20-year timescale, respectively. However, our overall conclusions are similar using both a 20-year and 100-year global warming potential, because the baseline emissions scale accordingly. For example, in the case of full pipeline buildout and use, the use of the 100-year global warming potential for methane would imply the need to reduce oil by 77% from 2015 levels to achieve 2030 targets as opposed to 83% if using the 20-year potential.

Another consideration depends on who is held accountable for the lifecycle emissions of greenhouse gases. In this analysis, we report both the lifecycle emissions for natural gas used in New York as well as the methane emissions for pipelines passing through the state but delivering gas elsewhere. However, if states in New England also included lifecycle methane emissions—including the transmission in New York—in their greenhouse gas inventories, this could lead to double-counting. In addition, two proposed pipelines (Northern Access 2016 and Atlantic Bridge) plan to bring a portion of their natural gas into Canada. This suggests that negotiations between the U.S. and Canada may be appropriate to discuss emissions occurring in the northeastern U.S. to, in part, supply fossil fuels for out-of-country use. A failure to include lifecycle emissions in CO_2e accounting can lead to unsound environmental policy decisions, such as oil-to-gas fuel switching. At the same time, numerous states and countries may be responsible for promulgating regulations that affect emissions across the natural gas lifecycle. It may be valuable to therefore differentiate between lifecycle emissions that result from in-state use decisions but occur out of state as compared to lifecycle emissions from infrastructure that may not be used in New York State but over which New York may have regulatory control. Both can be used to inform regulatory and policy decision-making, but perhaps should not be equated from a greenhouse gas inventory standpoint. For example, New York policymakers and regulators have direct control over decisions like pipeline or power plant permitting, whether or not that gas is delivered to New York State, and the in-state emissions may be included in the state's greenhouse gas inventory. New York State does not have direct control over upstream methane emissions from natural gas production, but a consideration of these upstream emissions may lead the state to incentivize measures like air source heat pumps to replace fuel oil rather than expanding natural gas distribution infrastructure. New York's decisions to permit pass-through pipelines may also have indirect impacts on gas consumption elsewhere.

Conclusion

As discussed, there are numerous pathways that New York State could take to reduce its greenhouse gas emissions over the coming decade. Under all reasonable approaches, however, the State needs to reduce its natural gas consumption in order to achieve its 2030 greenhouse gas targets. This finding means that building new pipelines and increasing the volume of natural gas supplied to the state would either greatly undermine these emission reduction efforts, or result in inefficient infrastructure investments that will be greatly underutilized by 2030 if the state succeeds in achieving its greenhouse gas targets.

A. Appendix

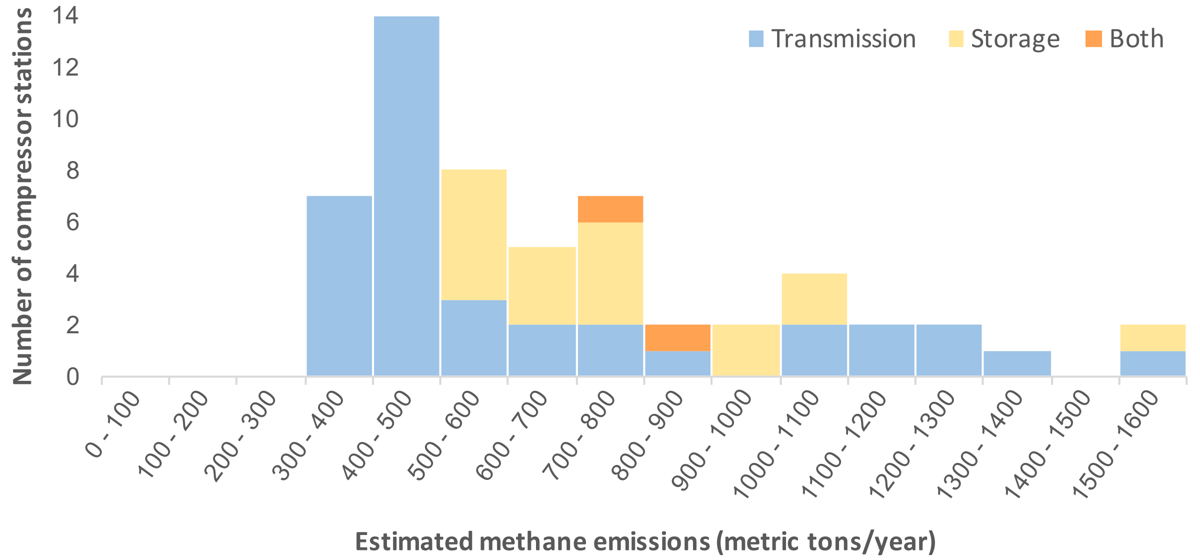

Figure A.1: Estimated methane emissions per existing transmission and storage compressor station in New York.

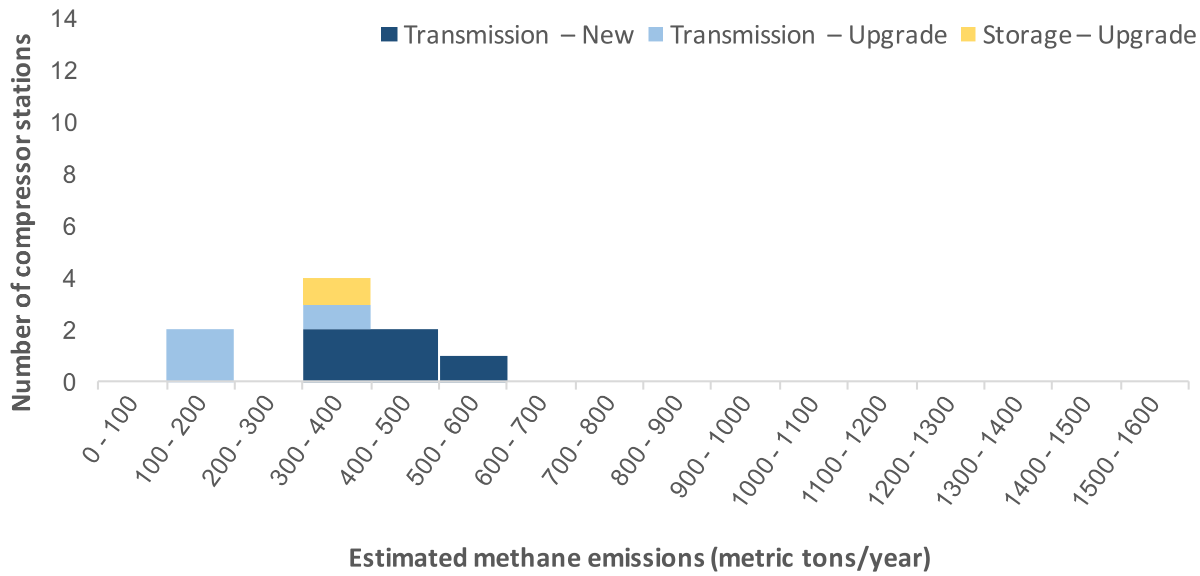

Figure A.2: Estimated methane emissions per proposed transmission and storage compressor station in New York, including both new builds and upgrades.

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