GAS PIPELINE CLIMATE METHODOLOGY: CALCULATING GREENHOUSE GAS EMISSIONS FOR NATURAL GAS INFRASTRUCTURE

Summary

Policy makers, regulators and gas industry proponents frequently highlight lower greenhouse gas (GHG) emissions from burning natural gas compared to that of coal and oil. However, this simple comparison of 'tailpipe' or 'chimney stack' emissions overlooks several issues that undermine the case that increasing natural gas production, transport and consumption can lower emissions and help meet crucial climate goals. These issues are both physical – in terms of the full life cycle emissions of natural gas production and use – and economical, in terms of the market impacts of building new natural gas infrastructure.

This document details these issues and presents Oil Change International's recommendations for calculating natural gas pipeline greenhouse gas (GHG) emissions. We estimate the full life cycle GHG emissions delivered by gas pipelines, in this case pipelines designed to increase takeaway capacity from the Appalachian Basin. Life cycle emissions include combustion emissions from burning the gas, as well as emissions from producing, processing, and transporting the gas, including methane leakage along the full supply chain. Our analysis assumes gas consumed within the United States and does not analyze gas exported via liquification (LNG). We note here that LNG export likely leads to higher life cycle emissions due to the energy intensive LNG liquification and regasification process.[i]

This document provides methodology and source information for a series of briefings that estimate GHG emissions for proposed Appalachian Basin pipelines. These can be found at www.priceofoil.org.

Our methodology and sources are detailed below. The key factors are:

- The level of methane leakage for the entire gas production, processing, transportation and storage system is estimated to be **3.8 percent of production**. This is a U.S. national average and may be conservative given that Appalachian Basin pipelines will carry fracked gas from the Marcellus and Utica formations. The fracking process often leads to greater methane leakage at the extraction phase than conventional gas production.
- Methane leakage is converted to carbon dioxide equivalent (CO_2e) using the Intergovernmental Panel on Climate Change's (IPCC) AR5 20-year global warming potential factor of 86, i.e. **one ton of methane vented or leaked to the atmosphere is equivalent to 86 tons of CO_2.**
- Each pipeline enables a commensurate amount of production growth in the source region.
- Each pipeline locks in demand for the gas it delivers. Without the additional supply of gas, energy needs could be met by cleaner sources of energy.

Methane Leakage

Leakage in the Gas Supply Chain is 3.8 percent of Production

Leakage from gas infrastructure is an increasing major source of greenhouse gases (GHGs) and adds substantially to the climate impact of producing and using natural gas.[ii] Natural gas – composed primarily of methane – is vented from extraction wells as part of the drilling and fracking process. It also leaks from equipment, including valves, pumps, storage tanks and pipelines, all along the gas production, processing, storage and delivery system.

Estimates of the amount of gas leaking from the oil and gas production system have become an important area of study and research is ongoing to better understand the role of this increasing source of climate altering gas.[iii] Recent studies measuring methane levels in the air above oil and gas production zones have led to higher estimates of leakage rates than those that rely on ground level reporting by producers.[iv] Study results range broadly due not only to different methodologies, but also because of fluctuating activity levels at the time of measurement.

We use a leakage rate of 3.8 percent of gross production. This is derived from a comprehensive review of existing research conducted by analysts at PSE Healthy Energy, published in November 2015.[v] As this is a U.S. average, and as some studies suggest that leakage rates are higher for fracked wells due to venting during the completion process,[vi] we believe this to be a conservative estimate for Appalachian Basin gas, which is primarily fracked gas.

The Global Warming Potential of Methane

Pound for pound, methane is a far more potent greenhouse gas than carbon dioxide (CO_2). As the measurement and analysis of GHGs is based on much more abundant CO_2, the impact of methane on the atmosphere is expressed as a carbon dioxide equivalent (CO_2e) according to its global warming potential (GWP).

The study of methane's GWP has evolved in the past decade and estimates of methane's GWP have increased. Methane lasts about 12 years in the atmosphere while CO_2 lasts for centuries. To calibrate methane's impact with that of CO_2, two time horizons have been used; 20 years and 100 years.

We use the 20-year GWP because whereas CO_2 accumulates in the atmosphere over the long-term, the impact of methane is felt in the short term. Its most important contribution to total warming occurs at the time of peak atmospheric CO_2 concentrations (i.e. net zero CO_2 emissions). According to IPCC scenarios, net CO_2 emissions need to reach zero around 2050 to have a 50 percent chance of limiting warming to 1.5 degrees Celsius, and around 2065 to have a likely chance of staying below 2 degrees Celsius of warming. For a goal of limiting warming to 1.5 degrees Celsius, the most important impact of methane for a 40-year pipeline built in 2017, will be between 0 and 33 years after the gas is transported, or between 2017 and 2050. For a goal of limiting warming to 2 degrees Celsius, the most important impact will be between 13 and 53 years, or between 2030 and 2070. In this respect, the shorter range GWP is the relevant measure for methane.[vii]

The 100-year GWP is most commonly used by government and industry. However according to the IPCC: *"There is no scientific argument for selecting 100 years compared with other choices. The choice of time horizon is a value judgement because it depends on the relative weight assigned to effects at different times."* [viii]

The U.S. Environmental Protection Agency (EPA) currently uses the 100-year metric. It also uses outdated IPCC AR4 figures in some cases while using AR5 figures in others.[ix] While the EPA has certain operational reasons for measuring methane based on the AR4 report in some cases, we strongly urge the EPA and all federal government agencies assessing the impact of natural gas systems to use the 20-year GWP from the latest IPCC report (AR5) to properly measure the impact of methane leaked to the atmosphere. This is particularly important at a time when the production of gas is growing so fast, driving increased gas consumption. Table 1 shows the difference between these reports and metrics.

Table 1: The Global Warming Potential of Methane (CH_4)

IPCC Report	AR4 (2007)	AR5 (2013)
20-year GWP	72	86
100-year GWP	25	34

Pipeline Emissions Calculation

Our emissions calculation involves seven key steps plus an additional step for subtracting the savings from the EPA Methane Rule. These steps are as follows:

1. Estimating the pipeline utilization rate.
2. Calculating the methane leakage quantity.
3. Conversion of methane leakage from volume to mass.
4. Conversion of methane mass to carbon dioxide equivalent (CO_2e).
5. Gas combustion to carbon dioxide (CO_2).
6. CO_2 from pipeline compression stations.
7. CO_2 emissions from exploration, extraction and processing.

Assumptions and sources used are detailed in Table 2.

Key Issues in Favor of Counting the Full Life Cycle Emissions of Gas Delivered by a Pipeline

Gas Emissions versus Coal or Oil

Proponents of natural gas argue that replacing coal-fired power generation with gas reduces the emissions of power generation by around 50 percent.[x] It is true that gas burns cleaner than coal in terms of both GHGs and other air pollutants. But when it comes to GHGs, measuring emissions only at the chimney stack of the power plant gives a false picture of the relative impact of these fuels on climate change. This is primarily because of the impact of methane leakage across the natural gas supply chain.

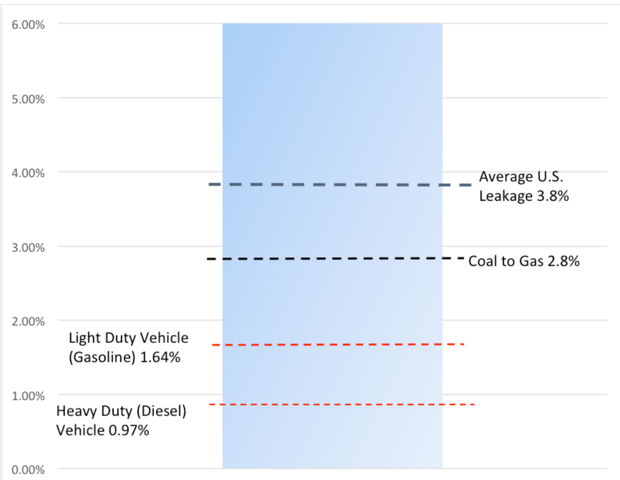
Analysts at PSE Healthy Energy estimate that a threshold for methane leakage used in power production is 2.8 percent of production.[xi] At leakage rates above this level, the GHG emissions per unit of electricity produced from a gas plant are greater than that of a coal plant.

Table 2: Assumptions and Sources for Pipeline Emissions Calculation

Calculation Step	Conversion Assumption or Standard	Source
Capacity Utilization	95%	Based on EIA https://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/usage.html
Methane Leakage	3.8%	PSE Healthy Energy (Nov 2015) http://www.psehealthyenergy.org/data/SS_Methane_Nov2015Final.pdf
Methane Volume to Mass	1Tcf = 19.26 Million Metric Tons	At standard temperature and pressure (60 degrees Fahrenheit and 14.73 pounds per square inch)
Methane Mass to CO_2e	86	IPCC AR5
Gas Combustion to CO_2	1Bcf = 59,726 tCO_2	2006 IPCC Guidelines for National Greenhouse Gas Inventories
CO_2 emissions from Pipeline Compression Stations	Unique to each project	FERC Environmental Impact Statements
Exploration, Extraction and Processing	5g CO_2 / MJ	International Institute for Sustainability Analysis and Strategy. http://iinas.org/tl_files/iinas/downloads/GEMIS/2014_Fracking_analysis_comparison.pdf

The threshold for natural gas vehicles is much lower, between 0.9 percent and 1.6 percent. With current average leakage rates of 3.8 percent, using gas to generate electricity or power vehicles is clearly dirtier than coal or oil in terms of GHGs (see Figure 1).

Figure 1: Methane Leakage Thresholds for Fuel Switching to Gas to Cut Overall GHG Impact



Source: Oil Change International [xii]

If the Obama administration's methane reduction target were to be achieved, reducing leakage by 45 percent, the result (leakage at an average of 2.1 percent) would be cleaner power generation from gas than from coal but not by nearly enough to meet the reductions needed to meet climate goals. This would also not bring gas emissions down enough to justify natural gas vehicles from a GHG perspective.

How Pipelines Lock-in Demand and Emissions

Appalachian Basin Gas Pipelines are a Key Driver of U.S. Emissions

Natural gas production in the Appalachian Basin has been growing at an unprecedented rate, particularly in the Marcellus and Utica shale formations in Pennsylvania, West Virginia, and Ohio. The development of fracking and horizontal drilling has opened up previously inaccessible formations and gas production in the region has grown over 12-fold since 2009, reaching over 21 billion cubic feet per day (Bcf/d) in 2016.[xiii]

Production in the Appalachian Basin could roughly double over current levels by the early 2030s.[1] By then, the Appalachian Basin could be providing over 45 percent of U.S. gas production compared to just 4 percent in 2010.

This prolific production growth from the Appalachian Basin could be the prime driver behind an EIA projected increase in U.S. gas production of 55 percent on 2015 levels by 2040.[xiv] The EIA also projects a 26 percent rise in demand to 2040 as well as a substantial rise in gas exports. This growth in both production and demand cannot be squared with U.S. climate goals.[xv]

New Pipelines Will Unlock a Surge of Fracked Gas

To enable this huge production expansion the industry needs new pipelines. Current takeaway capacity from the Appalachian Basin is close to its limits. Existing takeaway capacity is around 22.1 Bcf/d.[xvi] Five ongoing expansions of existing pipelines will add just over 2.66 Bcf/d in 2017.[xvii] Production in 2016 is estimated to have averaged 21.1 Bcf/d but may be higher at the end of the year.[xviii]

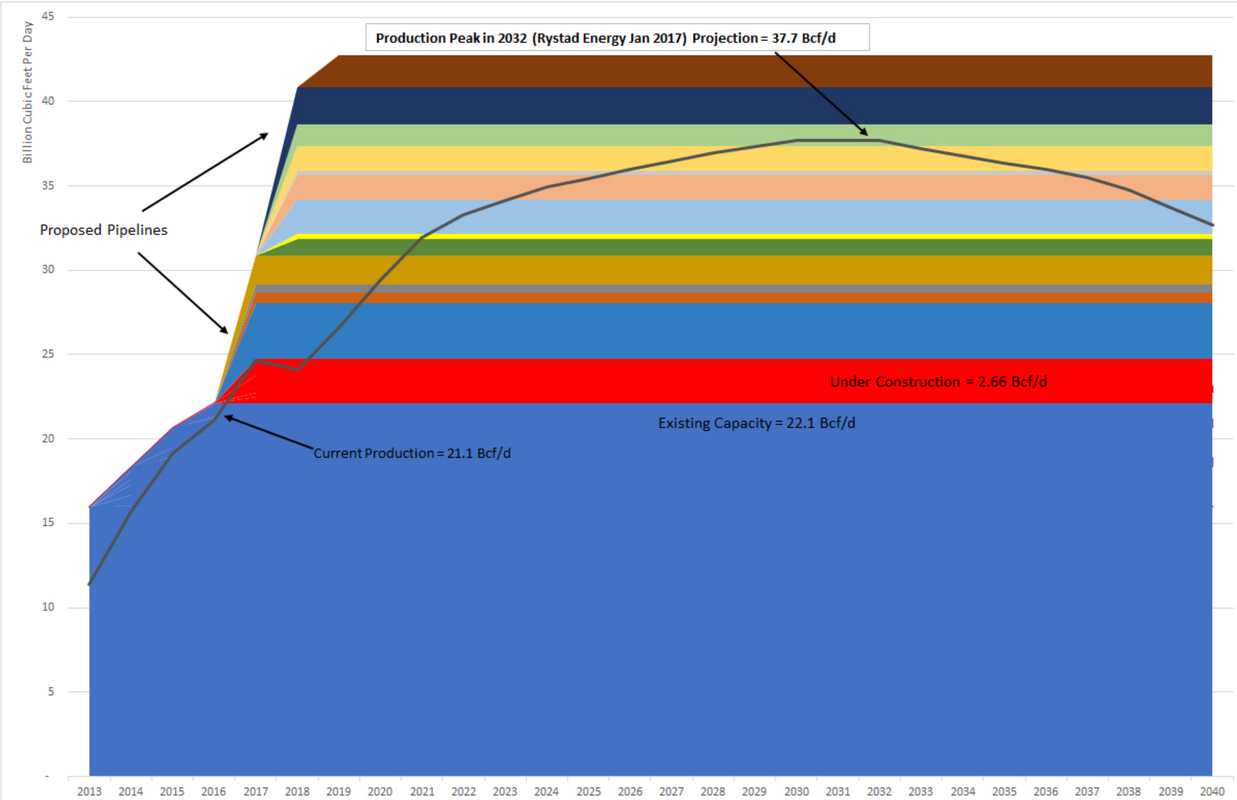
As Figure 2 shows, production is projected to jump dramatically in 2017 to over 24 Bcf/d, though this will require pipelines currently under construction to be completed before the end of the year. While production is expected to drop slightly in 2018, growth is expected to resume in 2019 and continue through to the early 2030s.

It is therefore clear that production can only grow with expanded pipeline capacity. This is even more the case considering that the utilization rate for the pipeline system may be lower than nameplate capacity due to maintenance or unexpected outages.

In this situation, every new pipeline creates additional takeaway capacity from the region and

[1] Rystad Energy's current projection (January 2017) is for production to peak in 2032 at 37.7 Bcf/d. However, this projected figure fluctuates with every monthly update of the Rystad database. While the year of peak production has been consistently placed in the early 2030s, the level of peak production has hovered between 37 and 42 Bcf/d.

**Figure 2: Gas Pipeline Capacity in the Appalachian Basin.
New Pipelines are Key to Production Growth**



Source: Oil Change International [xix]

thus enables a commensurate increase in production. Therefore, the life cycle emissions from the gas carried by the pipeline should be counted as additional emissions that would not otherwise occur without the existence of the pipeline. We address destination market issues below.

Pipelines Lock Gas into Markets

Pipelines enable the exploitation of oil and gas reserves, reduce the cost of doing so, and can lock in the use of oil and gas even as policies and markets shift toward zero-carbon sources. This is because once capital has been sunk into a pipeline, operators are incentivized to continue operation to recoup investment, even as policies or market alternatives try to move society away from the products they deliver.

Major interstate gas transmission pipelines generally cost billions of dollars to build. This requires many years of pipeline operation before this capital expenditure is recouped and net profits begin to flow.

What happens if the market for gas declines, perhaps because of policies aimed at addressing climate change that seek to reduce gas use, or rapid market adoption of clean energy technology, before the capital is paid off? As the cost of operating the pipeline is relatively small compared to the capital it took to build, pipeline operators are incentivized to reduce tariffs in order to keep some revenues flowing. As long as tariffs remain higher than the operating costs of pumping the gas through the pipeline, capital losses for the pipeline owners will decrease. After breaking even, operators will continue to increase returns on capital as long as tariffs exceed operating costs.

In other words, once the capital is sunk into the project, it is very hard to put the project out of business through market forces. If climate limits prescribe that the gas delivered by a pipeline should not be burned, it would take government action to force that closure. It would be a similar situation for the gas-fired power plants that the pipeline would feed.

Gas Competes with Clean Energy

While the rise of gas-fired power generation has clearly played a role in the demise of coal power in the U.S. and elsewhere in the past decade or more, this dynamic is set to change as clean energy investment surges and the cost of clean power competes with both gas and coal.

It therefore can no longer be assumed that new gas-fired power plants, supplied by new gas pipelines, are simply replacing coal plants and therefore, methane leakage aside, may be reducing emissions at the chimney stack. If we are to meet the goals set in the Paris Agreement on Climate Change, the necessary transition to zero carbon by mid-century means that coal and gas use must be wound down over the coming decades. Simply reducing coal burn while increasing gas burn cannot achieve the required emission reductions for keeping climate change within the limits prescribed by current climate science.[xx]

This is not only a policy driven objective. The cost of building and operating renewable energy plants is coming down fast and is close to parity with gas and coal, and in some cases, can already outperform those sources. This means that new gas plants are not only competing with existing coal plants, but increasingly with new wind and solar plant, not to mention other technological solutions such as efficiency, demand management and storage.

Renewable Energy Cost Reductions

Data from Bloomberg New Energy Finance shows that from 2004 to 2015 investment in clean energy globally rose 463 percent while installation capacity rose 635 percent (see Figure 3).

The marked increase in the ratio of capacity installations per dollar invested, particularly since

Figure 3: BNEF Chart Showing Rise in Global Clean Energy Investment

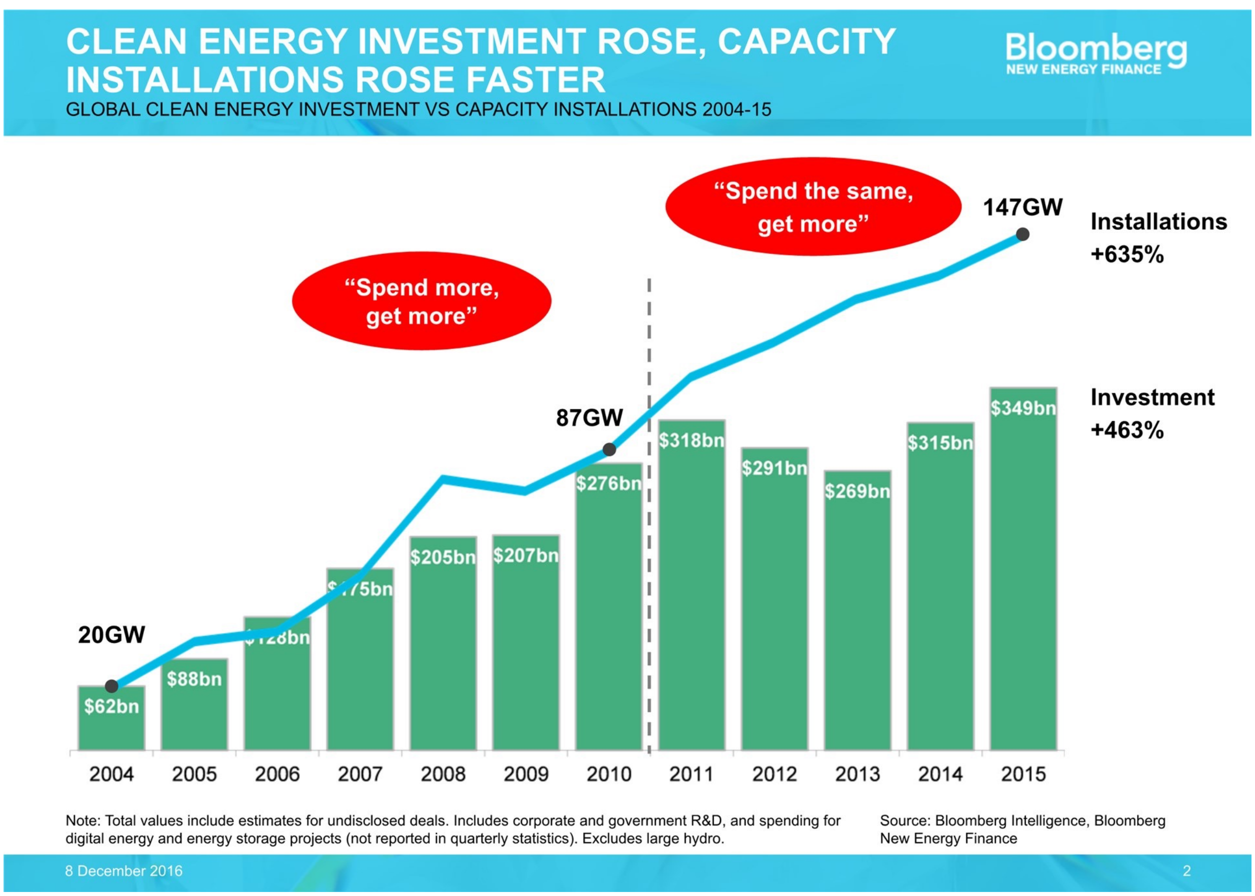
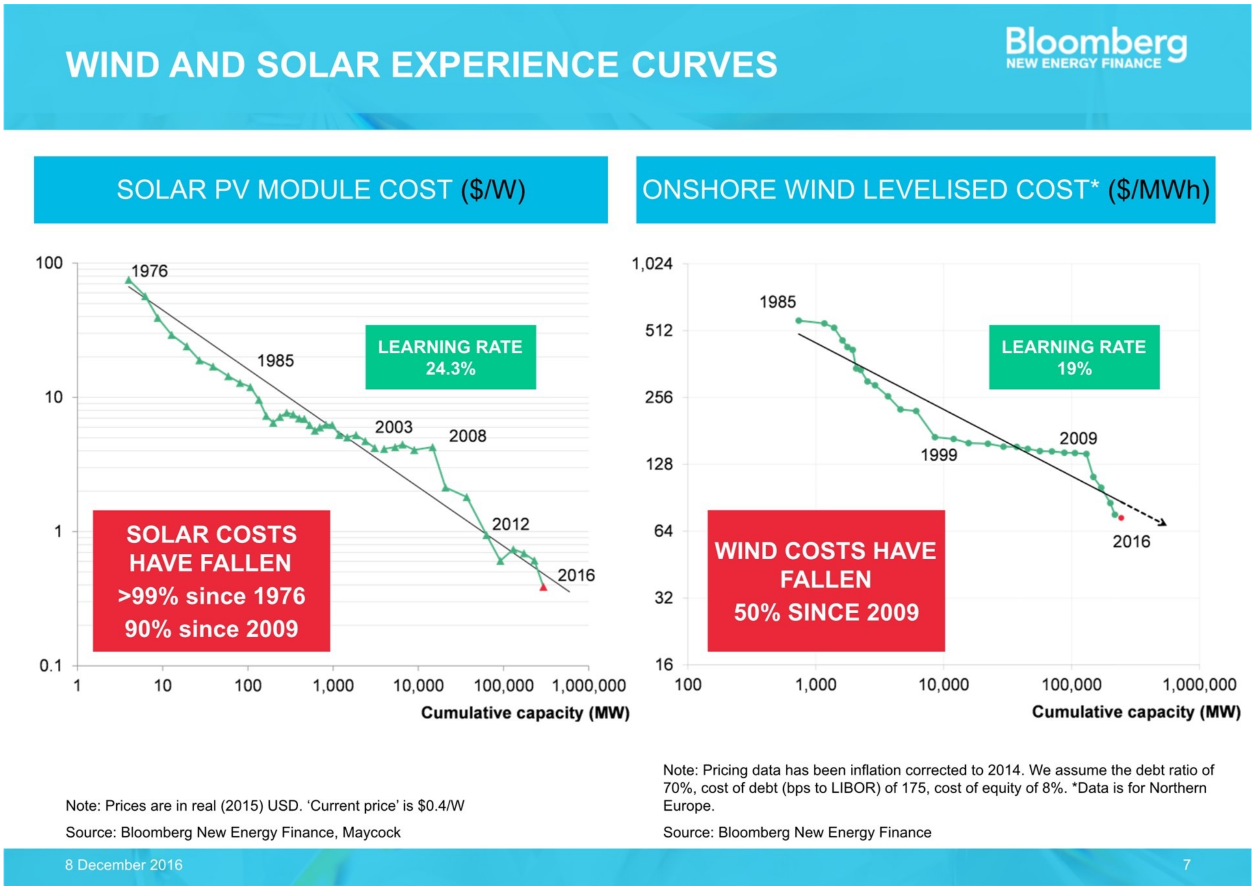


Figure 4: BNEF Chart on Wind and Solar Cost Reductions and Experience Curves



2010, is reflected in the dramatic cost reductions for solar and wind power installations over the period. The cost of solar has come down 90 percent since 2009, while wind costs have decreased 50 percent over the same period (see Figure 4).

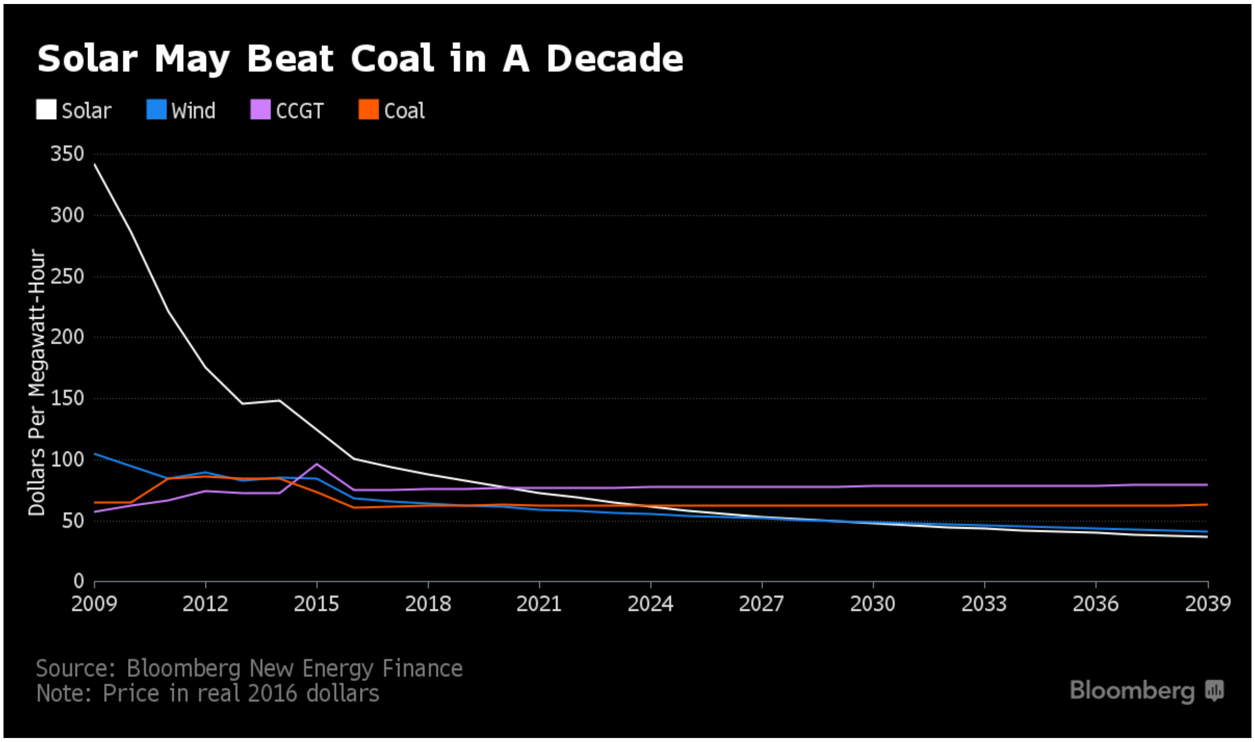
In December 2016, analysts at financial advisory firm Lazard published their latest update of unsubsidized levelized cost of energy estimates for a wide range of conventional and alternative energy sources.[xxi] These latest figures show that utility scale wind and solar projects are easily within range of the most efficient combined cycle gas turbine generators and in some cases, can deliver energy more cheaply.[xxii]

These trends are only likely to continue as technology costs continue to decline while the non-renewable supply of gas diminishes leading to rising fuel costs.

Projections published by BNEF in January 2017 suggest that solar will become the cheapest source of electricity by the mid-2020s based on average cost of generation globally. The analysis projects that solar will out compete gas CCGT plants by 2020 and coal plants by 2024. Wind is already competing with gas and closing in on coal (see Figure 5).

Therefore, gas power that is being supported by new pipeline build today is in direct competition with clean energy generation, and the emissions from producing, processing, transporting and combusting that gas, must be counted as emissions added to our atmosphere. Without the pipelines, the gas will not reach a market. And without the supply, new gas plant would not be built. In the absence of these new gas plants, clean energy solutions will out compete existing coal and provide the energy needed for our economy with none of the emissions.

Figure 5: BNEF Projects Solar and Wind Beating Gas and Coal on Cost [xxiii]



Projected U.S. Gas Growth is Out of Sync with Climate Goals

The potential for further growth in gas production represents a major challenge for U.S. climate policy. The Paris Agreement on climate change, which entered into force in November 2016, establishes the goal of "holding the increase in global average temperature to well below 2 degrees Celsius above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 degrees Celsius above preindustrial levels."[xxiv] The current U.S. long term emissions reduction target – which may not be enough to achieve the 'well below 2 degrees Celsius' goal set in Paris – is an emissions cut of 83 percent from 2005 levels by 2050.[xxv]

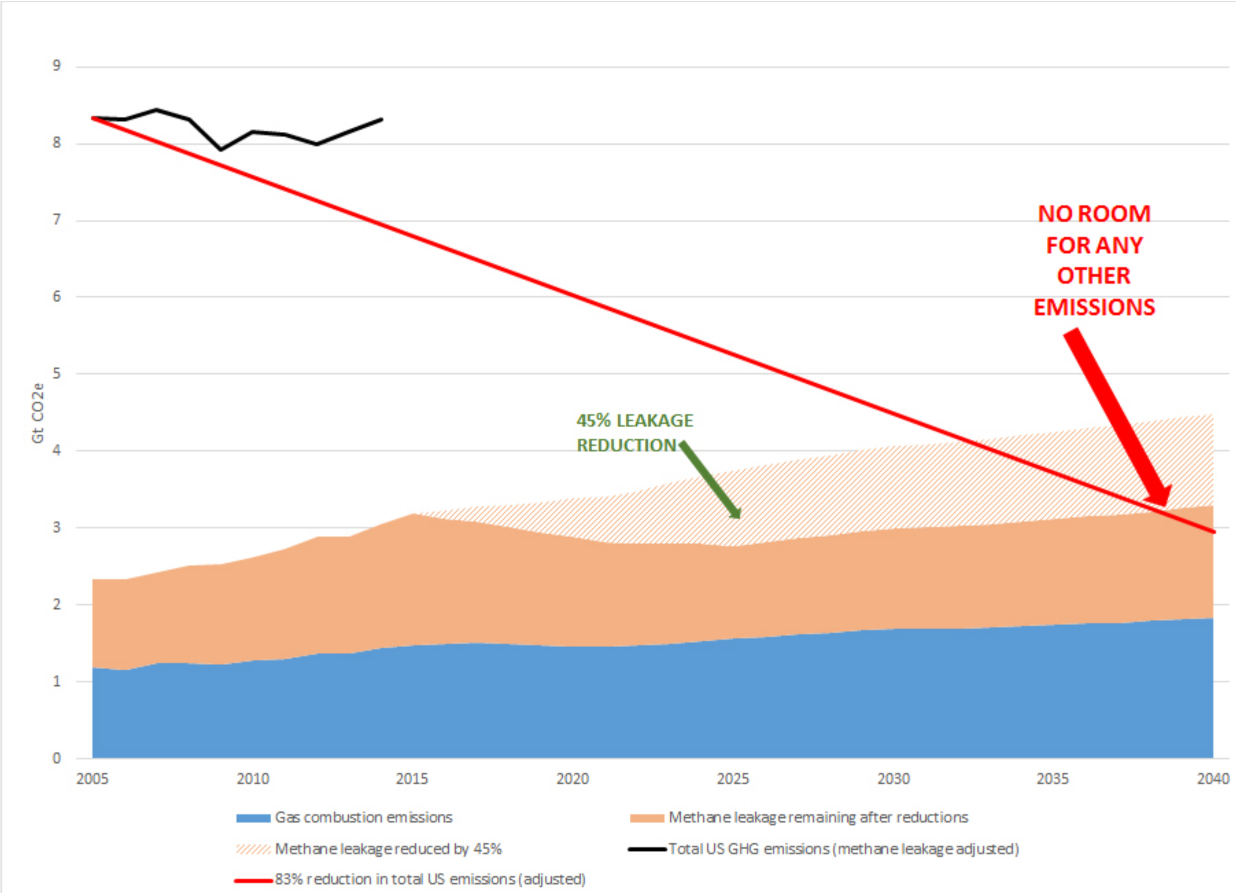
The U.S. Energy Information Administration's (EIA) 2016 projection for U.S. gas supply and demand (Annual Energy Outlook 2016) shows a 55 percent increase in production and a 24 percent increase in consumption over 2015 levels by 2040.[xxvi] This projection also sees U.S. energy-related CO_2 emissions declining only around 4 percent from 2015 levels, in stark contrast to the commitments enshrined in the Paris Agreement.

The currently planned gas production expansion in Appalachia would make meeting U.S. climate goals impossible, even if the previous administration's goal of reducing methane leakage in the oil and gas sector by 45 percent is achieved.

Our calculations show that the rise in gas consumption projected by the EIA would alone lead to emissions that would surpass the current long-term U.S. climate target before 2040, even after accounting for methane leakage cuts (see Figure 6). In other words, even if gas were the only source of U.S. GHGs in 2040, it would still blow the U.S. carbon budget. This makes it clear that the growing use of gas is out of sync with U.S. climate goals.

This analysis demonstrates the urgent need to assess the full GHG impact of new natural gas pipelines and infrastructure. It shows that a business as usual approach that assumes gas infrastructure necessarily has a helpful impact on GHG emissions is not a valid approach. All decisions on natural gas infrastructure permitting require a full life cycle emissions assessment and an assessment of the impact on achieving critical

Figure 6: Projected U.S. GHG Emissions from Gas Usage & Leakage vs. U.S. 2050 Climate Target



Source: Oil Change International [xxvii]

U.S. and international goals to address climate change.

Concluding Summary

This paper describes our methodology for estimating the greenhouse gas emissions from natural gas pipelines that increase takeaway capacity from the Appalachian Basin. It also describes how this pipeline infrastructure exacerbates GHG emissions.

There are three fundamental reasons why these pipelines increase GHG emissions.

- Each pipeline enables a commensurate amount of production growth in the source region.
- Each pipeline locks in demand for the gas it delivers. Without the additional supply of gas, energy needs could be met by cleaner sources of energy.
- Methane leakage in the gas supply chain means the displacement of coal or oil by natural gas increases net GHG emissions.

As renewable energy technologies are now cost competitive with natural gas-fired power, and because addressing climate change will require a phase out of all fossil fuel combustion by mid-century or soon thereafter, new gas supply infrastructure causes emissions equal to the full life cycle emissions of the gas being delivered. These are significant emissions and require a serious reevaluation of expectations for gas production growth in the United States. To achieve crucial climate goals and protect our society and economy from severe climate impacts, we must begin a just transition away from all fossil fuels. Building new gas pipelines is in direct conflict with this goal.

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