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Wind, Solar, and Gas: Managing the Risks of America's Clean Energy Transition

CLAYTON MUNNINGS
PROGRESSIVE POLICY INSTITUTE

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EXECUTIVE SUMMARY

President-elect Joe Biden has set an ambitious goal for achieving zero carbon emissions from the nation's power sector by 2035. The U.S. electric grid therefore faces a dual challenge: meeting growing demand for power while also decarbonizing the energy it supplies, which is essential to avert catastrophic climate change.

At the same time, the challenge of maintaining an affordable and reliable grid is becoming more complicated, because of the increased frequency of extreme weather and the rapid growth of distributed renewable power – especially wind and solar – that is variable and unpredictable. It's imperative that U.S. policymakers keep the nation's environmental and energy needs in balance as the shift to renewables accelerates.

Natural gas can play an indispensable role in managing the risk that a precipitous leap to renewables will make electricity more expensive and potentially less reliable. Gas already supports the expansion of renewable energy by providing an instantly dispatchable source of electricity. Unlike coal and nuclear plants, natural gas power plants turn on and off within minutes, allowing the grid to quickly match supply and demand even when the wind isn't blowing and the sun isn't shining. As the National Renewable Energy Laboratory[1] points out, this unique flexibility of natural gas generation thereby

facilitates the steady expansion of renewables. As we move toward decarbonization, retaining sufficient natural gas generation to backstop wind and solar power would reduce costs and increase reliability compared to a grid that relies entirely on renewables. Given these realities, demands to "ban fracking" or keep shale gas "in the ground" are not consistent with a balanced approach to decarbonizing the electric grid.

In the decades ahead, natural gas generation must move toward zero carbon emissions to be part of America's clean energy transition. To this end, U.S. policy makers and the natural gas industry should join forces to (1) invest more heavily in carbon, capture, and storage (CCS) technologies to quickly move gas-fired plants toward zero carbon emissions; and, (2) adopt and enforce ambitious goals for dramatically reducing methane emissions –– which are many times more injurious to the climate than carbon dioxide emissions –– from the natural gas lifecycle. This includes methane originating from abandoned wells that are no longer in use and have not been properly decommissioned.

Neither of these changes will be easy. Despite recent progress, the development of CCS technology is generally nascent and has not been specifically applied to a natural gas power plant in the United States. At the same time, methane emissions from the natural gas sector are underregulated at the federal level, and increasingly so as a result of the Trump administration's rollback of methane regulations proposed under the Obama administration. Yet America's ability to use our abundant gas resources to backstop and expand renewable energy on the electric grid requires swift progress on both fronts.

There also are other ways in which natural gas can contribute to a decarbonized electricity grid—including but not limited to fuel substitution with renewable natural gas, blending of hydrogen into gas pipelines[2], creation of "blue" hydrogen[3], and the potential of new generation technologies such as Allam Cycle plants[4]—that are important and beyond the scope of this report.

Yet the political debate around energy and climate policy often presents Americans with a false choice between natural gas and renewable energy. Today the two are intertwined. America needs natural gas now to enable and backstop the rapid deployment of renewable energy on the grid (not to mention supplying power to U.S. industries and homes, which lies beyond the scope of this report).

Rather than trying to ban fossil fuel production, progressives should keep their eyes on the real prize: achieving net zero carbon emissions. Because of the uncertainties surrounding the success of any of the technologies and methods mentioned above, no one can precisely predict how long it will take America to decarbonize its economy. If decarbonization techniques applied to fossil fuels fail, a successful clean energy transition will require phasing them out. If they succeed in driving greenhouse gas emissions toward zero, natural gas could play a role in the U.S. energy mix into the foreseeable future.

Therefore, this report urges President-elect Biden to strike a new bargain between the federal government and natural gas companies for decarbonizing the natural gas sector. Washington would acknowledge and support the role gas plays in enabling rapid deployment of renewable energy in exchange for industry's commitment to make consistent progress toward zero carbon emissions, achieved through

the rapid development of CCS technology and dramatic reduction of methane emissions throughout the natural gas lifecycle.

Crucially, this approach also could help to depolarize the debate over what to do about climate change. By rejecting unrealistic demands to abolish fossil fuels now, and speeding the technological advances necessary to decarbonize them, the incoming Biden administration could build a broader base of political support for a clean energy transition that meets America's climate and economic needs.

THE URGENT CASE FOR CLIMATE ACTION

Climate change poses a dire threat to our planetary health. Biden's victory will end a shameful four years in which the United States has been absent from the fight to slow down climate change. Biden pledged to resume U.S. international climate leadership by rejoining the Paris climate accords immediately upon taking office.

The Paris Agreement envisions limiting global average temperature increases to two degrees Celsius through a balancing of emissions sources and carbon sinks by midcentury.[5] Over 75 countries representing approximately 11 percent of global emissions recently submitted to the United Nations strategies or pledges to achieve carbon neutrality by 2050.[6] Meanwhile, China, which generates 29 percent of global emissions, making it the world's largest greenhouse gas emitter, recently pledged to reach net zero emissions by 2060, although its near-term targets are far less ambitious than what Biden has proposed.

Unfortunately, experts expect that, even if they are kept, country-level commitments under the Paris Agreement still leave us on an unacceptably dangerous trajectory toward a 3.3 degrees Celsius global average temperature increase, revealing an alarming ambition gap.[7] This degree of warming implies at least a 4 percent reduction in gross domestic product for the United States economy, with our poorest counties projected to lose between 2 and 20 percent of their income by the late 21st century.[8]

Climate policies that channel the power of American ingenuity toward zero-carbon innovations are the key to avoiding catastrophic climate change. Thanks to innovations over the last decade, the costs of operating solar photovoltaics and onshore wind turbines in the United States has dropped dramatically, from $359 to $41 and $135 to $40 per megawatt-hour, respectively.[9] Consequently, solar and wind energy have become booming economic sectors that employ over 350,000 workers.[10]

Moreover, the United States Energy Information Administration predicts that generation from renewables will provide at least 38 percent of our electricity by 2050.[11] The Biden administration is likely to press for a more ambitious target, possibly even approaching 100 percent. At high rates of deployment, however, the intermittency of renewables requires the installation of much more capacity than is necessary to meet demand, thereby resulting in high costs.[12,13] To avoid this dilemma, we need a comprehensive federal policy that achieves the dual objectives of high renewable energy deployment and low electricity prices. President-elect Biden's climate plan envisions achieving a carbon pollution-free electric grid that is then used to electrify the transportation and industrial sectors. That's not likely to happen, however, if electricity prices spike.

That's why we need backup power generation that moves toward zero carbon emissions. Potential sources of zero-carbon power generation include natural gas power plants with carbon capture and sequestration (CCS) technologies, geothermal, hydropower, nuclear power, and bioenergy. Natural gas is important because we already rely on it to generate about one-third of our electricity.[14]

In a zero-carbon electric grid, the role of natural gas power plants with CCS technologies would shift from producing bulk energy to supporting renewables with zero-carbon dispatchable backstop capacity. In this way, the pitfalls of a hasty rush to 100 percent renewable energy – high prices and low reliability -- can be avoided. Instead, natural gas power plants with CCS technology can work in partnership with renewable energy to rapidly achieve a decarbonized electric grid.

Unfortunately, the politics of energy and climate are deeply polarized. On the left, activists demand fracking bans and insist that shale gas and oil be left "in the ground." On the right, climate deniers want continued U.S. reliance on fossil fuels.[15] Although their voices are the loudest, a poll commissioned by the Progressive Policy Institute (PPI) for the 2020 election suggests that neither of these camps represent majority opinion.

The poll delved into public attitudes in two presidential battleground states, Pennsylvania and Ohio, that also happen to be among America's top five gas-producing states. The poll found that voters – including those in the "shale belt" counties where gas is produced -- overwhelming see climate change as a serious problem and want the government to take vigorous action against it. At the same time, voters also overwhelming oppose (by 74-21 percent) a ban on natural gas extraction. Even among liberal and younger voters, there's little appetite for a ban on gas production. That shouldn't come as a big surprise, considering how important shale gas is to jobs and the economies of both states.

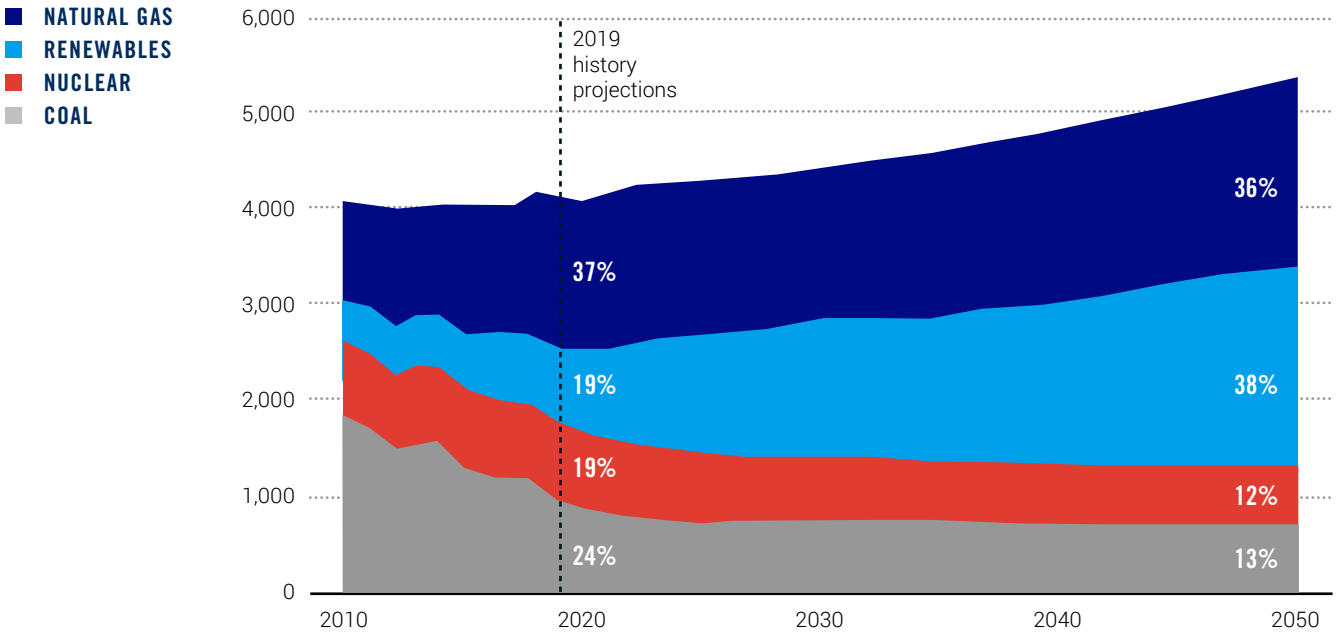
But the PPI poll shows that most voters have a pragmatic streak when it comes to energy and climate policy. Seventy-seven percent of voters in Pennsylvania and Ohio support using natural gas and nuclear power to support the expansion of renewable wind and solar power. They understand that gas plays many roles – generating electricity, fueling U.S. industries, and heating and cooling homes. Perhaps they also understand the role that gas plays in improving local pollution by displacing coal in the East Coast and Midwest States.[16]

The bargain proposed in this report is grounded in that spirit of pragmatism. It would hold a seat at the clean energy table for natural gas generators in exchange for assurances that U.S. lawmakers and the natural gas industry join forces to achieve zero carbon emissions through CCS technologies and dramatic reductions in methane leaks and emissions.

HOW TO DECARBONIZE THE U.S. ENERGY GRID

Natural gas is pervasive in the American economy as a fuel and a feedstock. Ample supply and low gas prices also have powerfully stimulated growth in the U.S. chemical industry, yielding a host of useful applications and creating a substantial number of jobs.[17] Recently, the United States has become a significant exporter of natural gas. In the context of the electric grid, as illustrated by Figure 1, natural gas powers our electric grid about one-third of the time.[18]

FIGURE 1: PROJECTED ELECTRIC GENERATION FROM NATURAL GAS IN THE UNITED STATES



Source: US EIA (2020)

Nearly all models that simulate what it would take for America to achieve deep decarbonization identify early action in the electricity sector as the linchpin to success. Models assume that a grid powered increasingly by renewable energy would then be used to electrify much of the transportation and industrial sectors, producing dramatic reductions in carbon emissions. For example, a study by Lawrence Berkeley and Pacific Northwest National Laboratories predicts a 60 to 110 percent increase in electricity demand by mid-century.[19]

In their comprehensive review of modeling efforts to date, Jenkins et al. (2018) identify two main paths to decarbonizing the electricity sector. The first path achieves a 100 percent renewable electric grid, primarily by relying on solar and wind. But there's a big problem: the intermittency of renewables requires overbuilding total installed capacity to produce sufficient energy during periods when available short-term wind or solar output is well below average. One finding from the literature is that total installed renewable capacity should be three to eight times larger than peak demand.

Such overcapacity directly increases electricity costs. When the amount of available wind or solar power is above average, utilities are forced to reduce energy output because they can't store the excess energy. When the amount of available wind or solar power is below average, then models rely on long-term expensive battery storage to keep the grid running. Finally, a 100 percent renewable grid tends to require optimistic modeling assumptions including continent-scale transmission lines and extremely flexible demand response.[20]

The second, more pragmatic path envisions a strategic backstop to wind and solar power by employing dispatchable forms of electricity.

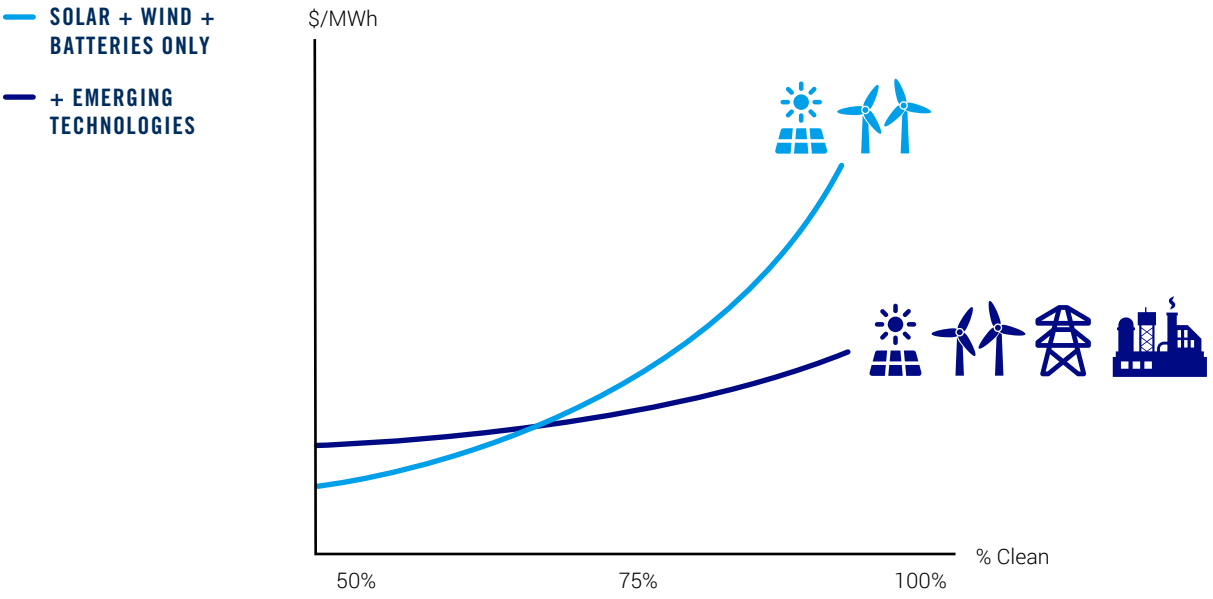
Most of the challenges associated with overreliance on renewables can be avoided by adopting a generation portfolio with some level of generation capable of fast ramp rates, low capital costs, and high variable costs. In this context, natural gas generators pair especially well with high buildouts of solar and wind.

Adding a backstop, for example natural gas, to alleviate the need for a limited quantity of renewables leads to total installed capacity that is much more closely sized to peak loads. This results in a reliable grid that delivers lower electricity prices. Moreover, the need for seasonal storage is completely avoided and thereby grid reliability is strengthened. Consequently, firm low-carbon resources are a consistent feature of the most affordable and reliable pathways to deeply decarbonizing the United States electricity grid.[21]

For example, a recent comprehensive exercise that models deep carbonization of the United States electrical grid finds that the availability of backstop power, such as natural gas generation with CCS, reduces electricity costs 10 to 62 percent compared to scenarios that rely exclusively on variable sources paired with energy storage.[22] Cheap prices and reliable electricity are critical to achieving a decarbonized economy via midcentury, as envisioned in President-elect Biden's climate plan.

As illustrated in Figure 2, a renewable-only approach is cheaper in the short-term but becomes exponentially expensive in the long-term the closer we get to a 100 percent renewable grid. Maintaining a role for natural gas with CCS technology can avoid the portion of the renewables only curve where costs grow exponentially and thereby lead to large cost savings. There's no doubt that renewable energy can and should form the backbone of our zero-carbon electricity grid. But natural gas power plants with CCS technology would enable more rapid and strategic development of renewable energy by serving as an emissions-free backstop that secures lower electricity prices and ensures grid reliability.

FIGURE 2: ELECTRICITY COSTS AND RENEWABLE PENETRATIONS FOR DIFFERENT DECARBONIZATION STRATEGIES



Source: Spokas et al. (2020)

GENERATING ZERO-CARBON NATURAL GAS

Models that simulate decarbonization of the electric sector typically include natural gas generation with CCS technologies. For example, a recent study by the University of California Berkeley Goldman School of Public Policy assessed the feasibility of a 90 percent clean United States electricity grid by 2035 and relied on natural gas with CCS to provide dispatchable power.[23] To achieve a 100 percent clean electricity grid, the authors highlighted two options: (1) further investments in CCS for natural gas, or, (2) further reliance on expensive alternatives—such as hydrogen or storage—that doubled marginal abatement costs into the range of 100 to 125 dollars per ton.[24]

Unfortunately, the use of CCS lags far behind what is required to meet America's carbon-reduction targets under the Paris Agreement.[25] The Petra Nova coal plant in Texas is the only U.S fossil-fuel powered plant capable of generating and capturing carbon in large quantities,[26] but its operations were suspended earlier this year amid low oil prices and falling demand for energy as a result of the pandemic. Outside of the electricity sector, the U.S. has 10 of the world's 19 large scale operating CCS projects. Most operate in natural gas processing plants, fertilizer production, synthetic natural gas production, or ethanol production.[27] There are no CCS projects operating on natural gas generators in the United States.

> **"Given the challenges now facing available firm low-carbon resources, it is tempting for policymakers, socially conscious businesses, and research efforts to bet exclusively on today's apparent winners: solar photovoltaics, wind, and battery energy storage. That would be a mistake," says Jenkins et al. (2020). Instead, the authors call for investing in a more technically diverse approach, which includes natural gas generation with CCS among other technologies, to secure low prices for zero-carbon electricity. Despite unfavorable economics today, the value of natural gas with CCS technology grows as renewable penetration or marginal costs of renewables become quite high. Therefore, Spokas et al. (2020) argue that excluding CCS technologies from our decarbonization toolkit based on present-day economics is likely shortsighted and fails to "recognize CCS may have significant value in the future and risks stunting CCS technology advancement."[28]**

A federal tax credit (45Q) provides an incentive for company investments in carbon sequestration. It is calculated by multiplying the metric tons of qualified carbon sequestered by a pre-determined value. Depending on the type of project, the incentive ranges from $11.70 to $28.74 and rises annually accounting for inflation. The incentive requires secure geological storage of carbon emissions in deep saline formations, oil and gas reservoirs, or un-minable coal seams. The claimer of the credit must capture at least 500,000 metric tons of carbon annually. If the carbon captured somehow leaks out, the incentive must be repaid to the Treasury.[29]

At the state level, California has a low-carbon fuel standard that uses market trading to price credits for carbon savings. Credits recently have traded around $200 per ton. This creates a strong incentive for producers to invest in CCS technologies, including direct air capture, CCS at oil and gas production facilities, and CCS at refineries.[30]

This patchwork of policies has led to an encouraging pipeline of new CCS projects across a broad range of geographies and technologies. The Clean Air Task Force's CCUS Project Tracker reports 32 projects announced since 2018 that have the potential to sequester 40 million metric tons of carbon dioxide annually. Eight of these projects leverage financing through California's low-carbon fuel standard in addition to using the federal 45Q incentive. Six of these projects aim to apply CCS technologies to natural gas power plants.[31] Spokas et al. (2020) argue that CCS technology on natural gas plants is technically feasible and could break even from an economic perspective if they combine 45Q with enhanced oil recovery, which is the use of captured carbon to extract oil that could not have otherwise been extracted.[32]

Ultimately, natural gas generators with CCS must be deployed at scale to achieve an effective zero-carbon backstop for renewables. The policy and technical inertia surrounding CCS development must be expedited to ensure that CCS technologies develop quickly enough to be applied successfully to a natural gas generator as soon as possible. Therefore, the federal and state policies that have spurred new CCS projects should be strengthened. For example, the Clean Air Task Force has proposed a modification of the 45Q incentive to expand the effective window of eligibility for new CCS projects.[33]

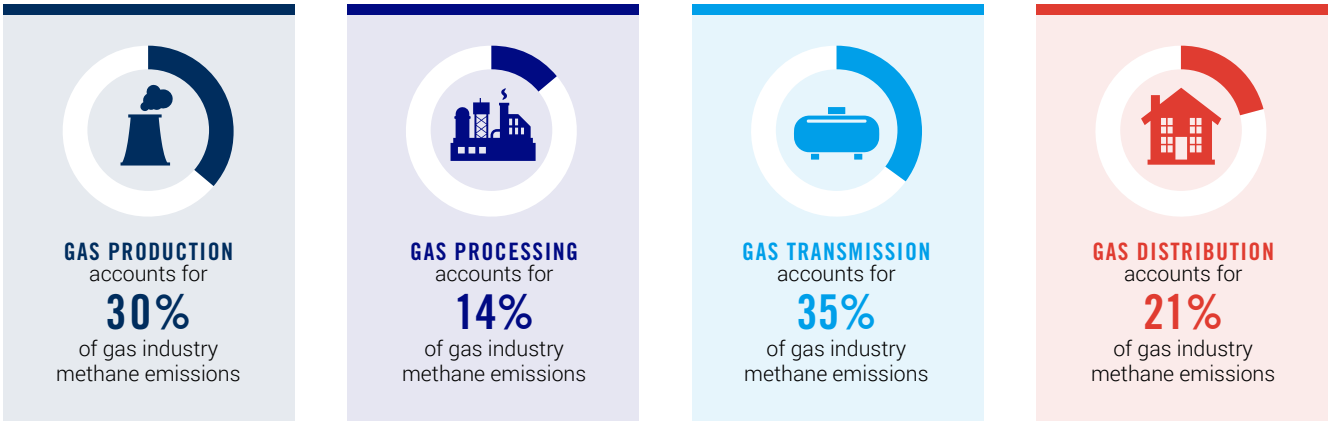
DRAMATICALLY REDUCING METHANE EMISSIONS FROM THE NATURAL GAS LIFECYLE

Natural gas emits about half as much carbon dioxide as coal when combusted. That is a primary reason why switching from coal to gas generation led to big reductions in carbon emissions from the electricity sector after the shale gas revolution started.[34]

However, natural gas producers emit significant amounts of gas by venting, inefficient flaring, and "fugitive" emissions through leaks in wells and equipment.[35] These emissions have a disproportionately large impact on the climate because the primary component of natural gas, methane, warms the globe 86 times more effectively than carbon dioxide over a 20-year time frame.[36] Therefore, fugitive methane emissions could more than offset the climate gains of switching to gas from coal.

Studies show that gas is more climate friendly than coal only so long as methane emissions are kept below 2.7 percent of gas production.[37, 38] As illustrated in Figure 3, methane emissions are generated in four natural gas "subsectors": production, processing, transmission and distribution. A recent study estimates that national methane emissions were 2.3 percent of total gas production in 2015, suggesting only a slight advantage to using natural gas over coal in that year.[39] Another recent study estimates that methane emissions from the Permian Basis, a major producing region in Texas, were 3.7 percent of production in 2018 and 2019, suggesting a significant disadvantage from using natural gas from this regional over coal.[40] Moreover, comparisons to coal are less relevant as coal-fired generation decreases and renewable generation increases. In short, methane emissions must be reduced dramatically if natural gas is to play its crucial role as a zero-carbon firm resource to backstop renewables.

FIGURE 3: RECENT ESTIMATES OF METHANE EMISSIONS FROM UNITED STATES NATURAL GAS SUBSECTORS



Source: Adapted from World Resources Institute (2019)[41]

The Trump administration, unfortunately, moved in the opposite direction. It rolled back one of the last Obama-era climate regulations that would have reduced methane emissions from oil and gas wells constructed after 2016 and prompted regulations on existing oil and gas wells.[42] Major oil and gas players including BP, Exxon, and Shell[43] supported the regulation. The main opposition came from smaller oil and gas players.[44]

The Clean Air Task Force estimates that Trump's collective rollback of methane regulations will increase emissions 4.3 million metrics tons in 2035 and warm the climate as much as the carbon emissions of nearly 100 coal-fired power plants.[45] Beyond climatic costs, the Trump administration's rollbacks threaten public health and safety. For example, methane leaks lead to ozone formation and often include emission of volatile organic compounds that are known to aggravate respiratory problems and can be carcinogenic.

Several states have stepped into the leadership vacuum. Led by former Governor and now U.S. Senator John Hickenlooper, Colorado imposed several types of regulations, most notably a leak detection and repair program that began in early 2010s. My own study from 2017, with Alan Krupnick from Resources for the Future, reports that the number of estimated leaks in Colorado has fallen by 75 percent since these rules went into effect.[46] California, Massachusetts, and New Mexico have followed Colorado's lead with their own forms of regulation, but by and large methane emissions remain largely under-regulated by state governments.

Some industry players are voluntarily reducing their emissions. ONE Future, for example, is a coalition of 30 natural gas companies working together to voluntarily reduce their methane emissions across the natural gas life cycle to 1 percent or less of produced natural gas by 2025. ONE Future reports that their methane emissions were well below one percent for 2017 and 2018. More recently, the American Gas Association and Edison Electric Institute launched the Natural Gas Sustainability Initiative which aims to measure methane emissions intensity across the natural gas lifecycle.[47] As a final example, The Environmental Partnership is a newly formed group of companies voluntarily

implementing best practices and installing certain equipment to reduce their methane emissions.[48] Many of these efforts build upon EPA's Methane Challenge Program, a voluntary program aimed at sharing information that facilitates methane emissions reduction.[49]

In addition, a host of non-profits and start-ups are also engaged in measuring, labeling, and trading "green" or "climate differentiated" natural gas with low methane emissions. My own study from this year, with Alan Krupnick from Resources for the Future, surveys these efforts, which started with a "sustainable" gas transition between Southwestern Energy and New Jersey Resources in 2018.[50] A similar trade for "carbon-neutral" liquified natural gas occurred in 2019 between Shell and Tokyo Gas.[51] The Rocky Mountain Institute has recently launched a digital platform that will offer emissions data from satellites, aircrafts, and monitoring stations to help companies assess methane emission against performance benchmarks.[52] While these efforts are encouraging, we argue that further involvement in these voluntary markets from the government is necessary to increase participation, enhance ambition, and improve both the accuracy and credibility of these efforts.[53]

Despite these fledgling efforts, federal action is imperative because methane emissions from the natural gas sector are still too high and may even be trending in the wrong direction. Based on EPA data, which likely underestimates methane emissions on average[54], methane emissions from the natural gas system have slightly increased since 2016, from 135.8 to 140.0 MMTCO2-eq.[55] Some methods for measuring methane emission carry high levels of uncertainty, which indicates a need for uniform standards. None of the voluntary efforts to date have achieved widespread industry participation that federal regulations could mandate. Nor have they set the type of ambitious targets that federal regulations could mandate, instead tending to identify modest reductions that ensure natural gas maintains its climate advantage over coal and gasoline, rather than prioritizing maximum abatement.

Federal methane regulation should be designed to set an appropriate level of ambition by requiring levels of abatement that not only reduces methane emissions but equates private and social costs of methane, which amounts to over 1,100 USD per ton.[56] Any methane regulation must address the downward bias and large uncertainties associated with the methane inventory maintained by the U.S. Environmental Protection Agency.

For starters, Washington lawmakers should aim at replicating Colorado's leak detection and repair programs, given that these programs can quickly remedy major leaks and potentially lead to improved inventories. My 2017 study, with Alan Krupnick of Resources for the Future, explores a variety of additional policies to reduce methane emissions that are compatible with possible federal climate policies, such as carbon taxes or clean energy standards. For example, a nationwide carbon tax could be modified for methane by imposing an assumed default rate of emissions per ton of natural gas produced. This default rate is necessary because of uncertainties regarding the quantification of methane emissions and the rate itself could be challenged by polluters via a pre-defined regulatory process. In this way, the default rate ensures that estimated methane emissions are not lower than in reality, while the challenge

process allows companies that beat the default rate to make their case. Similarly, a tradable performance standard could be constructed to achieve a certain leakage rate in the natural gas sector, an approach that could pair well with a broader clean energy standard as envisioned in President-elect Biden's climate plan.[57] Other proposals contemplate requiring the reporting of financial liabilities associated with methane and carbon emission on a company's financials, which would create a powerful incentive to maximize emission reductions.[58] Tougher federal regulation, combining the approaches outlined here, is an essential component of a comprehensive and credible strategy for reducing U.S. methane emissions.

PLUGGING OLD GAS WELLS

I managed a small team of researchers at Resources for the Future in 2015 and 2016 focused on estimating the economic and environmental impacts of end-of-life wells. We estimated that there are up to 2.67 million inactive oil and gas wells in the United States. Left unplugged, we found that these wells can emit methane, contribute to poor air quality, and contaminate surface water.[59] Moreover, our research uncovered that bonds posted by gas drillers, although intended to cover the cost of properly plugging wells, are not nearly enough to cover plugging costs in most states.[60] The result is a large pool of inactive wells that are improperly plugged. Methane emissions from abandoned wells are estimated to have the same climate impact as greenhouse gases emissions from 2.1 million passenger vehicles.[61]

Properly plugging abandoned wells is a prerequisite to achieve near-elimination of methane emissions from the entire natural gas lifecycle. Regulators should increase bonding requirements at the state and federal levels. Another approach would be the creation of a federal agency with dedicated funding to plug abandoned wells. Raimi et al. (2020) suggest that the Covid-19 pandemic in conjunction with low employment rates in the oil and gas industry justify such a federal program. The authors estimate that a significant federal program to plug abandoned wells could create tens of thousands of jobs.[62]

Near-elimination of methane emissions would also create lucrative new opportunities for U.S. natural gas exporters. For example, a recent strategy from the European Union on methane emissions suggests an imminent surge in demand for "green" natural gas exports with low methane emissions. Indeed, natural gas exports with anything more than low methane emissions may not be permitted to trade internationally. Concerns over methane emissions led the French government to recently block a liquified natural gas deal between a Texas company called NextDecade and a French company called Engie.[63] If methane emission are dramatically reduced, then exports of U.S. gas could help other countries reduce their carbon emissions.

MANAGING RISK AND UNCERTAINTY IN ENERGY POLICY

The evolution of America's zero-carbon energy transition is fraught with uncertainty. It is contingent on the evolution of technologies in various stages of development. Policymakers should therefore approach the subject with a degree of humility. After all, no one predicted 20 years ago that new drilling technologies would create a shale boom that has propelled the United States back to the forefront of world's leading oil and gas producers. Likewise, no one today can foresee the innovations and technological breakthroughs that could upend

today's prevailing assumptions about the best way to decarbonize our economy.

Uncertainty implies risk and the prudent way to manage risk is through diversification. Putting all our eggs in a single basket – through policies based on a singular vision of a zero-carbon grid powered by 100 percent renewables – is unwise. Unfortunately, some climate activists seem willing to bet everything on this single path to decarbonization.

The risk in taking this single path is that it will expose Americans to high electricity prices and potentially periodic energy shortages on the way to our destination. It may also, of course, lead to premature or unnecessary destruction of good jobs in the natural gas sector. The resulting political fallout could slow or even block American's clean energy transition. That is why President-elect Biden has made clear that, despite President Trump's claims to the contrary, he opposes fracking bans.

The pragmatic and progressive course forward is to pursue multiple avenues to decarbonization. Government and private industry should invest in a broad portfolio of energy sources and technologies that can lead us to zero-carbon energy generation and craft policies to ensure consistent and rapid progress. These energy sources and technologies include CCS and many other options including advancements in geothermal, hydrogen, and nuclear.

A bill introduced by Representative Diana DeGette, the Clean Energy Innovation and Deployment Act (CEIDA), embodies many of the principles discussed in this report.[63] CEIDA would create a standard that transitions the electricity sector to 100 percent clean energy. As part of that standard, zero and low emitting technologies will be rewarded by receiving credits that can be sold to dirtier technologies. Natural gas would receive partial credit, although associated methane emissions would be accounted for. Consequently, CEIDA strikes a balance between wind, solar, and gas that displays awareness about the risks of America's clean energy transition. In part because of this awareness, CEIDA received positive reviews from a wide array of environmental, industry, and labor groups.[64] Therefore, CEIDA provides a useful starting point for the Biden administration and Congress.

CONCLUSION

Natural gas generators can play an indispensable role in decarbonizing the electricity sector by providing dispatchable energy that backstops rapid deployment of renewable energy. A bargain that invests in CCS technologies while requiring that industry dramatically reduce methane emissions would facilitate the deployment of zero-carbon natural gas generation. Such a bargain would accelerate high penetrations of renewables while achieving low electricity prices and ensuring grid reliability. These conditions are tailored for achieving widespread decarbonization because cheap electricity prices in a zero-carbon electric grid can then be leveraged to electrify the entire economy, including industry and transport. Natural gas generators with CCS technologies paired with low methane emissions from the natural gas lifecycle represents a strong path forward for achieving President-elect Biden's goal of a carbon pollution-free electric sector by 2035 and a net-zero emissions economy by 2050.

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PROGRESSIVE POLICY INSTITUTE
1200 New Hampshire Ave NW,
Suite 575
Washington, DC 20036

Tel 202.525.3926
Fax 202.525.3941

info@ppionline.org
progressivepolicy.org