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Natural Gas: Bridge or Wall in Transition to Low-Carbon Economy?

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Natural gas as a power plant fuel has already played an important role in a transition to a low-carbon economy. Electricity-sector carbon dioxide emissions in many US states are at some of the lowest levels in the past two decades thanks to a variety of factors, including increased efficiency, deployment of renewables, and structural changes in the electricity sector, such as a transition from coal to natural gas–fueled power generation.[1]

This article focuses on the role natural gas has played in CO_2 reductions on the one hand, and the role it will continue to play on the other. Experience over the past two decades shows that natural gas enables a transition away from higher-emitting coal power plants, and looking forward, natural gas can help to integrate variable energy resources such as solar and wind within a smaller fossil-fuel footprint than today.

Putting too much investment today into this single strategy risks a long-term lock-in of CO_2/methane pollution levels that will allow global temperature to rise more than 2°C.

However, while a transition to gas-fueled electricity is a carbon-reduction strategy for a coal-reliant power system, putting too much investment today into this single strategy risks a long-term lock-in of CO_2/methane pollution levels that will

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allow global temperature to rise more than 2°C.[2] To achieve international climate targets, natural gas's role in electricity generation will need to be secondary to zero-emitting resources such as solar, wind, geothermal, and ocean energy by midcentury.

This article assumes positively that power generation from natural gas electricity has a lower greenhouse gas footprint than coal-fired electricity, megawatt-hour to megawatt-hour. While there are analyses that suggest that full wellhead-to-generation accounting for methane leakage could result in natural gas having a larger greenhouse gas footprint than oil or coal,[3] the question is beyond the scope of this article.

RGGI, CARBON REDUCTIONS, AND NEW ENGLAND

The nine US states that are members of the Regional Greenhouse Gas Initiative (RGGI) have experienced carbon emissions reductions from power plants by almost half (48.8 percent) since 2005. These reductions are not solely due to RGGI, but rather to a portfolio of complementary energy and environmental programs and market changes. The state program portfolios consist of energy efficiency; renewables; stringent air emissions limits on NO_x, SO_x, and air toxics; and power-sector electricity restructuring in eight of nine RGGI states, which in turn facilitated market changes.

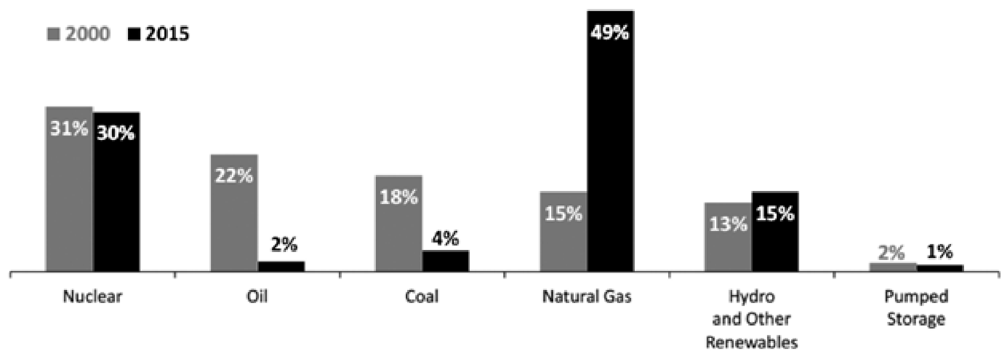
This state-led electricity restructuring at the end of the twentieth century, together with US federal legislation including the Public Utility Regulatory Policies Act and the Energy Policy Act of 1992, significantly opened the power-plant business to private merchant development of natural gas plants. As a result, there was a building boom of combined-cycle natural gas plants during this period. New England moved along more quickly than the rest of the country on switching from coal to natural gas. This transition led to the retirement of older, inefficient coal and oil burners.

By 2015, 45 percent of New England's net electricity was generated by natural gas-fueled power plants, compared to 15 percent in 2000.[4] Coal dropped from providing 18 percent of New England's electricity in 2000 to 4 percent in 2015, and oil dropped from providing 22 percent to just 4 percent of New England's electricity.[5] See **Exhibit 1**.

The Clean Power Plan (CPP), other US federal rules governing air toxics and criteria air pollutants, and market forces driven by inexpensive gas[6] will lead many other regions to a power mix that looks more like that of the RGGI states. To illustrate, the US government's official *Annual Energy Outlook* (*AEO* 2016) projects much more net electricity from natural gas (and renewables) nationwide. The projection is for even more natural gas-fired and renewable electricity with the CPP in place, but the trend will continue regardless. See **Exhibit 2**.

What lessons can we learn from the RGGI states and New England's transition? The formation of the RGGI program appears to have been the most significant explanatory factor behind the RGGI states' 48.8 percent CO_2 reductions to date. While natural gas, renewables, and the economy played a role, the formation of

Exhibit 1. Percentage of Total Electric Energy Production by Fuel Type (2000 vs. 2015)



Source: ISO New England Net Energy and Peak Load by Source
Other renewables include landfill gas, biomass, other biomass gas, wind, solar, municipal solid waste, and miscellaneous fuels

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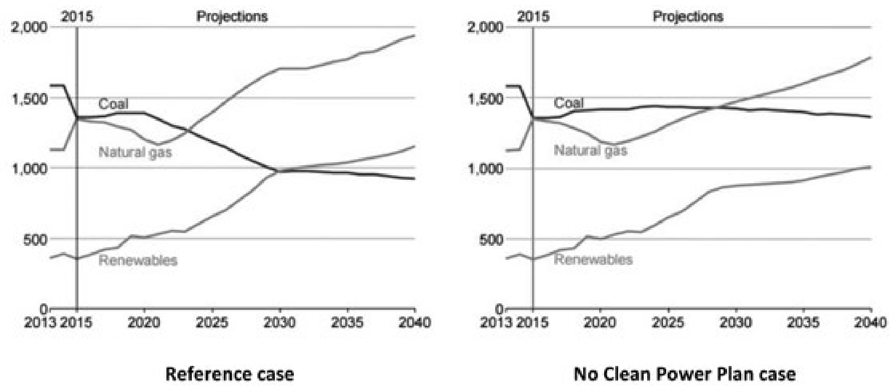
Exhibit 2. Net Electricity Generation From Coal, Natural Gas, and Renewables, 2013–40 (Billion kWh)1



[1] *AEO* 2016. Figures ES-1 and ES-2, p. ES-2; Figures MT-28 and MT-29, pp. MT-15–MT-16; Figures MT-30 and MT-31 and discussion on p. MT-17.

RGGI itself is the largest explanatory factor for the RGGI states' carbon reductions.

These conclusions are drawn from an analysis of the RGGI states' carbon reductions using econometric methods to compare the RGGI states' carbon-emission trends to the rest of the Lower 48 states over the same time period.[7] This analysis shows that RGGI itself had the strongest explanatory effect on the emissions reductions in the RGGI states.[8] Low natural gas prices, the recession, and state renewable portfolio standards (RPSs)[9] also had an impact on emissions reductions to a lesser degree than RGGI itself. To state it another way, the largest factor in the RGGI states' carbon-emission reductions was the RGGI program itself; the decrease in gas prices and recession played a substantial but lesser role in these emissions reductions.[10]

In fact, while natural gas was not the largest driver, the RGGI carbon program accelerated coal-to-gas switching in the power sector.[11] One study found that the RGGI states experienced coal-to-gas switching at a 10 to 15 percent higher rate than other states;[12] in other words, switching in the RGGI states was 10 to 15 percent higher than in non-RGGI states.

The lesson from the RGGI states' experience is that focused carbon programs, well-designed and well-implemented, make a difference together with other effective complementary programs, such as RPSs and electricity-sector reform, to facilitate a transition to a portfolio of lower-cost resources—more natural gas generation, but also energy efficiency, renewable energy, and demand-side management.

NATURAL GAS AS A "BRIDGE FUEL"

The RGGI experience supports the conventional wisdom that natural gas may act as a "bridge fuel" to move away from higher-polluting coal and oil. But the bridge fuel hypothesis also postulates that there will be a follow-on transition to renewables as a primary generation resource.

> The Achilles' heel in the bridge-fuel hypothesis may be that overinvestment in natural gas infrastructure can undercut the transition.

Though power plant emissions from natural gas are about half of coal's emission footprint on a per-energy-unit basis,[13] the Achilles' heel in the bridge-fuel hypothesis may be that overinvestment in natural gas infrastructure can undercut the transition to lower-emitting technologies. In the short run, there is a distinct possibility that optimistic gas-price financial models and cost-allocation constructs that encourage natural gas switching result in overbuilding interstate and intrastate pipelines, local gas distribution facilities, and gas power plants. This could permanently undercut a transition to renewables, efficiency, and other advanced energy technology resources.

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Eventually, to go beyond the modest 2030 CPP carbon-reduction goals will require more investments in solar, wind, other, and renewables to achieve long-term carbon reductions consistent with international agreements.[14] One analysis suggests that an overreliance on natural gas beyond the short term may entirely erase any climate benefit from the coal to gas transition in the early years.[15] Substituting natural gas for coal power plants may confer climate benefits, but delays in deploying low-emission power may offset natural gas's climate benefits in the long term.

There is another significant consideration in mature electricity markets in developed economies: a saturation of generation capacity. Most US regional transmission organizations (RTOs) and indeed Western economies have an abundance of generation capacity. End-use efficiency and demand-side management are reducing demand growth for electricity.

The "absorption capacity" for low- and zero-carbon resources will be yet lower with overcapacity and overinvestments in a bridge-fuel infrastructure, and will tend to make the economics of low-carbon resource investments harder in both the short and long term.

HOW FAR SHOULD THE BRIDGE GO?

Natural gas–powered turbines have the capacity to ramp up and down quickly.

That enables gas-fueled turbines including advanced combined-cycle units to provide valuable load-balancing, voltage support, and frequency regulation as wind and solar generation output varies. This role will become more important as more variable renewable resources are put in service.[16] Thus, the ability of natural gas units serves an important function to integrate renewables with today's technology.

There are, nonetheless, limitations on the flexibility of a natural gas–fired power plant caused by upstream gas supply and transportation arrangements. The gas may not be delivered. A gas turbine without fuel on a peak-demand day is neither flexible nor reliable.

For some natural gas combined-cycle turbines (NGCCs), flexibility varies widely, again further constrained by the upstream fuel arrangements, due to limitations on minimum stable load, restart after a shutdown, and the NGCC longevity impacts from multiple stop-start cycles. Again, for an NGCC turbine, ramping up and down is valuable but may imply that an NGCC needed in a few hours will need to be paid to be on-line at some rated load (as high as 40–50 percent) whether it is economic or not, resulting in curtailment of lower-marginal-cost resources (particularly zero-bidding renewables). It is likely less expensive and more effective to utilize some amount of controllable demand, including emerging end-use energy storage, and flexible demand-side options[17] than to use gas-fired combustion turbines (CTs) and NGCCs for integration, especially if one factors in the upstream fuel supply and transportation investments likely needed to accommodate more CTs and NGCCs.

Putting aside that debate of the long-term climate forcing effect of using more natural gas, there is a question of whether natural gas transition from coal, even assuming the best-case methane leakage scenario, will allow for the global temperature rise to stay under 2°C. Since this is a question of global temperature rise, it is appropriate to examine the best international analysis to determine if natural gas as a primary strategy can support an energy-sector transformation consistent with keeping the global temperature rise well under 2°C.[18] Analysis by the International Energy Association finds that even under the best set of assumptions for natural gas, including inexpensive gas production on multiple continents, the international goal of maintaining climate change to under 2°C will not be met.[19] This quite directly reinforces the lesson learned in the RGGI states that multiple complementary programs can be effective and also will be needed to reach deeper carbon-reduction targets—relying on any one strategy, whether a carbon market or natural gas switching, will not result in deep CO_2 reductions.

To achieve the requisite 80 to 90 percent reductions in greenhouse gases by 2050 under international agreements, the primary long-term role for natural gas without carbon sequestration is primarily as a fuel for power-balancing resources[20] together with other technologies. In a well-known study, four scenarios are modeled to achieve a 2050 emissions target of 750 metric tons of CO_2: "High Renewable," "High Nuclear," "High CCS," and "Mixed Case." The "High Renewable" scenario requires the highest demand for non-carbon-capture-and-storage gas as a balancing resource among the four pathways evaluated. In sum, most US states are fortunate that shale gas makes US CPP compliance affordable.

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But gas alone will result in less carbon reductions and more consumer expense than when paired with other complementary programs such as energy efficiency,[21] carbon markets such as RGGI, carbon pricing, innovation in demand-side flexibility options, and renewable requirements such as state RPSs.

A BRIDGE—OR A WALL?

Role of Government Policy

Efficiency dictates that policy should first encourage use of existing underutilized infrastructure**.**

The Federal Energy Regulatory Commission (FERC) and state public utility commissions could focus on making clear the cost of using pipeline, storage, peak shaving, and related gas infrastructure inefficiently, as well as ensuring that the benefits of more efficient use of this infrastructure have value. Policies and pipeline tariffs can ensure that flexible customers and innovative companies have the price signals and access to revenue opportunities to utilize existing infrastructure efficiently.

Natural gas pipeline companies are allowed to recover costs plus a profit without necessarily ensuring that their existing pipelines are fully utilized. That reflects regulatory requirements that do not reward capacity release and more frequent pipeline nomination cycles. Pipeline companies can effectively utilize existing assets through daily pipeline capacity nomination opportunities. The Algonquin/Spectra pipeline system does just that, compared with the Tennessee Gas Pipeline/Kinder Morgan pipeline system with less frequent nominations. Pipelines should make available and allow shippers to utilize the existing infrastructure fully before ratepayers are required to pay for more pipelines and other infrastructure.

Ratepayers should pay for and utilities should build what is needed and no more. If infrastructure is needed to ensure generation of peak-day electricity together with demand-side management, we know how to do that in each RTO and regulated utility service territory. If infrastructure is needed to ensure deliverability of a certain amount of natural gas to certain local distribution companies (LDCs) and to the power sector on a peak day, we do not know how to do that—so it should be a regulatory priority to develop FERC and public utility commission mechanisms to ensure that ratepayers do not pay for pipelines to ensure combined heating and power-sector gas deliverability.

For these reasons, federal and state policy can focus on getting natural gas and related electrical-sector investments right in the short and long term. Utilizing existing infrastructure efficiently should be the first priority. The initiative to facilitate and require better gas–electricity sector coordination by FERC is a good start. Market and rate designs that seek to have the real-time cost of meeting the demand for energy and reserves during critical-peak and critical-trough hours fully reflected in wholesale electricity prices—and, to the extent possible and equitable, in time-varying retail rates—will ensure that consumer and ratepayer demand is comparable to the real-time cost of energy supply. One move in the right direction is the ongoing FERC effort to root out and prohibit uplift payments that socialize the costs of inflexible fuel supply and transportation arrangements, rather than requiring costs to be recovered in the energy and ancillary services markets.

More effective utilization of existing pipelines together with diversifying supply and demand would keep incremental infrastructure additions at modest levels, according to US Department of Energy (DOE) analysis.[22] Procuring energy conservation, efficiency, and demand response, for example, diversifies electricity-sector demand for natural gas and can be more cost-effective than building pipelines to supply fuel to natural gas power plants to address peak electricity load.[23] Better management of LDC storage and peak-shaving facilities, as well as retrofitting existing facilities, may be more efficient than building entire new pipeline facilities. One aspect of the US DOE analysis that is right on point is the finding that more diverse sources of supply and demand and higher utilization of existing infrastructure reduces the need for new pipelines. DOE found that even implementation of a national carbon policy would only require modest incremental infrastructure needs.[24]

While effective utilization of existing resources and diversifying supply and demand will ensure ratepayers' costs for new pipelines are modest, these measures also reduce the risk of overinvestment (that ratepayers would be forced to pay for) and reduce investors' economic losses. With ratepayers protected, government policy can ensure that gas investment does not crowd out zero-emissions resources over the long term and become a climate wall. Careful design of programs to support zero-emissions resources through establishment and strengthened programs to support efficiency, renewables, and advanced energy technologies are necessary complements to natural gas and carbon markets in a long-term transition.[25]

Government Incentives

Government incentives should reflect economic efficiency—making the most of what infrastructure ratepayers have paid for; investment in the most cost-effective resources over the long term; and reserve policy incentives for clean resources, particularly nonemitting resources such as energy efficiency, demand response, and renewables. Energy conservation and efficiency is not only the most cost-effective resource, but it functions to stretch the use of natural gas as both an electricity and heating fuel.

Energy efficiency has the potential to eliminate the need for oil, coal, nuclear, and one-third of current gas use by 2050.[26]

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Recognizing Risk and Flexibility

While natural gas is projected by optimistic analysts to be inexpensive for a long time, it has been among the most volatile fuels in terms of price. Recent history reveals the price of natural gas has fluctuated by more than 400 percent over the past two decades. Future price projections vary but fall in the same range.[27]

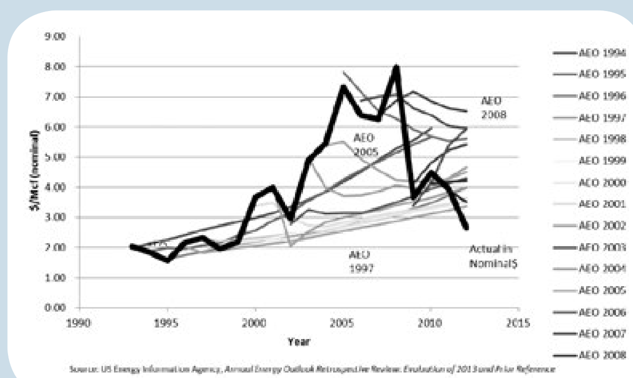
Even the experts have repeatedly been wrong on natural gas price projections. **Exhibit 3** shows how the Energy Information Administration's projections for natural gas costs have moved up and down—obviously this should not happen if projections are accurate. In reality, government and market experts alike have been far off on underlying fuel costs and how they translate into long-term prospects for electricity prices. This history suggests that there is hardly a guarantee that future natural gas prices will be any more stable than in the past.

There is a second reason why gas prices are unpredictable, particularly winter prices. Private industry actors make large-scale gas storage and storage release decisions. If the private actors get these decisions wrong in some winters when demand is high, it may not matter how much cheap gas is in the ground. In the winter, gas extraction, collection, processing, storage, pipeline, and distribution system cannot get cheap gas from the ground to power plants during an extended cold snap toward the end of winter. Government has to accept the outcome of private market actions that leave the power sector, energy stakeholders, ratepayers, and consumers exposed to some degree of risk, because to remove this risk would cost too much.

There is a third reason why addressing this risk in current markets is expensive: Even when gas is relatively cheap, the cost of new natural gas supply infrastructure is not. As the current market design relies on long-term take-or-pay contracts for pipeline capacity, payable irrespective of the extent to which the customer utilizes those transportation services, the actual cost-in-use under those contracts can be far more expensive than the natural gas being transported.

In short, there is price risk for a natural gas supply commitment that increases the risk of natural gas infrastructure investments. The commodity-price risk for fossil fuels is necessarily greater than the price risk of resources such as solar and wind that are not subject to fuel-price volatility. If natural gas prices increase in the future, expensive new infrastructure could become a stranded cost that ratepayers or investors bear as the market changes.

Exhibit 3. Historic Natural Gas Wellhead Price Projections and Actual (Heavy Black Line)



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CONCLUSION

Inexpensive natural gas provides a low-cost transition path from higher-carbon-content fuels such as coal and petroleum. For economic and pollution-reduction reasons, more natural gas is needed for electricity production in parts of the United States and around the world. But betting too much on natural gas and its infrastructure intensive requirements could result in overinvestment in infrastructure that is unnecessary in the short and long run, creates stranded assets, and suppresses investments in low-carbon resources.

As such, finding a careful balance of natural gas and renewable energy/advanced technology portfolios is one of the most pressing imperatives for governmental officials and energy industry stakeholders.

NOTES

1. California's CO_2 emissions from the electricity sector decreased 21.4 percent from 1980 to 2013, Connecticut's decreased 32.7 percent, Massachusetts's decreased 51.4 percent, and New York's decreased 40 percent. See EIA. Electric Emissions by State (1980 to 2013). Retrieved from http://www.eia.gov/environment/emissions/state/.
2. The goal of keeping global temperature risk well below 2°C is part of the Paris Agreement. Retrieved from http://unfccc.int/paris_agreement/items/9485.php.
3. Howarth, R. (2014, May). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas. *Energy Science & Engineering*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/ese3.35/abstract;jsessionid=B25B4608D6ED6DB7E289EB7ABBEF289A.f02t02. Compares warming potential of methane versus CO_2 over a 20-year period and concludes that both shale gas and conventional natural gas have a larger greenhouse gas footprint than coal or oil, for any possible use, but particularly for heating.
4. ISO-NE. (2016, January 26). *State of the Grid, ISO* on Background, slide 13.
5. Ibid.
6. Natural gas prices have been low and may stay low on a Btu basis for decades to come. See, for example, the *AEO* reference case pricing projections. See Energy Information Administration. (2016). *Annual energy outlook 2016*. Table 3, Energy Prices by Sector and Source, Appendix A, p. A-6. Retrieved from https://www.eia.gov/forecasts/aeo/pdf/0383(2016).pdf.
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8. Ibid.
9. Ibid. The point estimate in the study implies that an RPS increase of 10 percent would decrease emissions by about 3 percent.
10. Ibid., pp. 587–588. The counterfactual simulation removing RGGI from the RGGI states suggest that emissions would have been 24 percent higher without RGGI, whereas the counterfactual simulations for the recession, lower natural gas prices, and RPS policies suggest that each factor would have caused emissions to be 12 to 15 percent higher.
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12. Ibid., p. 330.
13. See, e.g., note 8, p. 583 ("Natural gas is the lowest GHG-emitting fossil fuel, producing about 47 percent of the carbon dioxide per energy unit of coal." Citing Moomaw et al., 2011).
14. Macedonia, J., Beasley, B., & Smith, E. (2016, June). Modeling the evolving power sector and impacts of the Final Clean Power Plan. Bipartisan Policy Center, slide 41.
15. Zhang, X., Myhrvold, N., Hausfather, Z., & Caldeira, K. (2016, April). Climate benefits of natural gas as a bridge fuel and potential delay of near-zero energy systems. *Applied Energy*. Retrieved from http://dx.doi.org/10.1016/j.apenergy.2015.10.016.
16. Hydroelectric generation can provide the same load-balancing, voltage support, and frequency regulation service. However, many regions do not have hydro capacities. Moreover, in restructured markets, hydro facility owners may not be willing to dedicate their units to supporting renewable generation.
17. Lazar, J. (2016). *Teaching the "duck" to fly—Second edition.* Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/knowledge-center/teaching-the-duck-to-fly-second-edition/.
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19. International Energy Agency. (2012). *Golden rules for a golden age of gas: World Energy Outlook special report on unconventional gas.* Paris: Author. Retrieved from http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf.
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26. See RMI's take on gas in *Reinventing Fire*. Retrieved from http://www.rmi.org/reinventingfire.
27. *AEO* 2016. Figure MT-42, p. MT-23.