The Natural Gas Gamble

A Risky Bet on America's Clean Energy Future

Union of Concerned Scientists

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This report and an accompanying technical appendix are available online (in PDF format) at *www.ucsusa.org/nautralgasgamble*.

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The U.S. electricity sector is in the midst of a major change, as power producers shift away from coal to natural gas as their primary fuel.

While this rapid shift is providing important near-term environmental and economic benefits, strong evidence suggests that becoming too reliant on natural gas poses numerous complex risks, including persistent price volatility, climate-changing emissions from combustion and the leakage of methane, and water and air pollution from natural gas production. Our analysis shows that a wholesale shift to natural gas makes less economic sense than would prioritizing investments in renewable energy and energy efficiency. A more diversified energy mix will result in an affordable and climate-friendly power sector. With sensible policies in place, natural gas could play a useful—though more limited—role in a clean energy system, especially if it came to be seen not as a replacement for coal but rather as an enabler of grid flexibility in support of renewable technologies.

A Historic Shift from Coal to Cleaner Forms of Electricity

From 2007 to 2013, coal's share of the U.S. electricity mix declined from about half to just 39 percent while natural gas generation's share grew from 22 percent to 27 percent (EIA 2014). Higher coal prices, standards aimed at limiting harmful pollution from coal-fired power plants, and sharp declines in natural gas prices driven primarily by U.S. shale gas production are leading utilities to choose natural gas over coal for meeting electricity demand. The choices being made in the power sector today to replace retiring coal power and meet our growing electricity needs merit further examination because they will have major consequences for our economy, health, and climate for decades to come.

[*Strong evidence suggests that becoming too reliant on natural gas poses numerous complex risks.*]

The Natural Gas Gamble examines the risks and near-term rewards of the recently growing contribution of natural gas combustion to electricity generation and explores the costs and benefits of various possible energy pathways as the United States transitions to a low-carbon economy. We present the findings of an analysis of the national electric sector which highlights how renewable energy and energy efficiency can reduce the risks of overreliance on natural gas, cut carbon emissions, and contribute to a diverse and well-balanced clean energy supply. This analysis also outlines a more balanced role for natural gas in a carbon-constrained power sector.

Risks and Rewards of the Natural Gas Surge

The burning of natural gas instead of coal to generate electricity offers important and immediate benefits, including reduced air and water pollutants emanating from power plants, fewer smokestack carbon emissions, less power plant water use, greater flexibility of the power grid, and renewed economic development in gas-rich regions of the country. These advantages, along with the current economic favorability of natural gas, have led some states to increase rapidly their dependence on natural gas. In just five years, Florida has increased the share of its electricity generated from natural gas from 44 percent to 62 percent. Many other states, including Virginia, Delaware, Ohio, and Pennsylvania, are following a similar path.

However, these rewards must be carefully weighed against the risks associated with this rapid adoption of natural gas as the electricity sector's new fuel of choice. Central among these risks is historical and continued natural gas price volatility. Despite the shale gas surge, upward pressure on prices is likely to result from increases in demand for natural gas for electricity and other competing uses—including home heating, industrial production, and transportation—uncertainties about supply, and potentially increased exportation of U.S. natural gas. Such price volatility can harm consumers and the economy.

Smokestack emissions from natural gas combustion are significantly cleaner than from coal combustion; however, the extraction, distribution, and storage of natural gas result in the leakage of methane, a powerful global warming gas 34 times stronger than carbon dioxide at trapping heat over a 100-year period. Methane leakage diminishes the climate advantages of natural gas over coal. Furthermore, increasing our reliance on natural gas could delay the deployment of much cleaner renewable energy, putting us at greater risk of failing to meet the level of emissions needed to avoid the worst consequences of climate change (Newell and Raimi 2014; Shearer et al. 2014; EMF 2013; Fleischman, Sattler, and Clemmer 2013).

Natural gas production, particularly hydraulic fracturing, also presents serious risks to public health and the environment. These risks include potential contamination of drinking water supplies by chemicals used in hydraulic fracturing and air pollution from natural gas operations (EPA 2012a; Haluszczak et al. 2012; EPA 2011; Rowan et al. 2011).

If natural gas use continues to grow, the industry will need to invest in costly new infrastructure, including pipelines and processing and storage facilities. These investments may lock us into a high-carbon future. And, as public pressure to address climate change grows, much of this costly infrastructure will have to be abandoned, rendering it a "stranded asset." Given limited financial resources and growing climate risks, investment in renewable energy infrastructure would involve less risk to consumers and the economy as a whole.

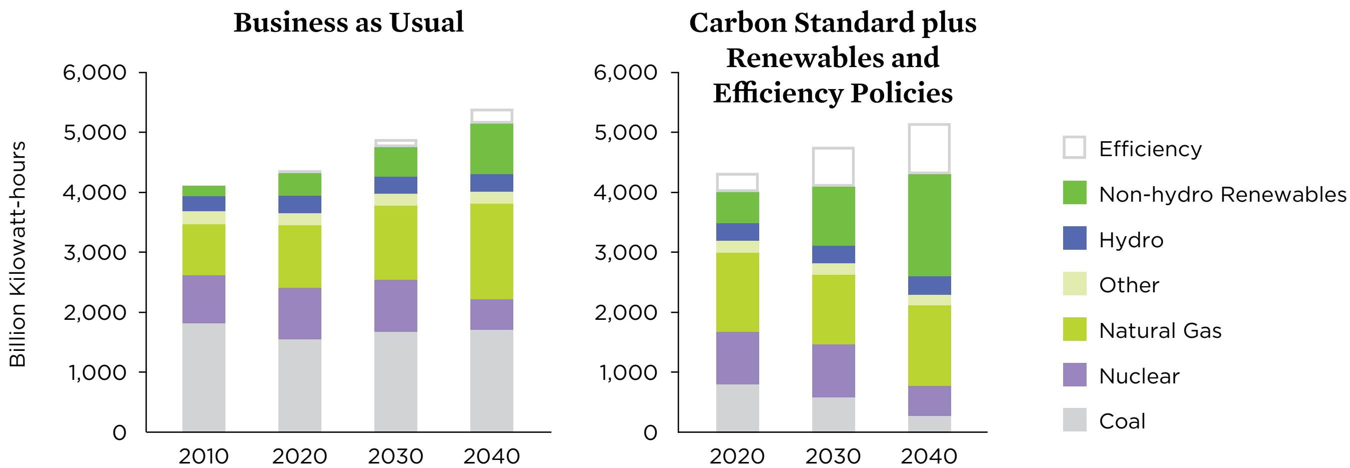
Investing in Renewable Energy and Energy Efficiency: A Better Path Forward

Using the Energy Information Administration's National Energy Modeling System, we analyzed the effects of climate and clean energy policy scenarios on the electricity sector, consumers, the economy, and carbon emissions for the period through 2040. We examined three main scenarios: the Business as Usual Scenario (the projected path of the U.S. electricity sector without changes to current policies); the Carbon Standard Scenario, which places a declining limit on carbon emissions from the U.S. electricity sector to achieve at least a 45 percent reduction from 2005 levels by 2030 and at least a 65 percent reduction by 2040; and the Carbon Standard plus Renewables and Efficiency Policies Scenario, which includes similar emissions limits as the Carbon Standard Scenario plus a suite of strengthened renewable energy and energy efficiency policies. We also separately examined the impact of different natural gas prices on the outcomes of these scenarios.

Our analysis reveals the following key findings:

- A business-as-usual electricity future would put the United States on a pathway of greater natural gas use, rising carbon emissions, and higher natural gas and electricity prices (Figure ES-1). In a Business as Usual scenario:
  - Total natural gas use is projected to increase by nearly 18 percent between 2013 and 2040, with the power sector representing the largest share of this increase at 49 percent.
  - Power sector natural gas prices are 2.3 times higher in 2040 than in 2013, and average consumer natural gas prices nearly double.
- By replacing gas- and coal-fired generation with renewables and efficiency, the Carbon Standard plus Renewables and Efficiency Policies Scenario results in a total electricity resource mix portfolio that is 14 percent less sensitive to long-term fluctuations in fossil fuel prices.
- Implementing a carbon standard along with renewable energy and energy efficiency policies results in long-term savings on consumer energy bills as it cuts carbon emissions and raises carbon revenues. While investments in renewables and efficiency result in net costs of $19 billion in 2020, consumers would see annual net savings add up to $40 billion by 2030, rising to $59 billion by 2040.
- Increasing the share of renewable energy and energy efficiency is an important way to hedge against economic

FIGURE ES-1. U.S. Electricity Generation, Business as Usual, and Carbon Standard plus Renewables and Efficiency Policies Scenarios



In the Business as Usual Scenario, the United States burns more natural gas than currently, even though the contribution of non-hydro renewables increases, to meet the projected growth in electricity demand. Although coal generation is projected to decline through 2016, due primarily to low natural gas prices and retirement of some older plants, model projections show that it rebounds some in the later years of the forecast in response to rising natural gas prices and growing electricity demand. The U.S. electricity generation mix would be cleaner and more diverse if a carbon standard were combined with strong renewables and efficiency policies. In the Carbon Standard plus Renewables and Efficiency Policies Scenario, the share of non-hydro renewables grows six-fold to 39 percent of total generation by 2040, energy efficiency reduces electricity demand by 16 percent, and the share of natural gas generation remains mostly constant.

and climate risks in a future that includes uncertain natural gas prices. This strategy helps lower consumer electricity bills and carbon emissions under a range of possible future natural gas price scenarios.

- Electricity bills in 2040 are lowest in the Carbon Standard plus Renewables and Efficiency Policies Scenario with baseline and high gas price forecasts.
- In 2020, the societal benefits of pursuing carbon emissions reductions are 2.6 times greater than the consumer compliance costs, or nearly $36 billion. By 2040, the compliance costs of the Carbon Standard plus Renewables and Efficiency Policies Scenario are actually slightly lower than business as usual, primarily because of lower fuel expenses as we shift to more renewable energy and energy efficiency. As a result, the net societal benefits grow to nearly $170 billion in that year (Figure ES-2, p. 4).
- Combining a carbon standard with renewable energy and energy efficiency policies can reduce power plant carbon emissions 70 percent below 2005 levels by 2040. As part of a global effort to help limit some of the worst consequences of climate change, further reductions in U.S. power sector carbon emissions will be needed by midcentury.

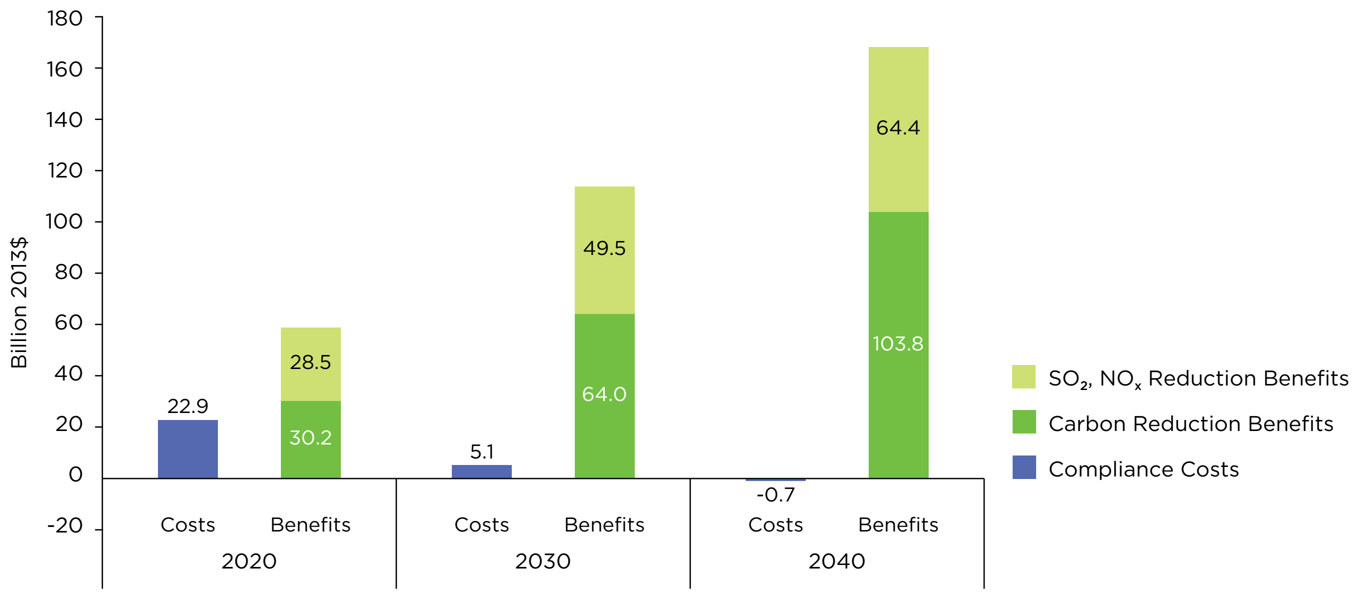
An electricity sector that will burn increasing amounts of natural gas, emit more and more carbon, and contribute to higher natural gas and electricity prices is clearly unacceptable. Our analysis shows that a combination of a carbon standard with complementary renewable energy and efficiency policies can cut power plant carbon emissions significantly while reducing our long-term reliance on natural gas, lowering costs, and providing important public health benefits.

Working Toward an Appropriate, Balanced Role for Natural Gas

Our analysis indicates there is a strong need for changes in policy if we want to minimize the pitfalls of an overreliance on natural gas. Investing more heavily in renewable energy and energy efficiency can put us on a smarter, shorter, and less risky pathway toward a more affordable, reliable, and diversified electricity system that delivers not just near-term economic and environmental gains but also the long-term goal of addressing climate change.

The Environmental Protection Agency's Clean Power Plan—a forthcoming federal standard designed to limit power sector carbon emissions—provides a valuable near-term

FIGURE ES-2. Benefits and Costs of Policies That Limit Carbon Emissions, relative to Business as Usual Scenario



Our modeled scenarios show that the benefits of transitioning to cleaner power clearly outweigh the costs. "Compliance costs" are the incremental costs of deploying a cleaner generation mix in our Carbon Standard plus Renewables and Efficiency Policies Scenario relative to costs included in our Business as Usual Scenario. "Benefits" are the monetized damages avoided by reducing emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x).

opportunity for utilities, regulators, and policy makers to accelerate the transition to an electricity system powered primarily by renewable energy and energy efficiency (Cleetus et al. 2014a). States play a crucial role in ensuring the success of the Clean Power Plan and should prioritize the use of renewable energy and energy efficiency to meet as much of their emissions reduction target as possible.

Policy makers should adopt additional or strengthen existing policies to hasten the deployment of renewable energy and energy efficiency resources. Such policies should include renewable electricity standards, energy efficiency resource standards, carbon pricing programs, extended tax incentives and other financial incentives for renewable energy and energy efficiency, and deployment of combined heat and power systems.

Strong state and federal laws and regulations are also needed to limit methane emissions from natural gas operations and to address the risks to public health and safety resulting from hydraulic fracturing. We must also modernize the U.S. electric grid and the rules that govern it as we transition away from coal to a cleaner, more modern, and efficient electric system.

The choice is clear. As the nation moves away from coal, setting course toward a diverse supply of low-carbon power sources—made up primarily of renewable energy and energy efficiency with a balanced role for natural gas—is far preferable to a wholesale switch to natural gas. By making smart energy choices today, we can transition to a more consumer-friendly and diverse electricity system, achieve cost-effective CO_2 emissions reductions, and face fewer risks stemming from an overreliance on natural gas.

There is a strong need for changes in policy if we want to minimize the pitfalls of an overreliance on natural gas.

> ***The transition away from coal presents an unprecedented opportunity to set a new course for how we supply electricity in the United States.***

In August 2014, Alabama Power Company announced that it would convert three coal units at the Barry plant in Mobile County to natural gas (Walsh 2014). That same month, Illinois-based NRG Energy Inc. reported that its coal power plant in Joliet would be converted to natural gas (Wernau 2014). Similarly, in November 2013, the Tennessee Valley Authority (TVA)[1] announced that it would retire two large, 1960s-era generating units at its Paradise coal plant near Drakesboro, Kentucky, replacing them with a $1 billion natural gas power facility at the same location (TVA 2013).

Recent announcements such as these reflect a predominant trend in the energy choices electric utilities have been making lately—contributing to the biggest shift to have occurred in the U.S. power sector in the past half century. Our nation's dependence on coal-fired power is decreasing as aging and polluting power plants struggle to remain competitive. Coal accounted for about half of our nation's electricity supply in 2007 but provided just 39 percent of the nation's electricity by 2013 (EIA 2014a). Since 2009, utilities have announced plans to close or convert to natural gas more than 430 coal generators in 37 states—equal to about 20 percent, or 70 gigawatts (GW), of total U.S. coal power capacity (Fleischman et al. 2013).

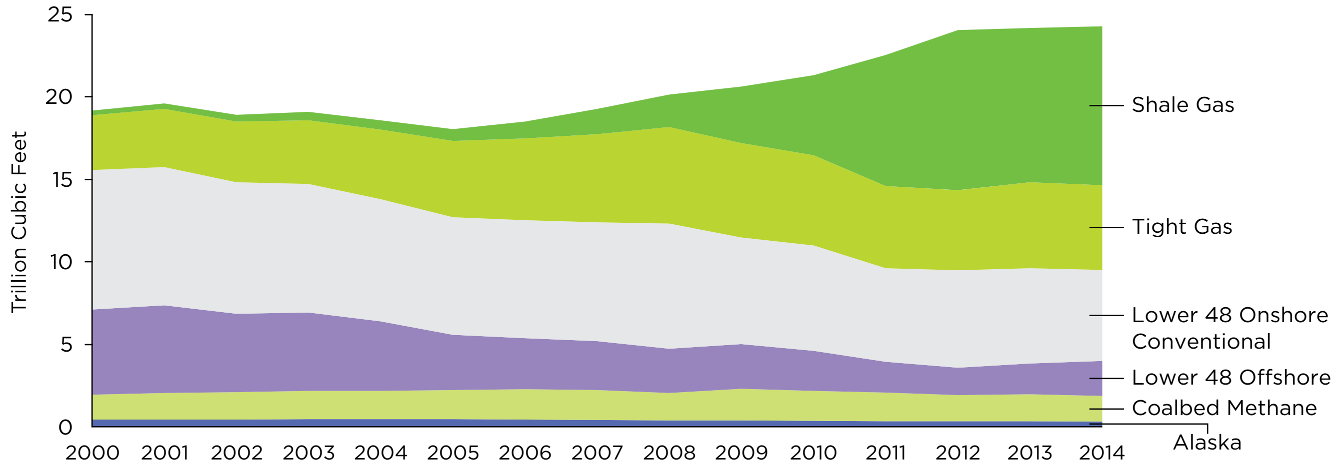
A combination of market and policy factors is driving these changes. The cost of coal has risen in recent years (EIA 2014b), especially in comparison with the competition, and many coal-fired generators have exceeded their intended design and economic lifespan. If older units are to remain in service, owners will face the cost of upgrading pollution controls in order to address serious public health risks in addition to the cost of general refitting (Cleetus et al. 2012). Other market factors making coal less attractive include low natural gas prices, reduced growth in electricity demand, and the rapid growth of energy efficiency and renewable energy resources due to falling costs and successful policy measures (Cleetus et al. 2012).

This transition away from coal presents an unprecedented opportunity to set a new course for how we supply electricity in the United States. All utility-scale energy decisions entail major financial investments in long-lived infrastructure that are not easily modified. Furthermore, the electric power sector is the largest single contributor to U.S. global warming pollution, and coal plants alone were responsible for 78 percent of electric sector carbon dioxide (CO_2) emissions in 2013 (EIA 2014c). These facts mean that the choices we make today to retire coal power and build infrastructure to meet our growing electricity needs will have major consequences—both risks and opportunities—for our economy, health, and climate for many decades to come.

As indicated by the recent Alabama Power, NRG Energy, and TVA announcements, many power providers are choosing to invest in natural gas to replace coal-generated electricity. On the surface, switching from coal to natural gas may appear a sound decision. Natural gas prices have fallen sharply in recent years, due largely to advances in hydraulic fracturing ("fracking") and horizontal drilling techniques that have made more natural gas reserves accessible and driven a more than six-fold increase in U.S. shale gas development

1 *The TVA is a federally owned corporation that largely produces wholesale power. It provides electricity to approximately 9 million customers in several southeastern states.*

FIGURE 1. U.S. Natural Gas Production by Source, 2000 to 2014



Recent advances in hydraulic fracturing and horizontal drilling techniques have spurred a rapid increase in the production of natural gas from shale resources. Since 2007, shale gas production has increased more than six-fold and now accounts for 40 percent of total U.S. natural gas production. The U.S. Energy Information Administration projects that the growth in shale gas production will continue through at least 2040 (EIA 2014c).

SOURCE: EIA 2014C.

since 2007 (Figure 1) (EIA 2014c). Compared with coal, natural gas generation also offers other important and immediate benefits, including reduced harmful air and water pollution from power plants, lowered smokestack carbon emissions, less water use, greater flexibility of the power grid, and renewed economic development in gas-rich regions of the country. These advantages have led to a surge in natural gas generation, resulting in a 23 percent increase in its share of the U.S. electricity mix from 2007 to 2013 (EIA 2014a).

Closer examination, however, reveals a number of serious and complex risks that call into question utility decisions to become increasingly dependent on natural gas for power generation. For example, even though supply has grown markedly, natural gas prices continue to be volatile. Natural gas price spikes not only harm consumers and the economy, but also can create perverse incentives for utilities to switch back to using old and polluting coal plants. And although natural gas plants' smokestack emissions are significantly cleaner than coal plants', the extraction, distribution, and combustion of natural gas result in the leakage of methane, a global warming gas that is 34 times stronger than CO_2 at trapping heat and presents serious environmental, public health, and climate change challenges (Myhre et al. 2013). Continuing to increase the nation's dependence on natural gas—as government forecasts project under current policy and market conditions—exacerbates these risks while delaying the transition to a diverse and truly low-carbon electric power system.

Instead of overrelying on natural gas to replace polluting coal and meet the growing demand for electricity, a better solution is to prioritize investments in renewable energy and energy efficiency. This report shows that, by avoiding an overreliance on natural gas and pursuing a diverse supply of low- and zero-carbon sources (made up primarily of renewable energy and energy efficiency), we can ensure a more consumer-friendly, resilient, and diversified electricity system, while also delivering cost-effective CO_2 emissions reductions and public health benefits.

Renewable energy resources, such as wind and solar power, are already ramping up quickly across the country and demonstrating that they can deliver affordable, reliable, and low-carbon power. Advances in technology, decreases in costs, and strong policy mechanisms are driving tremendous growth of these resources. Wind power capacity increased by 75 percent while solar capacity increased by 473 percent from 2009 to 2013 (AWEA 2014; SEIA 2014). The national average cost of wind power has dropped more than 60 percent since 2009, making it competitive with new fossil fuel plants in many regions (Wiser and Bolinger 2014). Solar photovoltaic system costs fell by about 40 percent from 2008 to 2012 and by another 15 percent in 2013 (Kann et al. 2014; Barbose et al. 2013).

Numerous studies have found that much higher levels of renewable energy can be reliably and affordably achieved with existing technologies and measures. Nationally, the share of non-hydro renewable resources represented 6 percent of the U.S. power supply in 2013, but these renewable sources could contribute 30 percent of the total U.S. power supply or more within the next two decades (UCS 2013b). And by 2050, with strong investments and modest improvements in existing technologies, renewable energy could supply 80 percent of the U.S. power supply (NREL 2012).

The Environmental Protection Agency's (EPA) Clean Power Plan—a forthcoming federal standard required under the Clean Air Act—provides a valuable near-term opportunity for utilities, regulators, and policy makers to accelerate the transition to an electricity system powered primarily by renewable energy and energy efficiency. The Clean Power Plan, set to be finalized in the summer of 2015, aims to protect public health and slow the pace of climate change by reducing carbon emissions from electricity generation. It establishes emissions rate reduction targets for the power sector state by state and would reduce national electric sector CO_2 emissions by an estimated 30 percent below 2005 levels by 2030. To meet the targets, states must choose from among a variety of emissions-reducing options to implement over the next few years. These options include increasing generation from renewable energy, nuclear, and natural gas power plants and investing in energy efficiency at fossil fuel plants and in buildings and industry.

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Renewable energy resources are rapidly expanding across the country, demonstrating that they can deliver clean, affordable, and reliable power. For example, solar photovoltaic experienced a nearly 5-fold increase from 2009 to 2013 thanks largely to advances in technology and declining costs.

© TVA Web Team/Creative Commons (Wikimedia)

The Tennessee Valley Authority's Paradise coal plant near Drakesboro, Kentucky is emblematic of the nation's shift away from electricity generated by coal and toward natural gas. Two large, 1960s-era generating units at the facility will be retired by 2017, and replaced with a $1 billion natural gas power facility at the same location.

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Investing in wind power and other renewable energy technologies is a smart and cost-effective solution for cutting CO_2 emissions and reducing the risks of an over-reliance on natural gas.

To fully capitalize on the promise of renewable energy and minimize the risks associated with an overdependence on natural gas, we must make smart energy decisions today. This report explores the costs and benefits of various energy pathways in the transition to a low-carbon economy. We begin by examining the rewards and risks resulting from the dramatic expansion of production and use of natural gas in the United States. Next, we describe and then present the results of a national electric-sector analysis that examines the interplay between various energy technologies under several climate and clean energy policy scenarios. We analyze the impacts these technology mixes might have on consumers, the economy, and carbon emissions. The analysis reveals the significant role renewable energy and energy efficiency can play in reducing the risks presented by an overreliance on natural gas. Finally, we discuss what might be an appropriate role for natural gas in a carbon-constrained power sector. And we recommend policies at the state, regional, and federal levels that can help accelerate the growth of renewable energy and energy efficiency in the shift toward a diverse and balanced electricity system that is reliable, affordable, and climate friendly.

[*Renewable energy resources are demonstrating that they can deliver affordable, reliable, and low-carbon power.*]

[**CHAPTER 1**]

Rewards and Risks of Natural Gas

An increase in shale gas development, made possible by horizontal drilling and improved hydraulic fracturing techniques, has cut domestic natural gas prices and led to a rapid shift from coal to natural gas electricity generation. However, the potential rewards of this rush to natural gas must be carefully weighed against its many risks.

Near-Term Rewards of the Natural Gas Surge

COAL DISPLACEMENT

Burning natural gas instead of coal results in a number of immediate public health and environmental benefits. Natural gas combustion releases much smaller amounts of soot- and smog-forming pollutants, including nitrogen oxides (NO_x), sulfur dioxide (SO_2), and fine particulates, which contribute to asthma and a variety of other lung and heart conditions. Also, unlike coal, natural-gas-fired electricity generation does not emit appreciable levels of mercury, arsenic, and other toxic substances that can cause adverse neurological effects in children and other health problems (EPA 2012b; CATF 2010; EPA 2010; Gentner and Bur 2010; NRC 2010a; Trasande, Landrigan, and Schechter 2005).

As recently as 2007, it looked as if the long-term future of the U.S. electricity sector would continue to be coal dominated. In that year, coal accounted for nearly half of total U.S. electricity generation. Experts projected that the sector would continue along the path of greater coal-fired generation for the next several decades, with 139 GW of new coal power capacity (the equivalent of about 230 new typical-size plants) to come online by 2030 (EIA 2007). These projections also showed natural gas playing a more limited role, which seemed plausible as domestic supply was constrained and wholesale natural gas prices were ranging from 3 to 4 times higher than historic trends.

But soon thereafter, the energy landscape began to change dramatically. The use of hydraulic fracturing spread rapidly, making vast shale gas reserves more easily and economically accessible (EIA 2014d). The EPA also began proposing and implementing tighter clean air, clean water, and public health standards for the power sector, including the long-awaited Mercury and Air Toxics Standard.

As a result, the generation fuel mix shifted away from coal toward more natural gas and renewable energy. Nationally, coal generation declined from 48 percent of the total U.S. electric power supply in 2007 to 39 percent in 2013

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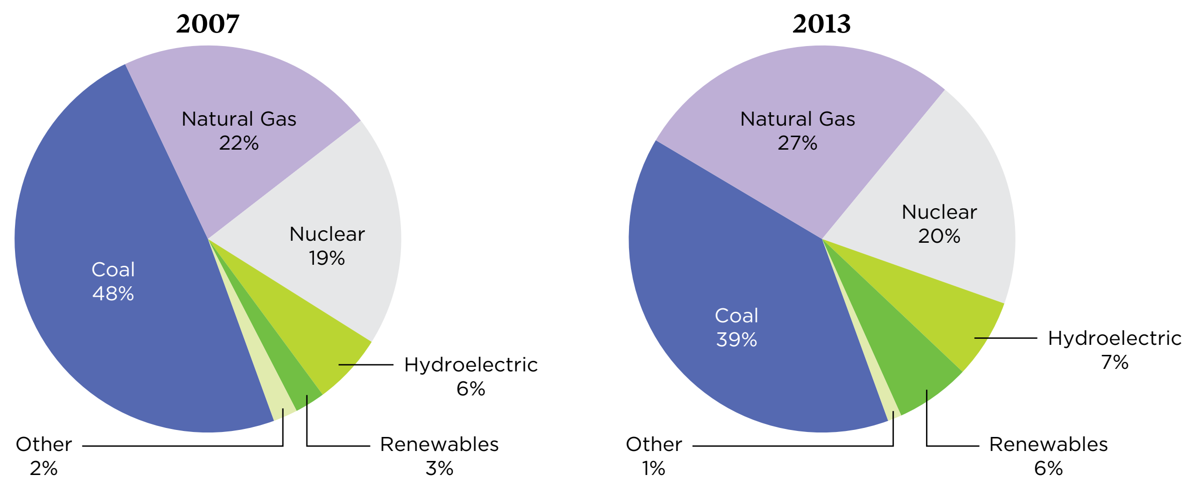
The transition toward greater use of natural gas for power generation has been especially dramatic in Florida, among other states. Between 2007 and 2013 Florida's dependence on electricity from natural gas increased from 44 percent of the generation mix to 62 percent, largely displacing coal power.

FIGURE 2. Change in U.S. Electricity Generation Mix, 2007 to 2013



A combination of market and policy factors has contributed to a major shift in the makeup of the U.S. electricity generation mix from 2007 through 2013. As coal generation declined, it was replaced by generation from a combination of cleaner power sources—led by natural gas.

SOURCE: EIA 2014A.

(Figure 2). During the same period, the contribution of natural gas increased from 22 percent to 27 percent—representing a 23 percent increase. In over 65 years of record keeping, coal generation had never dropped below 40 percent of the U.S. power supply until 2012.

The transition toward greater use of natural gas from 2007 to 2013 was even more dramatic in a number of states (Table 1). For example, natural gas generation in Georgia more than tripled from 11 percent to 34 percent, largely by displacing coal power. In Florida, the third largest electricity producer in the United States, dependence on electricity from natural gas increased from 44 percent of the generation mix to 62 percent. Even in heavily coal dependent states like Pennsylvania and Ohio, natural gas generation increased significantly during this period. In 2013, a total of 16 states generated more than 33 percent of their electricity from natural gas.

As coal power plants were either backed down or retired, underused existing natural gas power plants largely replaced their output. From 2008 to 2013, the capacity factor[2] of the U.S. coal fleet decreased from 73 percent to 60 percent while the capacity factor of existing U.S. natural gas combined-cycle power plants increased from 40 percent to 47 percent (EIA 2014e). In addition, some of the coal generation was displaced by generation from new power plants coming online. Between 2011 and 2013, 23 GW of natural gas, 21 GW of wind, and more than 9 GW of solar capacity were added while 19 GW of mostly smaller, less-utilized coal generators were retired. These trends are expected to continue, as power plant owners have announced plans to retire an additional nearly 44 GW of coal capacity through 2025. In addition, a recent analysis identified at least another 64 GW as economically vulnerable (Fleischman et al. 2013).

A combination of market and policy factors points to coal's continued decline. The advanced age of many coal plants, higher coal prices, and the ongoing need to cut pollution from coal plants are strong factors. So are the falling prices of wind and solar power, which combined with supportive state and federal policies, have led to the doubling of non-hydro renewable energy sources from 2007 through 2013. The reduced growth in electricity demand—caused by state and federal energy efficiency policies as well as a slow economic recovery—is also a contributing factor. But perhaps the strongest factors currently in play are the comparatively low price of natural gas, the better thermal efficiency and operating flexibility of natural gas power plants, and this fuel's ability to allow generators to meet state and federal public health and climate regulations more easily.

ECONOMIC DEVELOPMENT

While many U.S. industries suffered employment losses from 2007 to 2012, the oil and natural gas industry increased

2 *The capacity factor measures how often and intensively a generator is run over time. It is calculated as the ratio of actual power output to potential output if the generator had operated at full (100 percent) capacity over the same period.*

TABLE 1. Change in Natural Gas as a Percent of In-State Generation Mix 2007 through 2013, Ranking of States

	State	Natural Gas as % of Generation Mix (2007)	Natural Gas as % of Generation Mix (2013)	Change from 2007 to 2013, in Percentage Points
1	Delaware	22%	75%	53
2	Georgia	11%	34%	23
3	North Carolina	3%	22%	19
4	Florida	44%	62%	18
5	Mississippi	43%	60%	17
6	Virginia	14%	29%	15
7	Alabama	16%	31%	15
8	Connecticut	30%	44%	14
9	Pennsylvania	8%	22%	13
10	Ohio	3%	15%	13
11	New Jersey	30%	42%	12
12	Massachusetts	53%	63%	10
13	New York	31%	39%	8
14	Idaho	14%	22%	7
15	South Carolina	6%	13%	7
16	New Mexico	19%	25%	7
17	Minnesota	7%	13%	6
18	Tennessee	1%	6%	5
19	Indiana	3%	8%	5
20	Arkansas	15%	20%	5

The nationwide shift away from burning coal toward burning natural gas for electricity generation is more starkly reflected in a number of states. Some states now use natural gas to generate nearly two-thirds or more of their electricity, making them highly reliant on this one fuel.

SOURCE: EIA 2015.

employment by more than 30 percent, adding over 120,000 new jobs. Texas had the largest gains in employment, adding 64,515 oil and gas jobs over this period, while employment in the Pennsylvania oil and gas industry increased over 250 percent (BLS 2014a). As of 2012, the oil and gas industry employed about six times more U.S. workers than the coal mining industry. Oil and gas wage gains have also outpaced national averages over the last few years (BLS 2014b).

As the U.S. economy recovers, low natural gas prices and increased supplies are also contributing to a resurgence of domestic manufacturing and chemical industries. Natural gas can be used as a feedstock to make many types of products, including ethylene for plastics, carpets, clothes, tires, and ammonia for fertilizer. The U.S. chemical industry has invested an estimated $15 billion recently to increase ethylene production, including investment in a major expansion at a Dow Chemical facility in Texas (Bullis 2013; PWC 2013). Expanding low-cost ethylene production capacity can help spur growth in other domestic manufacturing.

LOWER ELECTRICITY PRICES

As a result of the dramatic expansion of U.S. shale gas production in recent years, natural gas has become a low-cost option for new power generation in many regional electricity markets. Gas prices began to fall in 2008 as drilling expanded

The recent surge in natural gas power generation, made possible by increased domestic supplies and low natural gas prices, offers important benefits compared with coal, including reduced air and water pollution, lowered smokestack carbon emissions, and greater flexibility of the power grid. However, the rewards of this rush to natural gas must be carefully weighed against its many risks.

in the eastern U.S. and demand tapered in response to a global recession. Advances in U.S. shale gas production have led to projections that domestic natural gas prices will remain relatively low over the next few years (EIA 2014c). Following declining gas prices, wholesale electricity prices dropped more than 50 percent on average from 2008 to 2011 (Johnsson and Chediak 2012). And even accounting for price increases starting in 2012 and recent price spikes related to extreme weather events, natural gas still remains cost-competitive in most power markets.

GRID RELIABILITY/FLEXIBILITY

Natural gas generators contribute to a more reliable electricity supply in several ways. They can provide continuous power or be ramped up and down quickly to meet ongoing changes in demand. In fact, natural gas peaking power plants have long been relatively inexpensive to build and used when the grid experiences extremely high demand, such as during summer heat waves, thereby preventing blackouts. In addition, natural gas can assist the integration of more renewable energy generation, thereby creating a more diverse and flexible electricity system (NREL 2012). Given the quick ramping ability of natural gas generators, the electricity they produce can be taken off the grid as wind, solar, and other renewable energy generators ramp up and then brought back on to help balance the grid as renewable generators ramp down.

Risks from an Overreliance on Natural Gas

ECONOMIC RISKS

Price Volatility. The natural gas industry has a well-documented history of price volatility. Due to the nature of its production, storage, and transmission; the fact that it supplies many end uses; and its susceptibility to extreme weather events, the price of natural gas fluctuates more than does the price of its competitors. For example, the natural gas market experienced a number of dramatic price swings between 2003 and 2014 (Figure 3). In 2005, the spot market price spiked to nearly $14 per million British thermal units (MMBtu) in response to hurricane activity in the Gulf of Mexico, where many gas wells are located. In contrast, prices dipped to about $2 per MMBtu in 2012 in response to decreased demand resulting from the economic recession and from a series of warm winters, which reduced competition between heating and electricity suppliers for limited natural gas pipeline resources.

FIGURE 3. Natural Gas Spot Prices*, 2002 through 2014

For more than a decade, U.S. natural gas prices have been subject to significant volatility, which can harm consumers and the economy.

*At the Henry Hub Terminal in Erath, Louisiana.

SOURCE: EIA 2014F.

In the past, price volatility has made some power producers cautious about relying too heavily on natural gas. Yet most utilities have typically responded to periods of low prices by investing in new natural gas power plants and using existing ones more frequently. For example, nearly 187 GW of natural gas capacity—more than 40 percent of the current U.S. fleet—was added between 2000 and 2003, when natural gas prices were near historic lows (EIA 2013a). Since 2009, when prices began to fall again, another 45 GW of natural gas capacity has come online, and an additional 48 GW of capacity is under construction or planned through 2020 (SNL 2015; EIA 2013a). This shift toward greater dependence on natural gas for power during periods of low prices can exacerbate the impact on consumers and the economy when prices spike higher.

Although the recent increase in U.S. shale gas production has resulted in lower natural gas prices, it has not eliminated price volatility. For example, a cold wave that began in December 2013, caused by a southward shift in the North Polar Vortex, resulted in record low temperatures that extended into March 2014. High natural gas demand—for electricity and heating purposes—combined with pipeline constraints and irregularities between the power and heating markets resulted in record-high delivered natural gas prices across much of the Northeast and parts of the Midwest. On January 7, 2014, average delivered natural gas prices spiked from $35 to $40 per MMBtu in the Northeast, 10 to 12 times higher than average prices for the prior several years (Rose et al. 2014).

Natural gas price volatility can have a negative effect on the economy, consumers, and the environment. For example, elevated natural gas costs contribute to higher electricity prices, especially in regions heavily reliant on natural gas. In New England, a region that generates 46 percent of its electricity from natural gas, wholesale electricity prices are closely linked to the price of natural gas (ISO New England 2014). When natural gas prices spiked in January 2014, wholesale electricity prices in the region also jumped to nearly $100 per megawatt-hour (MWh) (ISO New England 2014). These costs are then passed on to consumers. NStar and National Grid, the two largest electric utilities in Massachusetts, recently announced rate increases of 29 percent and 37 percent respectively, citing natural gas prices (Newsham 2014a; Newsham 2014b). Rate increases of this magnitude are particularly burdensome to families on fixed incomes, and the impact is even greater on families who heat their homes with natural gas.

In addition, higher natural gas prices could lead electricity generators to shift from gas back to coal, undermining efforts to reduce carbon emissions in the process. Evidence of this in the short run appeared in 2013, when higher gas prices resulting from responses to several particularly severe cold snaps led utilities in some regional markets to ramp down natural gas plants and ramp up coal plants. Fortunately, the rapid addition of wind and solar resources to the power system between 2008 and 2013 helped reduce the magnitude of this 2013 coal rebound (EIA 2014a), clearly demonstrating both the benefits of a more diversified electricity mix and the potential of renewable energy to provide reliable and affordable power for millions of consumers. Nevertheless, this event led some coal state officials and industry executives to question recent decisions to retire rather than upgrade some outdated coal power plants (Chediak and Weber 2014).

Many experts believe that low natural gas prices are not sustainable over the long term. For example, the U.S. Energy Information Administration's (EIA) Annual Energy Outlook projects that spot prices will significantly increase from the recent low point of $2.75 per MMBtu in 2012 to $6.03 per MMBtu in 2030 and $7.65 per MMBtu in 2040 (EIA 2014c). Factors that contribute to upward pressure on prices and the risk of price volatility include uncertain available supply and potentially increasing demand for natural gas from electric utilities, other competing domestic users, and exporters.

The use of natural gas for electric power is growing rapidly and currently accounts for 32 percent of total U.S. consumption of natural gas (EIA 2014c). Competing uses are industrial applications (34 percent), heating for homes and commercial buildings (31 percent), and transportation (3 percent) (EIA 2014c). Changes in demand or the market structure for any of these uses can influence prices and the other uses' access to supplies. Furthermore, regulators prioritize end uses like home heating over electric power generation during periods of supply constraints, which may lead to greater price and reliability concerns as dependence on natural gas increases in the power sector.

Added to these demand pressures is the natural gas industry's growing desire to export U.S. product to parts of the world where prices are higher (Colman 2013; EIA 2013b).

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Natural gas price volatility can have a negative effect on consumers, especially in regions heavily reliant on natural gas. Higher natural gas costs can contribute to increases in electricity prices of 30 percent or more, which is particularly burdensome to families on fixed incomes. The impact is even greater on families who also heat their homes with natural gas.

[***Many experts believe that low natural gas prices are not sustainable over the long term.***]

Typically, higher prices in overseas markets are due to supply constraints, smaller coal reserves, or stricter environmental policies that favor the use of natural gas over the use of coal. Now, with the domestic hydraulic fracturing production boom, a much greater price difference exists between North America and other markets. In response, expansion of U.S. export capabilities—via liquefied natural gas (LNG) terminals—is already well underway. As of October 2014, four LNG export terminals have been approved by federal authorities and another 14 have been proposed (FERC 2014a; FERC 2014b). Although it is unlikely that all these terminals will be developed, the EIA projects that annual U.S. LNG exports will increase from less than 0.01 trillion cubic feet (tcf) today to 3.5 tcf in 2030—which is equal to 43 percent of the gas consumed by the electric power sector in 2013 (EIA 2014c).

A dramatic expansion of natural gas exports could influence the price of natural gas and contribute to greater domestic price volatility. According to the EIA, increased natural gas exports will lead to higher domestic natural gas prices, despite more domestic production, and increased pipeline imports from Canada (EIA 2012a). Modeled scenarios in which natural gas exports increase to range from 2.2 tcf to 4.4 tcf annually project that average U.S. residential and industrial consumer energy bills will rise by an additional 3 to 9 percent for natural gas and 1 to 3 percent for electricity (EIA 2012a). There is still some debate about how much impact increased exports would have on domestic natural gas prices (NERA 2012), but it is clear they would be one more force pushing gas prices upward.

Stranded Assets. Choices made today to invest in infrastructure intended to lower costs and carbon emissions by replacing coal with natural gas risk leading to the unintended consequence of locking energy consumers into a high-carbon future. If natural gas use continues to grow, greater investment in pipeline and processing and storage facilities will be required. A recent report by the Interstate Natural Gas Association of America finds that their most-likely growth scenario would require 43 billion cubic feet a day (Bcfd) of incremental natural gas mainline capacity to be built from 2014 to 2035 (ICF International 2014). The report also projects that investments in new natural gas infrastructure—including pipelines, storage and processing facilities, and


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A recent report estimated that hundreds of billions of dollars in new infrastructure investments—including pipelines—would be needed over the next two decades to continue the growth in natural gas for power and other end uses. Such costly investments could become stranded assets, however, if sufficient political pressure mounts to make significant reductions in carbon emissions.

equipment leasing—needed through 2035 would average approximately $14 billion per year, totaling $313 billion (in 2012 dollars). This infrastructure would serve multiple sectors that use natural gas, not just the electricity sector. However, the study projects that about 75 percent of the incremental growth in natural gas demand through 2035 will be for power generation (ICF International 2014).

There are currently numerous proposals across the country to build new natural gas pipelines and storage facilities (EIA 2012b), in part to help reduce price volatility. Pipelines typically have a physical useful life of 50 to 100 years and are financed for as long as 40 years.

Investing in large amounts of infrastructure carries risk for the natural gas industry. As increasing public awareness of the dangers of climate change lead to increasing political pressure to cut carbon emissions, much of this costly infrastructure may have to be abandoned long before it ends its useful life. In the parlance of Wall Street, these pipelines and other facilities will become "stranded assets" (IEA 2014; McGlade and Ekins 2014; Carbon Tracker Initiative 2013). In contrast, a recent Department of Energy (DOE) study outlining a pathway to generating 80 percent of electricity from renewable energy by 2050 (with 80 percent reductions in carbon emissions) projected annual investments in new transmission infrastructure, including interconnections for all plants, ranging between $6.4 and $8.4 billion per year from 2011 through 2050 (NREL 2012). The more money is invested in natural gas infrastructure, the harder it will become for cleaner, renewable resources to eventually displace natural gas.

Greater emphasis on infrastructure investments made to support renewable energy would result in lower financial, industry, and climate risks.

Socioeconomic Impacts. The boom in unconventional natural gas extraction has led to a rapid expansion of operations in many rural, previously undeveloped, areas. While this development can result in increased tax revenue for struggling communities and extra income for property leaseholders, other nearby residents may suffer decreased property values due to elevated levels of dust, noise, odor, light, and pollution (Adgate, Goldstein, and McKenzie 2014). An increase in heavy truck traffic puts community members at greater risk from accidents and localized air pollution. The remarkable growth in industrial activity and population in gas-rich areas has been linked to higher rates of crime and substance abuse—straining local public safety and health services—as well as to steep inflation of housing rental prices, and dramatic changes to a community's character and landscape. These negative factors have a greater impact among low- and fixed-income members of a community (Adgate, Goldstein, and McKenzie 2014).

CLIMATE RISKS

Smokestack Emissions. As with any fossil fuel, burning natural gas for electricity generation results in the release of CO_2 and thus contributes to global warming. It is true that replacing coal plants with natural gas plants will likely reduce the amount of CO_2 emitted for each MWh of U.S. electricity generated. When combusted in an efficient, combined-cycle power plant, natural gas emits approximately 800 pounds of CO_2 per MWh—an amount some 50 to 60 percent less than the amount emitted from a typical new coal plant (NETL 2010). However, a number of recent studies have come to the conclusion that abundant natural gas will do little to reduce power sector heat trapping emissions (Newell and Raimi 2014; Shearer et al. 2014; EMF 2013).

One of the biggest reasons for this paradox is that increased reliance on natural gas will likely delay the deployment of renewable energy, as has been shown in extensive modeling of future scenarios. As demand for electricity grows and generating capacity is added to the system to meet it, demand that could have been met by new renewable energy resources may instead be met by natural gas. As a result, total carbon emissions would fail to approach the level of reductions needed to avoid the worst consequences of climate change. Under certain scenarios, power sector global warming emissions may actually increase (Fleischman, Sattler, and Clemmer 2013).

Fugitive Methane Emissions. Direct smokestack pollutants are not the only global warming emissions associated with natural gas. The drilling and extraction of the fuel from wells, as well as its processing, transmission, distribution, and storage, also result in the leakage of methane—a primary component of natural gas that is 34 times stronger than carbon dioxide at trapping heat over a 100-year period and 86 times stronger over 20 years (Myhre et al. 2013). Although there is still uncertainty about the precise quantity of these so-called fugitive methane emissions, preliminary studies and field measurements range from 1 to 9 percent of total natural gas production (Tollefson 2013; Cathles et al. 2012; Howarth et al. 2012; Petron et al. 2012; Skone 2012; Weber and Clavin 2012).

Currently, the natural gas industry is the largest industrial source of methane emissions, and its emissions are expected to increase as a result of the recent hydraulic fracturing boom. According to the EPA, methane amounted to 9 percent of total U.S. global warming emissions in 2012, which ranks it behind only CO_2 (EPA 2014). However, this is likely an underestimate. The EPA used an outdated measurement of global warming potential for methane; a more accurate Intergovernmental Panel on Climate Change estimate pegs the impact of methane over 100 years at a level 36 percent higher than the EPA estimate (IPCC 2014). Additionally, a 2014 study found that the EPA's current figures

[The natural gas industry is the largest industrial source of methane emissions—a highly potent global warming gas.]

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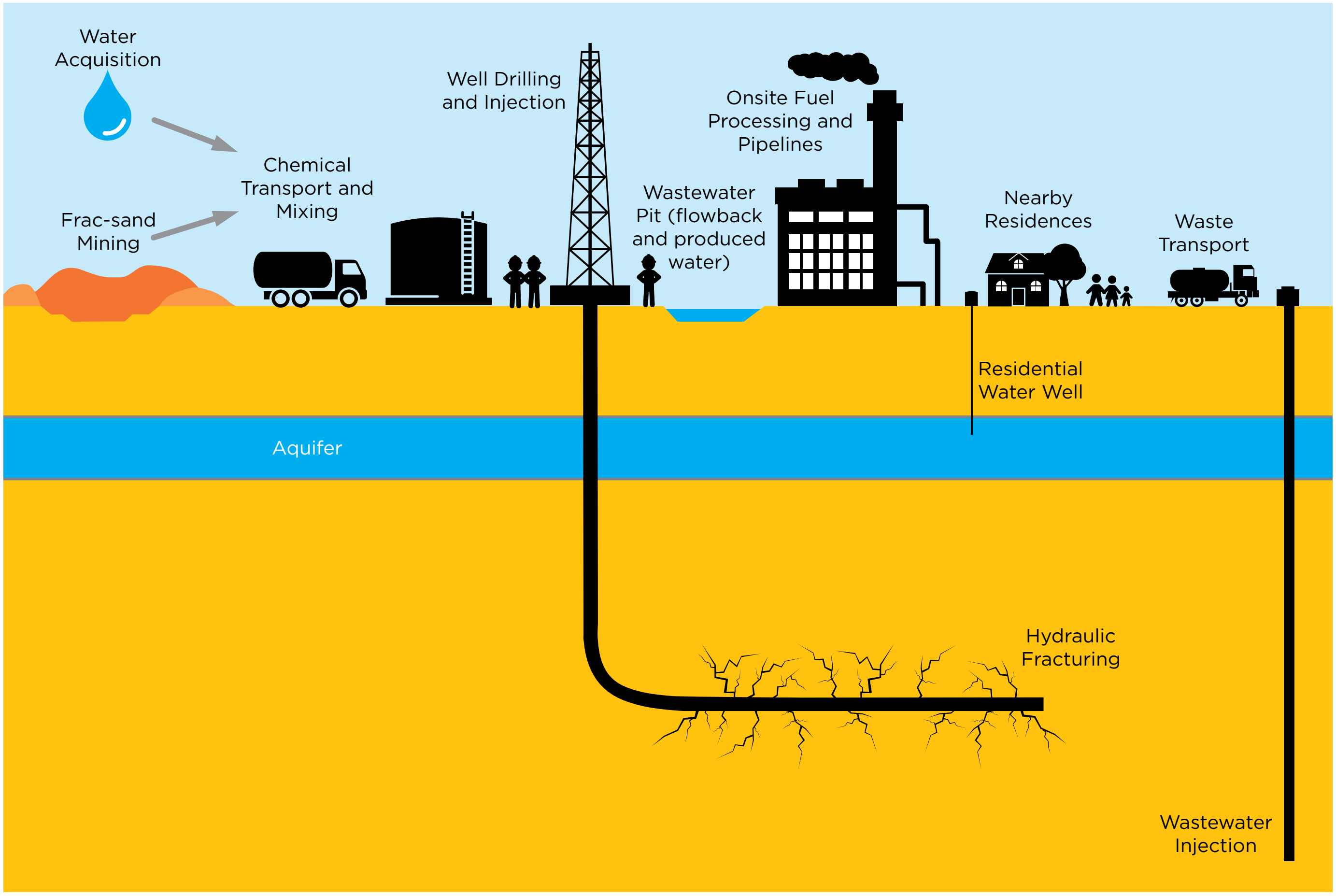
Like all fossil fuels, burning natural gas for electricity generation results in the release of CO_2 and thus contributes to global warming.

FIGURE 4. Illustration of Typical Steps of Unconventional Oil and Gas Development



Hydraulic fracturing, or fracking, has been used to extract natural gas from vertical wells for several decades. However, more recent advances in horizontal drilling techniques have led to a significant increase in shale gas development in the United States. This practice involves several environmental and public health risks, including local air and water pollution and the release of fugitive methane, a highly potent global warming gas.

SOURCE: GOLDMAN ET AL. 2013.

on methane leakage rates from oil and natural gas production and distribution may be underestimated by 25 to 75 percent (Brandt et al. 2014). Methane leakage diminishes claimed climate advantages of natural gas over coal while boosting the actual advantages of renewable energy and energy efficiency over natural gas.

ENVIRONMENT AND PUBLIC HEALTH RISKS

Water Quality Risks. The production of natural gas, particularly production resulting from the practice of hydraulic fracturing of shale and other deposits, poses several environmental and public health risks (Figure 4). One of the primary risks involves the water and associated chemicals injected into, left in, and withdrawn from natural gas wells during the fracking process.

Thanks to special exemptions for the oil and gas industry from many existing federal environmental laws, the exact composition of the fracking fluid injected into natural gas wells is often held as an industry trade secret (Rosenberg et al. 2014). The EPA reports that between 15,000 and 60,000 gallons of chemicals are mixed with the water used in each fracking well (EPA 2011). This fluid may seep into and contaminate aquifers. A comprehensive EPA study of the

Replacing generation from coal-fired power plants with primarily natural gas is not an effective long-term climate and energy strategy.

potential impacts of fracking on drinking water identified the presence of a number of toxic chemicals—including benzene, lead, and methanol—in fracking fluids. In addition, even in its undisturbed state, the shale or rock formation being fractured is usually permeated with water that commonly includes dissolved solids, salts, metal ions, radioactive compounds, and other substances naturally occurring deep underground (EPA 2012a). Some of this water, known as produced water, is released during the processes of drilling and hydraulic fracturing, and it is pumped to the surface as long as the well is producing oil and gas—a period of years or even decades. Thus, both drilling wastewater and produced water can be highly saline, toxic, or radioactive (Haluszczak, Rose, and Kump 2012; Rowan et al. 2011). The collection, transportation, and storage or disposal of these fluids presents risks to industry workers and to the public.

In addition to these impacts, fracking requires a tremendous amount of water. According to the U.S. Government Accountability Office, 2 billion gallons of fluids are injected into over 172,000 wells every day in the United States (GAO 2014). A single well can require 3 million to 12 million gallons of water when it is first drilled (Breitling Oil and Gas 2012; NETL 2009). A recent study by the World Resources Institute found that 35 percent of U.S. shale gas and oil resources are located in areas experiencing a high degree of water stress (Reig, Luo, and Proctor 2014). Fracking presents the risk of serious conflict between the needs of the natural gas industry and the needs of agriculture, other industries, and domestic consumers, particularly when water supplies are tight.

Air Quality Risks. The process of natural gas extraction and production emits ozone, silica from frac-sand, NO_x, and other hazardous air pollutants, including formaldehyde, benzene, and hydrogen sulfide (Macey et al. 2014; Srebotnjak and Rotkin-Ellman 2014; Ferrar et al. 2013; Goldman et al. 2013; EPA 2006). Industry workers and nearby residents are often exposed to these pollutants, as homes, schools, or workplaces are often close to wells and development and production areas (McKenzie et al. 2012). As a result, they are at risk of a range of health problems, including respiratory and cardiovascular disorders, as well as to adverse birth outcomes. According to one recent study, residents living less than half a mile from unconventional gas well sites were at greater risk of air-pollution-related health effects from natural gas development than those living farther from the well sites (McKenzie et al. 2012). Diesel emissions and dust from heavy trucks delivering water and other materials to and from the well sites also diminish air quality and increase public health risks for nearby residents (Goldman et al. 2013; Rodriguez and Ouyang 2013).

While natural gas does offer some important rewards in the near-to-intermediate term, the economic, environmental, and health risks involved argue that replacing generation from coal-fired power plants with primarily natural gas is not an effective long-term climate and energy strategy. Our analysis, described and presented in the next two sections, considers a different path forward in the transition away from coal—prioritizing renewable energy and energy efficiency and defining a more limited, balanced role for natural gas.

[CHAPTER 2]

Analysis Description and Methodology

For the period through 2040, we analyzed the effects of climate and clean energy policy scenarios on power plants, consumers, the economy, and carbon emissions. To conduct this medium-term analysis, we used the EIA's National Energy Modeling System (NEMS). NEMS is a comprehensive model that forecasts U.S. energy use and emissions from the electricity, transportation, industrial, and buildings sectors under a range of cost and performance assumptions for energy technologies.

Our analysis uses a modified version of NEMS that better reflects the research of UCS and other experts on the likely future conditions of the U.S. power sector. Our modifications include changes to assumptions in NEMS, such as some of the costs and operational efficiencies of power plants, based on published reports produced by various experts. UCS has been researching and modifying the assumptions in NEMS for more than 15 years, using a rigorous, peer-reviewed process. A detailed discussion of all our model modifications is in the Technical Appendix, available at www.ucsusa.org/naturalgasgamble.

[UCS has been researching and modifying energy model assumptions for more than 15 years, using a rigorous, peer-reviewed process.]

Scenario Summary

Our analysis primarily focuses on three main scenarios. It includes six additional sensitivity scenarios that allowed us to consider the effects of higher and lower natural gas prices. The three main scenarios are summarized in Table 2 (p. 20) and described below, followed by the descriptions of the sensitivity scenarios.

BUSINESS AS USUAL

The Business as Usual Scenario assumes that no state or federal policies beyond those which existed at the end of 2012 will be put in place in the future. This scenario provides a perspective on the direction the U.S. energy sector is headed on its current path. It also establishes a baseline for our analysis, to which we compare our policy scenarios.

CARBON STANDARD

The Carbon Standard Scenario analyzes the impacts of a carbon emissions reduction standard placed on the U.S. electricity sector while we continue to assume that existing renewable energy and energy efficiency policies in place at the end of 2012 will remain unchanged. For modeling purposes, we used a carbon price as a proxy for a carbon standard that achieves a declining limit on carbon emissions from power plants. The carbon price starts at $12 (2020$) per metric ton in 2020 and increases by 10 percent each year through 2040. We set these prices with the goal of reducing emissions below 2005 levels by at least 35 percent in 2025, 45 percent in 2030, and at least 65 percent in 2040. This scenario puts the electricity sector on a path to achieve even

TABLE 2. Descriptions of Policy Scenarios

Policy Scenario	Key Attributes
Business as Usual	No new policies are enacted beyond those in place in 2012
Carbon Standard	A carbon price is used as a proxy for a carbon standard that achieves a declining limit on carbon emissions from power plants. The carbon price starts at $12 (2020$) per metric ton in 2020 and increases by 10 percent each year through 2040, with the goal of achieving carbon emissions savings of: • at least 35% below 2005 levels by 2025; • at least 45% below 2005 levels by 2030; • at least 65% below 2005 levels by 2040.
Carbon Standard plus Renewables and Efficiency Policies	Includes the same carbon prices as the Carbon Standard Scenario, plus the following strengthened renewable energy and energy efficiency policies: • A federal renewable electricity standard (RES) of 25% by 2025 and energy efficiency resource standard (EERS) of 15% by 2025 • A full extension of the federal production tax credit through 2016, with a gradual ramp-down through 2018 • An extension and ramp-down of the current federal solar investment tax credit from 30% in 2016 to 10% in 2020 and thereafter • Adoption of lower-cost renewable energy financing mechanisms such as master limited partnerships and real estate investment trusts • Updated residential and commercial building codes and equipment efficiency standards and an extension of the federal investment tax credit for combined heat and power systems

deeper reductions needed by 2050. It is more aggressive than the EPA's draft Clean Power Plan; the Plan's target is an estimated reduction in emissions of 30 percent below 2005 levels by 2030.

CARBON STANDARD PLUS RENEWABLES AND EFFICIENCY POLICIES

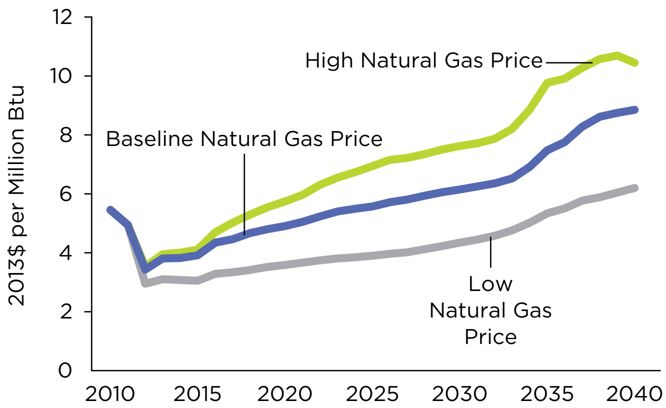
We then modeled a scenario that includes a federal carbon emissions reduction standard on the power sector (as in the Carbon Standard Scenario) complemented by strengthened federal renewable energy and energy efficiency policies (Table 2). Serving as our core policy scenario, this scenario explores the costs and benefits of spurring a more diversified clean energy portfolio within a carbon-constrained electricity sector. The inclusion of renewable energy and efficiency policies accelerates and increases the deployment of renewables and efficiency, especially in the 2015 to 2025 timeframe. The renewable energy and efficiency policies considered in this scenario are summarized in Table 2; additional details are in the Technical Appendix.[3]

SENSITIVITY SCENARIOS

Given the uncertainties associated with natural gas price projections and the importance of natural gas prices in determining energy sector outcomes, our analysis also evaluated the sensitivity of our scenarios to different natural gas prices. We developed two alternative projections for natural gas prices: a high price projection and a low price projection. Figure 5 illustrates the three projections for average delivered natural gas prices on power sector customers. We based the

3 *Although we modeled these strengthened renewable energy and efficiency policies at the federal level, federal action is not the only means of achieving these results. Our approach serves as a proxy for a range of enhanced policies that could be adopted at the federal, regional, state, or local level.*

FIGURE 5. Comparison of Natural Gas Price Forecasts (Average Delivered Price to Power Sector)



price sensitivity projections on modeling methodology the EIA staff use when they use NEMS. The difference between the high gas price and the baseline gas price differs from year to year; the average increase for the years between 2020 and 2040 is 23 percent. The average difference between the low gas price and the baseline gas price during this period is 29 percent. Our six sensitivity scenarios reflect the combination of each of the two different natural gas price projections with our three scenarios described above. See the Technical Appendix for the methodology we used to develop the alternative natural gas price projections.

Limitations and Uncertainties

It is important to note that although any forward-looking analysis comes with some inherent uncertainty, the NEMS model is a robust and widely respected analytic tool for understanding how different decisions may impact the costs, benefits, and reliability of the U.S. energy system under different circumstances. The results produced by our analysis are not statements of what will happen but rather of what could happen given the assumptions and methodologies used. It is in this context that we conducted this analysis—to inform decision-making processes with the best available data.

We examined several potential scenarios for spurring carbon emission reductions in the electricity sector. Other scenarios with different policies in place could achieve similar emission reductions, but with different effects on technology mixes, consumers, and the economy. As such, the construct of our scenarios was not intended to determine the optimal carbon emissions mitigation or clean energy pathway. Instead, by comparing a range of policy and technology scenarios, our analysis helps inform broad conclusions about policy priorities and design.

Projections of long-term changes in the supply, use, and price of energy are subject to uncertainty. Our sensitivity analyses consider the impacts of different natural gas price projections on the policy results. We also note that renewables and energy efficiency resources help reduce the impacts of fluctuations of fossil fuel prices on consumer energy bills.

Findings and Discussion

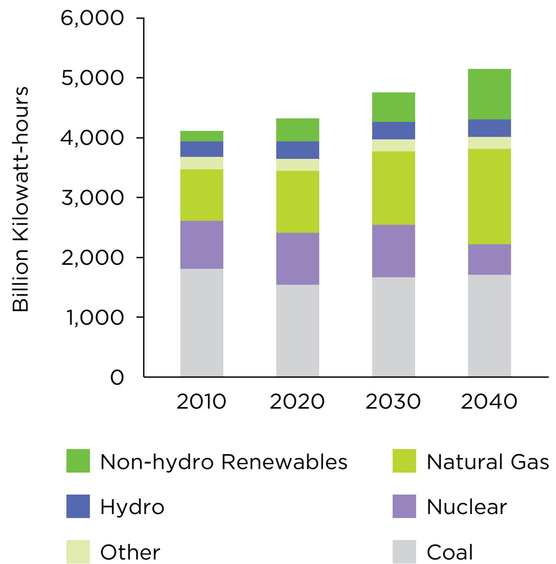
Key Findings

- A business-as-usual electricity future would put the United States on a pathway of greater natural gas use, rising carbon emissions, and higher natural gas and electricity prices. In our Business as Usual Scenario:
  - total natural gas use is projected to increase by nearly 18 percent between 2013 and 2040, with the power sector representing the largest share of this increase at 49 percent; and
  - power sector natural gas prices are 2.3 times higher in 2040 than in 2013 and average consumer natural gas prices nearly double.
- By replacing gas- and coal-fired generation with renewables and efficiency, the Carbon Standard plus Renewables and Efficiency Policies Scenario results in a total electricity resource mix portfolio that is 14 percent less sensitive to long-term fluctuations in fossil fuel prices.
- Implementing a carbon standard along with renewable energy and energy efficiency policies results in long-term savings on consumer energy bills as it cuts carbon emissions and raises carbon revenues. While investments in renewables and efficiency result in net costs of $19 billion in 2020, consumers would see annual net savings of $40 billion by 2030, rising to $59 billion by 2040.
- Increasing the share of renewable energy and energy efficiency is an important way to hedge against economic and climate risks in a future including uncertain natural gas prices. This strategy helps lower consumer electricity bills and carbon emissions under a range of possible future natural gas price scenarios.
- With baseline and high gas price forecasts, electricity bills in 2040 are lowest in the Carbon Standard plus Renewables and Efficiency Policies Scenario.
- In 2020, the societal benefits of pursuing carbon emissions reductions are 2.6 times greater than the consumer compliance costs, or nearly $36 billion. By 2040, the compliance costs of the Carbon Standard plus Renewables and Efficiency Policies Scenario are actually slightly lower than Business as Usual, primarily because of lower fuel expenses as we shift to more renewable energy and energy efficiency. As a result, the net societal benefits grow to nearly $170 billion in that year.
- Combining a carbon standard with renewable energy and energy efficiency policies can reduce power plant carbon emissions 70 percent below 2005 levels by 2040. As part of a global effort to help limit some of the worst consequences of climate change, further reductions in U.S. power sector carbon emissions will be needed by midcentury.

Natural Gas Use, Carbon Emissions, and Energy Prices Rise under Business as Usual

Our Business as Usual Scenario shows the projected trajectory of the U.S. electricity sector if the current policy environment stays constant; it serves as a benchmark against which to measure the impact of the policy changes included in our other scenarios.

FIGURE 6. U.S. Electricity Generation, Business as Usual Scenario



In the Business as Usual Scenario, the United States burns more natural gas than currently, even though the contribution of non-hydro renewables increases, to meet the projected growth in electricity demand. Although coal generation is projected to decline through 2016, due primarily to low natural gas prices and retirement of some older plants, model projections show that it rebounds some in later years in response to rising natural gas prices and growing electricity demand.

The power sector is currently experiencing significant changes. As previously discussed, a record number of coal-fired power plants have been retired over the last few years because of market conditions, which have included low natural gas prices, falling demand, declining prices for renewable energy technologies, and health-based standards designed to limit air pollution from power plants (Fleischman et al. 2013). Natural gas generation has grown alongside smaller growth in renewable energy and energy efficiency to replace a substantial amount of coal generation.

These conditions are reflected in the Business as Usual Scenario. The Business as Usual Scenario also projects that an improved economy, growing population, and other factors will lead to a 23 percent increase in electricity demand between 2013 and 2040, which will be met in part by both increased natural gas generation and a small and gradual rebound in coal generation (after declining through 2016) in the absence of new policies. The increases in natural gas and coal generation are also projected to replace some older coal and nuclear plants, even as wind, solar, and other renewable energy sources ramp up (Figure 6).

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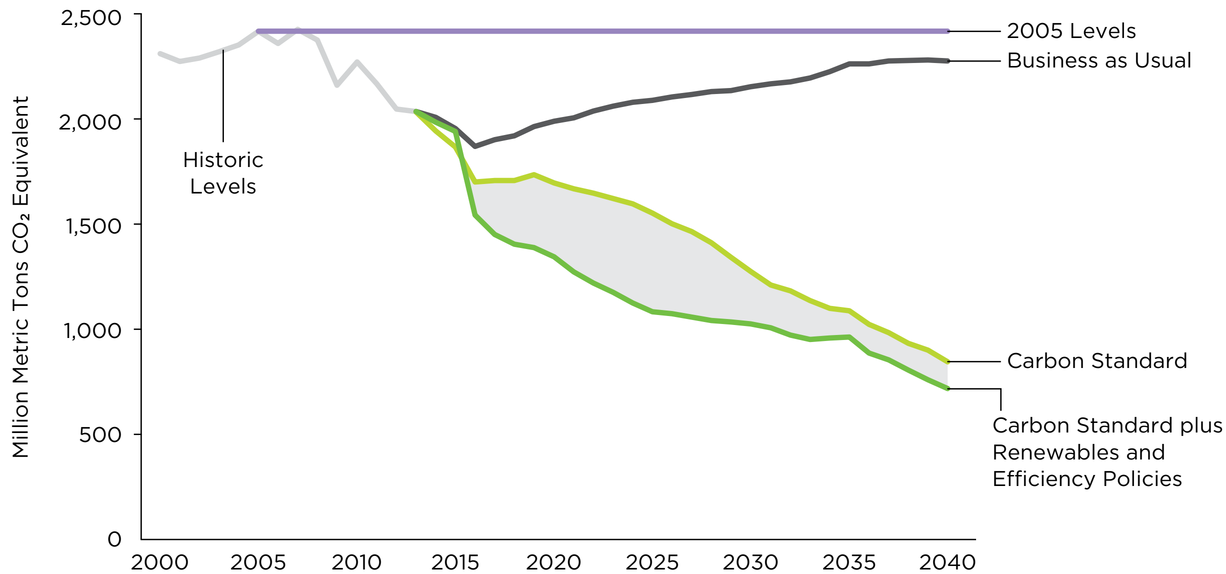
Increases in gas use result in higher natural gas prices for both the power sector and consumers under Business as Usual.

FIGURE 7. U.S. Power Plant CO_2 Emissions



Because CO_2 persists in the atmosphere, we must lower CO_2 emissions as quickly as feasible to limit climate risks. Implementing a combination of policies, including a carbon standard and strong renewables and energy efficiency policies, could cut power plant carbon emissions 55 percent below 2005 levels by 2025 and 70 percent by 2040 (dark green line). A carbon standard alone (light green line) would lead to lesser reductions, and they would occur later than with this combination of policies. The shaded area between these two lines represents additional cumulative emissions of 6.8 billion metric tons of CO_2 that would result from this delay. Without any new policies, emissions will continue to grow, increasing 12 percent above 2013 levels and nearly reaching 2005 levels by 2040 (dark gray line).

The increase in natural gas use in the power sector and other sectors, along with a projected increase in natural gas exports, results in higher natural gas prices for both the power sector and consumers under Business as Usual. Total natural gas use is projected to increase by nearly 18 percent between 2013 and 2040. The power sector represents the largest share of this increase at 49 percent, followed by the industrial sector (35 percent), transportation sector (24 percent), and the commercial sector (8 percent). The model also projects natural gas exports to more than triple by 2040, with the United States transitioning from a net importer of natural gas today to a net exporter after 2020. The impact of increased U.S. natural gas exports on global carbon emissions is uncertain and depends, in part, on which fuels are displaced in the importing countries. Because the NEMS model is primarily focused on the United States, with limited information about imports and exports from Mexico and Canada, we are not able to analyze global impacts.

Despite a significant increase in domestic natural gas production—primarily from shale gas—to meet this projected increase in natural gas demand, power sector natural gas prices in Business as Usual are 2.3 times higher in 2040 than in 2013, and average consumer natural gas prices nearly double. Because natural gas power plants often set the wholesale price of electricity, higher natural gas prices result in higher electricity prices for consumers. The Business as Usual Scenario projects that average consumer electricity prices will rise 20 percent between 2013 and 2040.

The recent shift away from coal helped reduce power plant carbon emissions in 2012 to their lowest levels since 2005. However, after several years of declining carbon emissions, recent data show that in 2013 and the first part of 2014 emissions rose slightly as higher natural gas prices led to a small shift back to coal-fired generation.[4] Our Business as Usual Scenario indicates that the decline in emissions is unlikely to continue in the absence of additional policies (Figure 7). By 2040, carbon emissions are projected to rise 12 percent above 2013 levels. These results are similar to the latest projections from the EIA in their Annual Energy Outlook 2014 report (EIA 2014c).

4 *The latest year of historical data in the AEO 2013 version of NEMS is 2011. Our Business as Usual projection of carbon emissions is slightly lower than this recent data.*

An Energy Mix that Balances Natural Gas with Increased Renewables and Efficiency Drives Deeper Carbon Reductions

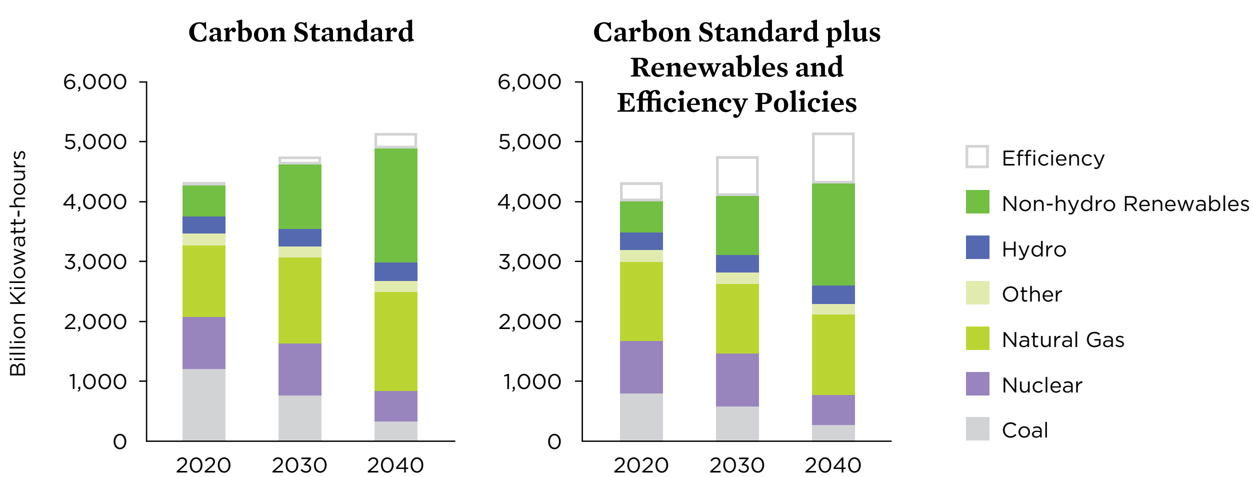
An electricity future characterized by greater natural gas use, rising carbon emissions, and higher natural gas and electricity prices is clearly the wrong path for the United States. Our analysis shows that a combination of a carbon standard with complementary renewable energy and energy efficiency policies can help cut power plant carbon emissions significantly while reducing our long-term reliance on natural gas, lowering costs, and providing important public health benefits (see Table 2 on p. 20 for policy details). In our Carbon Standard plus Renewables and Efficiency Policies Scenario—our core policy scenario—power sector carbon emissions are projected to fall 55 percent below 2005 levels by 2025 and 70 percent below by 2040. By comparison, a carbon standard alone cuts power sector emissions 36 percent below 2005 levels by 2025 and 65 percent by 2040 (Figure 7).

A key factor driving the emissions reductions seen in our Carbon Standard plus Renewables and Efficiency Policies Scenario is a transition away from coal to cleaner generation sources such as natural gas and wind and solar energy, as well as to energy efficiency. In this scenario, coal's share of U.S. electricity generation declines from 39 percent in 2013 to 7 percent by 2040 (Figure 8). Nuclear generation also declines between 2030 and 2040, as existing reactors are assumed to be retired after reaching a 60-year lifetime and our results show that new nuclear plants are not cost-effective options for replacing them. To help replace this decline in coal and nuclear power, generation from natural gas grows from 24 percent of the nation's power supply in 2013 to 34 percent in 2016 and then declines to 31 percent by 2040.

The model chooses the lowest-cost generation mix that would meet the policy specifications, under our assumptions. Although carbon capture and storage (CCS) technology for natural gas and coal plants is among the available technology choices, it is not chosen because other options such as renewable energy and conventional natural gas are more cost-effective. Our results also do not show any new nuclear plants being built for the same reason.

However, natural gas does not play an overly dominant long-term role in the Carbon Standard plus Renewables and Efficiency Policies Scenario. Instead, it contributes to a much more diverse mix of low-carbon sources. That is because wind, solar, and other renewable energy sources, which are already competitive with new natural gas plants in some parts of the country today, become more cost-competitive over time. As a result, the share of non-hydro renewables grows six-fold—from 6 percent of the electricity mix in 2013 to 39 percent by 2040—surpassing natural gas generation in 2036. Wind makes the largest contribution to this total, with

FIGURE 8. U.S. Electricity Generation, Carbon Standard, and Carbon Standard plus Renewables and Efficiency Policies Scenarios



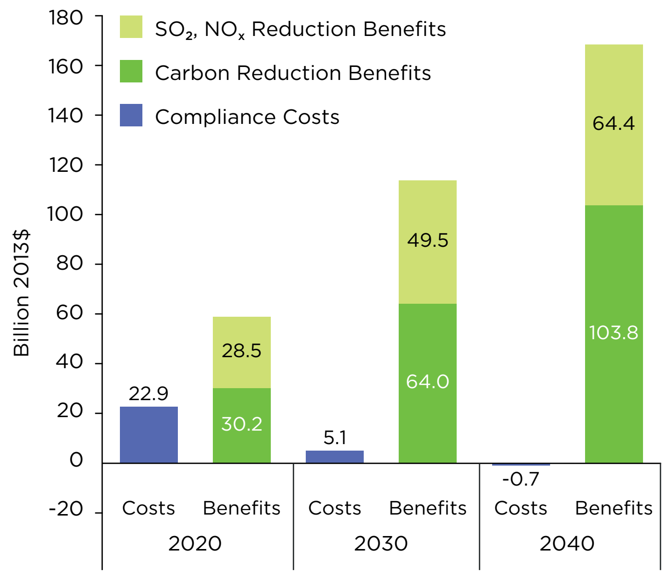
The U.S. electricity generation mix would be cleaner and more diverse if a carbon standard were to be combined with strong renewables and efficiency policies. In the Carbon Standard plus Renewables and Efficiency Policies Scenario, the share of non-hydro renewables grows six-fold to 39 percent of total generation by 2040, energy efficiency reduces electricity demand by 16 percent, and the share of natural gas generation remains mostly constant. In the Carbon Standard Scenario, which does not include strong renewables and efficiency policies, natural gas plays a bigger role after 2020 and energy efficiency reduces electricity demand much less.

solar, geothermal, and biomass energy also playing smaller but important roles. In addition, greater investments in energy efficiency measures cut U.S. electricity demand 7 percent below Business as Usual levels by 2020 and 16 percent below by 2040. We modeled only efficiency and renewable energy policies that ramp up through 2025 and then level off. Other studies have shown that it is cost-effective to continue increasing efficiency and renewable energy to much higher levels, as discussed in more detail below.

Reducing carbon emissions year by year is of course important, and our analysis shows that this goal is achievable under both of our carbon standard scenarios. But what also matters for atmospheric concentrations of CO_2 and for climate change is the amount of *cumulative* emissions. Because CO_2 persists in the atmosphere for decades, it is important not only to lower carbon emissions but also to lower them as quickly as feasible.

Combining a carbon standard with complementary energy efficiency and renewable energy policies drives deeper *and* earlier carbon reductions than would be achieved by a carbon standard alone. By 2040, 6.8 billion metric tons more cumulative CO_2 emissions are cut in the Carbon Standard plus Renewables and Efficiency Policies Scenario than in the Carbon Standard Scenario (as illustrated by the shaded area in Figure 7 on p. 24). These cumulative additional emissions savings, which are more than 3.3 times larger than the total power sector carbon emissions in 2013, illustrate the climate benefits of prioritizing renewables and energy efficiency as a strategy for complying with carbon limits.

FIGURE 9. Benefits and Costs of Policies That Limit Carbon Emissions, relative to Business as Usual Scenario



Our modeled scenarios show that the benefits of transitioning to cleaner power clearly outweigh the costs. "Compliance costs" are the incremental costs of deploying a cleaner generation mix in our Carbon Standard plus Renewables and Efficiency Policies Scenario relative to costs included in our Business as Usual Scenario. "Benefits" are the monetized damages avoided by reducing emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x).

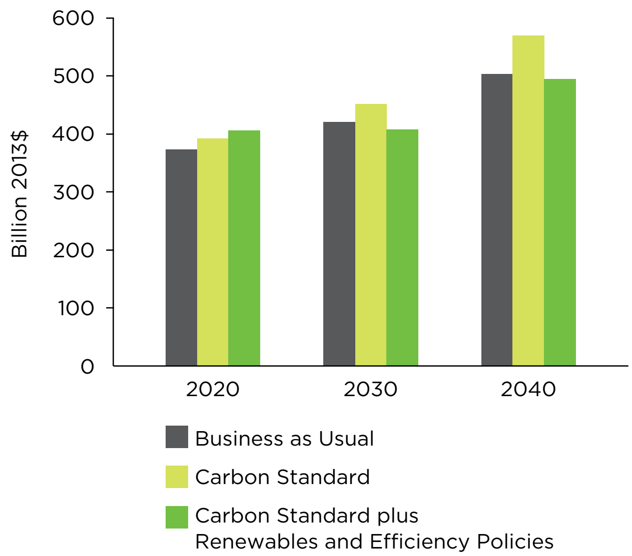
The Benefits of Policies That Limit Carbon Emissions Outweigh the Costs

Our analysis shows that the overall societal benefits projected by the Carbon Standard plus Renewables and Efficiency Policies Scenario are much greater than the costs. Benefits are calculated as the monetized benefits of reducing CO_2 emissions as well as SO_2 and NO_x emissions, which are major contributors to acid rain, smog, asthma, heart attacks, and premature death from heart and lung disease. The compliance costs are the incremental electricity system costs of deploying a cleaner generation mix in our Carbon Standard plus Renewables and Efficiency Policies Scenario relative to our Business as Usual Scenario, based on outputs from the model. In 2020, the benefits are 2.6 times greater than the compliance costs, or nearly $36 billion. By 2040, the compliance costs of the Carbon Standard plus Renewables and Efficiency Policies Scenario are actually slightly lower than those of the Business as Usual Scenario, primarily because of lower fuel expenses as we shift to more renewable energy and energy efficiency. As a result, the net benefits projected by the Carbon Standard plus Renewables and Efficiency Policies Scenario grow to $108 billion in 2030 and $169 billion in 2040 (Figure 9).

To calculate the monetary value of CO_2 reductions, we used the U.S. Government's estimates for the social costs of carbon (SCC) (Interagency Working Group 2013). The SCC is an estimate of the dollar damages caused by emission of an additional metric ton of CO_2 in a given year. We multiplied the metric tons of CO_2 reduced in our scenarios by the SCC to derive the CO_2 reduction benefits. To evaluate the benefits of reduced SO_2 and NO_x emissions, we used EPA estimates of the avoided health costs per ton of reduction of these pollutants from the electricity sector (EPA 2013). (See the Technical Appendix for more details on these calculations.)

The shift in the generation mix required to bring about the emissions reductions achieved in the Carbon Standard plus Renewables and Efficiency Policies Scenario do not raise electricity bills compared to those projected by the Business

FIGURE 10. U.S. Consumer Electricity Bills in Different Policy Scenarios



Compared to sticking with business as usual or adopting a carbon standard alone, implementing specific policies designed to encourage use of renewable energy and efficiency measures would result not only in deep cuts in carbon emissions but also in lower electricity bills by 2030. Revenues generated by implementing a carbon standard could be used to offset increases in electricity bills in the early forecast years. These revenues are not accounted for in the graph above.

as Usual Scenario because of the comparatively low cost of low-carbon options. Energy efficiency in particular helps offset the impact of higher electricity prices by lowering demand, resulting in a net reduction in electricity bills. And by displacing natural gas and coal generation, energy efficiency and renewable energy help restrain the growth in fuel and electricity prices. The carbon standard scenarios project slightly higher electricity bills than does the Business as Usual Scenario in 2020, due in part to some fuel switching from coal to natural gas, paying for the up-front costs of investing in renewables (including transmission upgrades) and efficiency, and the costs of implementing energy efficiency programs (Figure 10). However, by 2030, consumer electricity bills in the Carbon Standard plus Renewables and Efficiency Policies Scenario are slightly lower than in the Business as Usual Scenario, and this trend continues through 2040. For a typical household, we found that electricity bills under the Carbon Standard plus Renewables and Efficiency Policies Scenario would be about $4.00 per month more than under Business as Usual in 2020, but $3.70 per month less in 2030 and $3.20 per month less in 2040.[5]

In the Carbon Standard Scenario, electricity bills are higher than in the Carbon Standard plus Renewables and Efficiency Policies Scenario and in the Business as Usual Scenario by 2040. In both carbon standard scenarios, electricity bill impacts could be offset in part by implementing the carbon standard as a revenue-raising cap or fee and recycling a portion of the revenues.

Our analysis shows that if the carbon standard we modeled was implemented as a revenue-raising cap on carbon emissions, it could generate billions of dollars in revenue that could be used to offset electricity bill impacts or to address other needs. For example, the Carbon Standard plus Renewables and Efficiency Policies Scenario would raise $14 billion in 2020, $28 billion in 2030, and $50 billion in 2040 (all in 2013 dollars). This revenue could be used, in part, to help fund assistance programs for transitioning workers to new employment opportunities as we move to a low-carbon energy future, as well as to provide assistance for low-income households disproportionately impacted by higher electricity prices.

Implementing a carbon standard along with renewable energy and energy efficiency policies has impacts on consumer energy bills as it cuts carbon emissions and raises carbon revenues (Table 3). In the near term (2020), as investments in renewables and efficiency ramp up, consumers face net costs of $19 billion. However, annual net savings add up to $40 billion by 2030 and rise to $59 billion by 2040.

TABLE 3. Summary of Savings for the Carbon Standard plus Renewables and Efficiency Policies Scenario relative to the Business as Usual Scenario (in Billions 2013$)

	2020	2030	2040
Electricity bill savings*	-$33	$13	$9
Revenue from carbon standard	$14	$28	$50
Total net savings	-$19	$40	$59

*Note: The costs of implementing the carbon standard and the renewable energy and energy efficiency policies are included in electricity prices/bills.

5 *Assumes electricity consumption of 600 kWh per month for a typical (non-electric heating) household.*

Renewables and Efficiency Help Lower Natural Gas Price Risks

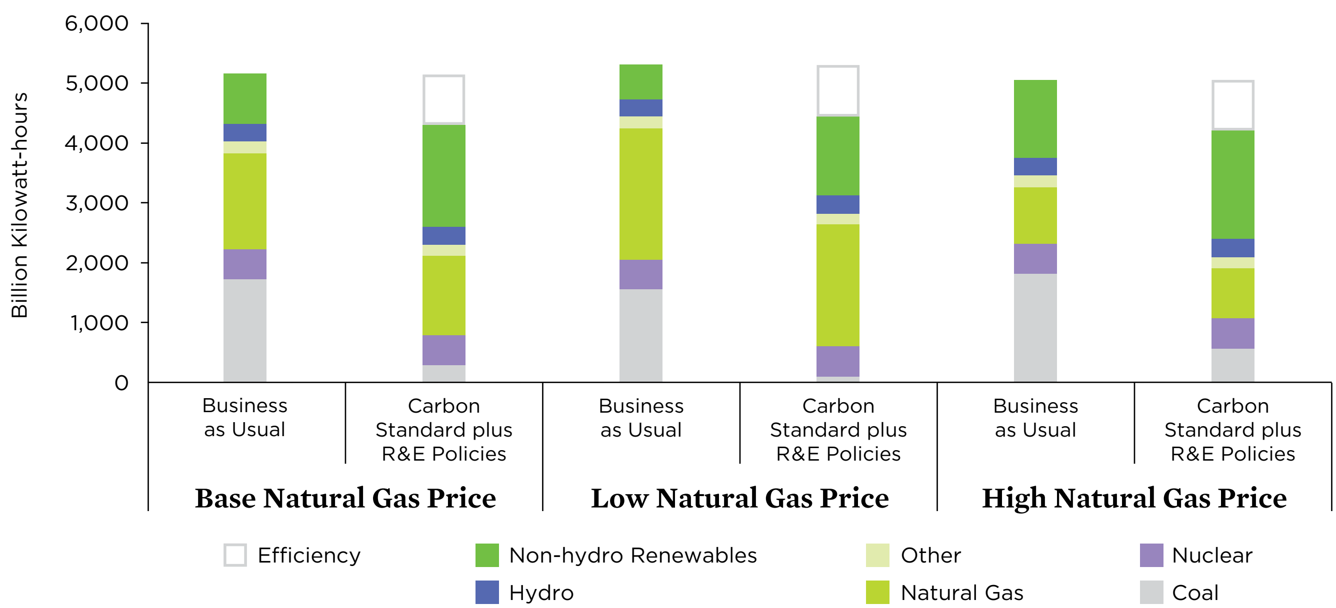
Our analysis indicates that there is a strong need for changes in policy if we want to cut carbon emissions, diversify our electricity mix, and avoid the pitfalls of an overreliance on natural gas. In both our Carbon Standard and Carbon Standard plus Renewables and Efficiency Policies scenarios, natural gas continues to play an important role in supplying U.S. electricity demand as we move away from coal. But the combination of a carbon standard and strengthened renewable energy and energy efficiency policies more strongly ensures that natural gas will play a contained role over the long term. With only a carbon standard, natural gas generation is 25 percent higher in 2040 than in the Carbon Standard plus Renewables and Efficiency Policies Scenario.

As we noted in the Analysis Description and Methodology section, we tested the sensitivity of our scenarios to higher and to lower natural gas prices (Figure 5, p. 21). Given the historic price volatility of natural gas, it is important to consider how competing policy approaches might play out under different future cost regimes. For example, higher natural gas prices in the Business as Usual Scenario lead to burning of more coal, higher emissions of CO_2 and other pollutants that pose public health risks, and higher electricity prices, along with use of slightly more renewable energy.

We first looked at what might occur in the Carbon Standard plus Renewables and Efficiency Policies Scenario if natural gas prices were an average of 23 percent above the baseline price forecast between 2020 and 2040. Natural gas use in the power sector drops to 37 percent lower in 2040 than if the baseline natural gas price is in place (Figure 11). We also found that higher natural gas prices raise the costs of driving down emissions but that those cost increases are lower when there are additional renewables and efficiency policies in force. In 2040, electricity prices are 4.1 percent higher with the high natural gas price than with the baseline natural gas price, but for both price levels the Carbon Standard plus Renewables and Efficiency Policies Scenario delivers an approximately similar percentage of emissions reductions.

We also examined what might occur if natural gas prices were an average of 29 percent below the baseline price forecast. In the Carbon Standard and Carbon Standard plus Renewables and Efficiency Policies scenarios, low natural gas prices trigger a much greater reliance on natural gas. This overreliance is particularly pronounced when there is just

FIGURE 11. U.S. Generation Mix Comparison in High and Low Natural Gas Price Sensitivities for the Business as Usual and Carbon Standard plus Renewables and Efficiency Policies Scenarios, 2040



In all three natural gas price regimes (baseline, low, or high prices), a combination of a carbon standard with policies aimed at encouraging renewable energy and efficiency (R&E) measures results in much less coal burning and considerably lower electricity demand compared with business as usual projections. When natural gas prices are the same as or higher than projected in the Business as Usual Scenario, less natural gas is burned. When prices are low, there is a rush to natural gas whether a carbon standard or other policies are implemented or not.

TABLE 4. 2040 Electricity Bills (in Billions 2013$)

Scenario	Baseline Natural Gas Price	Low Natural Gas Price	High Natural Gas Price
Business as Usual	$504	$449	$504
Carbon Standard	$570	$515	$563
Carbon Standard plus Renewables and Efficiency Policies	$495	$453	$494

Note: Electricity bills include costs of implementing the carbon standard and renewable energy and energy efficiency policies. Carbon revenues that could be used to offset potential electricity bill increases are not included.

a carbon standard. The additional renewables and efficiency policies included in the Carbon Standard plus Renewables and Efficiency Policies Scenario help ameliorate the rush to gas and also help to restrain the increase in natural gas prices that a greater dependence would likely cause. Implementation of only a carbon standard results in 24 percent more natural gas generation in 2040 than with implementation of a carbon standard plus additional renewables and efficiency policies when natural gas prices are low.

Natural gas prices have always been volatile and will likely continue to remain unpredictable in the future. Our analysis shows that, under a range of future price projections—illustrated by the baseline, high, and low natural gas price sensitivities—the best economic choice for consumers is a generation mix that includes more renewable energy and energy efficiency. For example, a comparison of the three scenarios (Business as Usual, Carbon Standard, and Carbon Standard plus Renewables and Efficiency Policies) subjected to the different natural gas price forecasts (baseline, high, and low) shows that electricity bills in 2040 are lowest in the Carbon Standard plus Renewables and Efficiency Policies Scenario for the baseline and high gas price forecasts we modeled (Table 4). Under the low gas price forecast, electricity bills in the Carbon Standard plus Renewables and Efficiency Policies Scenario are less than one percent higher in 2040 than compared with Business as Usual.

The Carbon Standard plus Renewables and Efficiency Policies Scenario is also a more effective power sector pathway for limiting climate risks. Regardless of natural gas prices, this scenario results in significantly lower cumulative carbon emissions by 2040 than do the other two scenarios (Table 5).

Natural gas price volatility creates cost risks for power producers which are usually passed through to consumers. In contrast, utility-scale wind and solar generation, for example, offer the opportunity for more stable long-term contract pricing. A recent study by the DOE shows that greater deployment of wind energy places downward pressure on natural gas prices, lowers consumer natural gas bills, and reduces the long-term natural gas price risk to the electricity system (DOE 2014). The study found that increasing wind power to 20 percent of U.S. electricity generation by 2030 and 35 percent by 2050 would result in $280 billion in cumulative savings on consumer natural gas bills (outside of the power sector) while making total electric system costs 20 percent less sensitive to natural gas price fluctuations.

Following the methodology in the DOE study, we quantified the benefits of reducing reliance on natural gas. We did this by calculating the net present value (using a 7 percent discount rate) of total electricity system costs—which include total capital, operation and maintenance, and fuel expenditures—for the Business as Usual and the Carbon Standard

TABLE 5. Cumulative Carbon Emissions (in Million Metric Tons CO_2, Cumulative 2010 to 2040)

Scenario	Baseline Natural Gas Price	Low Natural Gas Price	High Natural Gas Price
Business as Usual	65,419	62,814	65,553
Carbon Standard	46,333	43,982	47,710
Carbon Standard plus Renewables and Efficiency Policies	39,553	37,293	40,720

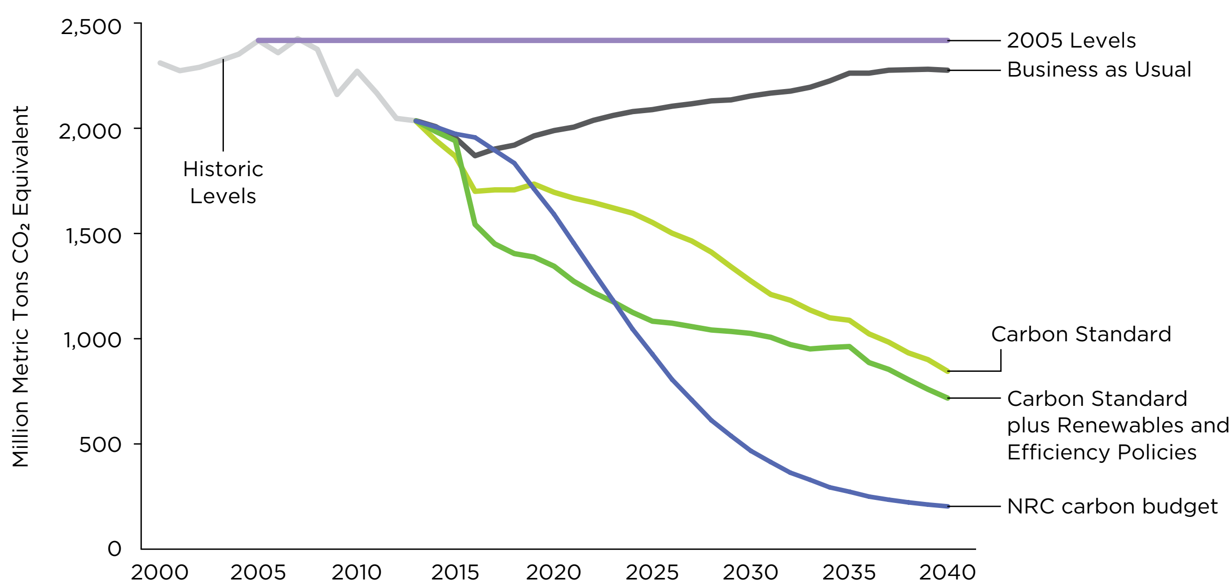
plus Renewables and Efficiency Policies scenarios. We compared total system costs in the two scenarios for baseline and high natural gas prices and found that by replacing gas- and coal-fired generation with renewables and efficiency, the Carbon Standard plus Renewables and Efficiency Policies Scenario results in a total portfolio that is 14 percent less sensitive to long-term fluctuations in fossil fuel prices, providing some insurance against rising costs to consumers due to higher-than-expected fossil fuel prices.

Other Studies Show that a Limited Role for Natural Gas Is Necessary to Meet U.S. Climate Goals

Although the scenarios we modeled achieve significant near-term cuts in carbon emissions, they do not achieve deep enough reductions over the long term to meet U.S. climate goals. The most aggressive scenario we modeled resulted in power sector emissions reductions of 55 percent below 2005 levels by 2025 and 70 percent by 2040. To limit some of the worst consequences of climate change, a 2010 study by the Natural Research Council (NRC) recommended an economy-wide carbon budget for the United States of 170 billion metric tons of cumulative CO_2 equivalent emissions from 2012 to 2050 as part of a global effort to limit emissions (NRC 2010b). Considering cost and available technologies, government and academic researchers found that the electricity sector would account for more than three-quarters of total reductions by 2050 (Fawcett et. al. 2009). This translates into a power sector carbon budget that would reduce emissions by more than 90 percent by 2040 (Figure 12) as part of an economy-wide emissions reduction goal of at least 80 percent by 2050.

A 2013 UCS study that analyzed different pathways the U.S. electricity mix might follow to meet the NRC power sector carbon budget found that almost all existing coal generation (lacking CCS) would need to be retired by 2030 and that, while natural gas would play an important temporary role in the transition, it too would need to be scaled back considerably by 2050 while energy efficiency and renewable energy are ramped up (Fleischman, Sattler, and Clemmer, 2013; Rogers et al. 2013). The study also found that a high renewables and efficiency pathway was the most effective at reducing the economic and climate risks of an overreliance on natural gas. This scenario also had the lowest cost. By 2050, consumer electricity bills were nearly one-third lower than those in a business-as-usual projection, and average consumer natural gas prices were about half as high.

FIGURE 12. Deeper Carbon Reductions Are Needed to Meet U.S. Climate Goals



More ambitious policies than we have modeled will be needed to limit the worst consequences of climate change. In our Business as Usual Scenario, U.S. power sector emissions continue to rise (dark gray line). Our Carbon Standard and Carbon Standard plus Renewables and Efficiency Policies scenarios achieve emission reductions of approximately 65 and 70 percent below 2005 levels by 2040, respectively (light green and dark green lines). A 2010 study by the NRC found that to meet climate goals, power sector emissions would need to be reduced more than 90 percent by 2040 (dark blue line).

What Do Our Results Mean for the EPA's Clean Power Plan?

In June 2014, the EPA proposed first-ever draft standards to limit carbon emissions from existing power plants. The EPA's proposal sets emissions rate reduction targets for states and specifically recognizes that using greater amounts of renewable energy is an affordable way for states to meet those targets. The standards can be met through use of four major components: improving heat rates (or boiler efficiency) at existing coal-fired plants, shifting generation from coal to natural gas, generating electricity from low-carbon resources (including increasing renewable energy generation and preserving nuclear generation at risk of retiring), and increasing energy efficiency. States are free to combine these in a flexible manner to meet their target.

However, the EPA's proposal underestimates the potential role of renewables because it does not accurately capture renewables deployment rates already achieved by many states or likely continued growth and falling costs of renewable energy. UCS has developed a more realistic and ambitious proposal for ramping up renewable energy to meet the state targets in a cost-effective manner (Cleetus et al. 2014a). The UCS "Demonstrated Growth Approach" is based on the real-world experience of states in deploying renewable energy, the latest available market data, and existing state commitments to deploy renewables. If the EPA and states were to use the UCS approach to its full extent, they could achieve renewables deployment equaling 23 percent of national electricity sales by 2030. Greater use of renewable energy could also help increase the total emissions reductions achieved by the Clean Power Plan from 30 percent below 2005 levels by 2030 to approximately 40 percent.

The results of our current analysis show that it is cost-effective to go even further, reaching 27 percent renewables as a share of electricity sales by 2030. (This is actually a constraint in our scenario driven by a renewable electricity standard (RES) policy of 25 percent by 2025, which could be ramped up further). Together with increased energy efficiency, this higher level of deployment results in even greater emissions reductions—58 percent below 2005 levels by 2030.

The EPA's proposal relies heavily on a switch from coal to natural gas as one of the pathways for state compliance with emissions rate reduction targets. This pathway risks overreliance on natural gas in several states and excessive addition of long-lived gas infrastructure. For example, Florida is already at risk, with 68 percent of its total electricity generation coming from natural gas in 2012. Existing combined-cycle natural gas plants in the state were being run at an approximately 52 percent capacity factor in 2012. If Florida fully utilizes this pathway in the EPA's proposal and runs these plants at a 70 percent capacity factor, it will depend on natural gas for

Source: morgueFile

The EPA's new Clean Power Plan is an important step toward limiting CO_2 emissions from existing power plants, which are the nation's largest source of this heat-trapping gas. By setting state-specific emissions rate reduction targets for the power sector, the plan would reduce national electricity sector emissions by an estimated 30 percent below 2005 levels by 2030.

89 percent of its power. Floridians would clearly face electricity price risks even greater than those they face today. Recently proposed interstate natural gas pipelines could help meet this increase in demand and reduce potential supply constraints and price volatility, but they could also lock in additional carbon emissions and crowd out investments in new zero-carbon renewable and energy efficiency technologies. More natural gas is a poor choice given that the state has other low-cost electricity options, including solar power.

Nationwide, expanding natural gas generating capacity could also lead to investment in long-lived infrastructure, such as pipelines, that would become stranded assets as utilities inevitably need to make the shift to low-carbon electricity. The EPA could strengthen the Clean Power Plan and provide a cost-effective long-term pathway to a cleaner power sector by restricting the amount of natural gas that can be used to comply with the state targets and by providing a greater incentive for adding renewables and efficiency instead.

A strengthened Clean Power Plan would be a significant step forward in curtailing the emissions that fuel climate change. These carbon standards provide an opportunity to states to boost their use of renewable energy and to reap the economic, health, and climate benefits of doing so. States should prioritize meeting their target by expanding renewable energy resources and energy efficiency and limiting the risks of overreliance on natural gas. State carbon reduction programs that generate revenue, such as carbon caps or taxes, could provide resources for transition assistance for workers.

The National Renewable Energy Laboratory's (NREL) *Renewable Electricity Futures Study* showed that renewable energy technologies available today could reliably supply 80 percent of U.S. electricity and cut carbon emissions nearly 80 percent by 2050 (NREL 2012). To achieve these goals, natural gas generation would decline to 2.5 percent of total generation by 2050 and would be used primarily for peak electricity demand needs and integrating variable renewable generation.

These results are consistent with another recent UCS analysis that showed a cost-effective pathway to reducing U.S. power sector emissions 60 percent below 2005 levels by 2030 through expanded use of renewable energy and energy efficiency (Cleetus et al. 2014b).

Energy efficiency and renewable energy help restrain the growth in fuel and electricity prices.

Other recent reports also come to the conclusion that the development of shale gas resources and natural gas plants lacking CCS can play only a limited role in meeting 2050 climate goals (Williams et al. 2014; EMF 2013).

Recent studies from the International Energy Agency (IEA) have shown that a global rush to gas would make it infeasible to keep atmospheric CO_2 concentrations below 450 parts per million (ppm), which would provide a good chance of limiting global warming to 3.6 degrees Fahrenheit above the pre-industrial level (IEA 2012; IEA 2011). The IEA's 450ppm scenario showed the use of natural gas peaking before 2030 (IEA 2013). This finding was mirrored in a recent study focused on the United States that suggested that the country's natural gas use must peak by 2030 and a swift transition to primarily zero-carbon energy accomplished to help meet climate-stabilization targets (Banks and Taraska 2013).

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A recent study by the National Renewable Energy Laboratory found that wind and other renewable energy technologies available today could supply 80 percent of U.S. electricity in 2050, while reliably meeting power demand.

[CHAPTER 4]

Working toward an Appropriate, Balanced Role for Natural Gas

As we transition to a cleaner, more sustainable power supply, our analysis shows that natural gas will continue to play an important role. Fuel switching from coal to natural gas can contribute to near-term carbon reductions and increase the flexibility of the grid by aiding the integration of larger amounts of renewables. Ultimately, though, unbridled use of natural gas comes with significant climate, health, economic, and environmental risks. And because new and upgraded power plants and natural gas pipelines can be in service for 40 years or more, the policy and investment choices made in the next few years will largely define the shape of the U.S. power sector—and its emissions—for decades to come. By deploying more renewable energy and efficiency resources to meet our power needs and to cut climate-changing emissions, we can diversify our electricity mix and help minimize the risks of overrelying on natural gas.

Natural gas could continue to contribute to a lower-carbon power supply if greater regulation of fugitive methane emissions from its extraction, transport, and storage, and of smokestack emissions from electricity generating plants is introduced. Recent studies have demonstrated several cost-effective technologies that may reduce methane leaks from the natural gas supply chain by 40 to 80 percent (Allen et al. 2013; Bradbury et al. 2013; Harvey, Gowrishankar, and Singer 2012). In fact, recapture of fugitive methane emissions can even provide an immediate return on investment, especially if natural gas prices rise, and any savings could buffer consumers from increases on their bills. But we need stronger policies and regulations that would require the industry to deploy these technologies (Bradbury et al. 2013; Harvey, Gowrishankar, and Singer 2012; IEA 2012).

Another strategy for reducing carbon emissions resulting from use of natural gas would be to require plant owners to build or retrofit plants with CCS technology. However, adding CCS to existing plants and building new plants with CCS are both costly and greatly reduce plant efficiency—by approximately 17 percent for an advanced natural gas combined-cycle facility (EIA 2014c). Moreover, the long-term viability of geologic carbon sequestration is uncertain and risky (Freese, Clemmer, and Nogee 2008). A great deal of research and development effort must be devoted to this technology if it is to work as an effective long-term climate solution. Still, whether fugitive methane emissions reduction efforts or CCS efforts are undertaken or not, the price of electricity flowing from natural gas plants will rise and continue to fluctuate, which is risky to both local economies and to carbon reduction efforts.

With strong climate and energy policies and sufficient regulatory oversight, natural gas could play a useful—though more limited—role in a clean energy system, especially if it came to be seen not as a replacement for coal but as an enabler of grid flexibility in support of renewable technologies. The cost of reliably integrating wind energy into the power system is now comparable with integrating large conventional power plants (UCS 2013b). Renewable technologies are not subject to fuel price volatility and can offer fixed prices for 20 years or more. In contrast, natural gas prices are difficult to lock in for any significant duration, as shown by its most recent volatility. A recent study comparing prices from a large sample of wind power purchase agreements to a range of long-term natural gas price projections found that wind projects provide a long-term hedge against natural

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Natural gas can play a useful role in a clean energy system, especially as an enabler of grid flexibility in support of integrating greater amounts of renewable energy sources. For example, this natural gas combined-cycle plant in Hermiston, Oregon now operates as a balancing plant to complement the area's recent growth in wind power.

gas price increases, even in an era of low natural gas prices (Bolinger 2013).

As we have shown, there are many reasons to believe that renewable energy resources and efficiency measures are more certain solutions to the climate change and cost problems facing us than is our growing reliance on natural gas. Scaling up renewable energy sources and efficiency measures now is therefore critical to transitioning to a low-carbon energy system. From a climate perspective, the window for this transition is very small and growing smaller. Every year we delay continues our reliance on fossil fuels, putting us at greater risk of more extreme climate-related disasters. Delay also heightens the risk of reverting to increased coal combustion whenever natural gas prices rise, further complicating efforts to cut CO_2 emissions. It is therefore imperative to start instituting proper resource-planning and decision-making processes now, in concert with strong clean energy and climate policies. Doing so will ensure that a balanced natural gas portfolio can support, and not thwart, long-term efforts to mitigate climate change.

[*Unbridled use of natural gas comes with significant climate, health, economic, and environmental risks.*]

[CHAPTER 5]

Recommendations and Conclusions

For many power producers, natural gas has become the fuel of choice as the U.S. electricity system transitions away from aging and polluting coal generators. But compared with doubling down on natural gas, our analysis shows that investing more heavily in renewable energy and energy efficiency offers a smarter, faster, and less risky means of achieving a more affordable, reliable, and diversified electricity system that delivers not just short-term economic and environmental gains but also long-term reduction of emissions causing climate change.

To accelerate and maximize the use of renewable energy and efficiency in this transition will require stronger climate and clean energy policies nationwide, as well as appropriate planning and decision making by regulators, grid operators, utility companies, and power producers. Toward that end, we offer the following recommendations.

Adopt and Implement a Strong Federal Carbon Standard for Power Plants

The EPA should strengthen, finalize, and then implement the power plant carbon standards included in its proposed Clean Power Plan. Although the EPA sensibly allows renewable energy and energy efficiency to be used in meeting the standards, it significantly underestimates the contribution renewable energy should make. Before finalizing the Plan in the summer of 2015, the EPA should expand the role of renewable energy in establishing state emissions rate reduction targets—from 12 percent of total 2030 U.S. electricity sales to 23 percent (Cleetus et al. 2014a). Strengthening other parts of the Plan could help achieve additional emissions reductions.

States have a critical role to play in ensuring the success of the Clean Power Plan. They should develop and implement strong compliance plans that prioritize the use of renewable energy and energy efficiency to meet as much of their emissions reduction target as possible. States should also look for ways to work with other states when complying with the Clean Power Plan, as multistate and regional-level efforts have proven successful in delivering cost-effective carbon reductions.

Although the Clean Power Plan is an important step forward in limiting CO_2 emissions from the electricity sector, it is not sufficient to meet our long-term climate goals. Our nation's response to climate change should therefore also include a federal policy that charges polluters for their CO_2 emissions and sets limits that by 2050 reduce power sector emissions by at least 90 percent below 1990 levels and economy-wide emissions by at least 80 percent.

[The EPA should strengthen, finalize, and then implement the power plant carbon standards included in its proposed Clean Power Plan.]

In addition to limiting carbon emissions, the EPA is also in the process of implementing standards designed to limit other pollutants from coal-fired power plants, such as SO_2, NO_x, mercury, and coal ash. These standards, which include the Cross-State Air Pollution Rule and the Mercury and Air Toxics Standards, will result in major public health and carbon reduction co-benefits while encouraging a transition away from coal-fired generation to cleaner forms of energy.

Strengthen and Enact Strong State and Federal Clean Energy Policies

Policy makers at all levels of government should adopt new or strengthened policies and programs aimed at hastening the deployment of renewable energy and energy efficiency. These measures should include:

Renewable Electricity Standards. RESs require utilities to increase their reliance on renewable energy sources over time. Twenty-nine states and the District of Columbia have adopted RESs—with 17 states setting targets of 20 percent or more. Over the past 15 years, these standards have proven to be one of the most successful and cost-effective means for driving renewable energy development in the United States (Heeter et al. 2014; UCS 2013a). Congress and state governments should enact new or stronger RES policies that require electric utilities to procure at least 25 percent of their power from renewable sources by 2025. Leading states that have already committed to that target level should consider expanding their RES policies to at least 40 percent by 2030.

Energy Efficiency Resource Standards. Congress and state governments should enact strong standards requiring electricity and natural gas providers to meet annual targets for cutting energy use in homes, businesses, and factories by investing in efficiency technologies and measures. Twenty-four states have already adopted such a standard, with leading states requiring utilities to reduce electricity use by 1.5 to 2 percent each year (Gilleo et al. 2014). The federal government should also continue to strengthen efficiency standards for home appliances and other equipment to help spur innovation. And states should tighten energy efficiency codes for buildings over time to ensure that builders use the most cost-effective and energy-saving technologies and best practices.

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Stronger state and federal policies are needed to prioritize the deployment of renewable energy and energy efficiency, and accelerate the transition to a diversified, reliable, and affordable low-carbon power system.

Carbon Pricing Programs. The nine Northeast states that participate in the Regional Greenhouse Gas Initiative (RGGI) and California have successful programs in place that put a price on carbon, limit carbon emissions, and raise carbon revenues. To date, the RGGI states have collectively lowered their power sector emissions 40 percent below 2005 levels and have raised more than $1.6 billion in carbon revenues that have benefitted the states' residents (Hibbard et al. 2011; RGGI 2014). California's Global Warming Solutions Act (or AB32) requires California to lower global warming emissions to 1990 levels by 2020 through a combination of a carbon cap and complementary energy efficiency and renewable energy programs. Other states and regions can build on this experience to accelerate a clean energy transition.

Extend Tax and Other Financial Incentives for Renewable Energy and Energy Efficiency. Congress should extend by at least four years federal incentives for renewable energy and energy efficiency, including the federal production tax credit for wind power and other renewable sources. Congress should also pass legislation that levels the playing field by allowing renewable energy technologies to be eligible for master limited partnerships (MLPs). MLPs are a tax-advantaged corporate structure used by the fossil fuel industry for more than three decades. Allowing the renewable energy industry to use MLPs would expand their pool of investors and lower project financing costs by 40 percent or more (Flannery and Rickerson 2014).

Advance the Deployment of Combined Heat and Power (CHP) Systems. CHP systems generate both electricity and heat from a single fuel source and are noteworthy for delivering significant efficiency advantages (Cleetus, Clemmer, and Friedman 2009). The United States can encourage greater deployment of CHP systems by establishing federal standards for permitting and grid connections and by developing market-based payment mechanisms for the power they produce. Well-funded federal and state programs that foster CHP system development through education, coordination, and direct project support are also needed (Cleetus et al. 2012).

Strengthen Regulations for Fugitive Methane Emissions and Hydraulic Fracturing

In January 2015, the Obama administration revealed a new goal: cutting methane emissions from the oil and gas industry by 40 to 45 percent from 2012 levels by 2025 (White House 2015). The most significant step toward meeting this goal is an EPA rule written under the Clean Air Act that will set standards for emissions of methane and volatile organic compounds from new and modified oil and gas production sources and from new and modified natural gas processing and transmission sources. However, these rules will not cover existing sources, which will remain the major source of methane emissions. To ensure this goal is achieved, the EPA should develop regulations that establish technology-based emissions limits throughout the oil and gas supply chain, including new and existing sources. And to complement this effort, the Obama administration should follow through on the measures identified in its multisector strategy to reduce methane emissions, including an update of standards controlling venting and flaring from oil and gas production on public lands, new and tighter standards for methane emissions from coal mines and landfills, and enhanced leak detection and emissions reporting (White House 2014).

Strong state and federal laws and regulations are also needed as part of a comprehensive framework for monitoring, evaluating, and mitigating the potential public health and safety risks associated with hydraulic fracturing as well as its broader climatic, environmental, economic, and social impacts. These measures include:

- requiring improved disclosure of the chemical composition, volume, and concentration of all fracking fluids before drilling activities;
- requiring careful monitoring and control of discharge and disposal of fracking waste water;
- ensuring that federal and state regulation of the shale gas and oil industry work in a complementary and comprehensive fashion;
- ensuring a comprehensive dissemination of information to the public on the risks as well as the benefits at local, state, regional, and federal levels; and
- fast-tracking critical scientific research on the risks of shale gas and oil extraction to people, communities, agriculture, and the environment (UCS 2013c).

Improve Grid Operation and Resource Planning

As we transition away from coal toward a cleaner, more modern and efficient electric system based on greater use of renewable energy, efficiency, and natural gas, it is essential that utilities, regulators, and grid operators ensure a reliable and adequate power supply. To modernize the U.S. electric grid and the rules that govern it, a number of measures will be required:

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Renewable electricity standards have been a successful and cost-effective driver of solar PV and other renewable energy development in the United States. Congress and state governments should enact new or stronger RES policies requiring electric utilities to procure at least 25 percent of their power from renewable sources by 2025.

- **greater investment in transmission and smart-grid technologies,** including high-voltage direct current transmission lines, new smart-grid applications that can improve the performance of the electric grid at both the transmission and local distribution levels, and demand-response tools and measures that reduce power consumption during peak periods (Cleetus et al. 2012);
- **better integration of renewable energy sources such as wind and solar,** including improved weather forecasting and scheduling of power deliveries, sharing of energy reserves to balance electricity supply and demand over larger areas, adding more flexible power plants to the grid, better management of customer demand, and investments in storage technologies (UCS 2013b);
- **full compliance with Federal Energy Regulatory Commission Order No. 1000,** which requires grid operators, system planning authorities, and transmission planning entities to consider how existing state and federal clean energy policies will shape the supply and demand for power and related transmission and distribution infrastructure in the future (Cleetus et al. 2012); and
- **state utility-regulator-driven comprehensive resource planning processes** that require utilities to evaluate fully and fairly the economics of all available alternatives for meeting projected electricity needs in their state, including demand-side resources and available clean energy technologies. A comprehensive evaluation of the risks of overrelying on natural gas and overbuilding natural gas infrastructure should also be incorporated into utilities' long-term planning decisions.

Conclusions

Recent increases in domestic supplies of natural gas and resulting low prices have impelled utilities and power producers across the country to become more greatly dependent on natural gas as they move away from burning coal to generate electricity. This shift from coal to natural gas is driving near-term reductions in air pollution and carbon emissions and providing an economic boost to some regions of the country.

But the dramatic expansion of natural gas leads to complex risks that should not be ignored. A power system dominated by natural gas exposes consumers to price volatility and makes it much harder to achieve long-term global warming emissions reduction goals. Natural gas extraction and transport also threaten to degrade local land and water resources and raise legitimate public health and safety concerns.

Where natural gas comes up short, renewable energy and energy efficiency can deliver. Shifting to these clean, low-carbon power sources is a swift and cost-effective way to achieve the deep cuts in carbon emissions needed to tackle the climate crisis, diversify the electricity mix, and create healthier, more productive communities.

Prioritizing renewable energy and energy efficiency and avoiding the pitfalls of an overreliance on natural gas requires changes in policy. Our analysis shows that a strong and well-designed limit on power plant carbon emissions, combined with a suite of renewable energy and energy efficiency policies, can accelerate the transition to a truly clean energy economy while ensuring that natural gas plays an important but contained role.

According to our analysis, deploying additional renewable energy and efficiency measures will result in a total electricity resource mix that is 14 percent less sensitive to long-term fluctuations in fossil fuel prices. Such price stability would be beneficial not only for the electricity sector but also for other domestic and industrial consumers of natural gas. In 2020, the societal benefits of this deployment are 2.6 times greater than the costs and in 2040 would amount to nearly $170 billion.

The choice is clear. As the nation moves away from coal, setting course toward a diverse supply of low-carbon power sources—made up primarily of renewable energy and energy efficiency with a balanced role for natural gas—is far preferable to a wholesale switch to natural gas. By making smart energy choices today, we can transition to a more consumer-friendly and resilient electricity system, achieve cost-effective CO_2 emissions reductions, and face fewer risks stemming from an overreliance on natural gas.

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The Natural Gas Gamble

A Risky Bet on America's Clean Energy Future

A power system dominated by natural gas exposes consumers to price volatility and makes it much harder to achieve long-term global warming emissions reduction goals.

Recent increases in domestic supplies of natural gas and resulting low prices have led utilities across the country to become significantly more dependent on natural gas as they move away from burning coal to generate electricity. While this unprecedented shift is delivering near-term environmental and economic benefits, the dramatic expansion of natural gas also leads to complex risks that should not be ignored. A power system dominated by natural gas exposes consumers to price volatility and makes it much harder to achieve long-term global warming emissions reduction goals.

Where natural gas comes up short, renewable energy and energy efficiency can deliver. Shifting to these clean power sources is a swift and cost-effective way to achieve the deep cuts in carbon emissions needed to tackle the climate crisis, create healthier, more productive communities, and avoid the pitfalls of an overreliance on natural gas.

A strong and well-designed limit on power plant carbon emissions, combined with a suite of renewable energy and energy efficiency policies, can accelerate the transition to a truly clean and diverse energy economy while ensuring that natural gas plays an important but contained role. This analysis shows that deploying additional renewable energy and efficiency measures will—by 2040—cut U.S. power demand by 16 percent, increase renewable energy sources to 39 percent of the electricity mix, and reduce power plant carbon emissions by 70 percent below 2005 levels. The reduction in carbon and other harmful air emissions leads to net societal benefits that reach nearly $170 billion in 2040.

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