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Stephen P.A. Brown, Alan J. Krupnick, and Margaret A. Walls

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Natural Gas: A Bridge to a Low-Carbon Future?

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1. Introduction

Over the next 20 years, the United States and other countries seem likely to take steps toward a low-carbon future. Looking beyond this timeframe, many analysts expect nuclear power and emergent energy technologies—such as carbon capture and sequestration, renewable power generation, and electric and plug-in hybrid vehicles—to hold the keys to achieving a sustainable reduction in carbon dioxide (CO_2) emissions. In the meantime, however, many are discussing greater use of natural gas to reduce CO_2 emissions.

Recent assessments suggest that the United States has considerably more recoverable natural gas in shale formations than was previously thought, given new drilling technologies that dramatically lower recovery cost. Because natural gas use yields CO_2 emissions that are about 45 percent lower per Btu than coal and 30 percent lower than oil, its apparent abundance raises the possibility that natural gas could serve as a bridge fuel to a future with reduced CO_2 emissions. Such a transition would seem particularly attractive in the electric power sector if natural gas were to displace coal.

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[1] Stephen Brown is a nonresident fellow, Alan Krupnick is a senior fellow and director of research, and Margaret Walls is a senior fellow at Resources for the Future. The authors thank Tina Bowers, Kara Callahan, Joel Darmstadter, Bob Fri, Less Goudarzi, Kristin Hayes, Tony Knowles, Jan Mares, Karen Palmer, Ian Parry, Michael Schaal, Phil Sharp, Sharon Showalter, Dana Van-Wagener, and Frances Wood for helpful discussions and comments. Funding for this research was provided by the National Energy Policy Institute, a project of the George Kaiser Family Foundation.

To assess the role of natural gas as a bridge fuel to a low-carbon future, we compare four scenarios that reflect different perspectives on natural gas availability and climate policy. These scenarios run through 2030 and were modeled using NEMS-RFF.[2] Two scenarios are business-as-usual cases and assume that the United States adopts no new policies to reduce CO_2 emissions. The first uses what now seem to be conservative estimates of shale gas resources; the numbers date from 2007 but have been used as recently as early 2009 by the Energy Information Administration. The second uses newer, more optimistic estimates developed by the Potential Gas Committee (2009).

The third and fourth scenarios assume that the United States adopts a low-carbon policy with CO_2 emission targets similar to those in the American Clean Energy and Security Act proposed by Representatives Henry Waxman and Edward Markey, and to those proposed by the Obama administration prior to the UN climate conference in Copenhagen. Like the first scenario, Scenario 3 uses conservative estimates of U.S. shale resources of natural gas. Scenario 4 uses the more optimistic estimates.

By comparing these four scenarios, we assess how the relative abundance of natural gas might affect its usage and potential to reduce CO_2 emissions. We find that more abundant natural gas supplies result in greater natural gas use in most sectors of the economy. More importantly, we find that with appropriate carbon policies in place—such as a cap-and-trade system or a carbon tax—natural gas can play a role as a bridge fuel to a low-carbon future.

Having low-carbon policies in place is crucial. Without such policies, more abundant natural gas does not reduce CO_2 emissions. Although greater natural gas resources reduce the price of natural gas and displace the use of coal and oil, they also boost overall energy consumption and reduce the use of nuclear

Scenarios for This Project

- *Scenario 1 (BAU–Low Gas)* represents business as usual with the low estimates of U.S. shale gas resources at 269.3 trillion cubic feet. This case is based on the AEO2009 as revised in April to include energy provisions in the stimulus package, but it pulls new Corporate Average Fuel Economy standards forward from 2020 to 2016.
- *Scenario 2 (BAU–High Gas)* represents business as usual with the higher estimates of U.S. shale resources. It is based on Scenario 1 with PGC estimates of U.S. shale gas resources at 615.9 trillion cubic feet.
- *Scenario 3 (CO_2 Policy–Low Gas)* represents implementation of a low-carbon policy with the low estimates of U.S. shale gas resources. It is based on Scenario 1 with a cap-and-trade policy with CO2 emissions targets similar to those in the Waxman–Markey bill, and to those proposed by the Obama administration prior to the UN climate conference in Copenhagen.
- *Scenario 4 (CO_2 Policy–High Gas)* represents an implementation of a low-carbon policy with the high estimates of U.S. shale gas resources. It is based on Scenario 3 with the higher estimates of U.S. shale gas resources.

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[2] The National Energy Modeling System (NEMS) is a computer-based, energy-economy market equilibrium modeling system for the United States developed by the U.S. Department of Energy. NEMS-RFF is a version of NEMS developed by RFF in concert with OnLocation, Inc. NEMS-RFF projects market-clearing prices and quantities across a number of energy markets, subject to assumptions about macroeconomic and financial developments, world energy market conditions, demographics, resource availability and costs, cost and performance characteristics of energy technologies, behavioral and technological choice criteria.

and renewable energy sources for electric power generation. As a result, projected CO_2 emissions are almost one percent higher.

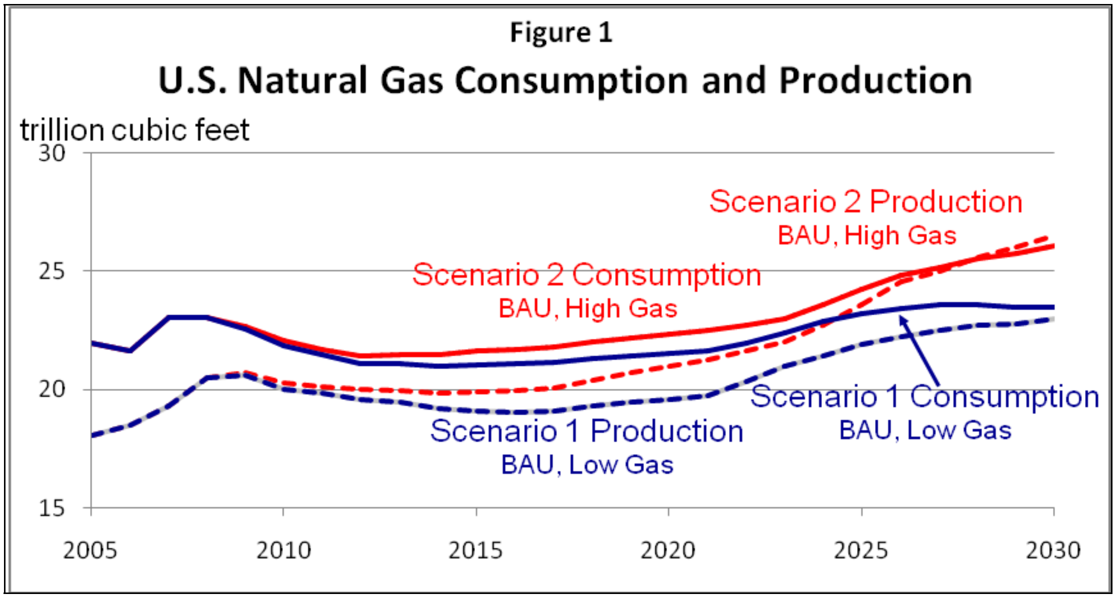
With a carbon cap-and-trade system in place, however, we find that greater natural gas supplies contribute to achieving carbon-reduction goals. With more abundant natural gas, the use of natural gas in electricity generation increases significantly and overall natural gas consumption remains robust, which lessens slightly the burden on other measures to reduce CO_2 emissions. In addition, the price of CO_2 allowances falls slightly, which lessens the economic cost of reducing CO_2 emissions. Thus, it is this ability to lower the costs of climate policy that makes natural gas an attractive bridge fuel to a low-carbon future.

From a broader perspective, our analysis suggests that the most cost-effective means for reducing CO_2 emissions depends greatly on projected resource availability and technology changes—both of which are highly uncertain. If policymakers seek meaningful and cost-effective ways to control CO_2 emissions, they must develop policies that are robust across different projected futures.

2. The Baseline Case (Scenario 1)

The baseline scenario (Scenario 1) represents business as usual. It is based on the 2009 Annual Energy Outlook (AEO2009) of the U.S. Energy Information Administration (EIA), as revised in April to include energy provisions in the stimulus package. It also advances implementation of more stringent Corporate Average Fuel Economy standards from 2020 to 2016, as required by an Obama executive order in May 2009. Following estimates from the AEO2009, the baseline scenario assumes U.S. shale natural gas resources of 269.3 trillion cubic feet and total U.S. natural gas resources of 1759.5 trillion cubic feet.

As shown in Figure 1, U.S. natural gas consumption is projected to grow insignificantly from 2008 to 2030 under Scenario 1. Moreover, the projection shows natural gas consumption falling through 2014, particularly in electricity generation, as renewable energy, coal, and nuclear power crowd out natural gas because of recent changes in regulatory actions. After 2014, the adjustment to regulatory change is mostly complete, and the electric power sector shows increasing use of natural gas.



3. Implications of Abundant Natural Gas Supply (Scenario 2)

EIA's estimates of U.S. natural gas supplies in the AEO2009 date from 2007. Given recent technological changes in extracting natural gas from shale deposits through hydraulic fracturing, the cost of recovering natural gas from shale formations has dropped significantly. In addition, more natural gas is recoverable. Reflecting these developments, the Potential Gas Committee (PGC) estimates U.S. shale gas resources at 615.9 trillion cubic feet. PGC estimates are carefully researched and well documented, and previous PGC estimates have been used in EIA analyses.

The second scenario builds on the first but relies on the PGC estimates for U.S. shale gas resources by assuming that more natural gas can be produced from each well. This approach yields both lower production costs and increased shale gas resources, with total U.S. natural gas resources boosted to 2106.1 trillion cubic feet.[3]

Together, Scenarios 1 and 2 offer a wide range of plausible estimates for shale gas resources and reflect the considerable uncertainty about the supply and production profiles from shale gas formations. EIA will soon release its preliminary AEO2010 report, which we expect will place shale resources between the estimates used for AEO2009 and those of the PGC. In contrast, Navigant (2008) offers a mean estimate of 274 trillion cubic feet with a maximum of 842 trillion cubic feet.

With this change, U.S. natural gas production is much stronger than in Scenario 1 (Figure 1). U.S. natural gas production shows only a mild decline from 2009 to 2014, with steady gains coming after that. With additional natural gas supplies, natural gas prices are lower—with the sharpest

[3] The more conservative approach of increasing basin size or areas would capture increased resources but not reduced costs.

differences projected after 2025. By 2030, the projections show Henry Hub[4] natural gas prices more than 20 percent lower than in Scenario 1. Lower natural gas prices delay development of a natural gas pipeline from Alaska to the lower 48 states by three years and lead to less offshore production (1.0 trillion cubic feet less in 2030). Even with such secondary effects, the responsiveness (elasticity) of U.S. natural gas production to changes in price is considerably greater.[5]

With more abundant supply, natural gas consumption is sharply higher than in Scenario 1. The biggest difference in natural gas use between Scenario 1 and Scenario 2 is found in the electric power sector, where natural gas consumption is 22.4 percent higher (Table 1). Most of the gains in natural gas used in the electric power sector come from substitution for other energy sources. Some come from slightly increased electricity use brought about by lower electricity prices.

Table 1. Natural Gas Use in 2030, by Selected Sector

	Scenario 1 trillion cubic feet	Scenario 2 trillion cubic feet	Difference
Electric power generation	6.7	8.2	22.4%
Industrial natural gas use	6.3	6.9	9.5%
Commercial natural gas use	3.4	3.6	5.9%
Residential natural gas use	4.9	5.0	2.0%

Perhaps surprisingly, enhanced natural gas supplies yield nearly 1 percent higher CO_2 emissions in 2030 compared with Scenario 1. Lower natural gas prices cause natural gas to displace coal, a shift that reduces CO_2 emissions, but lower prices also encourage the displacement of some zero-carbon (nuclear and renewable) electric power sources. In addition, complex market interactions reduce projected prices for other energy resources and boost total energy consumption (by a little more than 1 percent in 2030). Together, these energy market changes increase CO_2 emissions. These findings suggest that greater shale gas resources by themselves do not promote reduced CO_2 emissions.

4. How Natural Gas Supply Affects Carbon Policy

The third and fourth scenarios represent a cap-and-trade policy without and with enhanced natural gas reserves, respectively. The CO_2 emission targets are similar to those in H.R. 2454, the

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[4] Henry Hub is the principal trading hub for natural gas in the United States, and the price at this location is used as a standard reference for U.S. natural gas pricing.

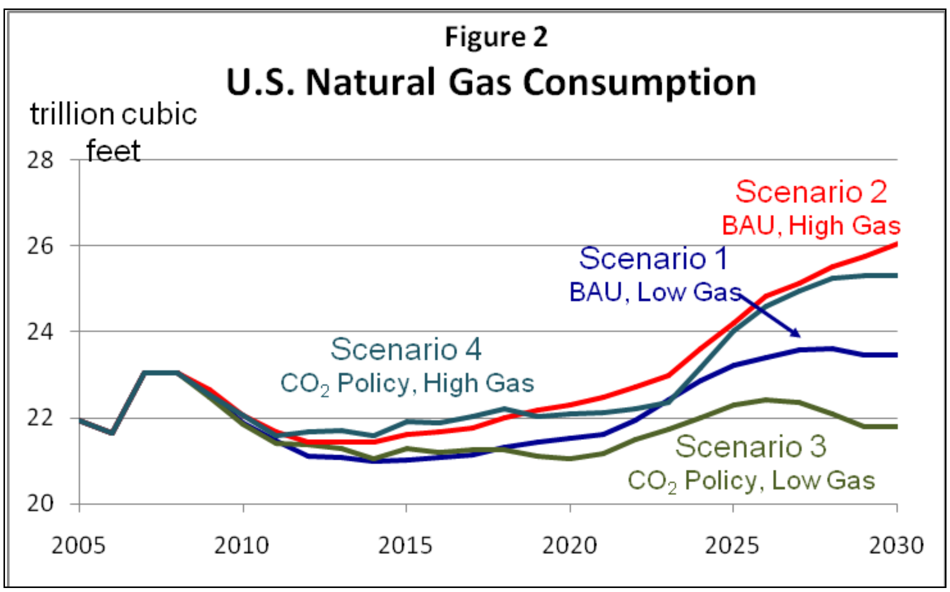
[5] The model's implied supply elasticity for 2030 increases from 0.27 to 0.93.

American Clean Energy and Security Act, proposed by Representatives Henry Waxman and Edward Markey, but with only one billion offsets instead of two billion.[6]

4.1 LOW-CARBON POLICY WITHOUT ABUNDANT NATURAL GAS (SCENARIO 3)

As shown in Figure 2, implementation of the low-carbon policy without abundant natural gas supplies (Scenario 3) results in reduced U.S. natural gas consumption compared with Scenario 1. Coal and oil use are also reduced, but substantial increases are found in nuclear and renewable power generation. Overall energy consumption is 5.4 percent lower in 2030, with electric power generation 8.2 percent lower. Energy consumption is lower in all sectors of the economy, and CO2 emissions in 2030 fall from 6.2 billion tons in Scenario 1 to 4.8 billion tons in Scenario 3.

In 2030, U.S. natural gas consumption is 1.7 trillion cubic feet (7.1 percent) lower than in Scenario 1. For the same year, domestic natural gas production is 1.6 trillion cubic feet (7.0 percent) less. Imports are reduced slightly. As shown in Table 2, natural gas consumption is lower in all major sectors of the economy. The biggest reduction in natural gas use is in the electric power sector, where natural gas and coal are both displaced by conservation and gains in nuclear and renewable power generation.



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6 Offsets are emissions reductions achieved outside the sectors covered by the cap-and-trade program, either domestically or internationally. Proposed legislation would allow regulated entities to purchase offsets as an alternative to reducing emissions.

Table 2. Natural Gas Use in 2030, by Selected Sector

	Scenario 1 trillion cubic feet	Scenario 3 trillion cubic feet	Difference
Electric power generation	6.7	5.7	–14.9%
Industrial natural gas use	6.3	6.1	–3.2%
Commercial natural gas use	3.4	3.3	–2.9%
Residential natural gas use	4.9	4.7	–4.1%

4.2 LOW-CARBON POLICY WITH ABUNDANT NATURAL GAS (SCENARIO 4)

With abundant natural gas supplies (Scenarios 2 and 4), the implementation of a cap-and-trade program yields a greater overall reduction in energy use than would occur without the abundant supplies (Scenarios 1 and 3). Because greater natural gas supplies foster higher overall energy consumption and higher CO_2 emissions in the absence of policy intervention, bigger reductions in energy use are required to meet the CO_2 emission targets (about 4.8 billion tons in 2030). Nonetheless, natural gas production and consumption are only slightly reduced by the introduction of a low-carbon policy (Figure 2).

In the process, the use of natural gas for electric power generation rises, although its use falls in other sectors (Table 3). The opportunities for fuel switching between natural gas and other fuels are not quite as plentiful in residential, commercial, and industrial sectors (which together account for about 65 percent of natural gas use), so emissions reductions in these sectors depend more heavily on energy conservation. Consequently, implementation of a low-carbon policy reduces natural gas consumption in these sectors, even though natural gas is more plentiful.

Table 3. Natural Gas Use in 2030, by Selected Sector

	Scenario 2 trillion cubic feet	Scenario 4 trillion cubic feet	Difference
Electric power generation	8.2	8.5	3.7%
Industrial natural gas use	6.9	6.5	–5.8%
Commercial natural gas use	3.6	3.4	–5.6%
Residential natural gas use	5.0	4.8	–4.0%

With abundant natural gas supplies, the share of natural gas in electric power generation in 2030 rises from 23.9 to 27.8 percent when the low-carbon policy is implemented (Table 4). In contrast, without additional shale gas resources, the same low-carbon policy yields a decline in the share of natural gas in electric power generation, from 19.4 percent to 18.8 percent. With more abundant, less expensive natural gas supplies, power generation from nuclear and renewable sources loses some advantages, and the use of coal sees greater reductions. In short, plentiful natural gas supplies mean that policies to reduce CO_2 emissions will yield a market-driven substitution of natural gas for other fuels.

Table 4. Electric Power Generation in 2030, by Selected Source

	Scenario 1 billion kWh	Scenario 3 billion kWh	Scenario 2 billion kWh	Scenario 4 billion kWh
Total	5058	4640	5159	4696
Natural gas	981	872	1233	1305
Coal	2311	1306	2223	1070
Nuclear	890	1204	849	1183
Renewable sources (including hydro)	795	1186	778	1067

4.3 HOW NATURAL GAS CONTRIBUTES TO A LOW-CARBON POLICY

Beyond greater use in electric power generation as documented above, the importance of abundant natural gas to a low-carbon policy is found by comparing the prices for the carbon allowances under the various scenarios. The price of the carbon allowance rises from $18.61 per metric ton of carbon in 2012 to $67.26 in 2030 under Scenario 3.[7] Under Scenario 4, the price of the carbon allowance is slightly lower, rising from $18.49 per metric ton of carbon in 2012 to $66.83 in 2030. The lower allowance prices translate into an avoidance of costs to the economy that amounts to about $30 million in 2012 and rises to about $300 million in 2030. Overall, welfare gains are modest over the period for which policy is modeled (2012–2030)—about $1 billion in present discounted value terms.[8]

In short, abundant natural gas creates a bridge to a low-carbon future under a cap-and-trade system without a renewable portfolio standard or other government mandates. As Table 5 shows, the combination of abundant natural gas and a cap-and-trade system yields more natural gas consumption than is found under the baseline scenario that reflects neither abundant natural gas nor a cap-and-trade system. Economic theory suggests that other carbon-pricing systems, such as carbon taxes, would yield similar results.

[7] These prices and all others are in 2007 dollars.

[8] Discounted to 2010 using an interest rate of 5 percent.

Table 5. Natural Gas Use in 2030, by Selected Sector

	Scenario 1 trillion cubic feet	Scenario 4 trillion cubic feet	Difference
Total	23.5	25.3	7.7%
Electric power generation	6.7	8.5	31.1%
Industrial natural gas use	6.3	6.5	3.2%
Commercial natural gas use	3.4	3.4	0.0%
Residential natural gas use	4.9	4.8	–2.0%

4.4 A COMPARISON WITH EMF 22

As reported by Weyant (2009), the Energy Modeling Forum 22 (EMF 22), a biannual conference representing the work of 18 energy-modeling teams, is in the process of examining the effects of climate change mitigation policies on energy use. The six models with complete results reported in the EMF 22 study generally find that natural gas is an important fuel for policies to reduce CO_2 emissions by 2050.

Several factors drive the increased use of natural gas in the EMF 22 projections for the United States. Through the increased use of electric and plug-in hybrid vehicles, electric power displaces petroleum in the transportation sector, which increases overall electricity consumption and the potential for natural gas use in electric power generation. In addition, the use of nuclear and renewable power generation is constrained in the EMF 22 analysis, which increases reliance on natural gas in the power sector to meet overall CO_2 emissions standards.

We find similar results for natural gas consumption but through somewhat different avenues than the EMF study. In our scenarios, plug-in hybrids penetrate only slightly into new automobile sales by 2030, contributing to a very slight shift toward electricity use in the transportation sector—not nearly as much the EMF 22 study shows for 2050. In addition, none of our scenarios constrain the use of renewable power generation, and some might consider the 50 megawatt limit we placed on additions to nuclear power capacity too optimistic for 2030. Indeed, with limits on the use of renewable energy supplies and tighter limits on nuclear power capacity, we are confident NEMS-RFF would show substantial further gains in natural gas use.

5. Shale Gas Uncertainty and the Transition to a Low-Carbon Future

The extent of shale gas resources and their likely supply profiles remain highly uncertain. In addition, the U.S. Environmental Protection Agency (EPA) is taking steps toward regulating the hydraulic fluids that have been important to enhancing the production of shale gas and boosting the estimates of recoverable resources from shale gas formations.[9] Industry sources variously say that EPA regulation could have no effect, could slightly increase the cost of shale gas production, or could completely shut it down.

This uncertainty about shale gas resources and their potential development has important implications for policy. Some policies—such as those mandating the use of specific technologies—require accurate predictions about future resource availability and technology change to be cost-effective. Policies that provide carbon pricing—such as cap-and-trade systems or carbon taxes—do not. With pricing, market participants have an incentive to seek out the most cost-effective means for reducing CO_2 emissions, which makes such policies robust across different scenarios.

6. Summary and Conclusions

To examine how natural gas supplies affect the implementation of policies to reduce CO_2 emissions, we compare four scenarios that address different perspectives on natural gas availability and climate policy. These scenarios were implemented with NEMS-RFF and run through 2030. A comparison of the scenarios shows how the relative abundance or scarcity of natural gas supplies might affect the use of natural gas as a bridge fuel to a low-carbon future.

We find that abundant natural gas supplies increase use in most sectors of the economy but do nothing by themselves to create a bridge to a low-carbon future. Without a carbon policy in place, abundant and inexpensive natural gas fosters greater energy consumption and displaces the use of nuclear and renewable resources to generate electric power. Even though coal and oil use fall, the result is higher CO_2 emissions.

On the other hand, if a market-based policy, such as cap-and-trade, is in place to reduce CO_2 emissions, abundant supplies of natural gas can make a contribution in the transition to a low-carbon future. With abundant natural gas resources, the estimated price of CO_2 emissions in a cap-and-trade system is slightly lower and policy implementation is less costly. Moreover, the share of electric power generation from natural gas is greater in 2030 than 2010 and much greater than with less abundant natural gas resources. If the use of nuclear and renewable energy for electric power generation develops more slowly than is projected in our climate-policy cases, natural gas could prove a more important bridge fuel to a low-carbon future, which is an issue we are investigating.

Our analysis assumes no intervening mandates—such as renewable portfolio standards—for specific technologies to reduce CO_2 emissions, but previous research has shown that the addition of such mandates to a cap-and-trade system can substantially alter market outcomes and

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[9] See Obey 2009.

increase the cost of reducing emissions.[10] For this reason, we are in the process of developing model runs to investigate how climate-policy mandates could affect U.S. energy markets and natural gas use in particular.

From a broader perspective, our analysis finds that the most cost-effective means for reducing CO_2 emissions depend greatly on projected resource availability and technology changes—both of which are uncertain. If policymakers are to develop cost-effective policies for controlling CO_2 emissions, they must accurately predict the future or develop policies that are robust across different projected futures. Economic theory suggests that pricing schemes—such as cap-and-trade systems or carbon taxes—are robust in finding the most cost-effective means for reducing CO_2 emissions—regardless of how technology evolves or how much natural gas or other energy resources are available.

[10] See Böhringer and Rosendahl 2009.

References

Böhringer, Christoph, and Knut Einar Rosendahl. 2009. Green Serves the Dirtiest: On the Interaction between Black and Green Quotas. Discussion Paper 581. Statistics Norway.

Navigant Consulting. 2008. North America Natural Gas Supply Assessment. July.

Obey, Doug. 2009. Rulings Strengthen NEPA Oversight of Gas Drilling Absent SDWA Rule. *Inside E.P.A. Weekly Report* 30(37). September 18.

Potential Gas Committee (PGC). 2009. Potential Supply of Natural Gas in the United States: Advance Summary. June.

U.S. Energy Information Administration (EIA). 2009. *2009 Annual Energy Outlook* (revised). Washington, DC: U.S. Department of Energy.

Weyant, John P. 2009. Overview of Energy Modeling Forum Study 22: Climate Change Control Scenarios. Energy Modeling Forum, Stanford University.