Energy Project

Shale Gas: New Opportunities, New Challenges

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BIPARTISAN POLICY CENTER

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Introduction

The outlook for North America's natural gas supply has improved dramatically in recent years as horizontal drilling and hydraulic fracturing technologies have made it possible to commercially develop tight and shale gas reserves. These shale gas basins are located in diverse geographical areas, including Arkansas, Colorado, Ohio, Oklahoma, Pennsylvania, New York, West Virginia, Texas and Louisiana.[1] Effective and responsible development and use of these newly accessible resources provide an enormous opportunity for the United States and has the potential to fundamentally improve our nation's economic and energy security.

The rapid expansion of shale gas production, however, has also given rise to concerns regarding potentially adverse environmental effects — such as water, land, air quality and greenhouse gas emission impacts. In response, many of the states where hydraulic fracturing operations are occurring have recently stepped up their regulatory oversight, and some states have placed development on hold until they can implement more rigorous requirements for drilling and hydraulic fracturing operations. In 2010, New York issued a temporary moratorium on additional shale gas development to allow the state's Department of Environmental Conservation (DEC) to finish its Supplemental Generic Environmental Impact Statement (SGEIS) on issues surrounding natural gas drilling. New York recently published new rules on September 28, 2011, which are now open for public comment.[2] If the rules are finalized in their current form, development in New York could begin in 2012. In June 2011, Maryland Governor Martin O'Malley issued an order calling for a three-year study of the economic and environmental effects of drilling the Marcellus Shale before permits to drill can be issued. And in August 2011, New Jersey Governor Chris Christie placed a one-year moratorium on hydraulic fracturing so that the Department of Environmental Protection "can further evaluate the potential environmental impacts of this practice in New Jersey, as well as evaluate the findings of ongoing federal studies."[3] (Note, however, that no hydraulic fracturing operations were taking place in New Jersey when the moratorium was issued.) Several other states, however — including Wyoming, Pennsylvania, Arkansas, Colorado, Louisiana and Texas, among others — have passed new legislation or regulations in response to the increased activity associated with natural gas development.

Reaping the full economic and environmental benefits of an expanded U.S. gas resource base requires building public confidence that shale gas resources will be developed in a safe and environmentally sound manner. This paper identifies emerging issues and opportunities for capturing the economic benefits associated with this new and significant domestic energy resource.

Context

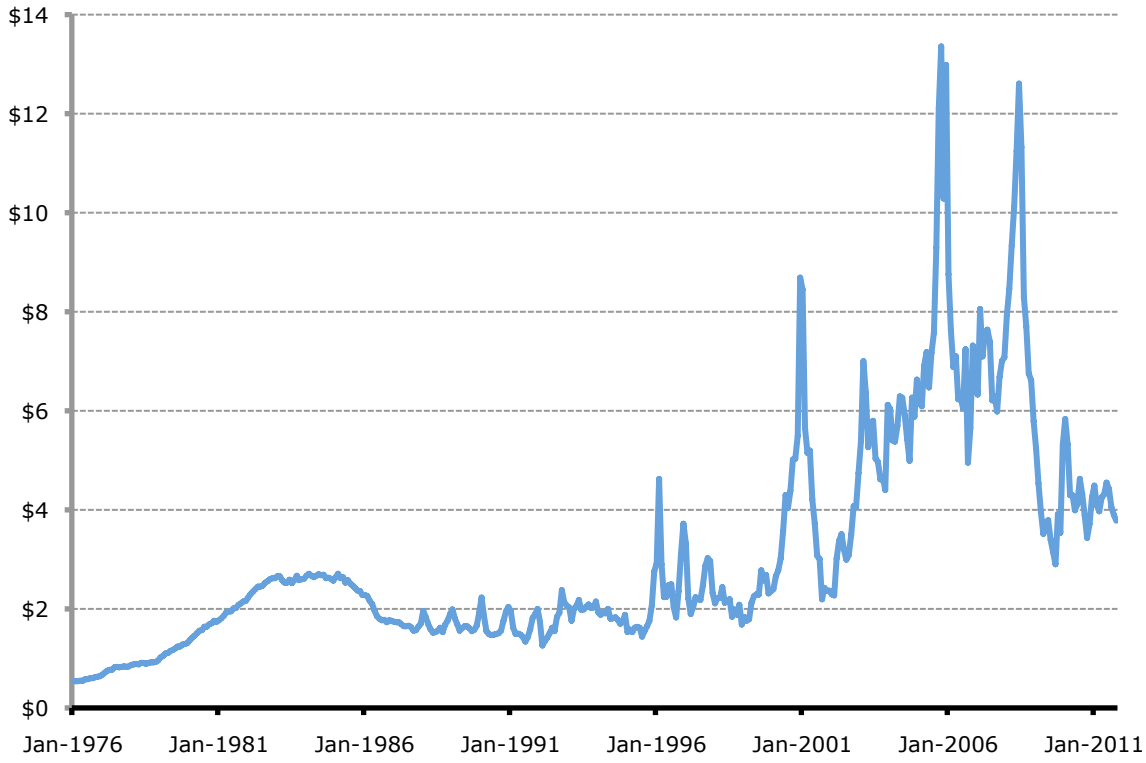
Natural gas is one of America's most important and abundant energy resources. Comparatively clean burning and less carbon intensive than oil or coal,[4] it is an important energy source in a wide variety of applications throughout the economy, as well as a critical chemical feedstock in the industrial sector. Natural gas fuels approximately 25 percent of power generation, supplies more than 30 percent of energy use and feedstocks in the industrial sector (e.g., petrochemicals, fertilizer manufacturing, etc.), and provides heat for 56 million homes.[5,6,7] Until recently, U.S. supplies of natural gas were considered to be sufficient to serve historical levels of usage, but would require increasing imports in future decades as demand grew. This meant that opportunities to advance long-term environmental or energy security goals through expanded reliance on domestic natural gas would necessarily be constrained. It also implied that natural gas markets would continue to be susceptible to the price volatility that had captured news headlines in the mid-1990s, and again in the last decade.

However, this picture of natural gas as an attractive but constrained domestic resource has changed dramatically in just a few short years.[8] The advanced applications of hydraulic fracturing and horizontal drilling have provided a relatively cost-effective means to recover gas from previously non-commercial North American shale gas resources. This has led to a dramatic increase in estimates of the economically recoverable supplies of natural gas. Indeed, current assessments suggest that domestic U.S. gas resources could support as much as 100 years of domestic demand at present levels of consumption.[9,10,11]

With these developments in gas supply, the availability of natural gas as both a fuel and a feedstock has changed in a profound way. As the full impact of these new technologies and processes for identifying and developing natural gas resources has been realized, the result has been abundant new supplies and much less volatile prices (Figure 1). Natural gas prices have already declined relative to coal for power generation, causing changes in the dispatch of some gas plants over coal plants, and helping to lower electric energy prices in markets where natural gas already plays a substantial role.[12] New estimates of supply have increased, and estimated costs of producing shale gas have declined as more wells have been drilled and as more efficient techniques have been developed. In its 2011 Annual Energy Outlook, the Energy Information Administration (EIA) referred to the "enormous potential" of shale gas, but also noted that future natural gas prices are expected to rise above current levels — albeit at a modest pace. Specifically, EIA's 2011 Outlook forecasted that the "average wellhead price for natural gas [will] increase by an average of 2.1 percent per year, to $6.26

(2009 dollars) per million Btu in 2035. Henry Hub prices increase by 2.3 percent per year, to $7.07 per million Btu in 2035." According to the EIA's projections, neither the Henry Hub price nor the average wellhead price of natural gas will exceed $5.00 per million Btu until 2020 and 2024, respectively.[13]

Figure 1: U.S. Natural Gas Price History, 1976 to 2011 (Nominal Dollars)

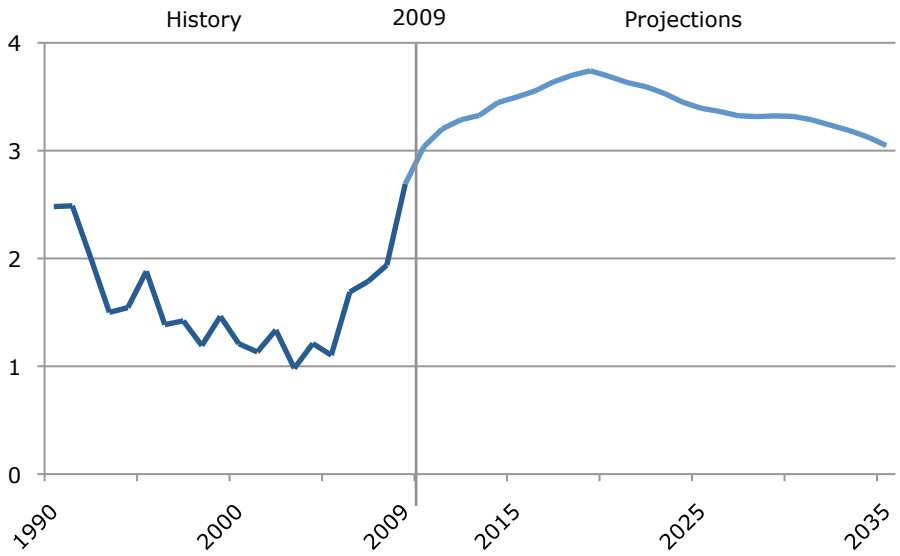


Source: Energy Information Administration, U.S. Department of Energy. Wellhead prices through 1994. Henry Hub prices from 1995 – 2011.

Combined with new investments designed to expand infrastructure, recent expansion of the natural gas resource base offers the U.S. market the potential to respond more smoothly to future demand fluctuations and to substantially alleviate long-standing concerns about supply adequacy. Over the last two decades and until recent years, such concerns have driven relatively close alignment between natural gas and crude oil prices (Figure 2); since 2008, however, the prices of the two have diverged substantially and the outlook is for this trend to continue. The confidence in sufficient domestic gas supply has established a new relationship that could fundamentally change the way primary energy sources are used in the future. This is good news from multiple perspectives — whether the objective is to save money for consumers, reduce emissions from power plants, ease U.S. dependence on imported energy sources, or maintain a competitive industrial base and create new jobs. Given the highly efficient conversion and end-use

technologies for natural gas (such as combined heat and power, new gas-fired power plants, and building heating systems), natural gas now appears available to energize a new view of the future.

Figure 2: Ratio of low-sulfur light crude oil price to Henry Hub natural gas price on an energy equivalent basis, 1990-2035



Source: Energy Information Administration, Annual Energy Outlook 2011

Along with the rapid growth in natural gas extraction from shale formations, there has been an increasing focus on the environmental impacts associated with shale gas production, in part driven by the move to produce substantial quantities of shale gas in areas unaccustomed to such activity (such as New York). While the public debate is often centered on shale gas production in general, and hydraulic fracturing in particular, some of the concerns that have arisen are not specific to either. All oil and gas operations must protect air and water by careful attention to construction and operational practices. One such concern for oil and gas development is protection of surface and subsurface fresh water zones, with a particular focus on reducing spills associated with human error and failure of wellbore integrity.

Parallels in Shale Oil

Some shale formations contain oil as well as natural gas; examples include the Eagle Ford shale in South Texas, the Bakken formation in North Dakota and eastern Montana, the Niobrara in Colorado and Wyoming, the Woodford in Oklahoma and Texas, and the Tuscaloosa in Louisiana and Mississippi. Because all of these formations have very low permeability (and porosity), it was not economically feasible in the past to extract the oil and associated gas resources they contain. With improvements in horizontal drilling and hydraulic fracturing, these resources are being developed economically today.

It is difficult to know just how much shale oil exists globally, since most assessments to date have focused on the natural gas resources trapped in these formations. In its September 2011 report, "Prudent Development," the National Petroleum Council (NPC) published estimates of the unconventional/tight oil recoverable resource base in the United States and Canada, with a high-end potential in the range of six to 34 billion barrels recoverable, with expected production levels possibly in the range of two to three million barrels per day.[14] Technologies to improve recoveries from these challenging reservoirs can be transformative to the resource outlook.

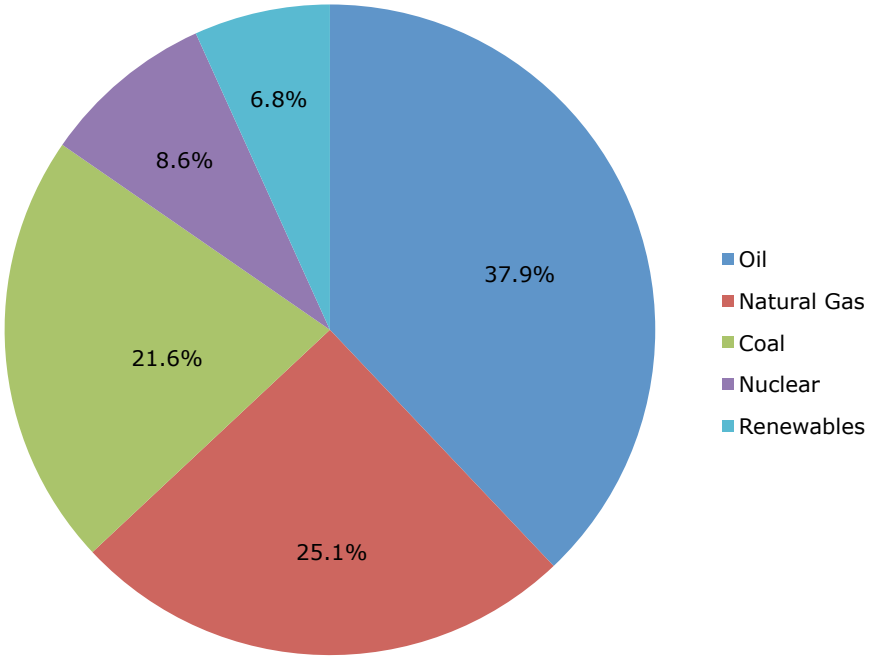
The first major shale play to feature large volumes of crude oil was the Bakken play, followed by the Eagle Ford, Niobrara, Wolfberry (Texas), and the Tuscaloosa Marine Shale. Quietly, but not without important consequences and large amounts of capital investment, drilling rigs started moving to these plays in search of more valuable liquid hydrocarbons.

In its short history, more money has been spent on the Eagle Ford development than in any other shale play to date. According to a study by FBR Capital Markets, "At the current pace of drilling, the industry is set to double its Eagle Ford well count every 12 to 15 months" and oil and condensate production could reach 1.5 million barrels per day by 2015, a volume that exceeds the current throughput of the Trans Alaska Pipeline System.[15] Given that total U.S. oil consumption is currently 19.1 million barrels per day,[16] these figures suggest that the Eagle Ford shale oil production alone could potentially meet 7.8 percent of domestic demand and eclipse the supply estimates made in the recent NPC study on its own.

Benefits and New Opportunities from Developing Unconventional Natural Gas

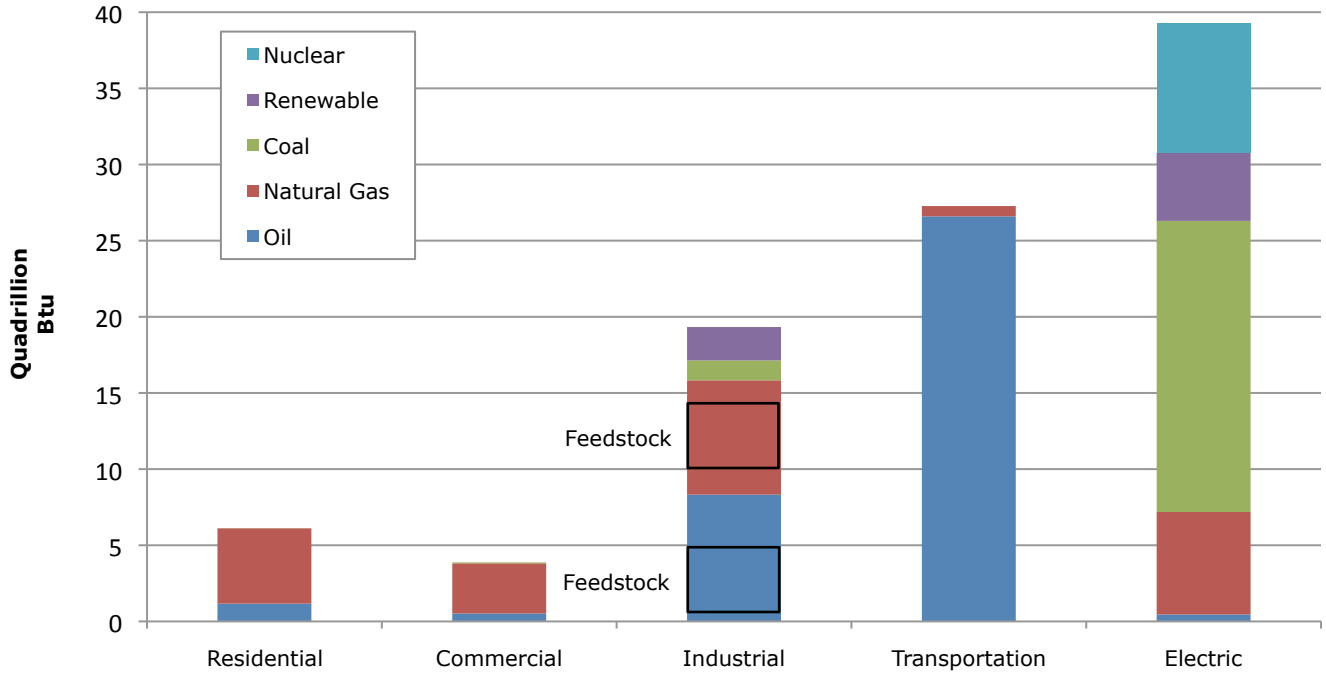
Natural gas is the second largest primary source of energy consumed in the United States, behind petroleum and slightly ahead of coal (Figure 3). However, natural gas is also unique among current energy sources in that it plays a major role in multiple, diverse sectors of the economy. As Figure 4 below demonstrates, coal, nuclear and hydro are used almost exclusively in the power sector. Petroleum is primarily used for transportation, and only secondarily as an energy source and petrochemical feedstock in the industrial sector. Hydro and nuclear power are used solely for electricity generation. Natural gas, by contrast, is used as a fuel in the residential, commercial, power and industrial sectors, and as a chemical feedstock.[17]

Figure 3: U.S. Energy Mix - 2010



Source: U.S. Energy Information Administration, Annual Energy Outlook 2011.

Figure 4: U.S. Energy Consumption by Sector - 2010



Source: U.S. Energy Information Administration, Annual Energy Outlook 2011.

Given the diversity of end-use applications for natural gas, the behavior of natural gas markets has a direct and significant impact on many sectors of the broader economy. An expansion of the low-cost, domestic supply base, in particular, would have a number of benefits, including:

- **Lower and more stable natural gas prices for all market participants.** Natural gas prices declined roughly 37 percent from February 2008 to January 2010, a trend that was driven by increased shale gas production as well as softened industrial demand due to the recession. Lower prices have created what is essentially an economic stimulus, benefitting gas-consuming households and businesses alike in their capacity as direct gas users, as well as electricity consumers with higher reliance on natural gas.[18]

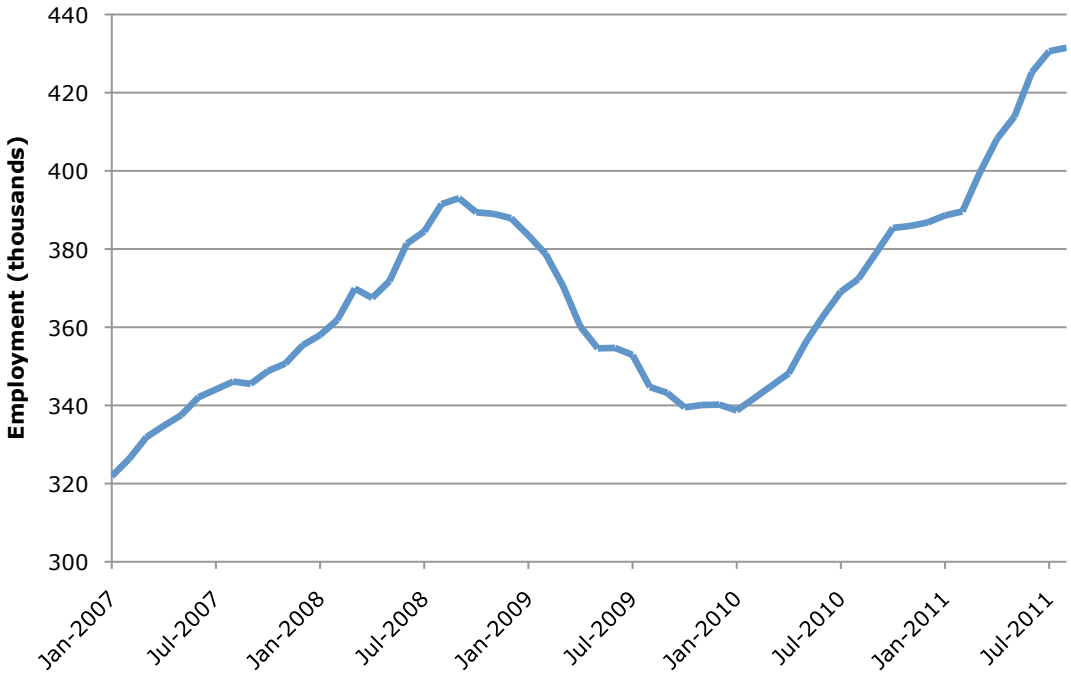
- **The potential to invigorate domestic manufacturing.** Access to low-cost, abundant domestic natural gas is a boon to U.S. manufacturers. A wave of reinvestment in gas-based infrastructure is already underway, with Dow Chemical announcing in April 2011 that it would re-commission and upgrade its ethylene

and propylene production facilities in the Gulf Coast region. (Dow's announcement specifically cited shale production as a driver behind this investment decision.[19]) Sasol recently announced plans to build a new plant in the U.S. that will convert natural gas into diesel fuel, and fertilizer manufacturers are planning to re-open plants in the U.S. Gulf coast.[20] Many more opportunities exist within the chemical industry and beyond. Capturing these near-term opportunities is critical, as is identifying additional prospects for expanding domestic manufacturing as a result of increased natural gas supplies.

- **New opportunities to couple gas-fired power generation with intermittent renewables.** In March 2011, Florida Power and Light unveiled the second largest solar power plant in the United States. This 500-acre facility, located north of West Palm Beach in Florida, includes 190,000 solar thermal collectors capable of generating 75 megawatts of power.[21] The plant is directly coupled with a combined-cycle natural gas power plant, which is concurrently powered by steam from the solar thermal collectors and natural gas combustion. As a result of its hybrid design, the project realized a 20 percent cost savings in comparison to a stand-alone solar facility with a separate natural gas turbine backup. Many similar opportunities exist around the country. Even without co-location of facilities, lower natural gas prices should mean reduced costs for integration of the nation's rapidly expanding base of intermittent wind and solar generation.

In addition to the direct benefits for natural gas users, expanded natural gas production creates jobs not only where shale gas resources are located but in those industries that supply the equipment and other inputs needed in natural gas production as well. According to the Bureau of Labor Statistics, employment in oil and gas extraction and support services has increased by 27 percent since January 2010, and similarly by 11 percent since October 2008, when employment in the industry peaked prior to the recession.[22] Expanded production also results in increased government revenues at the local, state and federal level.

Figure 5: Employment in Oil and Gas Extraction and Support Services



U.S. Department of Labor, Bureau of Labor Statistics, Current Employment Statistics, October 2011.

Increased supplies of natural gas have prompted interest in expanding efficient gas applications in new sectors such as transportation — either directly as a fuel or indirectly in generating power for electric vehicles — as a way of reducing U.S. oil dependence and carbon emissions, as well as lowering transportation costs. Many cities and several private businesses already utilize natural gas in centrally refueled fleets. There are also vocal advocates for converting heavy-duty truck fleets from petroleum-based fuels to compressed or liquefied natural gas.[23]

Additionally, the expanded U.S. supply outlook is prompting interest in gas export opportunities. Recently, some owners of liquefied natural gas (LNG) import terminals have applied for export authorization and have indicated that they plan to install liquefaction facilities. Even if such facilities are built, however, the extent of exports is likely to be modest (i.e., less than five percent of the market) for at least the next decade.[24] How expanded exports might affect U.S. gas markets is currently a topic of active analysis and debate within the energy policy community. Some argue for moving aggressively to capitalize on new export opportunities, while others caution that it may be worth preserving the U.S. economy's relative insulation from global natural gas markets.

Environmental Challenges

Domestic shale gas production has grown rapidly — increasing 12-fold over the last decade — and now comprises roughly 25 percent of total U.S. natural gas production.[25] This has brought significant job creation, tax revenues and economic development to many states. Though the industry has been safely using vertical hydraulic fracturing in the completion of oil and gas wells for over 60 years, the rapid expansion of the shale gas industry has prompted increased focus on environmental concerns centered on shale gas production in general, and on the high-volume, horizontal hydraulic fracturing process in particular.[26] (Hydraulic fracturing is used in nearly two-thirds of the natural gas wells drilled in the United States.[27]) However, several of the issues that have been raised are not specific to shale gas and hydraulic fracturing and would apply to any type of natural gas production. These include potential impacts on water supplies and air quality, management and disposal of wastewater, destruction of wildlife habitat, as well as traffic, air emissions, noise, land-use tensions, and other cumulative impacts on communities not accustomed to drilling.

Hydraulic Fracturing

The U.S. Environmental Protection Agency (EPA) has initiated a congressionally directed study to review the extent to which hydraulic fracturing and other activities related to shale gas extraction pose a threat to drinking water resources.[28] The fracturing process itself is unlikely to directly impact fresh water aquifers because fracturing typically takes place at a depth of 6,000 to 10,000 feet, while drinking water tables are typically less than 1,000 feet deep.[29] Fractures created during the hydraulic fracturing process are generally unable to span the distance between hydrocarbon and fresh water bearing zones.[30] However, there is the potential for fracturing fluids or methane gas to migrate into drinking water resources if wellbore integrity is not assured, or if proper surface handling procedures are not followed (e.g., problems stemming from surface spills of fracturing fluids or other operational incidents, or potentially in certain porous geological settings where there is a history of gas development).

Well Casing and Cementing

There have been incidents where methane from producing and shallow formations have impacted surface and well water supplies due to poor cement integrity associated with the shallower strings of cemented casings.[31] This risk is not unique to shale gas production but its expansion into new areas has increased concern regarding this issue.

Further complicating this issue, some claims of methane migration into water supplies may also be the result of natural methane seepage.[32]

Water Consumption for Fracturing

The average well requires about three to five million gallons of water for both drilling and hydraulic fracturing.[33] While these volumes are large in their own right, they are relatively modest in comparison to other uses of water, including industrial, agricultural and recreational purposes. Even with the water volumes used for fracturing, unconventional gas production uses significantly less water than coal production, and on a lifecycle basis natural gas fired electric power generation uses far less water than coal or nuclear power generation.[34] Water used in shale development is a fraction of total water usage in the states contained within the borders of the shale basins. In the Marcellus, for example, the total volume of water needed to meet estimated peak shale gas development would be about 0.65 billion barrels per year, which represents about 0.8 percent of the 85 billion barrels per year that are currently consumed in the Marcellus basin states.[35] There is concern, however, about the potential cumulative impact on water resources in areas where water supplies may be more limited. Many producers are now applying water recycling methods to both reduce consumption and to lower the potential and actual environmental footprint from disposal trucks, pipelines and/or ponding.

Management and Disposal of Fracturing Fluids and Produced Water

Following a fracturing job, anywhere from 10 to 50 percent of injected water is returned to the surface. The flowback fluid can contain chemicals used during the fracturing operation as well as naturally occurring radioactive, organic and other materials picked up from the producing formation, and must therefore be managed and disposed of properly.[36] State agencies regulate the handling of produced fluids to ensure proper management and environmental protection. The fact that producers have generally not been required to disclose the exact composition of fracturing fluids (because some of the information has been considered proprietary) has added to public concerns. Many producers have adopted self-reporting policies and are using the publicly accessible website, FracFocus.org, to disclose volumes and constituents of their fracture treatments. In most shale gas regions, the return flow and produced water is disposed of by injection into deep saline formations, using wells permitted under the Safe Drinking Water Act Underground Injection Control Program (Class II injection wells). In some areas, particularly in much of the Marcellus Shale region, the ability to inject these wastes into saline formations is limited either by poor geologic conditions or the lack of injection wells. In such regions, flowback water may be treated and recycled for use in future hydro-fracturing treatments, trucked to disposal wells in other areas, or delivered to a third-party water-treatment facility.

General Emissions and Disruption

Developing and operating shale gas production sites involves the use of trucks and other heavy equipment, as well as possible construction of new roads, gathering lines and drill pads. These activities can potentially impact the immediate area of a site, such as air emissions, odors, noise, risk of spills, changes in land use and potential disruption of wildlife. Although the duration of drilling and completion activities is relatively short (weeks to months) compared to the total life of a well (years if not decades), it can be highly disruptive to individuals and communities. Industry's use of multi-well-pad development strategies that consolidate infrastructure help to limit the extent of many of these impacts, in particular surface impacts, potential disruption to communities and wildlife and noise exposure.

Air Quality Impacts

Increased emissions from equipment operation, venting, flaring and vehicle traffic are areas of concern as shale gas operations concentrate in some regions. Requirements for compression, gas treating, or general production operations can introduce additional emission point sources to a region. In July 2011, the EPA proposed amendments to its air regulations for oil and gas operations designed to control ozone precursors, particulates and toxic air pollutants.[37] This proposed rule would apply to all new hydraulically fractured wells and to existing wells that are refractured.

Methane Leakage

Because natural gas or methane is itself a potent greenhouse gas, an important aspect of the natural gas industry's environmental performance involves minimizing methane leakage in all phases of extraction, transportation, storage and delivery. In July 2011, the EPA proposed amendments to its New Source Performance Standards for air emissions from oil and gas operations. The proposed regulations would require the use of control equipment and procedures that, in practice, will result in reductions in both air emissions as well as methane leakage. These reductions will build on the industry's improvements on leakage rates over the past several years through the EPA's voluntary Natural Gas Star program.[38] Failure to build and sustain confidence in further efforts to measure and reduce the level and impact of methane emissions, however, might hinder the full expansion of natural gas. Improved technologies, protocols and practices are being developed to measure, report and control methane emissions in all cycles of production and delivery.

Finding Solutions

An abundant domestic supply of natural gas could fundamentally improve the outlook for our nation's energy security and economy, but only if the shale gas resource base is responsibly developed.[39] The industry and federal and state regulators recognize this fact and have launched multiple initiatives to address environmental concerns and overcome other potential barriers to development.

The oil and gas industry has undertaken significant steps to improve its drilling, completion and water handling practices as well as its land footprint over the last decade (particularly in shale and other unconventional resource plays).[40] The industry's national trade association, the American Petroleum Institute, has developed a widely adopted set of standards and best practices for drilling and production, including a recent "HF-Series" to specifically address hydraulic fracturing best practices. The Marcellus Shale Coalition, an industry group formed to engage government regulators and the public in dialogue, has developed a set of guiding principles for responsible natural gas development in the Marcellus Shale.[41] The Interstate Oil and Gas Compact Commission (IOGCC), a federally chartered compact representing oil and gas producing states, has surveyed individual state practices, developed a platform for sharing best practices via the website, Groundwork, and hosted multi-stakeholder biannual meetings to facilitate conversations about current issues.[42] The industry also collaborated with the IOGCC and the Groundwater Protection Council to develop FracFocus.org, a new online registry for the voluntary disclosure of fracturing fluid additives.[43]

A number of individual companies within the natural gas industry have made public commitments and undertaken high-profile efforts to promote and establish principles for process safety. For example, in June 2011, Shell publicly released its "Global Onshore Tight/Shale Oil and Gas Operating Principles," establishing requirements for all Shell-operated hydraulic fracturing operations. The principles encompass five areas: safety, water, air, footprint and community engagement.[44]

A technically based state oil and gas regulatory framework with strong enforcement is a critical component for building public confidence. Regulators are taking concrete steps to ensure the adequacy of their programs in view of increased activity associated with shale gas development. States that have historically had active and dynamic oil and gas sectors are adapting their regulatory programs to address expanded applications of hydraulic fracturing. Other states where oil and gas development is less mature have taken, or are taking, substantial actions to upgrade their regulatory frameworks. For example, in February 2011, the Pennsylvania Department of Environmental Protection adopted new, stronger regulations for shale gas development. The regulations address

several major issues: well design and integrity; disclosure of the full list of chemicals used on a well-by-well basis; and handling and disposal of recovered fluids.[45] Wyoming similarly strengthened its regulations on shale gas development last year, the Arkansas Oil and Gas Commission initiated mandatory disclosure of fracturing chemicals, and New York has published revised regulations for implementing hydraulic fracturing, which are currently open for public comment (see text box on page 18).

Several states (PA, LA, OH, OK, CO) have undergone formal review of their regulatory frameworks with an emphasis on hydraulic fracturing operations by State Review of Oil and Natural Gas Environmental Regulations (STRONGER). STRONGER was established in 1999 to assist states in assessing the adequacy of environmental regulations associated with waste management in the exploration, development and production of crude oil and natural gas. Most recently, it expanded its reviews to include hydraulic fracturing regulations. The voting members of the STRONGER board include representatives from industry, state and environmental groups. The reports issued by STRONGER provide a state with an overall assessment of their regulatory framework as well as recommendations on improvements. Actions from the reviews conducted to date have improved stakeholder alignment and improved the framework for prudent development. Value derived from the STRONGER approach to development of effective state regulations underscores the importance of support for collaborative organizations to meet the needs of state regulators. More states should volunteer to have their practices reviewed by STRONGER, and states should go back to STRONGER for more frequent reviews. Additionally, STRONGER should incorporate air emissions and regulatory issues into the scope of state environmental reviews. To accomplish these outcomes, the organization needs more public funding and stronger incentives for states to participate actively.

One common area of action being considered by most states is regarding the public disclosure of the chemicals used in hydraulic fracturing operations. In June 2011, Texas became the first state to pass a law requiring *public* disclosure of chemicals used in hydraulic fracturing operations. Specifically, the Texas legislature passed a new law (HB 3328) that requires chemical ingredients subject to Material Safety Data Sheets to be posted to a public website (FracFocus is specifically referenced); in addition, information about other ingredients must be provided to the Texas Railroad Commission and made publicly accessible. Information about the total volume of water used in fracturing operations must also be publicly filed with the Commission. To address competitiveness concerns, the Texas rule also includes processes to protect trade secrets that might otherwise be exposed by disclosure obligations. Several other states (LA, NM, CO, OK) are developing similar regulations.

New York State — Moratorium and Process Forward

A process is underway in New York State to ensure public confidence that resource development will not negatively impact the environment. In December 2010, then New York State Governor David Paterson issued an executive order placing a moratorium on issuing new permits for high volume horizontal hydraulic fracturing until July 1, 2011 and directing the state's Department of Environmental Conservation (DEC) to issue its draft Supplemental Generic Environmental Impact Statement (SGEIS) on a range of issues surrounding natural gas drilling in New York by this same date. While the moratorium has lapsed at the time of this writing, a de-facto moratorium is in place until the DEC finishes the SGEIS and issues its regulations.

The DEC issued its draft SGEIS on July 8, 2011. Among other provisions, the draft SGEIS identifies a number of areas where high volume horizontal hydraulic fracturing will be prohibited[46], including:

- In the New York City and Syracuse watersheds, including a buffer zone;
- Within primary aquifers and within 500 feet of their boundaries; and
- On state-owned land including parks, forest areas and wildlife management areas (in this instance, the prohibition applies to surface locations).

Consistent with these restrictions, the draft SGEIS states that high volume fracturing will be permitted only on privately held lands and must be conducted in accordance with a rigorous set of requirements and controls.[47]

The DEC issued a draft update to the SGEIS with information on socio-economic impacts in early September 2011. The draft was open for public comments until December 12, 2011. The DEC also announced that it would be creating a High Volume Hydraulic Fracturing Advisory Panel, which presumably will provide input on any changes that might be made in response to public input.[48] Once a final SGEIS has been issued (expected in 2012) and if the new rules are approved, the DEC could begin issuing permits for high volume horizontal hydraulic fracturing.[49]

The U.S. Department of Energy is also leading several efforts tied to shale gas development and hydraulic fracturing. In January 2011, the Secretary of Energy's Advisory Board (SEAB) established a Shale Gas Production Subcommittee, and in May 2011 the Secretary of Energy charged it with making recommendations designed to improve the safety and environmental performance of shale gas hydraulic fracturing operations and protect public health and safety.[50,51] Its first report was issued in August 2011, with a set of recommendations aimed at improving measurement and disclosure,

strengthening information on and regulation of air emissions, sharing of best practices, and other steps. In developing its reports, the SEAB was aware of ongoing state, stakeholder and industry-led efforts to develop best practices. In November 2011, the SEAB Subcommittee on Shale Gas Production released its final report, which reviewed implementation of its August recommendations and urged continued attention to the full range of environmental performance issues including drilling best practices, air quality and methane emissions, public disclosure of fracturing fluid composition, and water quality management.[52]

Also, in 2009 the secretary charged the NPC with conducting a study to estimate the size of North American oil and natural gas resources, examine the potential for natural gas to reduce greenhouse gas emissions, and assess the implications of these resources for improving the nation's energy security, economic competitiveness, and environmental protection.[53] In September 2011, NPC membership approved its study entitled "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," and transmitted the report to Secretary Chu. The NPC study is comprehensive in scope, and was spurred by a broad charge from the secretary to reassess the character and potential of North American natural gas and oil resources, along with the contribution that natural gas can make to a transition to a lower carbon energy mix while achieving objectives of environmental protection, economic growth and energy security. While the overall scope of the NPC study was much broader than that of the SEAB study, it contains a number of recommendations that touch upon many of the same environmental performance issues covered by that of the SEAB. The table below summarizes the suite of recommendations on environmental performance contained in the SEAB and NPC reports.

Consensus is growing that North American shale gas and oil resources are potentially transformative, and that industry, regulators and stakeholders must work together to implement solutions and build public confidence that these resources will be developed responsibly.

Table 1 — Comparison of Key Environmental Performance Recommendations in the SEAB and NPC Reports

	SEAB	NPC
SHARING BEST PRACTICES	• The subcommittee recommends that an organization "dedicated to continuous improvement of best practices" be created. • The subcommittee envisions that the "industry organization would be governed by a board of directors composed of member companies, on a rotating basis, along with external members, for example from non-governmental organizations and academic institutions, as determined by the board." [54] • The subcommittee noted that "industry intends to establish 'centers of excellence' regionally, that involve public interest groups, state and local regulatory and local colleges and universities."[55]	• The NPC recommends the establishment of industry-led "regionally focused council(s) of excellence in effective environmental, health, and safety practices." • "The governance structures, participation processes, and transparency should be designed to: promote engagement of industry and other interested parties; and enhance the credibility of a council's products and the likelihood they can be relied upon by regulators at the state and federal level."[56]
TRANSPARENCY AND DISCLOSURE	• The subcommittee recommends public disclosure of fracturing fluid composition, noting that while companies and regulators are moving in this direction with participation in the FracFocus database, progress needs to be accelerated. • Funding should be provided for STRONGER and for the Ground Water Protection Council's project to extend and expand the *Risk Based Data Management System.*[57] • The subcommittee welcomes the announcement of the Department of Interior of its intent to require disclosure of fracturing fluid composition on federal lands. Similarly, the subcommittee welcomes the GWPC and IOGCC announcement that their members will require disclosure of all chemicals by operators utilizing the FracFocus registry.[58]	• "Natural gas and oil companies should engage affected communities to establish shared understandings of expectations and awareness of issues and facts." Such engagement must be transparent and science-based.[59] • Industry should also participate in predevelopment planning in order to identify concerns and seek ways to mitigate them. • STRONGER should be bolstered and increase the scope of its activities. All states with natural gas and oil production should actively participate in STRONGER and use its recommendations to continuously improve regulation. It should be adequately funded, including from the federal government. • All companies should participate in the FracFocus project in order to ensure industry transparency.[60] • The Department of the Interior should require every natural gas and oil company that uses hydraulic fracturing on federal lands to participate in FracFocus.

AIR EMISSIONS	• SEAB recommends that federal agencies should work with industry to investigate the total amount of greenhouse gases emitted by shale gas drilling in order to resolve the conflicting studies on how natural gas compares to coal in terms of life cycle greenhouse gas emissions. • The subcommittee recommends "enlisting a subset of producers in different basins, on a voluntary basis, to immediately launch projects to design and rapidly implement measurement systems to collect comprehensive methane and other air emissions data."[61] • The subcommittee also recommends "industry and regulators immediately expand efforts to reduce air emissions using proven technologies and practices."[62] • The subcommittee also recognizes "the need for a thorough assessment of the greenhouse gas footprint for cradle-to-grave use of natural gas."[63] • The subcommittee is aware that "operating companies are considering projects to collect and disclose air emissions data from shale gas sites."[64] • The subcommittee commended EPA for proposing the New Source Performance Standards and National Emissions Standards for Hazardous Air Pollutants for the oil and gas sector. However, the subcommittee noted its disappointment that these rules do not directly control methane emissions, and that the NSPS rules do not cover existing shale gas sources except for fractured or re-fractured existing wells.[65]	• The NPC recommends taking action to measure and reduce methane emissions, as well as the establishment of industry-government partnerships to facilitate adoption of control technologies. • The council recommends making use of "industry-government partnerships to promote technologies, protocols, and practices to measure, estimate, report, and reduce emissions of methane in all cycles of production and delivery. Ensure greater adoption of these technologies and practices within all sectors of the natural gas industry, with a focus on significantly reducing methane emissions while maintaining high safety and reliability standards."[66] • The NPC recommends "the federal government should complete development of and adopt consistent methodologies for assessing full fuel cycle effects."[67]
GROUNDWATER PROTECTION	• The subcommittee recommends that shale gas companies and regulators "measure and publicly report the composition of water stocks and flow throughout the fracturing and clean-up process." • In addition, regulatory agencies should "adopt requirements for background water quality measurements (e.g., existing methane levels in nearby water wells prior to drilling for gas) and report in advance of shale gas production activity."[68] • The subcommittee noted, "EPA has a number of regulatory actions in process… [including] an announced schedule setting waste water discharge standards that will affect some shale gas production activities.[69]	• Although the NPC report does not address groundwater quality specifically, it does note that the recommended "councils of excellence" could "benefit from the substantive work of many existing industry and public-sector organizations" such as the Groundwater Protection Council.[70]
REGULATORY RESOURCES	• Although it was "not within the scope of [its] 90-day report to make recommendations about the proper regulatory roles for state and federal governments," the subcommittee emphasizes "effective and capable regulation is essential to protect the public interest." • The subcommittee suggests "fees, royalty payments and severance taxes are appropriate sources of funds to finance these needed regulatory activities."[71]	• The NPC recognizes that regulators require adequate resources, and notes that "a fee-based funding mechanism is one approach that could provide these resources in states where there are neither the resources nor adequate industry contributions to support this function, provided that such fees support the institutional mission of efficient and effective regulation and are not used solely to increase taxes for general budgetary support."[72]

A Path Forward

Efficient and environmentally responsible production of shale gas resources has the potential to transform our nation's economic and energy security. Natural gas is a cost-effective fuel that can be used efficiently with existing technology, and development of these resources will create new jobs, provide additional government revenues, and renew opportunities for the expansion of gas-driven industries. While several recent studies — in particular the NPC study — have explored these opportunities, additional analysis to more fully understand how these new shale gas resources will affect the dynamics of the overall energy sector could prove useful.

Building upon the work of the NPC and SEAB, the BPC will examine how these additional supplies of natural gas could impact other fuels and sectors, and how changing patterns of natural gas supply and demand could shape future infrastructure needs.

While new shale gas resources provide exceptional opportunities for the country, the environmental challenges are clear. Fortunately, however, they are not insurmountable. Both the SEAB and the NPC have laid out clear sets of recommendations to improve safety and mitigate community and environmental impacts from shale gas development. A number of states are moving forward with improved regulation, and several industry and stakeholder efforts are underway to address these issues. While there is still much work to be done on these issues, progress continues to be made. BPC will track these efforts to implement SEAB and NPC recommendations.

Endnotes

[1] Gas-rich shale formations are ubiquitous throughout the United States, and the states listed here represent where the resources are located. The Energy Information Administration maintains a map of shale gas basins in lower 48 states at the following location: http://www.eia.gov/analysis/studies/usshalegas/images/shalemap-lg.png.

[2] State of New York, Department of Environmental Conservation, "High Volume Hydraulic Fracturing Proposed Regulations, 6 NYCRR Parts 52, 190, 550-556, 560 and 750," Sept. 28, 2011. http://www.dec.ny.gov/regulations/77353.html.

[3] State of New Jersey Press Release, "Governor Chris Christie Stands Up for Sound Policymaking By Issuing One-Year Moratorium on Fracking," Aug. 25, 2011. http://www.state.nj.us/governor/news/news/552011/approved/20110825c.html.

[4] In making this observation, we recognize the growing technical debate surrounding about the impacts of emissions of methane (a relatively potent greenhouse gas compared to carbon dioxide) from natural gas production.

[5] U.S. Department of Energy, Energy Information Administration, *Electric Power Monthly*, Table 1.1, "Net Generation by Energy Source: Total (All Sectors), 1997 through May 2011," Sept. 15, 2011. http://www.eia.gov/electricity/data.cfm#generation.

[6] U.S. Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey, Table 1.2, "2006 Energy Consumption by Manufacturers." http://www.eia.gov/emeu/mecs/mecs2006/2006tables.html.

[7] American Petroleum Institute, "Hydraulic Fracturing Q&A's." http://www.api.org/policy/exploration/hydraulicfracturing/questions_answers.cfm?renderforprint=1.

[8] In March 2011, the BPC's Task Force on Ensuring Stable Natural Gas Markets released its report examining the historic causes of instability in natural gas markets and exploring potential remedies. Task Force members included natural gas producers and distributors, consumer groups and large industrial users, as well as independent experts, state regulatory commissions and environmental groups. The Task Force report is available at www.bipartisanpolicy.org/naturalgas.

[9] Potential Gas Committee, "Potential Gas Committee Reports Substantial Increase in Magnitude of U.S. Natural Gas Resource Base," April 27, 2011. http://potentialgas.org/.

[10] In its September 2011 report, The National Petroleum Council estimated U.S. resources in the range of 1,500 to 4,000 Tcf. See National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. 1-28. http://www.npc.org/Prudent_Development.html. See also, MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," May 28, 2010, p. xii, where MIT researchers estimated that the current mean projection of the recoverable U.S. shale gas resource is approximately 650 Tcf.

[11] Estimates on the U.S. gas resource vary and are sensitive to assumptions on price, technology and access. In August 2011, the United States Geological Survey released an updated assessment of the oil and gas resource potential of the Marcellus Shale within the Appalachian Basin. This resource estimate attracted a great deal of attention from the media, because at 84 Tcf it was 80 percent lower than the EIA's estimate of 410 Tcf. However, USGS geologists note that comparing these two estimates are not "an apples-to-apples comparison," as the USGS estimate includes just undiscovered resources while EIA's estimate included both undiscovered resources as well as resources under active development. See USGS estimate at http://pubs.usgs.gov/fs/2011/3092/ and USGS commentary at http://www.washingtonpost.com/blogs/ezra-klein/post/hold-off-on-those-marcellus-shale-obituaries/2011/08/25/gIQAyP83fJ_blog.html.

[12] Federal Energy Regulatory Commission, "State of the Markets 2010," Item NO: A-3, April 21, 2011, p. 5. http://www.ferc.gov/market-oversight/reports-analyses/st-mkt-ovr/som-rpt-2010.pdf.

[13] U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2011," Report Number DOE/EIA-0383 (2011), p. 78. http://www.eia.gov/forecasts/aeo/pdf/0383%282011%29.pdf. See also MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," May 28, 2010, p. xii, where MIT researchers concluded that the mean price production for recoverable shale gas resource would be at or below $6.00 per million Btu at the wellhead.

[14] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, Chap. 1 (Crude Oil and Natural Gas Resources and Supply), p. 1-31.

[15] FBR Capital Markets, "Eagle Ford: Predictable Nature of the Learning Curve Portends Material Revaluation Yet to Come," July 6, 2011, p. 1.

[16] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, Nov. 2011.

[17] A very small amount of natural gas — approximately three percent of total U.S. consumption — is used in the transportation sector.

[18] Natural gas as a percentage of power generation rose from 20 percent around 2008 to about 25 percent in 2010-2011; coal, by contrast, dropped from 50 percent of generation to 45 percent of generation over the same time period. Lower natural gas prices have had a significant impact in electricity markets (like PJM, New York, New England, California and Texas) where marginal electricity prices are heavily influenced by natural gas commodity prices.

[19] The Dow Chemical Company, "Dow Announces Plans to Fully Integrate and Grow North American Performance Businesses with Shale Gas Liquids," Company News Releases, April 21, 2011. http://www.businesswire.com/news/dow/20110421005922/en.

[20] For additional examples see Financial Times, "Shale gas boosts US manufacturing," Sept. 19, 2011. http://www.ft.com/intl/cms/s/0/dbfeaa42-e2d2-11e0-93d9-00144feabdc0.html#axzz1fyOz8dm6.

[21] Florida Power and Light, "FPL Unveils World's First Hybrid Solar Energy Center," Florida Power and Light News, March 5, 2011. http://www.fpl.com/news/2011/030511.shtml.

[22] Bureau of Labor Statistics, Current Employment Statistics, NAICS 211 and 213112, Oct. 2011. http://www.bls.gov/data/#employment.

[23] There are debates in different arenas with regard to whether natural gas is more economical and efficient to introduce at larger penetration rates into the transportation sector directly, through compressed or LNG, or indirectly, through electric vehicles with back-up power generated reflecting incremental supplies of natural gas.

[24] In May 2011, Cheniere Energy Partners, LP received final approval from the Department of Energy to export domestically produced natural gas from their Sabine Pass LNG terminal as liquefied natural gas. Final approval is still needed from the Federal Energy Regulatory Commission (FERC) before construction can begin on the export facilities. Freeport LNG also filed an LNG export application with the U.S. Department of Energy on December 17, 2010. The application, available under FE Docket No. 10-160-LNG, contemplates the export of 225 million metric tons of LNG over a 25-year period to countries with which the United States currently has entered into free trade agreements or may enter free trade agreements in the future.

[25] U.S. Department of Energy, Energy Information Administration, "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays," July 8, 2011. http://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf.

[26] The August 11, 2011 "90-Day Report" of the Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board pointed to "the urgency of addressing environmental consequences" of shale gas development: "There are serious environmental impacts underlying these concerns and these adverse environmental impacts need to be presented, reduced and, where possible, eliminated as soon as possible. Absent effective control, public opposition will grow, thus putting continued production at risk," p. 8.

[27] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. 1-128. http://www.npc.org/Prudent_Development.html.

[28] United States Environmental Protection Agency, Office of Research and Development, "Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources," EPA/600/R-11/122/November 2011/www.epa.gov/hydraulicfracturing.
http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/FINAL-STUDY-PLAN-HF_Web_2.pdf.

[29] Notably, on December 8, 2011, the EPA released draft findings relating to its investigation of public and private drinking water in Wyoming. As noted in the press release, "EPA's analysis of samples taken from the Agency's deep monitoring wells in the aquifer indicates detection of synthetic chemicals, like glycols and alcohols consistent with gas production and hydraulic fracturing fluids, benzene concentrations well above Safe Drinking Water Act standards and high methane levels. Given the area's complex geology and the proximity of drinking water wells to ground water contamination, EPA is concerned about the movement of contaminants within the aquifer and the safety of drinking water wells over time." The release goes on to note, "EPA also updated its sampling of Pavillion area drinking water wells. Chemicals detected in the most recent samples are consistent with those identified in earlier EPA samples and include methane, other petroleum hydrocarbons and other chemical compounds. The presence of these compounds is consistent with migration from areas of gas production. Detections in drinking water wells are generally below established health and safety standards." However, EPA cautioned that the "draft findings announced today are specific to Pavillion, where the fracturing is taking place in and below the drinking water aquifer and in close proximity to drinking water wells — production conditions different from those in many other areas of the country." The draft findings are currently undergoing a peer review by a panel of independent scientists and should be considered preliminary until the review is completed.

http://yosemite.epa.gov/opa/admpress.nsf/20ed1dfa1751192c8525735900400c30/ef35bd26a80d6ce3852579600065c94e!OpenDocument.

[30] See Groundwater Protection Council (GWPC), "State Oil and Gas Agency Groundwater Investigations and Their Role in Advancing Regulatory Reforms, A Two-State Review: Ohio and Texas," Aug. 2011, pgs. 46 and 81. http://gwpc.org/e-library/documents/general/State%20Oil%20&%20Gas%20Agency%20Groundwater%20Investigations.pdf. In its review, the GWPC did not find any instances where groundwater contamination occurred during the hydraulic fracturing portion of well stimulation; rather, the GWPC identified other portions of the well completion process and well abandonment process that resulted in contamination.

[31] On Nov. 4, 2009, Pennsylvania's Department of Environmental Protection released a statement indicating that well integrity issues led to groundwater contamination associated with natural gas production activities in Dimock Township, PA: "DEP inspectors discovered that the well casings on some of Cabot's natural gas wells were cemented improperly or insufficiently, allowing natural gas to migrate to groundwater." See Commonwealth of Pennsylvania, Department of Environmental Protection, "DEP Reaches Agreement with Cabot to Prevent Gas Migration, Restore Water Supplies in Dimock Township Agreement Requires DEP Approval for Well Casing, Cementing," Press Release, Nov. 4, 2009. http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=2418&typeid=1.

[32] New York State Department of Environmental Conservation, "Revised Draft: Supplemental Generic Environmental Impact Statement On the Oil, Gas and Solution Mining Regulatory Program," Sept. 30, 2009. Available at http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf.

[33] Arthur, D., Uretsky, M, and Wilson, P. Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region," All Consulting, p. 3. http://www.netl.doe.gov/technologies/oil-gas/publications/ENVreports/FE0000797_WaterResourceIssues.pdf.

[34] Macknick, J., Newmark, R., Heath, G. and Hallett, KC, "A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies." Technical Report NREL/TP-6A20-50900, March 2011. http://www.nrel.gov/docs/fy11osti/50900.pdf.

[35] Arthur, D., Uretsky, M, and Wilson, P., "Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region," All Consulting, p. 3. http://www.netl.doe.gov/technologies/oil-gas/publications/ENVreports/FE0000797_WaterResourceIssues.pdf.

[36] Haliburton recently introduced a new, safer fracturing fluid system "made with ingredients sourced from the food industry" although the company notes that the "fluid system should not be considered edible." http://www.halliburton.com/ps/default.aspx?pageid=4184&navid=93&AdType=JPTCSTC.

[37]U.S. Environmental Protection Agency, "EPA Proposes Air Rules for the Oil and Gas Industry." July 28, 2011. http://www.epa.gov/airquality/oilandgas/actions.html.

[38] Additional information regarding the Natural Gas Star Program can be found at http://www.epa.gov/gasstar/index.html.

[39] This is one of the four fundamental findings of the National Petroleum Council's September 2011 Study.

[40] The American Petroleum Institute, the Interstate Oil and Gas Compact Commission, the Marcellus Shale Coalition, the State Review of Oil and Natural Gas Environmental Regulation (STRONGER), the Groundwater Protection Council, and the Intermountain Oil and Gas Project, are prominent examples of efforts to identify best practices today.

[41] For more information see http://marcelluscoalition.org/wp-content/uploads/2010/09/Guiding-Principles-Poster-Final.pdf.

[42] Groundwork, available at http://groundwork.iogcc.org/, provides a platform for sharing state experiences and information on the most current oil and natural gas regulatory topics.

[43] FracFocus Chemical Disclosure Registry. http://fracfocus.org/.

[44] U.S. Shell, "Shell Onshore Tight/Shale Oil & Gas Operating Principles," June 2011. Available at http://www.shell.us/home/content/usa/aboutshell/shell_businesses/onshore/principles/.

[45] Pennsylvania Department of Environmental Protection, "Marcellus Shale: Tough Regulations, Greater Enforcement," Report 0130-FS-DEP4288, April 2011. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-84024/0130-FS-DEP4288.pdf.

[46] New York State DEC: http://www.dec.ny.gov/press/75403.html.

[47] Resources Technologies Corporation. Resource Technologies Outlook. Volume 1, Issue 2. August 15, 2011. http://www.resourcetec.com/Portals/0/Harrys%20Folder/August2011.pdf.

[48] New York State DEC Press Release. DEC Commissioner Appoints Members to Hydraulic Fracturing Advisory Panel. July 1, 2011. http://www.dec.ny.gov/press/75416.html.

[49] The Wall St Journal: . *Regulators Back 'Fracking' in New York.* July 1. 2011. http://online.wsj.com/article/SB10001424052702303763404576418193848488766.html.

[50] See http://shalegas.energy.gov/aboutus/index.html.

[51] U.S. Department of Energy, "Energy Secretary Steven Chu's May 5, 2011 Memo to SEAB." http://www.energy.gov/news/documents/Fracking_subcommittee_charge.pdf.

[52] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee Second Ninety Day Report," Nov. 18, 2011. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[53] National Petroleum Council, "Report on Prudent Development of Natural Gas & Oil Resources Featured at National Petroleum Council Meeting," Press Release, Sept. 2, 2011. http://www.npc.org/90211-mtgpr.pdf.

[54] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee 90-Day Report," Aug. 18, 2011, p. 28. http://shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

[55] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee Second 90-Day Report," Nov. 18, 2011, p. 9. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[56] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. ES-27. http://www.npc.org/Prudent_Development.html.

[57] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee 90-Day Report," Aug. 18, 2011, pgs. 14, 24. http://shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

[58] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee Second Ninety Day Report," Nov. 18, 2011, p. 6. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[59] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. ES-30. http://www.npc.org/Prudent_Development.html.

[60] Ibid, p. ES-30.

[61] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee 90-Day Report," Aug. 18, 2011, p. 16. http://shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

[62] Ibid p. 18.

[63] Ibid p. 17.

[64] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee Second 90-Day Report," Nov. 18, 2011, p. 5. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[65] Ibid, p. 5.

[66] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. ES-31. http://www.npc.org/Prudent_Development.html.

[67] Ibid p. ES-37.

[68] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee 90-Day Report," Aug. 18, 2011, p. 2. http://shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

[69] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee Second 90-Day Report," Nov. 18, 2011, p. 7. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[70] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. ES-25. http://www.npc.org/Prudent_Development.html.

[71] U.S. Department of Energy, "Secretary of Energy Advisory Board Shale Gas Production Subcommittee 90-Day Report," Aug. 18, 2011, p. 11. http://shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

[72] National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," Sept. 15, 2011, p. ES-29. http://www.npc.org/Prudent_Development.html.