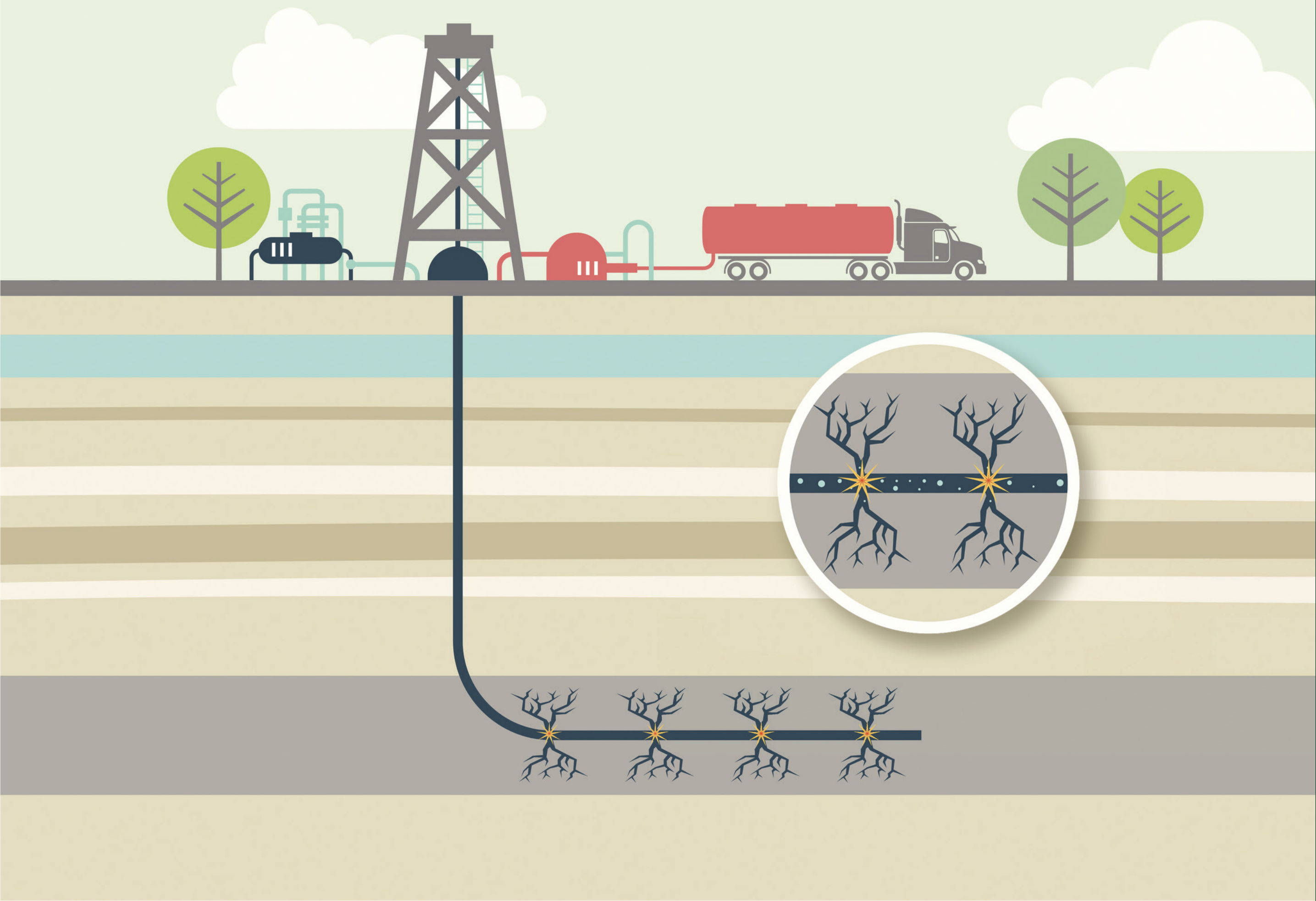
ASAN REPORT

A New Golden Era?

Unconventional Oil and Gas Regulation in the US: Implications for Korea

Edited by J. James Kim and Shin Chang-Hoon

October, 2013



THE ASAN INSTITUTE for POLICY STUDIES

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About

The Asan Institute for Policy Studies is an independent, non-partisan think tank that undertakes policy-relevant research to foster domestic, regional, and international environments that promote peace and prosperity on the Korean Peninsula, East Asia, and the world-at-large.

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Contents

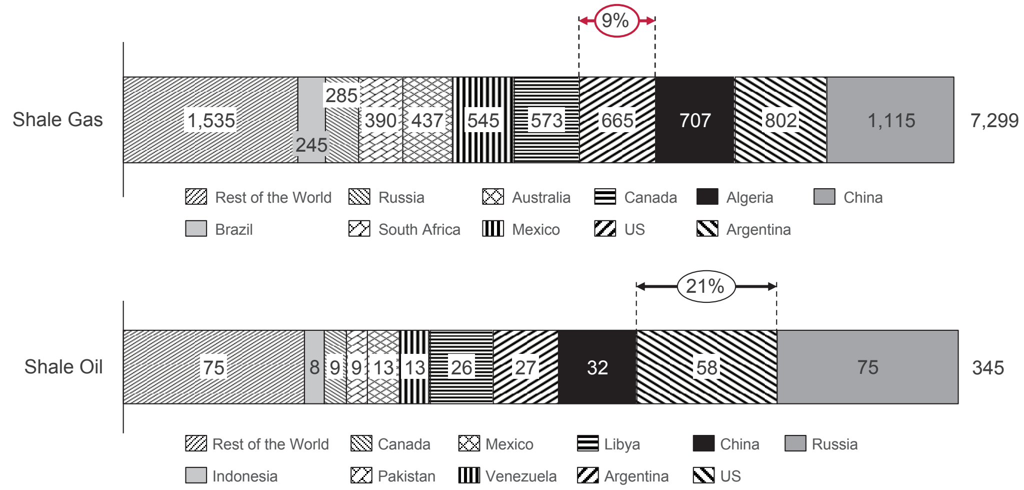
Executive Summary

The widespread use of new technology enabling the extraction of natural gas and oil from tight underground shale formations (i.e. hydraulic fracturing or "fracking") has ushered in a new era of rapidly changing landscape in the global energy supply and production. While the US Geological Survey estimates that there is an abundance of untapped energy from this source in various locations around the world, much of the recent activity associated with extracting oil and gas from deep underground tight formations has been concentrated in North America (i.e. United States and Canada). Estimates and projections vary, but the latest figures issued by the US Energy Information Administration (EIA) indicate that there are approximately 58 billion barrels of recoverable shale oil and 665 trillion cubic feet (tcf) of recoverable shale gas in the United States (See Figure 1).[1]

What this has meant, of course, is that there is now an abundant supply of natural gas and oil in North America and this remains likely to be the case for the foreseeable future. As far as the economy of the global energy market is concerned, this also means a significant drop in the price of these resources. For the time being, this trend has largely been localized around the price of natural gas in the United States with the Henry Hub price dropping from approximately US$9 per million British Thermal Units (BTU) in 2008 to US$2 to US$3, which is comparable to rates not seen since the late 1990s. One interesting observation is the divergence in the price of gas between North American and non-North American counterparts since 2008/9 (See Figure 2).

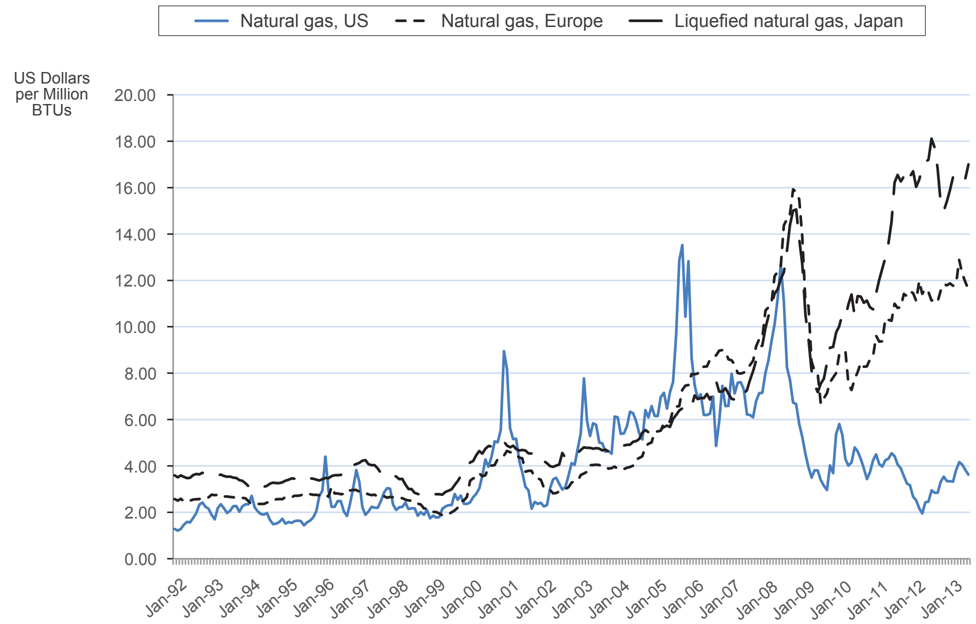
It is hardly surprising that the drop in price has coincided with the rise in natural gas production. According to the EIA's latest estimate, 95 percent of

Figure 1: Technically Recoverable Shale Gas (in tcf) and Oil (in billion barrels)



Source: US Energy Information Administration (EIA)

Figure 2: Comparison of Natural Gas Prices, 1992-2013



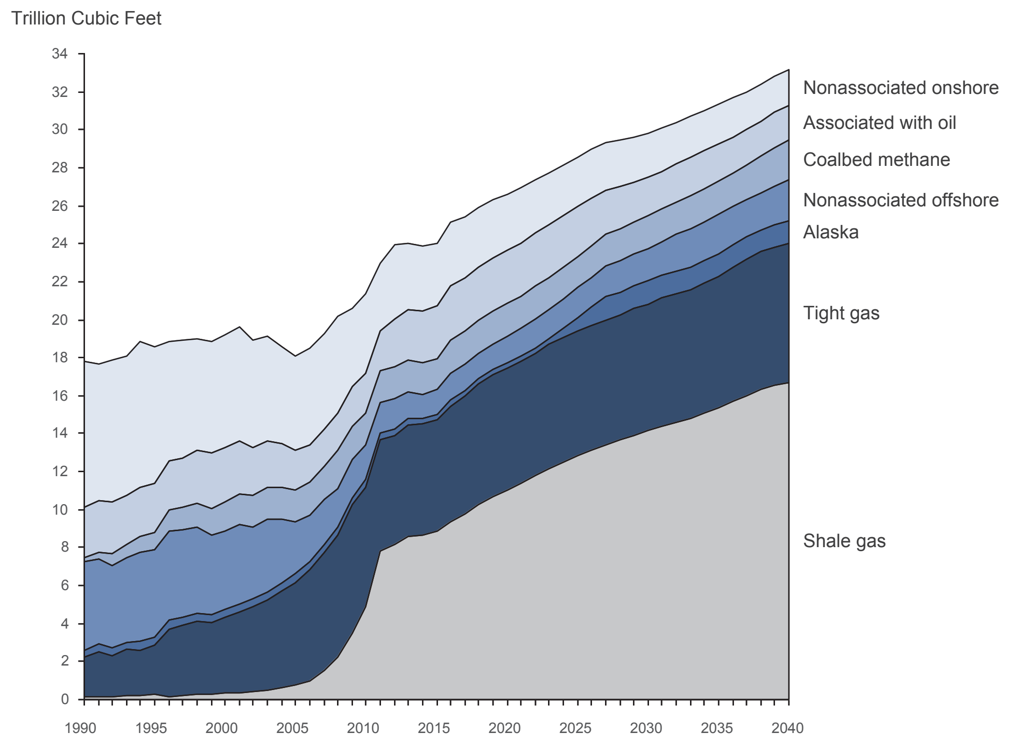
Source: World Bank

natural gas consumed in the United States as of 2011 were produced domestically.[2] Another important point to note is the pace and scope with which this development is currently taking place in the United States. According to the EIA, US shale gas production increased at an annual average rate of 17 percent during 2000-2006 and at 48 percent during 2006-2010. As a comparison, the annual average growth rate of overall natural gas production in the United States since 2007 has been +4.7 percent as compared to the same figure for 1970-2006 which is -0.3 percent. Finally, the latest projection suggests that the overall share of shale and other forms of tight gas is likely to increase into the future (See Figure 3).

As far as the broader economic impact is concerned, the evidence is generally positive. A recent set of reports published by IHS, for instance, indicates that shale development is responsible for over 600,000 jobs in 2010 and approximately 1.7 million jobs as of 2012.[3] This figure is expected to more than double by 2035. In terms of value added contribution to gross domestic product (GDP), shale development is projected to add more than US$400 billion to the US economy by 2020.[4] Between 2012 and 2035, the estimated impact on the federal and state revenue will approximately be about US$2.5 trillion.

There are some studies that refute the validity of these assessments and outlook;[5] however, other signs suggest that there is no early end in sight as far as fossil fuel extraction from tight formations is concerned. One observable trend is the rise in the level of foreign investments in the US shale industry. According to the EIA, total investments in the US shale plays totaled US $133.7 billion during 2008-2012 with about 20 percent of this figure coming from joint ventures involving foreign corporate entities.[6] A trade press report released by the EIA in early 2012 lists about 11 companies from seven differ-

Figure 3: US Dry Natural Gas Production by Source, 1990-2040



Source: EIA

ent countries that have made significant investments in eight different shale plays.

This trend is not likely to change any time soon given the rise in the number of export permit applications pending the approval from the US Department of Energy (DOE); thus far, the DOE has only approved two of 23 applications that it has received to permit overseas export of natural gas. However, it is clear that preparations are well underway to begin full-fledged export of both liquefied natural gas (LNG) as well as liquefied petroleum gas (LPG) from the United States. Consumer nation-states like Japan and South Korea, two of the largest importers of LNG and LPG, are looking to step up imports of both products from the United States within the next three to four years.[7] If these trends continue, the EIA projects the United States to be a *net exporter* of natural gas and oil by 2020 and 2025, respectively.

There is little left to doubt that change in this area has been vast and rapid; however, there is also much left to understand about the range of impact that these developments can and will have on the environment and the broader community. With increasing use of new methods and technology for extracting valuable resources from tight formations, there is a growing concern about the possible externality implications of fracking. One obvious suspect is the impact that fracking will have on surface and groundwater supply. Availability of water for other uses, impacts on the aquatic life, contamination from flowback, spills or leaks, as well as the handling of wastewater are all concerns that have been raised by various members of the civil society and government. Some have even questioned the possible connections between seismic activities in and around the injection wells and drilling pads.[8]

As concerns about the environmental and social impacts of fracking continue to grow, there is an increasing potential for the kind of regulatory intervention that may pose severe restrictions on unconventional oil and gas development. Discussions in the preceding chapters reveal several important lessons that may prove useful in estimating the likelihood for this kind of shift.

We know, for instance, that there are extensive regulatory controls on licensing, planning, leasing, development, and reclamation on federal lands, but we also know that these existing regulations may not be adequate given that drilling operations vary according to subsurface geology and technology.

Secondly, we also know that public concerns about well-bore integrity, transparency, and water management have pushed various federal agencies, such as the BLM, to adapt new rules which themselves are subject to change depending on negotiations with various social interests. In short, what this suggests is that there is some room for uncertainty about the direction of regulatory controls as we speculate on the future of unconventional oil and gas development on federal parcels.

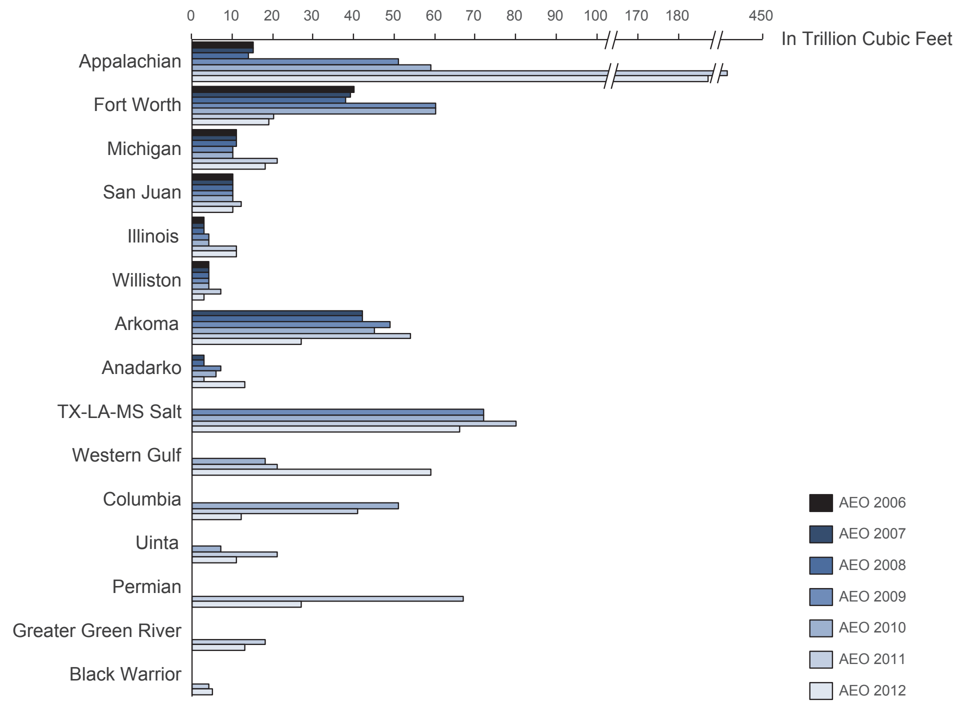
With respect to state-level regulation, we found significant variations in enforcement as well as pre-conditions on various drilling sites across different states. The single greatest challenge appears to be the lack of comprehensive regulatory framework as far as fracking is concerned; however, development of a one-size-fits-all policy with respect to unconventional gas and oil development is problematic given that geological specificity and variations in climate as well as topography largely determine the method and technology used to extract resources from tight formations. Given also that certain regulatory environments are more favorable for certain types of extraction methods and technology, the impact that more or less stringent regulation can have on overall productivity is likely to be cushioned by the variation in regulation, holding all else (i.e. recoverable supply) constant. However, spots of poor regulation can potentially be areas of risk whereby a single environmental or public health fallout can prove to be the basis for harsh regulatory backlash against the industry as was the case in the recent BP Deepwater Horizon drilling rig disaster and the restrictions on drilling that followed shortly thereafter.

While the discussion suggests that state-level regulation, in conjunction with federal, regional, and local regulations, perform relatively well in addressing many concerns, it also appears to be the case that existing regulations are dated in relation to the change in technology and methods. Some potential problems point to a lack of adequate information about the state of regulations across different states as well as personnel resources to enforce existing regulations. Clearly, it seems to be the case that there is room for improvement on this front meaning this is an area in flux and much like federal regulation can change for better or worse.

The question about the kinds of regulation that we may see developing across different states may depend, in part, on how well the industry or the market may manage public concerns as well as the risks associated with drilling. The evidence from the above discussion suggests that there are improvements in at least two fronts in addition to changes in government regulation. One is on the technological front. Innovative approaches to managing water use along with the utilization of multi-well pads and green completion technology have assuaged some environmental concerns. Second area is in inclusive cooperative engagement. Multi-stakeholder approach, which brings together players from the industry, academia, government, as well as other interest areas, have allowed for better problem identification, greater transparency and more effective solutions to potential problems in unconventional oil and gas development. Finally, we also see the emergence of best industry practice which incorporates all of these elements along with effective regulation in order to minimize well construction failures and other potential fallouts. Whether these market-based developments will be able to adequately address public concerns and thereby preclude the need for a comprehensive regulatory control remains to be seen.

Aside from the above non-market factors, there are other critical dimensions that cannot be overlooked. First and foremost is the supply of oil and gas in shale and other tight formations. According to the EIA, estimates of techni-

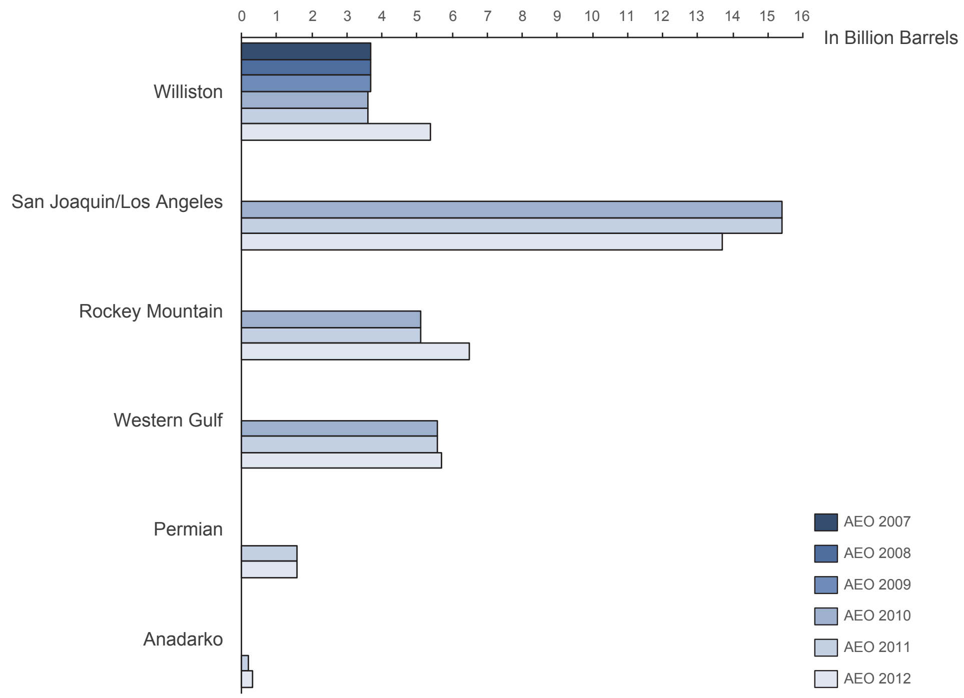
Figure 4: Unproved Technically Recoverable Shale Gas Estimates Outlook by Basin



Source: EIA

cally recoverable resource (TRR) are a function of land area, well spacing, percentage of area untested, percentage of area with potential, and estimated ultimate recovery (EUR) per well. Unproved TRR refers to estimates of resources that can be recovered using current technology without concern for additional economic or operating conditions. As wells are drilled and resources are extracted, unproved TRR become proved TRR and then ultimately catalogued as production. The problem is that the projection figure has a high degree of variance (See Figures 4 and 5). The EIA reasons that since the economics and timing of development can affect production, TRR does not necessarily reflect projected production. One of the criticisms against the development of shale and tight formations, however, is that the projected

Figure 5: Unproved Technically Recoverable Tight Oil Estimates Outlook by Basin



Source: EIA

supply is grossly overestimated. Whatever may be the case, volatility in projected estimates of supply should be weighed in towards decisions about future investments in unconventional oil and gas.

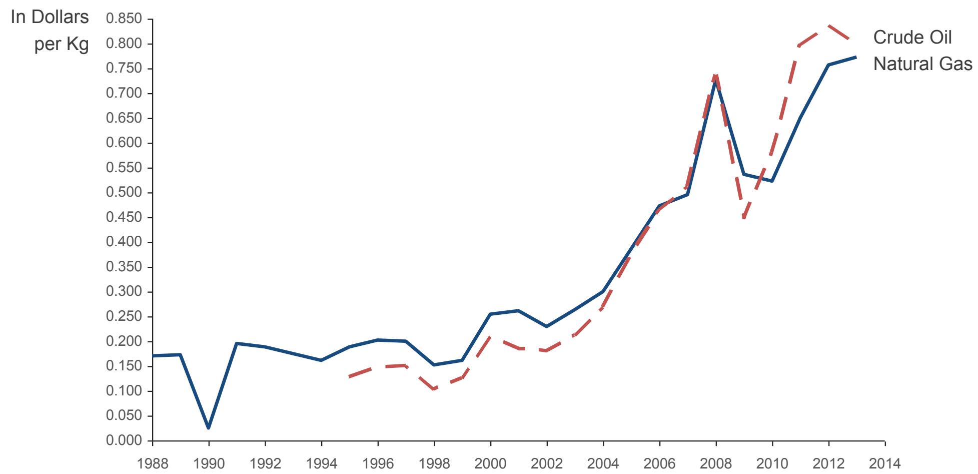
Infrastructure conditions are also critical in processing and delivering natural gas for domestic as well as foreign consumption. LNG terminals and storage facilities as well as pipelines will be required to prevent bottlenecking and stranded supplies from areas that previously were not considered as a resource base for natural gas. Some estimates suggest that the cost of new natural gas transmission infrastructure and processing facilities will require about US$160 billion of infrastructure investment by 2035.[9] Of course, infra-

structure development itself poses a whole new set of questions with respect to regulation and environmental as well as public health concerns.

Implications for South Korea

Short-term trends in US shale gas and tight oil should not be underestimated. Some recent estimates suggest that the exploitation of shale oil, for instance, will boost GDP of large net oil importers, such as Japan, by around 4 percent to 7 percent by 2035.[10] The impact on South Korea, which stands as the world's second largest importer of LNG and the seventh largest importer of oil, is significant. As shown in Figure 6, the price of crude oil and natural gas imports in South Korea has consistently increased over time. Similar to the Japanese counterparts, both the Korea National Oil Corporation (KNOC) and the Korea Gas Corporation (KOGAS) have responded by increasing their investment in US shale plays. The Korean Ministry of Knowledge has long

Figure 6: Import Price of Crude Oil and Natural Gas in South Korea, 1988-2014

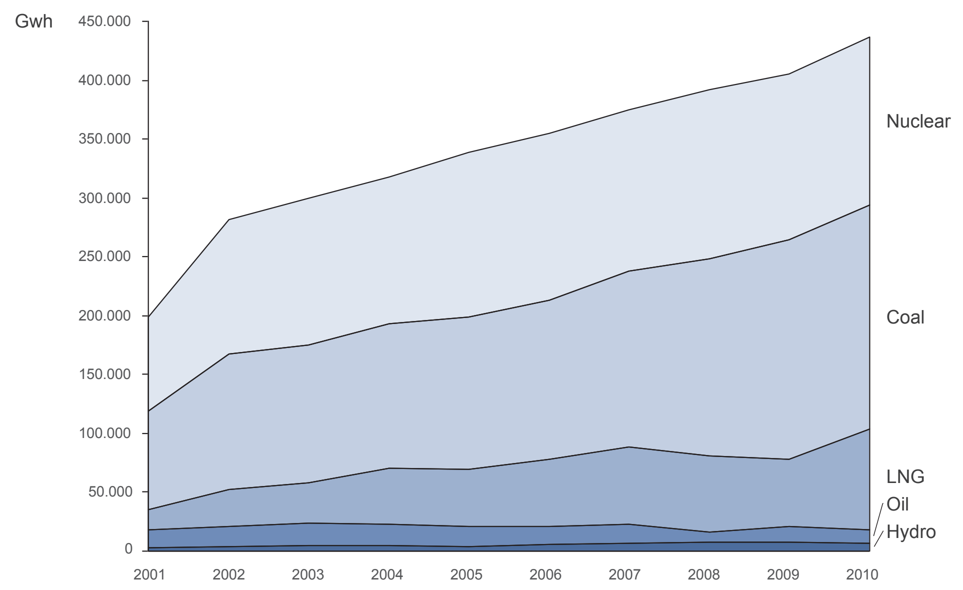


Source: KITA

maintained that it will promote the expansion of shale gas imports to 20 percent of all natural gas imports by 2020. Private companies, such as the E1 Corporation and SK Innovation have announced that the import of LPG from US shale source will begin as early as 2014, timed to the Panama Canal expansion project. At the moment, the price of LPG produced from shale formations in the United States is 10 percent to 20 percent cheaper than the imports from the Middle East. As the number of stakeholders from other countries for unconventional oil and gas development in the United States grows, South Korea finds itself with a particular edge that some of these other players do not yet possess. As a recent signatory of the free trade agreement with the United States, South Korea has the ability to sidestep the time-consuming licensing process for US exports of natural gas and oil.

These conditions, however, do not necessarily imply unabashed optimism as far as energy prospects for South Korea are concerned. As discussed in the previous section, there are many risks and unknowns with respect to long-term outlook on unconventional oil and gas in the United States. Perhaps a more forward looking approach that problematizes risk management could prove useful. A step in this direction is strategic emphasis on optimal energy mix. As of today, nuclear power stands as one of the most important sources of electricity generation in South Korea and this is not likely to change into the future (See Figure 7). Dependence on coal, which currently stands to account for little over a third of electricity generation, will decrease into the future. In its place, LNG has emerged as an important alternative. As of 2001, only 8 percent of all electricity generated in South Korea came from LNG. This figure is more than doubled by 2010. Given that much of this energy source cannot be homegrown and the geopolitical risks associated with over-dependence on Middle East sources have gone up, South Korea is likely to shift its attention to the development of unconventional oil and gas in North

Figure 7: Sources of Electricity Generation in South Korea, 2001-2010



Source: Korea Statistical Information Service

America. The exact measure of how much South Korea will rely on this energy source, however, should be tempered with the outlined risks as it forges ahead.

Chapter 1.
Lessons and Implications from Non-Market Considerations in the Development of Unconventional Oil and Gas in the United States

J. James Kim
The Asan Institute for Policy Studies

The widespread use of new technology enabling the extraction of natural gas and oil from tight underground shale formations (i.e. hydraulic fracturing or "fracking") has ushered in a new era of rapidly changing landscape in the global energy supply and production. While the US Geological Survey estimates that there is an abundance of untapped energy from this source in various locations around the world, much of the recent activity associated with extracting oil and gas from deep underground tight formations has been concentrated in North America (i.e. United States and Canada). Estimates and projections vary, but the latest figures issued by the US Energy Information Administration (EIA) indicate that there are approximately 58 billion barrels of recoverable shale oil and 665 trillion cubic feet (tcf) of recoverable shale gas in the United States (See Figure 1.1).[1]

What this has meant, of course, is that there is now an abundant supply of natural gas and oil in North America and this remains likely to be the case for the foreseeable future. As far as the economy of the global energy market is concerned, this also means a significant drop in the price of these resources. For the time being, this trend has largely been localized around the price of natural gas in the United States with the Henry Hub price dropping from

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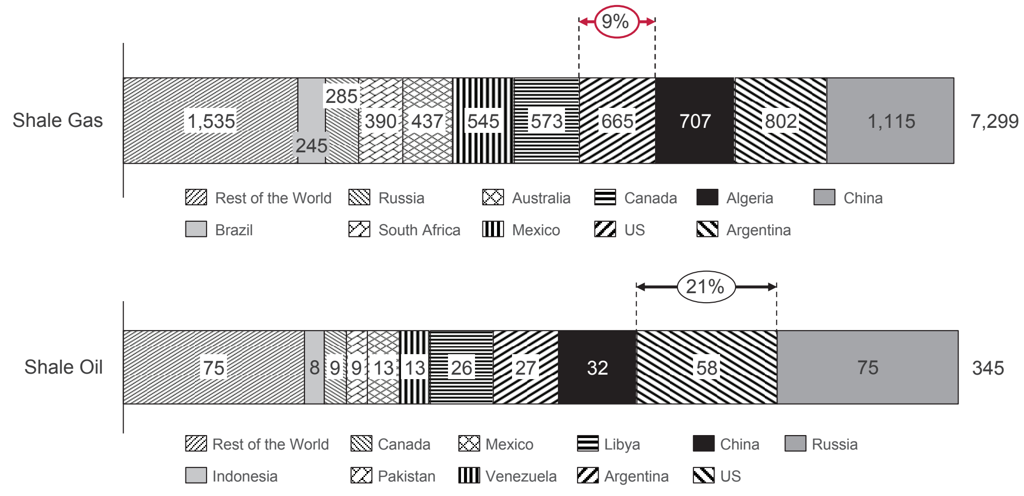
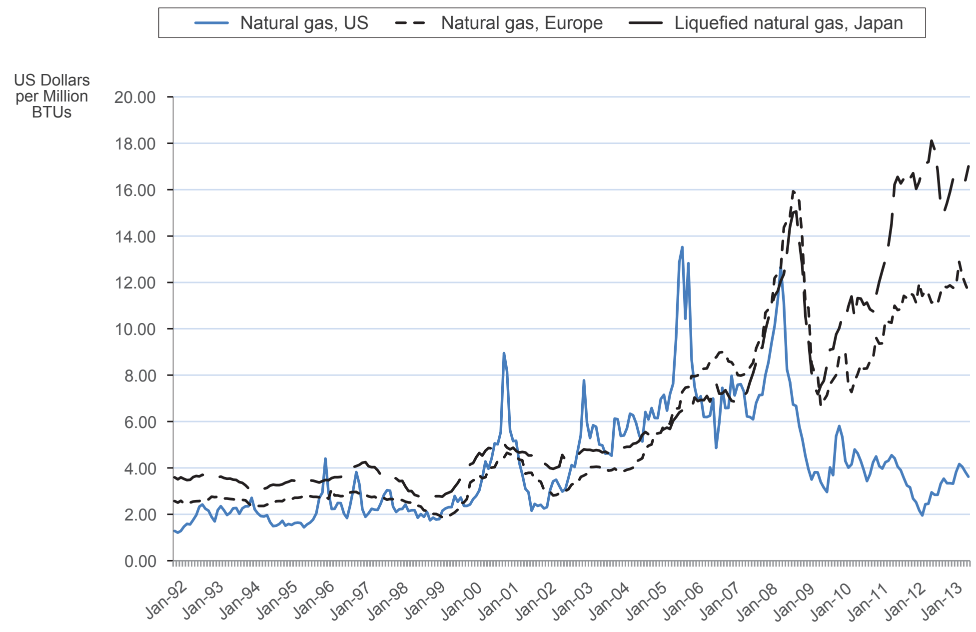


Source: US Energy Information Administration (EIA)

Figure 1.2: Comparison of Natural Gas Prices, 1992-2013



Source: World Bank

approximately US$9 per million British Thermal Units (BTU) in 2008 to US$2 to US$3, which is comparable to rates not seen since the late 1990s. One interesting observation is the divergence in the price of gas between North American and non-North American counterparts since 2008/9 (See Figure 1.2).

It is hardly surprising that the drop in price has coincided with the rise in natural gas production. According to the EIA's latest estimate, 95 percent of natural gas consumed in the United States as of 2011 were produced domestically.[2] Another important point to note is the pace and scope with which this development is currently taking place in the United States. According to the EIA, US shale gas production increased at an annual average rate of 17 percent during 2000-2006 and at 48 percent during 2006-2010. As a comparison, the annual average growth rate of overall natural gas production in the United States since 2007 has been +4.7 percent as compared to the same figure for 1970-2006 which is -0.3 percent. Finally, the latest projection suggests that the overall share of shale and other forms of tight gas is likely to increase into the future (See Figure 1.3).

As far as the broader economic impact is concerned, the evidence is generally positive. A recent set of reports published by IHS, for instance, indicates that shale development is responsible for over 600,000 jobs in 2010 and approximately 1.7 million jobs as of 2012.[3] This figure is expected to more than double by 2035. In terms of value added contribution to gross domestic product (GDP), shale development is projected to add more than US$400 billion to the US economy by 2020.[4] Between 2012 and 2035, the estimated impact on the federal and state revenue will approximately be about US$2.5 trillion.

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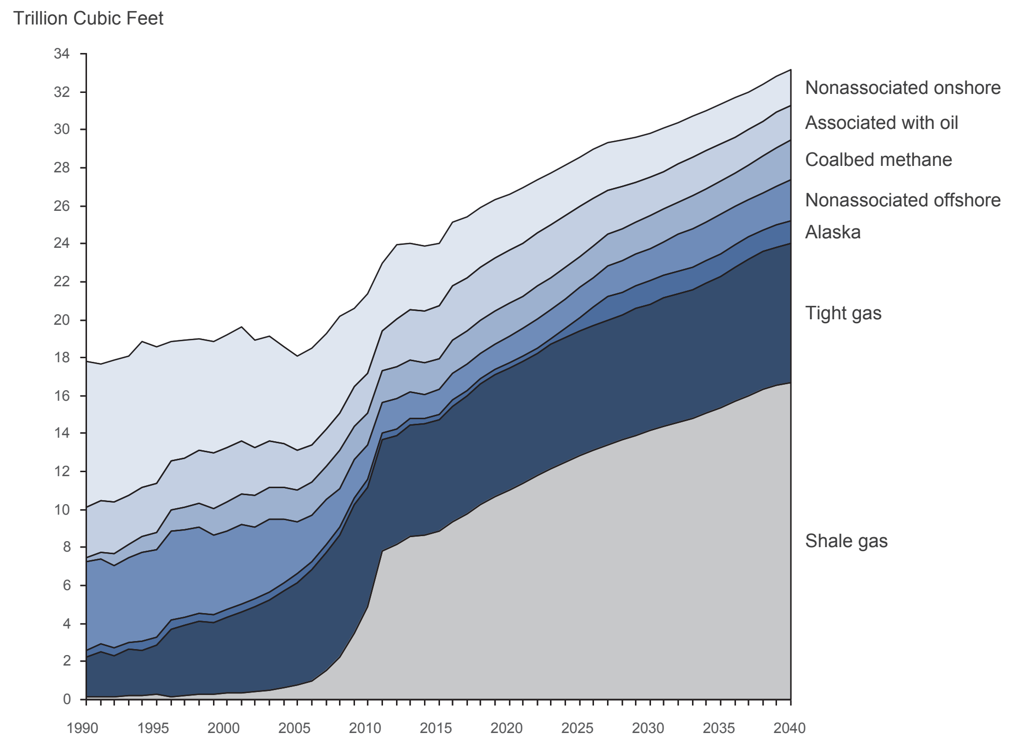

Source: EIA

far as fossil fuel extraction from tight formations is concerned. One observable trend is the rise in the level of foreign investments in the US shale industry. According to the EIA, total investments in the US shale plays totaled US$133.7 billion during 2008-2012 with about 20 percent of this figure coming from joint ventures involving foreign corporate entities.[6] A trade press report released by the EIA in early 2012 lists about 11 companies from seven different countries that have made significant investments in eight different shale plays.

This trend is not likely to change any time soon given the rise in the number of export permit applications pending the approval from the US Department of Energy (DOE); thus far, the DOE has only approved two of 23 applications that it has received to permit overseas export of natural gas. However, it is clear that preparations are well underway to begin full-fledged export of both liquefied natural gas (LNG) as well as liquefied petroleum gas (LPG) from the United States. Consumer nation-states like Japan and South Korea, two of the largest importers of LNG and LPG, are looking to step up imports of both products from the United States within the next three to four years.[7] If these trends continue, the EIA projects the United States to be a *net exporter* of natural gas and oil by 2020 and 2025, respectively.

There is little left to doubt that change in this area has been vast and rapid; however, there is also much left to understand about the range of impact that these developments can and will have on the environment and the broader community. With increasing use of new methods and technology for extracting valuable resources from tight formations, there is a growing concern about the possible externality implications of fracking. One obvious suspect is the impact that fracking will have on surface and groundwater supply. Availability of water for other uses, impacts on the aquatic life, contamination from flowback, spills or leaks, as well as the handling of wastewater are all concerns that have been raised by various members of the civil society and government. Some have even questioned the possible connections between seismic activities in and around the injection wells and drilling pads.[8] Needless to say, the key to addressing these concerns are adequate regulatory controls and/or forward-looking industry standards.

These factors are critical as we look to the future of unconventional gas and oil in the United States. Aside from the challenges posed by commercial/market as well as infrastructure lags, regulation and industry practice can be a

barrier as well as a catalyst for sustained shale rig production. The purpose of this report is to explore this aspect of shale gas and oil development in the United States. This report is a product of a day-long workshop that brought together experts from the industry and policymaking community from both the United States and South Korea to discuss the current state of regulations and industry practice with regard to shale developments.

In Chapter 2, entitled "Managing Oil and Natural Gas Development on Federal and Indian Lands in the United States," Lonny Bagley provides a broad sweeping overview of the US Department of the Interior, Bureau of Land Management's regulations of onshore land use with respect to oil and natural gas developments on federal and Indian lands in the United States. Aside from detailing a fairly extensive set of regulations for application, inspection, and enforcement of oil and natural gas development on federal lands, Bagley's discussion also suggests some areas for possible improvements. For instance, the BLM currently employs about 190 certified inspectors to cover 33,000 inspections per year, which amounts to about 173 inspections per year per inspector. While the certification training for inspectors is fairly extensive and procedures for well inspections are comprehensive, increasing rates of well development and licensing could mean a strain on personnel resources for the BLM. Increasing concerns about the surface and subsurface environment arising from fracking and directional drilling has also pushed the BLM to develop a new set of rules that would seek to improve wellbore integrity, increase transparency, and elevate water management standards. The concern here, of course, is how quickly this new set of proposed rules will go into effect.

In Chapter 3, which is entitled "US Regulation of Unconventional Oil and Gas Development: Progress and Challenges," Hannah Wiseman provides a more thorough account of existing regulations on unconventional oil and gas developments at the state level. In particular, Wiseman points to three challenges with respect to regulation at the state level: One is the significant amount of variation on regulation and enforcement across different states; second is the overlapping jurisdiction in those areas where the directional drilling will be such that it will require crossing a state boundary; finally, the timing of regulation is such that it typically lags industry development and growth. What all of this means is that there is a significant level of uncertainty surrounding the regulation of shale oil and gas industry on non-federal lands for the foreseeable future. On the other hand, this can also be viewed as an opportunity for the industry to work in coordination with the civil society and government to develop the kind of standards and practices necessary to match the advances in technology and methods utilized in drilling rigs.

James Slutz covers this issue in Chapter 4, entitled “Challenges for Shale Oil and Natural Gas: Environmental Stewardship and Opportunities through Innovation.” Slutz points out that there are several innovations that stand to reduce negative externalities arising from fracking and directional drilling. One is wastewater disposal and reuse. By removing suspended solids and reusing clean brine, there can be a saving of about 50-80 percent of water used in a single well. There are also efforts to make use of Environmentally Friendly Drilling (EFD) systems, which promote multi-well pads, modular compact drilling rigs, and low impact access roads as well as green completion technology. Multi-stakeholder engagement as well as efforts to combine best practices and regulation, as in the case of the North Dakota Industrial Commission, stand as effective benchmarks for the rest of the industry.

In sum, the discussion shows that there are areas for improvement when it comes to the regulation of unconventional oil and gas development. One challenge seems to be the high level of variation in state-level regulation as well

as a lag in regulatory standards across numerous state and federal jurisdictions. These are serious concerns since lack of timely development on these fronts may fail to assuage public concerns about the potential environmental and health problems arising from unconventional oil and gas development. However, it is precisely the lack of a uniform standard that can also provide an impetus for industry experts and government regulators to coordinate an effective pragmatic response that makes use of an innovative combination of best industry practice with existing policy.

Chapter 2.
Managing Oil and Natural Gas Development on Federal and Indian Lands in the United States

Lonny R. Bagley
US Department of the Interior

The Department of the Interior's Bureau of Land Management (BLM) manages more federal land than any other federal agency—about 245 million surface acres as well as 700 million subsurface acres of mineral estate. About half of these 700 million subsurface acres are believed to contain oil and/or natural gas. Advancements in horizontal drilling and hydraulic fracturing have opened vast reserves of oil and natural gas that were once not reachable.

These vast stretches of public lands also give the BLM a leading role in fulfilling the Obama administration's goals for a new energy economy based on a rapid and responsible move to large-scale production of solar, wind, geothermal, and biomass energy. As these lands are increasingly tapped to develop clean, renewable energy, the United States lessens its dependence on foreign oil and provides opportunities for creating new jobs to support local communities. Public lands also provide sites for new modern transmission facilities needed to deliver clean power to consumers.

This paper will focus on the development of onshore Federal oil and natural gas resources. This occurs in five phases: land use planning; parcel nomination and lease sales; well permitting and development; operations and development; and finally plugging and reclamation.

The importance of the BLM oil and natural gas program is significant in terms of its contribution to domestic supply and revenues to the American economy. Domestic production from more than 92,500 federal onshore oil and natural gas wells accounts for 14 percent of the nation's natural gas supply and 6 percent of its oil. The sales value of the oil and natural gas produced from public lands exceeded US$22.6 billion in 2012. Royalties, rentals, and bonus payments vary from year to year. In fiscal year 2012, these contributions totaled US$4.3 billion from federal onshore energy leasing and production. Half of this money is sent back to the states and half goes to the US Treasury.

A significant portion of funding in the BLM oil and natural gas program is used to fulfill the federal government's trust responsibilities to American Indian tribes and individual Indian mineral owners. The BLM supervises operational activities on 3,700 Indian oil and natural gas leases, and provides advice on leasing and operational matters to the Bureau of Indian Affairs, Indian tribes and Indian mineral owners.

The Secretary of the Interior (Secretary) has the authority under various federal and Indian mineral leasing laws to manage oil and natural gas operations on federal and Indian (except Osage) lands. The Secretary has delegated this authority to the BLM, which issues onshore oil and natural gas operating regulations codified at 43 CFR part 3160. These statues include, but are not limited to, the:

- Mineral Leasing Act, 30 U.S.C. 181 et seq., which authorizes leasing and development of leasable minerals, including oil and natural gas, on public lands and on lands having federal reserved minerals;
- Mineral Leasing Act for Acquired Lands, 30 U.S.C. 351 et seq.;
- Federal Land Policy and Management Act, 43 U.S.C. § 1701, which establishes

criteria for unnecessary or undue degradation, multiple resource management, sustained use for present and future generations and land use planning;
- National Environmental Policy Act, 42 USC § 4321 provides for disclosure of impacts from development;
- Federal Oil and Gas Leasing Reform Act of 1987, 30 U.S.C. § 181 requires quarterly lease sales wherever eligible lands are available for leasing;
- Title III of the Energy Policy Act of 2005, 42 USC § 15801 streamlines permit processing timelines;
- Indian Mineral Leasing Act, 25 U.S.C. 396a et seq., 25 U.S.C. 396, and the Indian Mineral Development Act, 25 U.S.C. 2101 et seq.; and
- Federal Oil and Gas Royalty Management Act, as amended, 30 U.S.C. 1701 et seq., establishes the authorities and responsibilities of the Secretary of the Interior for royalty management for oil and natural gas leases on Federal lands and the enforcement practices for ensuring collection of oil and natural gas revenues owed to the United States.

Within the operating regulations at 43 CFR 3160, detailed operating requirements are further developed through Onshore Oil and Gas Orders and Notices to Lessees when necessary to implement and supplement the operating regulations.

Not all lands with energy potential are appropriate for development. The BLM is a land and resource management agency with a multiple use mission. Through its land use planning process, the BLM has discretion in determining lands to lease for oil and natural gas development.

Land use plans are completed and updated periodically and identify various uses of public lands and analyze impacts to resources resulting from development, like oil and natural gas. If necessary, it provides measures to protect other resources that could be affected by exploration and development activities, basically setting the stage for site-specific permitting decisions.

The public is encouraged to participate and provide a key role regarding the use of lands. The bureau works with local communities, the states, industry, and other federal agencies in this process to ensure all views are heard. Numerous opportunities for public involvement during land use planning and then during environmental review of specific projects help ensure that development is both efficient and environmentally responsible, which includes restoring the land for other uses for current and future generations.

Lands are nominated for lease through an expression of interest process. Using the land description provided in the expression of interest, BLM consults the land use plan to determine if the lands are available for leasing. Once BLM confirms that lands are available, they are offered through an open competitive bidding process. Minimum bids begin at a US$2.00 per acre. Lease sales are held on a quarterly basis.

A lease is a contract to explore and develop (all horizons) for a period of 10 years. If production is established, the lease is held by production until production ceases. The lessee pays an annual rental ranging from US$1.50 to US$2.00 per acre. The royalty rate is set at 12.5 percent.

Application for Permit to Drill

Once a lease is obtained, an operator submits a site-specific proposal known as an Application for Permit to Drill, or APD, to begin exploration and development of their lease rights. Operators submit their application following comprehensive procedures that have been established through various regulatory processes by the BLM. Their application will have two parts: 1) a drilling plan and 2) a surface use plan of operations.

To cover the BLM's cost for processing the APD, operators are required to pay a US$6,500 fee for each permit. Operators are also required to have a bond in place before beginning operations. Bonds help assure sound operations, proper royalty payment, and protection of the environment. Current minimum bond amounts are set at US$10,000 for an individual lease bond; US$25,000 for a statewide bond; and US$150,000 for a nationwide bond. The BLM can require additional bonding based on the operator's performance and liabilities.

The drilling plan portion of their application addresses the geology of the area and anticipated formation tops; anticipated pressures they expect to encounter and the pressure rating of well control equipment they plan to use; various casings they plan to use, size, weight and grade, and setting depth; volume, type, and grade of cement they plan to use in setting casings; mud systems (fresh water, salt based, inverted, additives, and weight) they will utilize during the drilling of the entire well; any testing or logging they plan to conduct; pressures and potential hazards they may encounter while drilling the well; and directional or horizontal designs they plan to utilize. Upon submission, BLM performs an extensive review of their application to ensure their plans meet our minimum requirements.

The BLM will be looking to ensure wellbore integrity. The BLM's first priority when reviewing a permit to drill on public and Indian land is to ensure the wellbore is constructed in a manner that will protect the environment and public safety. Our review to this regard will be to ensure that the proper

casings (size, weight, grade, and setting depth) are used; proper type, grade, and volume of cement is used to secure the casing in the wellbore; appropriate pressure rated well control equipment is used; and testing procedures of casings and well control equipment are outlined to ensure they are functioning properly. Protections for other important minerals and water zones are another critical area where the BLM pays close attention. Using the geology and other information sources we will ensure these resources are isolated through sound casing and cementing practices. A third aspect of the review is the assurance that the public is protected. This is achieved by making sure the casing program is adequate; well control measures are in place; any expected hazards are addressed; and warning signs are in place.

In the second part of the application, the operator addresses how they plan to use the surface during all phases of the project. Based on a given set of criteria, the operator identifies surrounding surface resources and uses; then proposes how they will utilize the surface for their needs. The BLM will conduct an analysis of the proposed use to determine if it is appropriate. This includes conducting a site visit of the proposed location with the operator. This visit is designed to ensure the well is placed in a good location and to discuss any initial issues the operator should address in their permit application.

Based on the size (number of wells and facilities) and scope (surface impacts; resources affected and conflicts; etc.) of the project, the BLM determines the appropriate level of environmental review. The types of review consist of: 1) Environmental Impact Statement (EIS); 2) Environmental Assessment (EA); 3) Determination of NEPA Adequacy (DNA); or 4) Categorical Exclusion (CX). Each of these processes has varying degrees of analysis and time to complete. The selection of one over the other depends on the degree of resource conflict(s) and protection measures the BLM has in place.

This is a public and transparent process and allows the BLM to make an informed decision, weighing the impacts and balance of the resource(s). Project proposals are reviewed by a team consisting of biologists, archaeologists, soil/air/water specialists, geologists, engineers (civil and petroleum engineers), etc. The BLM may require further analysis or surveys before it can make an informed decision. Surveys may include cultural, wildlife, and air analysis. Based on the BLM's review and analysis, mitigation measures known as Conditions of Approval (COAs), may be attached to instruct the operator of certain actions that must be taken to address surface use conflicts. In some cases where impacts cannot be fully addressed onsite, the BLM may require mitigation offsite. An example is where extensive development in one area may require habitat improvement in another area.

The permitting process is also an important opportunity for the BLM and the applicant, to work with other agencies and the surface owner(s) when the surface is not controlled by the BLM.

The BLM has developed and published best management practices in the *Gold Book* to provide operators with known mitigation measures they can incorporate in their permit to address surface impacts. However, additional measures can be taken as opportunities present themselves.

In areas of critical wildlife habitat, the BLM is working with oil and natural gas operators to reduce their footprint using new technology to explore and develop their leases. With the advancement of directional drilling, multiple wells can be drilled from one surface location. In cases in Colorado, the BLM is seeing 15 to 20 wells drilled from one pad. As a result, truck traffic is significantly reduced and can eliminate the need to construct additional well pads, roads and utility corridors. Instances in Pinedale, Wyoming, the number of wells drilled from one well pad has reached 64 wells.

The feasibility of directional drilling is dependent on the subsurface geology and the depth of the hole. Drilling costs are typically greater and may add risk to the operation. However, the benefits of reducing habitat fragmentation are significant and allow an operator to explore more resources that would otherwise be restricted. Options like directional drilling allow the BLM to be more responsive to resource conflicts; help operators in securing future leasing and permits; reduce our protests and litigation costs; and lead to improved efficiency and program effectiveness.

Inspection and Enforcement

Our stewardship mandate requires the BLM to manage the valuable assets of our public lands. A critical aspect of that responsibility as it relates to oil and natural gas development is to make sure operations are sound and ensure compliance with operational and environmental requirements during all phases of development. The BLM's Inspection and Enforcement Program is designed to ensure: 1) compliance with all lease terms, conditions of approval in the drilling permit, and all other applicable laws and regulations; 2) production is properly handled, accurately measured; and reported correctly; 3) protection of the surface and subsurface environment; and 4) protection of the public health and safety.

On an annual basis the BLM prepares a strategy that identifies inspection priorities. Priorities are based on a number of criteria including, operator compliance; production rates; reporting violations; and environmental and public health and safety concerns. The BLM employs 190 certified inspectors across 33 field offices. They complete about 33,000 inspections each year covering 49,000 leases containing 37 million acres.

Inspectors go through an extensive certification program to ensure they have the knowledge and skills necessary to ensure operations are in compliance. The BLM strives to help prevent problems early and have visibility in the field, so operators are reminded of their responsibilities. In an effort to ensure compliance and reduce the number of violations found during inspections, BLM inspectors take an active role to provide training to operators and their representatives.

The following provides a list of the major inspections BLM performs and a brief description of their purpose.

Drilling Inspections

Drilling inspections are conducted on wells to ensure that equipment, practices, and procedures are in accordance with regulatory requirements and permit condition(s) of approval. Inspections make observations to ensure proper weight and grade of casing is used, casings are set and cemented as required, well control equipment is installed and operating properly and safety equipment is installed and operating properly.

Inspection of plugging operations is critical to ensure the well will not contribute to contamination of usable water and other resources. Inspections ensure approved plugging operations are followed, plugs are properly placed in the well, and the appropriate amounts of cement are used.

Inspections for production facilities are performed to ensure production is properly handled, accurately measured, and reported correctly. Inspection activities include: Site security, witness measurement activities, and ensuring measurement devices are functioning properly and are calibrated as per BLM and industry standards. Independent measurements are conducted and compared to the results taken by the operator. Audits of operator records ensure proper accounting of production. Accurate measurement and reported volumes leads to the proper revenue collection. 50 percent of the oil and natural gas proceeds collected from federal lands are disbursed to the states to support schools, hospitals, and other local needs.

In cases where theft or fraud is suspected, BLM's law enforcement arm is called upon to further investigate the case. Environmental inspections are conducted to ensure operators take appropriate measures to protect the environment. Inspections include observation for erosion concerns; topsoil stock piling, location, road, and pit construction and use, spills, water disposal methods, spill prevention and containment measures, surface hazards, and interim and final reclamation.

Hydraulic Fracturing

Hydraulic fracturing (known as "fracking") practices used to develop oil and natural gas resources are drawing much attention across the county from proponents and opponents alike. Hydraulic fracking is a process that uses high pressure to create small fractures in the hydrocarbon formation that aids extraction of oil and natural gas deposits that could not be recovered previously. Hydraulic fracturing is a 60-year-old process that is now being used more commonly as a result of advancements in technology. The BLM estimates that roughly 90 percent of wells currently drilled on BLM-managed lands (approximately 3,100 per year) are stimulated using hydraulic fracturing techniques.

Fracturing fluid is typically more than 98 percent water and sand, with small amounts of additives used to control the chemical and mechanical properties of the water and sand mixture. The increased use of hydraulic fracturing in recent years has generated concern about its potential effects on both water quality and availability, particularly with respect to the chemical composition of the fracturing fluids, and wellbore integrity.

As previously discussed, when permitting a well on federal or Indian lands, wellbore integrity is the first and most important component to ensure measures are in place to protect fresh water, other resources and the public. When operators submit an Application for Permit to Drill they are required to describe their plans for drilling and completing the well. As part of the review process, the BLM identifies the risks and ensures the appropriate protective measures are in place to ensure fresh water and other resources are protected. This includes all potential safety or health risks that may need special protection measures during drilling, or that may require specific protective well construction measures. Once this analysis is completed, the BLM reviews the company's proposed casing and cementing programs to ensure the well construction design is adequate to protect the surface and subsurface environment. Once drilling commences, the BLM conducts inspections throughout the operation to ensure they are in compliance as previously discussed.

As a result of concerns raised by the public, the BLM developed the proposed rule to address hydraulic fracturing practices. The proposed rule would strengthen the requirements for hydraulic fracturing performed on federal and Indian lands.

The proposed rule would address three main areas: 1) improving assurances on wellbore integrity so we know fluids going into the well aren't escaping; 2) requiring public disclosure of chemicals used in hydraulic fracturing, with appropriate protections for trade secrets; and 3) ensuring companies have a water management plan in place for fluids that flow back to the surface.

Some states have started requiring similar disclosures and oversight for oil and natural gas drilling operations under their own jurisdiction. This proposal seeks to create a consistent oversight and disclosure model that will work in concert with other regulators' requirements while protecting federal and tribal interests and resources.

The proposed rule would require that disclosure of the chemicals used in the fracturing process be provided to the BLM after the fracturing operation is completed. This information is intended to be posted on a public web site, and the BLM is working with the Ground Water Protection Council to determine whether the disclosure can be integrated into the existing website known as FracFocus.org.

The final release of these rules is still pending. For more information, visit: www.blm.gov/wo/st/en/info/newsroom/2012/may/NR_05_04_2012.html or www.blm.gov/wo/st/en/prog/energy/oil_and_gas.html.

Chapter 3.
US Regulation of Unconventional Oil and Gas Development: Progress and Challenges

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Development of natural gas from "tight" formations in the United States, which include densely-packed, low permeability sandstones, shales, and coal-beds,[2] has recently expanded. Two key technological changes have enabled this expansion. First, entities that develop oil and gas wells, which are called operators, began drilling horizontal wells[3] that extend laterally through a formation. After drilling straight down into a formation—often up to one mile beneath the earth's surface—the operator angles the drill bit to cut horizontally through the formation from which oil or gas will be extracted, thus exposing more surface area. Second, in the late 1990s in the State of Texas, energy companies with the help of the US government[4] perfected a technique called "slickwater" hydraulic fracturing.[5] Although hydraulic fracturing has occurred since the 1950s,[6] slickwater fracturing of multiple well segments is a specialized technique. After the operator drills a well into a formation that contains petroleum and lines the well with steel tubing and cement, the operator sends an instrument down the well that discharges electric charges or bullets at a particular point underground. This perforates the portion of the well around which fracturing will occur. The operator then injects between one and seven million gallons of water,[7] mixed with a small quantity of chemicals, down the well at high pressure. The water is forced out of the perforations in the wellbore and fractures the formation. A "proppant" injected with the water, which is often sand or a similar substance, holds open the fractures, allowing natural gas to flow through them and up the well.[8]

Slickwater fracturing is different from previous types of fracturing used in the United States because it employs larger quantities of water and, in some cases, different chemicals.[9] The chemicals used in this process serve several purposes. An acid injected before the fracturing treatment cleans the shale around the wellbore. Substances mixed into the fracturing fluid help to reduce the friction generated by water forced down the well at high pressure, and other substances help to carry the proppants and then release the proppants into the fractures. Further, biocides mixed with the injected water kill bacteria in the shale that could interfere with the fracturing process.

In recent years, oil and gas operators have applied horizontal drilling and slickwater fracturing techniques to tight formations in several regions of the United States and have produced surprising quantities of natural gas and oil. The International Energy Agency (IEA) estimates that the United States will be nearly "self-sufficient" in energy by 2035[10] and will be an exporter of natural gas; the country will also produce large quantities of oil—possibly leading the United States to become the world's largest oil producer.[11] This "renaissance" in energy, as the IEA calls it,[12] will have important environmental implications, which could potentially lead to investment uncertainty— particularly because the risks of this type of development cannot yet be fully quantified. This paper explores and briefly assesses the laws, including statutes, regulations, and agency directives, that govern the environmental impacts of fossil fuel development in the United States, including development that uses hydraulic fracturing.

Most oil and gas laws do not address hydraulic fracturing specifically, but rather apply to various stages of the well development process required to fracture a well. Because hydraulic fracturing is only one step within a complex process, this paper addresses regulation of all stages of development. In describing and partially analyzing the many laws that apply to these well development stages, this paper will suggest that the regulations have not yet caught up with the significant expansion of drilling and fracturing in the United States. Fragmented authority over different parts of the process may leave some gaps, and states—which have the most regulatory authority—often have regulations that differ substantially in substance. Furthermore, some states have not updated their old oil and gas regulations to address expanding environmental challenges.

The extent of the risks of expanded oil and gas development and fracturing remains unknown, but the incidents at well sites of drilled and fractured wells so far show that there are indeed some risks.[13] One spill of a drilling fluid or diesel fuel at a well site is likely insignificant, yet a thousand spills could be problematic.[14] And the sheer increase in the scale of well development may not only expand impacts linearly; as well numbers grow, this could push wells closer to sensitive natural resources, thus threatening high environmental costs if, for example, a substance spills into a rare wetland habitat or on permeable soil overlying an aquifer[15] and cannot be easily recovered.

In light of these risks, improved regulation is important, and much of the regulatory landscape in the United States is rapidly changing. This paper begins by introducing the general legal approach to controlling the environmental impacts of oil and gas development in the United States and then explores the details of certain regulations. It concludes with an assessment of the need for further changes in some areas, suggesting how the legal landscape should continue to evolve.

The Stages of Unconventional Well Development

The process of developing an unconventional well in a tight formation begins with testing for the presence of petroleum underground. Engineers typically estimate the presence of underground petroleum resources through a process called seismic testing,[16] in which scientists drive trucks over the surface. They use equipment on the trucks to strike the ground; this creates sound waves underground,[17] and the waves bounce back to a computer; data about the velocity of the signal traveling through the formation suggest the location of petroleum resources underground. Based on these data, operators select a surface location at which to drill; after obtaining the property rights (called "mineral rights") and regulatory permits necessary for drilling, operators then begin the well development process—a temporary yet intensive industrial operation.

To develop a well, operators construct a well site and well pad—the flat surface on which all surface operations occur, and an access road to the site and the well pad. Operators then bring to the site drilling rigs and other materials required for drilling, including drilling muds that cool the drill bit as it cuts far underground. During and after the drilling process, the operator temporarily stores wastes either in surface pits or tanks; these wastes include salty produced water,[18] which comes up naturally out of the formation, and drill cuttings—rocks and soil that emerge from the wellbore as it is being drilled. Both produced water and drill cuttings can contain low levels of naturally-occurring radioactive materials.[19] In addition to the natural wastes from drilling, operators also store used drilling muds and fluids on the surface before permanently disposing of them. Surface storage of wastes poses some of the greatest environmental challenges, as improperly-lined pits or leaking tanks can pollute soil and groundwater beneath soil.[20] Migratory birds also are attracted to the pits and have been found dead in them.[21] After drilling wastes are stored at the surface—sometimes for up to a year—the operator disposes of them by drying and spreading them on the surface of the well site, spreading salty produced water on roads, or sending solids to a centralized state-regulated landfill. Drill cuttings are sometimes reinserted back down the wellbore. Disposal practices vary among states due to varying regulations for acceptable disposal practices.

Following the initial drilling operation, if operators determine that the well will be economically productive, the completion stage of the well begins. The operator lines the well with steel tubes called "casing," which are cemented into the wellbore to keep it from collapsing and to prevent water from mixing with oil or gas flowing through the well. The casing and cementing process is very important; if the steel casing is compromised and the cement surrounding the casing does not completely fill the area between the casing and the well (the "annulus"), methane can escape into groundwater. There have been a number of incidents involving methane contamination of underground sources of drinking water in Pennsylvania, although it is not fully clear what is causing this contamination—in some cases, abandoned wells and naturally-occurring sources of stray methane appear to be causing the contamination, whereas in other cases, improperly-cased wells have leaked during the well drilling stage.[22]

As described in the introduction, after the well is drilled and cased, an operator perforates the small portion of the well that will be fractured. The operator then injects water and chemicals down the well at extremely high pressure, causing the formation around the well to crack and expanding existing networks of fractures. Following the fracturing operation, a portion of the one to seven million gallons of water returns to the surface as "flowback"

water. As with drilling wastes, operators store this water on site in a pit or tank. Depending on the availability of disposal sites and the state regulations defining available disposal operations, operators then dispose of these wastes by injecting them underground in an underground injection control (UIC) well, sending them to a wastewater treatment plant, or reusing or recycling them.

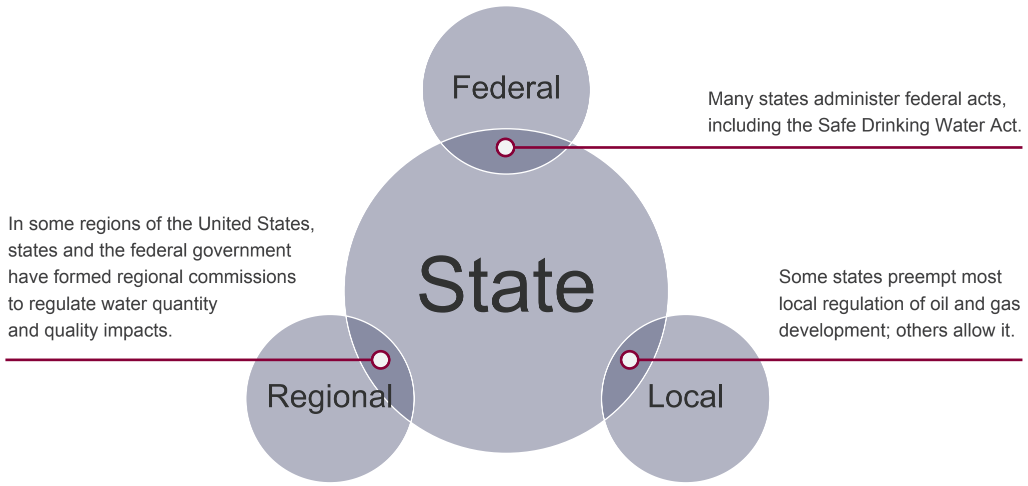
These many stages of well development pose several environmental risks. Diesel spills on well sites from construction equipment during the well site development phase and from rigs and other diesel-powered equipment during drilling and fracturing.[23] Drilling and flowback wastes also spill when being transferred from the well to storage, or they leak from tanks and pits.[24] Construction equipment and rigs on site release air pollution, and the flowback water that flows up out of a well after fracturing emits volatile organic compounds.[25] Methane that flows from the well before the well is fully producing and connected to gathering lines is sometimes released into the air in a process called venting, which is problematic because methane is a highly-potent greenhouse gas.[26] Methane also may be flared off (burned), which produces certain air emissions.[27]

Several rare yet somewhat dramatic environmental incidents associated with oil and gas production also have occurred during the waste disposal stage. One underground injection control well in Texas, which appears to have only accepted wastes from conventional—not fractured—wells, leaked into an aquifer, polluting large volumes of drinking water.[28] Other underground injection disposal wells in Ohio and elsewhere have caused small earthquakes.[29] A variety of regulations attempt to mitigate these risks, as discussed in the following sections.

The US Legal Landscape of Oil and Gas

An array of statutes, agency regulations, and common law (court-created) legal doctrines apply to many stages of the oil and gas process introduced in the first section. Federal and state legislatures, city councils and town selectmen (municipal "legislatures"), regional governing bodies comprised of state governors, and state and federal courts all influence oil and gas development. The fifty states, however, are the most important actors, as summarized in Figure 3.1.

Figure 3.1: An Overview of the Division of Jurisdiction Over Oil and Gas Activities in the United States



Most discussions of environmental regulation in the United States begin by addressing the jurisdiction of the federal government, which is primarily responsible for controlling the externalities of industrial activities. Indeed, a number of federal environmental laws apply to drilling and fracturing, although drilling and fracturing also enjoys several exemptions. As discussed below, the most important federal statutes that apply to drilling and fracturing include the Endangered Species[30] and Migratory Bird Treaty Acts[31] (where certain species are present), small portions of the Clean Water and Clean Air Acts, and the Comprehensive Environmental Response, Compensation, and Liability Act,[32] which makes operators liable for cleaning up contaminated sites (other than sites contaminated solely with oil or gas substances, which are not covered by the Act[33]). For drilling and fracturing on federal lands, the Bureau of Land Management (BLM) also has developed draft rules for fracturing.[34] Federal courts impact how these statutes—and regulations issued by agencies in order to implement the statutes—apply to oil and gas development. Parties challenging agency interpretation or application of a statute or regulation, or a federal civil penalty or criminal enforcement action, use the federal courts.[35]

Despite federal laws that apply to certain stages of oil and gas development, states are responsible for controlling the core potential environmental impacts of drilling and fracturing. This is because oil and gas development and fracturing enjoy certain key exemptions, or simply omissions, from federal statutes. Operators need not disclose their annual emissions of toxic substances, for example, unlike a number of other industries.[36] Operators that fracture with substances other than diesel fuel need not obtain a permit under the Safe Drinking Water Act,[37] thus leaving states to ensure that drilled and fractured wells do not contaminate underground sources of water. Perhaps most significantly, most wastes associated with oil and gas development are exempt from federal regulation of hazardous waste handling and disposal,[38] despite the fact that these wastes sometimes contain low levels of hazardous substances.[39] This exemption allows states, rather than the federal government, to regulate the operation of surface pits and tanks as well as certain waste disposal methods, such as landfills that accept oil and gas wastes.

In light of these federal exemptions, and the fact that federal regulatory authority over oil and gas is often delegated to state environmental agencies, states play a key regulatory role. Most states, for example, are responsible for administering federal Clean Water Act and Clean Air Act regulations, including the issuance of permits under these Acts. And for the stages of oil and gas development that are not federally regulated, states have the primary regulatory authority in the following areas: disclosure of fracturing chemicals (if states choose to require disclosure, as many have begun to[40]), the use of certain types and depths of well casing and cement, the use and maintenance of surface pits and tanks to store drilling and fracturing wastes, the prevention of surface spills during oil and gas drilling, disposal of oil and gas wastes, and the withdrawal of water from surface or underground sources. State oil and gas and/or environmental agencies write regulations governing many of these areas, and state legislatures also write statutes that impose certain requirements on regulatory agencies and oil and gas operators. Furthermore, state courts review agency interpretations of statutes and regulations as well as the constitutionality of statutes and regulations. In Pennsylvania, for example, a court recently struck down a state statute that would have required municipalities to allow gas development in most areas; the court concluded that the statute violated the state constitution.[41] The highest court of Pennsylvania is now reviewing this decision.

Some effects of industrial development (including oil and gas development) cross state boundaries, and some states have therefore developed regional coalitions to address interstate issues. In the United States, the federal Congress has the authority to govern interstate issues; state coalitions therefore must receive federal permission to conduct regional governance across state boundaries, which intrudes into traditional federal authority. In the Northeastern United States, several states have formed "compact commissions" (regional governing coalitions) with Congress's permission. These commissions, which are comprised of governors from states and one federal voting member, address the quantity and quality of water in shared rivers. The Delaware River Basin Commission[42] and the Susquehanna River Basin Commission[43] have been most active in addressing drilling and fracturing issues—requiring that operators withdrawing water for fracturing obtain a permit prior to obtaining water, for example, and do not harm aquatic life during the water withdrawal process.

Finally, local governments—boroughs, towns, townships, cities, and counties—have important land use authority over fracturing. Local governments only have as much authority as is delegated to them by states, however. Under the US constitution, states retain what are called "police powers"—the power to regulate to protect health, safety, and welfare of their citizens, and states delegate certain of these powers to local governments. Through zoning, which divides municipalities into various areas (zones) and designates the types of land uses allowed in each zone, local governments can sometimes prevent oil and gas development altogether, or constrain its location.[44] They also can govern nuisance-like activities—requiring fencing around well sites, for example, constraining the time of day during which fracturing and drilling may occur, and requiring operators to obtain insurance for environmental liability. In some states, like Pennsylvania, states are attempting to retract some local powers over oil and gas development because they are concerned that too many municipalities will block fracturing.[45] In other states like Texas[46] and New Mexico,[47] municipalities have exerted relatively broad control over drilling and fracturing. Here, too, state courts play a role: In Pennsylvania[48] and New York,[49] state courts have been very active in determining whether state statutes, which preempt (prohibit) certain municipal control over fracturing, are valid and prevent certain types of local oil and gas regulation. The following section describes the content of local, state, regional, and federal regulations in more detail.

The Content of Oil and Gas Law

In most industrial areas, the federal government has relatively broad authority to regulate environmental impacts; as introduced in the second section, this authority is narrower for oil and gas, although several federal laws apply. If an oil and gas operator conducts operations in the habitat of a species listed as endangered, for example, the Endangered Species Act[50] would require him or her to obtain a permit from the Fish and Wildlife Service. This permit would constrain the activities of the operator or require certain mitigation efforts in order to limit the number of species "taken" (harmed) by oil and gas activities. The Migratory Bird Treaty Act (MBTA)[51] also prevents operators from killing migratory birds, although there is currently a disagreement in the federal courts as to the reach of the Act. In North Dakota, a federal district court determined that the simple maintenance of surface waste pits at a Bakken Shale site was not a violation of the MBTA; the fact that migrating ducks appeared to have been attracted to the pits and died in or near them did not make the operator criminally liable for the deaths.[52] In contrast, a district court in Texas held that an oil refinery maintaining open tanks in which migratory birds were killed *was* covered by the Act.[53]

Limited federal water quality laws also apply to oil and gas operators. The Clean Water Act applies to the quality of surface waters of the United States, and operators constructing access roads and well sites—and thus disturbing soil through excavation—must obtain a stormwater permit under the Clean Water Act. In most states, the federal Environmental Protection Agency (EPA) has delegated to state environmental agencies the authority to issue Clean

Water Act.[54] In most states, the federal Environmental Protection Agency (EPA) has delegated to state environmental agencies the authority to issue Clean Water Act permits. In the case of stormwater permitting, state environmental agencies issue permits that include best management practices for preventing soil erosion and sedimentation during the construction of oil and gas sites. Although Congress and the EPA attempted to limit stormwater permitting requirements for oil and gas operators, a court decision made clear that oil and gas operators still must obtain stormwater permits.[55] Beyond erosion control, the Clean Water Act further prohibits operators from dumping oil and gas wastes into waters of the United States without a permit.[56] And finally, the EPA is writing specific wastewater treatment standards for flowback from fractured oil and gas wells; draft standards likely will be available in 2014.[57]

The federal Safe Drinking Water Act (SDWA), like the Clean Water Act, protects water quality, but the Act primarily addresses underground water quality. Oil and gas operators that dispose of wastes by injecting the wastes underground must ensure that the underground injection control (UIC) well is properly permitted under the SDWA. A UIC permit—which is typically issued by a state environmental agency acting under authority delegated to it by the federal EPA—is designed to prevent the contamination of underground waters. Operators injecting fluids as part of the fracturing process (with the exception of fracturing with diesel fuel) do not have to obtain a UIC permit under the Safe Drinking Water Act, however.[58] The EPA has developed draft SDWA guidelines for fracturing that uses diesel fuels.[59]

Moving from water to air, the federal Clean Air Act, as recently revised by the EPA, controls the emissions of volatile organic compounds (VOCs) from newly fractured and refractured gas wells.[60] The Act requires operators to install "green completion technologies," which capture most of the VOCs emitted from flowback water that comes out of the well after fracturing.[61]

In addition to new Clean Air Act regulations, the EPA has recently attempted to apply other federal environmental statutes to fracturing. In Pennsylvania, the agency expressed concern that flowback water being sent to wastewater treatment plants was not being adequately treated prior to being discharged into rivers.[62] The agency sent several letters to the Pennsylvania environmental agency discussing this concern,[63] and Pennsylvania eventually agreed to strongly discourage the disposal of flowback through wastewater treatment plants.[64] Also, as mentioned above, the EPA is drafting treatment standards for wastewater from shale development,[65] and the agency—as directed by Congress—is conducting a detailed study of the impacts of fracturing on water quality and quantity.[66] Further, the BLM has proposed guidelines for fracturing that occurs on federally-owned and tribal lands; these would require disclosure of the chemicals used in fracturing, the completion of cement logs that show adequate cementing in well casing, and other measures.[67]

Despite some federal efforts to expand regulation—and one prominent law professor's proposal that fracturing be federally regulated[68]—most regulatory control over oil and gas development remains with the states. As introduced in the first section, states both implement federal regulations and apply a number of their own regulations to drilling and fracturing. Most importantly, most states set standards for the casing and cementing of wells; set minimum distances between wells or well sites and natural resources; describe how surface pits for oil and gas waste must be constructed and managed; require operators to implement plans for preventing spills at the surface; require the disclosure of fracturing chemicals (in some cases); govern the quantity of water that may be withdrawn from surface and underground sources

for fracturing; and, aside from the federal SDWA, determine how oil and gas wastes may be disposed of. Many state regulations are highly variable, though, despite recent state efforts to update certain regulations. The following tables show some of this variability.

As introduced in the second section, one of the states' most important regulatory functions is to ensure that oil and gas operators properly line ("case") their well and cement this casing in place. This prevents the contamination of underground water resources with oil, gas, salty brine that flows back up out of the well, or chemicals. A number of states, including, for example, Pennsylvania recently updated casing requirements,[69] and Texas has proposed to do so.[70] Others, though, have not, and many of the casing regulations vary—particularly in their requirements for how far casing must extend below underground water resources.

Table 3.1: Examples of State Regulations Requiring Casing to be a Minimum Depth Below Groundwater[71]

AR	"Surface casing shall be set and cemented at least . . . 100 feet below the deepest encountered freshwater zone."[72] All Fayetteville Shale fields:[73] min. 500 ft. of surface casing.[74]
CO	50 ft. if "unanticipated fresh water aquifers are encountered." Casing must be set "in a manner sufficient to protect all fresh water and to ensure against blowouts or uncontrolled flows; individual casing program adopted for each well.[75]
KY	30 ft. (surface, intermediate, or long string). 805 KY. ADMIN. REGS.. 1:020 Section 3:1 (Westlaw 2012).
LA	Casing lengths and strengths differ depending on "total depth of contact"; standard lengths and strengths only apply "where no danger of pollution of fresh water sources exists." LA. ADMIN. CODE tit. 43: XIX, § 109 (Westlaw 2011). Below 9,000 feet, more than 1,800 ft. of casing requ. and test pressure at least 1000 lbs. per sq. inch. *Id.*
MD	100 ft. or deepest known workable coal, whichever deeper. MD. CODE REGS. 26.19.01.10 (o)(4) (Westlaw 2012).

MI	100 ft. below all fresh water strata and at least 100 feet below based of glacial drift into competent bedrock. MICH. ADMIN. CODE pt. 615, r. 324.408 (Westlaw 2012). In certain portions of Antrim Formation, production casing must be set at least 50 feet below shoe of surface casing.[76]
MT	"Sufficient surface casing must be run to reach a depth below all fresh water located at levels reasonably accessible for agricultural and domestic use."[77]
NM	"[A]s may be necessary to effectively seal off and isolate all water-, oil- and gas-bearing strata." N.M. CODE R. § 19.15.16.10 (Westlaw 2012).
NY	75 ft. or 75 ft. into bedrock, whichever deeper (100 ft. primary and principal aquifers).[78]
ND	"[A]t sufficient depths to adequately protect and isolate all formations containing water, oil, or gas or any combination of these." At least 50 ft. "below base of Fox Hills Formation."[79]
OH	50 ft.;[80] no agency specific review if at least 500 ft. between highest perforated portion of casing and lowest groundwater.[81]
OK	50 ft. or 90 ft. below surface, whichever deeper.[82]
PA	50 ft. or 50 ft. into consolidated rock, whichever deeper; if encounters additional freshwater, centralizers required.[83]
TX	"[S]et and cement sufficient surface casing to protect all usable-quality water strata."[84]
WV	"(30) feet below the deepest fresh water horizon (that being the deepest horizon that will replenish itself and from which fresh water or usable water for household, domestic, industrial, agricultural, or public use may be economically and feasibly recovered)."[85] May require special casing and special review of drilling procedures in Karst terrain areas.[86]
WY	"[B]elow all known or reasonably estimated utilizable groundwater."[87]

In addition to protecting groundwater through various casing regulations, states, to varying degrees, prevent some contamination of natural resources by requiring that wells, well sites, pits, tanks, or oil and gas disposal locations be a minimum distance from these resources. By requiring these "setbacks," as they often are called, states can help to prevent pollution from entering surface waters and other important natural resources. Some states appear to lack these regulations, however, and setback regulations differ widely, as shown in Table 3.2.

Table 3.2: Examples of State Regulations Requiring Minimum Distances between Wells and Streams[88]

AR	Closed-loop systems required if oil-based drilling fluids used and mud or circulation pit is w/in 100 ft. of stream;[89] 300 ft. for protected streams, 200 for others (crude oil tanks and tank batteries, gas well produced fluids storage tanks).[90]
CO	300 ft. if suitable for or intended to become potable (see buffer zone requirements).[91]
KY	Holding pits (for produced water) may not discharge pollutant into state waters, in violation of CWA or Kentucky water laws.[92]
NM	300 ft. (temporary or permanent pit or below-grade tank[93]).
NY	NY: site-specific review within 150 ft. (well pad).[94] Proposed regulation for drilling within the Delaware Basin watershed (regional regulation): greater of 300 ft. (wellbore) or 100 ft. (nearest disturbance).[95]
ND	No reserve pits "in, or hazardously near, bodies of water." N.D. ADMIN. CODE 43-02-03-19 (Westlaw 2012).
OK	No land application of produced water, drill fluids/cuttings, petroleum-based drill cuttings within 100 ft. of perennial stream, 50 ft. of intermittent stream. OKLA. ADMIN. CODE 165:10-7-17; 10-7-19; 10-7-26 (Westlaw 2012). No commercial soil farming within 100 ft. OKLA. ADMIN. CODE 165:10-9-2 (Westlaw 2012).
PA	300 ft. (vertical wellbore) or 100 ft. (edge of well site, whichever greater).[96] No well site permitted within floodplain if pit or impoundment with drill cuttings, flowback, produced water, or a tank with hazardous chemicals or condensate will be on site.[97]
TX	*Appears to have no setback requirement.*
WV	100 ft. (well pad or well); 300 ft. (naturally producing trout stream).[98]

A number of other state regulations also differ. In many cases, these differences likely are justified by variable climate, topography, geology, and other conditions. Relatively dry areas of Texas, for example, contain fewer streams, and requiring minimum distances between wells and streams therefore may be less important than, setbacks of oil and gas drilling from streams in Pennsylvania. In some cases, however, it is not clear that major gaps or omissions in state regulations are justified by these legitimate differences.

Some states[99] have addressed this variability, making relatively broad revisions to their codes. Colorado, as part of comprehensive revisions to its oil and gas code, established "buffer zones" around water supplies, in which various protective measures, such as storage of drilling and fracturing wastes in steel tanks, are required.[100] In 2013, the state also required testing of water wells near drill sites before drilling operations occurred (although capping the number of wells to be tested)[101] and imposed new statewide setback rules for well sites.[102] Pennsylvania has similarly completed several regulatory and legislative reforms, first updating its casing and cementing requirements[103] and rules for treating total dissolved solids in wastewater, and later expanding setbacks between well sites and protected natural resources, among other protections.[104] In this later amendment to its statutes, Pennsylvania also expanded the rebuttable presumption that contamination of a water supply—within a certain distance and time following oil and gas activity—was caused by the oil and gas activity.[105] New York has embarked upon a full environmental review of hydraulic fracturing that uses large volumes of water and has avoided issuing Marcellus Shale drilling permits as it completes this review and proposes detailed environmental standards.[106] West Virginia also has completed a relatively comprehensive revision of its oil and gas laws, requiring setbacks between wells and certain natural resources, a waste management plan for drilling and fracturing wastes, and a water management plan, among other protections.[107]

Some regulations at the regional and local level also help to fill gaps. The Delaware River Basin Commission has proposed relatively detailed regulations for gas drilling and fracturing within the Delaware River watershed, including stringent erosion control measures both during site construction and well operation within the watershed, testing of nearby water supplies prior to drilling, limits on where fracturing wastes may be disposed of, and other protections.[108] These regulations have not yet been implemented, however.

At the local level, municipalities such as Arlington and Fort Worth, Texas[109] and Farmington, New Mexico[110] have enacted a number of measures to constrain the impacts of fracturing, although some of these measures focus more on local nuisances, such as the noise of drilling and fracturing rigs, than on environmental protection. Figure 3.2 provides an example of provisions in Arlington, New Mexico's ordinance.

Figure 3.2: Code of City of Farmington, New Mexico, Chapter 19, Oil and Gas Wells: Examples of Environmental and Nuisance-Based Controls[111]

- Requires operators proposing to drill wells within city limits to obtain a special use permit from the city council and a license and permit to drill from the city clerk. § 19-2-66.
- Requires operators to file a minimum $20,000.00 bond with the city clerk. § 19-2-101(b).
- Establishes a city Oil and Gas and Geologic and Engineering Hazards Advisory Commission ("Oil and Gas Commission") to serve as an advisory body to the city on oil and gas-related zoning matters, drilling and maintenance and wells, and other oil and gas issues. §§ 19-2-31, 36.
- Prohibits wells within 200 feet of residences, commercial, and industrial buildings and 300 feet of buildings used for public assembly. § 19-1-3(a).
- Prohibits the construction or moving of a building within 100 feet of a wellhead. § 19-1-3 (c).
- Requires "all waste substances" to be "retained in watertight receptors." § 19-1-5 (a).
- Places restrictions on excavations and use of public rights-of-ways for gathering lines and pipelines, establishes maximum allowed pressure for gathering lines and pipelines. § 19-2-72.
- Requires rigs, steel pits, and tanks to be removed from sites and pits to be emptied, dried, and leveled within 30 days after the well has been completed. §§ 19-1-4, 19-1-5 (a)-(b).
- Encourages the co-location of multiple wells on single well sites. § 19-1-8.
- Establishes maximum allowed decibel increase measured at 300 ft. from pumping units or at the

nearest building. § 19-3-12(c).

- Requires chain link fencing with double strands of barbed wire around well site. § 19-3-10(a).
- For operations at existing well sites proposed to be modified, provides minimum construction standards for access roads. § 19-2-74(f)(7).
- For operations at existing well sites proposed to be modified, prohibits the "[u]se of the municipal sewer system for water discharge." § 19-2-74(f)(9).
- Requires landscaping plan if principal uses occur within 300 feet of a well site or there is a paved street within 100 feet of the well site. § 19-3-10(b).
- For operations at existing well sites proposed to be modified, if security lighting is used, requires that it be "downward-casting" and shielded. § 19-2-74(f)(12).

Together, federal, regional, state, and local regulations play a very important role in regulating the environmental impacts of oil and gas drilling and fracturing. In light of the fact that federal regulation does not apply to certain stages of development, however, and that sub-federal regulations are variable, more action may be needed, as discussed in the following part.

Improving Regulation

A number of efforts will be needed to fill certain gaps in US regulation of the environmental impacts of oil and gas drilling and fracturing. First and foremost, states need means by which to compare the content of their regulations in a consistent manner. There is currently no database in the United States that comprehensively collects and directly compares US state oil and gas regulations. With improved means of comparing regulations, states could better identify the leaders in regulation—other states that have taken the most aggressive steps to limit environmental impacts, for example—and could identify the regulations that may be most relevant in particular climates and topographies.

Second, mere comparison of regulation may insufficiently incentivize states to change regulations, and some federal intervention may be needed. David Spence of the University of Texas has described when federal as opposed to state action is typically justified within the United States, and he suggests that federal regulation of oil and gas and fracturing should primarily be limited to areas in which impacts clearly cross state boundaries.[112] Other professors, such as Professor Jody Freeman of Harvard Law School, have proposed more comprehensive federal standards for fracturing, which the states would implement.[113] In light of states' historic expertise in regulating areas such as the casing of oil and gas wells, as well as state regulators' geographic proximity to regulated oil and gas operations, it is not clear that federal regulation in all areas of drilling and fracturing is the best solution, but it is certainly being debated—at least in the legal literature. Several bills for federal regulation also have been proposed but have so far failed.[114]

Finally, states, which at least for now retain primary control over the environmental impacts of drilling and fracturing, must ensure that they have adequate staff, and adequately-trained staff, to inspect oil and gas sites. Table 3.3 demonstrates the low levels of staff numbers as compared to the total number of active oil and gas wells (*not* just fractured wells) in selected states.

Table 3.3: State Oil and Gas Inspectors and Total Active Wells in States[115]

Colorado[116]	Michigan[117]	New Mexico[118]	Ohio[119]	Pennsylvania[120]	Texas
2012: 36 inspectors[121] for 49,062 wells[122]	2012: 27 inspectors[123] for 15,742 wells[124]	2012: 12 inspectors for 56,366 wells[125]	2012: 40 inspectors for 55,083 wells[126]	2010: 76 inspectors[127] for approximately 92,326 wells[128]	2012: 153 inspectors for 279,856 wells[129]

Related to the need to ensure adequate staff for inspecting well sites and enforcing violations at sites is the need for states to better record enforcement actions. Only Pennsylvania and a handful or other states have an easily-searchable database of violations at well sites, including fractured well sites;[130] information on enforcement is much more difficult to obtain in most other states, although some, like New Mexico, have limited information about incidents at well sites in a "spill database."[131] It is important to produce better enforcement data in order to better understand whether and how states are applying regulations to oil and gas development and to identify the types of incidents that occur at these sites.

Much progress remains to be made in US oil and gas regulation. As described in this paper, some states are changing their regulations, and the EPA and BLM have taken some actions at the federal level. Local and regional governments, too, have adopted certain regulations to address drilling and fracturing. Moving forward, it is unclear whether there will be more dramatic changes, such as more sweeping federal regulation. Overall, it appears that oil and gas development, including fracturing, will continue to occur at a relatively rapid pace, although there will perhaps be enhanced regulation of this development. As the United States rushes forward with the development of gas from shales, this country will likely continue to learn from and respond to incidents, and to explore ways of reducing environmental impacts while reaping the benefits of gas.

The greatest challenge moving forward may be the sheer abundance of oil and gas from shales: With large fossil fuel sources, the United States may be tempted to ignore needed investments in renewable energy. The IEA, although noting the US energy "renaissance," has also noted the perils of this renaissance for efforts to mitigate climate change.[132] Natural gas, although likely

emitting fewer greenhouse gases than coal or oil, will not independently solve our climate problems. Yet it could distract from needed investments in renewables, which are the energy sources to which we must transition in the future. Treating fossil resources as an ultimate energy solution, rather than a bridge to a more sustainable energy future, would set us on a perilous course. Much work remains to be done to improve the regulation of unconventional oil and gas development and ensure that gas leads us to a more sustainable energy future.

Chapter 4.
Challenges for Shale Oil and Natural Gas: Environmental Stewardship and Opportunities through Innovation

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The recent development of shale oil and natural gas in the United States has been called a game changer. One recent study estimated that by 2035, the US unconventional oil and gas industry would support three million jobs.[1] While the economic and energy benefits are clear, the environmental and social impact of shale oil and natural gas development are areas of concern. These issues must be addressed to protect the environment and ensure public support for future development.

There are many issues when looking at the impact or trade-offs in oil and natural gas drilling and production. To understand the dynamics facing the industry and communities around the non-market issues of oil and natural gas development, it is helpful to understand the context of shale oil and gas development in the United States, including the key enabling technologies of horizontal drilling and hydraulic fracturing. Environmental issues need to be reviewed in the context of key areas of concern, such as ground water, surface water, land disturbance, and air quality. Community and social impacts are different but are related to environmental ones. Both environmental and community impacts can be mitigated through effective regulation and best practice, which may establish effective standards of operations and provide for innovation to improve future operations. Effective environmental and social stewardship in turn is important to maintain public confidence and financial performance.

Shale Oil and Gas Development in the United States

The shale oil and natural gas revolution have been critical to the US economy over the past five years. The United States is the largest natural gas producer and the third largest oil producer in the world. In 2011, natural gas production in the United States was 23 trillion cubic feet (tcf), 20 percent of global production. The EIA's 2012 Annual Energy Outlook projects by 2022 that the United States will be a net exporter of natural gas. This is a complete change in outlook from just a few years ago when, the EIA projected that the United States would import about 20 percent of the US natural gas supply by 2030. This change is related to the significant increase in natural gas production from shale. EIA projects that from 2010 to 2035, natural gas production from shale formations will rise from 23 percent to 49 percent of the US gas supply. The nation's natural gas resource base, which includes proved and unproved reserves, is now estimated at 2203 tcf, or almost 90 years of supply.

Regarding oil production, the United States for the past three years is increasing oil production and reversing a long-term decline. Perhaps the best example is the State of North Dakota, which has a significant portion of the Bakken shale within its borders. In six years, North Dakota's oil production has increased 380 percent from 40 million barrels/year in 2006 to 153 million barrels/year in 2011.

These increases in production have been singularly important to the nation's economy, creating more than 600,000 new jobs at a critical time when the economy desperately needed new jobs. These energy developments have occurred on private property and under state regulation with effective stewardship of the environment and protection of public health and safety. Industry has drilled thousands of wells with relatively limited adverse environmental impact; however, there is still room for improvement in reducing environmental and community trade-offs.

History

The shale revolution is the culmination of the work by a committed visionary, George P. Mitchell. Geologists have known that the shale formations throughout the United States contained hydrocarbons. In fact, they are known to be the source rock (origin) of oil and natural gas that has accumulated in conventional oil and gas-bearing geologic zones. Mitchell's vision was that he could figure out the technology necessary to commercially produce the natural gas, and he began drilling shale natural gas wells in the Barnett formation around Dallas, Texas in 1984. After many years and many attempts, Mitchell was successful in effectively applying hydraulic fracturing to the shale formations. The real breakthrough in shale gas production came with the application of both horizontal drilling and multi-stage hydraulic fracturing, which resulted in more wide-scale shale gas development beginning around 2005.

Key Factors in Shale Oil and Gas Success

Shale oil and gas development is both similar and different from conventional oil and gas. It is similar in that it uses advanced petroleum engineering and information technology to access difficult-to-reach resources. The oil and gas industry is one of the most high technology industries in the world. It takes a combination of advanced materials, supercomputing, and sophisticated communications to drill two miles deep and turn and drill horizontally another mile or more and stay on target in a vertical interval of just a few feet.

The oil and gas industry has made these developments look easy. However, shale oil and gas production is a high cost exploration and development activity. Where shale oil and gas development is different from conventional production is that success is critically tied to managing costs and maximizing productivity. Managing productivity is absolutely critical to continued investment. A key element of managing costs is effective planning of not just one well, but the entire drilling and production site. An industry measure of the effectiveness for a company is monitoring drilling rig utilization in terms of "days per well drilled." The industry has dramatically reduced drilling time through technology and improved management. Regulations that cause delays or uncertainty will result in decreased rig efficiency. This is especially troublesome when regulatory delays do not contribute to environmental protection or public health and safety. Any reduction in rig efficiency will directly impact the number of wells drilled and will also have an impact on long term investment decisions.

Environmental Implications and Mitigation

The process of exploring, drilling, and extracting oil and natural gas impacts the environment. These impacts are manageable and long-term harm to the ecosystem can be prevented with a proactive and comprehensive approach. Effective environmental protection requires advance planning and operational processes designed to protect ground and surface waters, minimize land impacts, and manage methane and other air releases.

Effective environmental stewardship is critical for maintaining a *social license to operate.*[2] It is also essential to effective long-term corporate financial performance. There are many aspects of environmental protection. For purposes of this discussion, the focus is on a primary set of environmental issues regularly found in shale gas development. On a site-specific basis, additional issues may need to be considered. For instance, endangered or protected flora and fauna may require additional measures. Archeological surveys may be necessary to protect historically important artifacts or cultural resources. The primary environmental impacts and mitigation common to all shale oil and natural gas development include ground water, surface land and water, land disturbance, and air emissions. Associated with waste disposal wells in a few instances, a relatively new issue of concern is induced seismicity. Following are reviews of the major environmental protection components and the mitigation measures generally used by the oil and gas industry.

Ground Water

One of the primary long-term risks in drilling oil and natural gas wells is potential impact to groundwater. The very process of drilling a well creates a potential pathway for lower quality water, oil, and natural gas to migrate from deeper geologic zones to the shallower freshwater bearing formations. To protect freshwater zones (sometimes referred to as underground sources of drinking water), wells are constructed using steel casing and cement to isolate the different geologic formations. In the few cases where contamination or degradation of freshwater zones have occurred, it has typically been because of a failure in one of the well construction components.

The protection of underground sources of fresh water is accomplished by first drilling through the freshwater zones. Before drilling further, a steel pipe called surface casing is set through the freshwater zone and cement is circulated through the casing and up around the outside, sealing the fresh water bearing rocks. The drilling is then continued through the inside of the surface casing. Additional strings of casing (pipe) are set to isolate other zones when necessary to protect the well or facilitate deeper drilling. A final casing is set and cemented through the oil and gas bearing target zone to isolate the oil and natural gas. This casing and cement must be properly engineered to hold the pressure of the fracture treatment as well as pressure created by the flowing oil and natural gas. Properly monitoring casing and cementing processes, pressure testing casing, and additional geophysical tools can be used to determine construction effectiveness.

Regulatory agencies and oil and gas developers have known about the need for adequate well construction for decades and all state regulatory programs in the United States have well construction requirements to protect freshwater sources. However, the advent of shale gas drilling introduced technology and subsurface environments, which in some cases exceeded the design standards that were anticipated by older regulations. For example, formation pressures from some shale zones have exceeded pressures encountered previously in some regions. Regulators have moved to update construction standards to solve these issues. While the well construction issue has largely been solved, this does illustrate the need to identify areas of potential changes in practice and regulation as a result of technology advancements.

Surface Land and Water Pollution

Material handling on the surface around the well site creates a potential for surface water and land pollution. The best mitigation is to prevent any releases of contaminates into the environment. Depending on the material released, the cleanup may be difficult and have the potential to lead to ground water contamination. Historically, surface spills have been one of the greatest environmental threats related to oil and gas development.

A number of different fluids must be properly handled when drilling an oil or natural gas well. Fluids are required as part of the drilling process to circulate drill cuttings to the surface, fuel and lubricants to run the pumps and drilling rig, and chemical additives for the hydraulic fracturing process. When properly managed, these fluids have a minimal adverse impact on the environment. However, if an unintended release occurs, the potential for damage may be significant. To prevent damage from spills, mitigation measures involve containment systems, reducing the volume of fluids, and substituting less hazardous materials.

Containment systems are required for storing all materials that can cause environmental damage. This is in addition to the primary storage container or tank. A secondary containment system capable of holding the entire contents of the primary vessel is a critical component of spill prevention. In addition, the system must include design and procedures to prevent material loss during transfers of fluids. In areas with a high environmental risk, additional precautions such as requiring steel tanks for drilling operations instead of lined impoundments may be necessary.

Land Disturbance

A drilling site requires several acres of land for the drilling rig and equipment, as well as the land required for a road to each site. Historically, each well required a separate drilling site or pad. With the advent of horizontal drilling, however, one well pad is now able to accommodate four to six wells. This also means that protective measures, such as drilling rig secondary containment systems, drilling fluids storage, and drill cuttings storage systems, can all be used as part of the same operation. In many cases, hydraulic fracturing for all of the wells on one pad can be coordinated, also reducing surface land use.

Roads and pipeline corridors constitute a significant portion of the land impacted by oil and gas development. Multi well drilling pads have reduced the number of roads required for drilling and well servicing. In sensitive ecosystems, new technology is available for temporary road construction that minimizes impact and speeds restoration. New regions of oil and gas development require new pipelines to gather and produce oil and natural gas for delivery to transmission systems. One way to minimize land disturbance from multiple pipelines is to coordinate pipeline corridors among well operators in a region. Technology and practices regarding pipelines are an aspect of oil and gas development, which may warrant further review.

Air Emissions

Drilling oil and natural gas wells result in air emissions from engines and potential methane escape during the drilling and fracturing process. In addition, in areas where both oil and gas is produced, but the infrastructure to market the gas is under development, gas flaring can also be a problem. One of the challenges to setting more effective air emissions requirements is the lack of a clear baseline data on methane and other emissions during the drilling and production process. Several research and data collection projects are currently underway to obtain necessary baseline data.

There are several new approaches to reducing air emissions during shale oil and gas development and production. New engine technology that uses natural gas as fuel either fully or in combination with diesel fuel is one option. Several operators are using liquefied natural gas (LNG) engines to power drilling rigs. Services companies are developing and using combination natural gas and diesel engines to support pumps for hydraulic fracturing, thereby reducing engine emissions. There are regulatory hurdles to implementing these new measures, but the applications appear promising.

In developed natural gas fields, operators are implementing “green completion” technology to capture methane, which would otherwise be vented or flared during the well completion process. This requires a higher degree of coordination and in some cases may result in delaying well completion until the natural gas gathering pipeline is completed. In the area of gas flares resulting from gas associated with oil production, progress is being made. Gathering and transmission pipelines are being put in place and regulatory systems are stricter; however, the volumes flared are still high suggesting that there is yet more room for improvements. The answer is in commercializing gas associated with oil production. Both infrastructure development to connect gas production to the pipeline network and new technology, such as small-scale gas to liquids technology, are possible solutions. To expedite this process, more aggressive state regulations and standards may prove useful.

Induced Seismicity

Induced seismicity is minor earthquake activity that is caused by injection of fluids into a geologic formation. Induced seismicity has been observed in the vicinity of a few wells used for the disposal of oil and gas wastewater. No significant or long-term impact has been observed from induced seismicity; however, there is limited information on this issue. In cases where seismicity has been observed, regulatory agencies have restricted injection activity.

One effort to establish a scientific basis of induced seismicity is the University of Southern California’s Induced Seismicity Consortium (USC-ISC). The USC-ISC project seeks to bring a multi-stakeholder approach to understanding induced seismicity by engaging technical expertise from engineering, geology, geophysics, and other university departments to study sites around the country. The California Earthquake Center and public communication experts will assist in developing tools to communicate the very unique technical language of seismicity in an understandable way. The participation of environmental groups, regulators, and other stakeholders along with technical experts will guide the research and recommend risk mitigation strategies for induced seismicity.

Public and Community Impacts

While related to the environmental trade-offs, public and community impacts of shale oil and gas development are the specific effects directly linked to local residents in the vicinity of the oil and gas activity. Whether the residents consider these impacts significant varies from region to region. Not surprisingly, in those areas with a long history of oil and gas development, the impact is seen as less of a problem. Some of the primary public and community impacts are related to traffic, construction activity, and commercialization of rural areas.

Vehicle Traffic and Road Congestion

The equipment and materials for a single shale oil and gas drilling operation requires hundreds of truckloads per well. In addition, the material needs are concentrated during specific periods of development, such as rig mobilization and hydraulic fracturing. Many areas with oil and gas development are in rural or agricultural areas with low levels of truck traffic prior to drilling operations. Some of the community issues that arise include road congestion, traffic safety, and road maintenance. The roads, which are normally under the jurisdiction of the local government, may fall into disrepair because of the increased truck use. Failure of the oil and gas developers to work effectively with the local regulators and to identify benefits (direct or indirect) from oil and gas development can create negative perceptions within the community. In most areas, specific permits and bonding are required for very heavy equipment, such as drilling rigs, to ensure that roads are repaired when damaged. Oil and gas development companies should not underestimate the importance of road and traffic issues.

Construction Activity

Oil and gas drilling is a twenty-four hour a day and seven day a week industry. The cost of well drilling requires this around the clock operation. In rural areas, this activity dramatically changes the evening and nighttime hours. Needless to say, sound can travel long distances and disrupt traditional lifestyles. Sound barriers and careful use of lighting can minimize the impact of drilling operations. For long-term production operations, noisy equipment, such as compressors, can be housed in soundproof buildings to restrict noise impact to surrounding residents.

Community Changes—Rural/Agricultural to Commercial Activities

Oil and gas development is an industrial activity with positive and negative spillover effects. In high growth areas such as the Bakken shale in North Dakota, housing shortages and an in flux of temporary workers can create problems for local residents. The new activity can drive up local prices of goods and services, lowering the standard of living for those who have not

directly benefited from the oil and gas developments. But this is not to downplay the benefits derived from job creation and economic development, which have resulted in an unemployment rate of 3.2 percent in the case of North Dakota. The state can soften the negative impact by implementing the right kinds of policies, such as promoting housing growth.

Technology Solutions—Illustrative Examples

There are many innovations that are vying to solve problems and reduce environmental impact. Oil and gas companies have a primary objective of producing oil and gas, so it is not at all surprising that most environmental technologies emerge from service companies supporting the industry (rather than the oil and gas industry itself). One challenge is the environmental trade-offs between solutions. For example, a more intensive water treatment program may improve water quality from wastewater treatment processes, but at the expense of increased air emissions. This is just one of the challenges of implementing new technology for reducing environmental trade-offs. In addition, new technology takes time to demonstrate capability in the field, at scale. Even with the challenges, new technology to support reduction of negative externalities is moving from laboratories to field applications. Below are just two examples of areas where technology is playing an important role mitigating environmental trade-offs.

Water Use/Wastewater Disposal

Technologies around water management are becoming an important area of innovation in shale oil and gas development. These technologies range from reducing water requirements for hydraulic fracturing to methods for treating wastewater for reuse or recycling. While research is ongoing in different areas, following is a discussion on two specific areas of development: water reuse and water recycling.

Water reuse refers to the practice of reusing fracture treatment flow back water for other fracture treatments. Hydraulic fracturing requires a significant amount of water, along with sand and some additives, which is pumped under high pressure into the oil and natural gas bearing shale formation to crack the shale formation. After the fracture treatment is completed, water is recovered from the well, usually 20 to 50 percent of the original volume pumped into the well. The recovered water, called frac flow-back water, contains both dissolved and suspended solids that are introduced into the original fracture treatment fluid or are picked up in the shale formation. The types and concentrations of minerals in the frac flow-back water vary from basin to basin.

Technologies to process frac flow-back water for reuse involve removing the suspended solids from the wastewater and creating clean brine. This processed water can then be added to other make-up water for future hydraulic fracturing operations, reducing the total amount of new water required. There are many companies providing different technology solutions for processing flow-back water for reuse. The most common are filtration or chemical flocculation systems. The differentiation between service providers generally revolves around portability, capacity, and wastewater chemistry capability. Reusing frac flow-back water is a key water management strategy in many operating regions.

A move up from reuse is recycling. In water recycling, the wastewater stream is cleaned to a higher standard, potentially to freshwater standards. The typical technology used to recycle frac flow-back water is mechanical vapor recompression (MVR), a version of evaporation and distillation. One company, Fountain Quail Water Management, has been operating semi-potable MVR units in United States shale plays for more than 8 years. These units are skid mounted and can be set up in new drilling areas and moved as gas development areas progress. The MVR technology produces distilled water with a very low level of total dissolved solids. With necessary regulatory approvals, the processed water can be used for other applications, such as agriculture, or released back into the environment. The typical use of recycled water is as make up water for additional fracture treatments. Water recycling to the higher freshwater standard is used in limited areas, because of the cost and a lack of need for better water quality.

Choices in water management strategy vary for many reasons in each oil and gas basin. Some of the issues that must be considered include water availability, cost, treatment and disposal options, and transport. In addition, indirect cost issues such as public perception, environmental liability, and risk may also be considered. Generally the industry has not internalized a full lifecycle cost of water management. Better tools for evaluating the range of options and costs are likely to support better water management and support new technology commercialization.

Footprint

The “footprint” of a drilling location refers to the land area impacted by the drilling site and related infrastructure. The size of the footprint or disturbed area varies depending on the size of the rig and other local factors. The vast majority of on-shore wells drilled in the United States were drilled with one well on each drill pad. The advent of drilling in Arctic Alaska resulted in technology advances of drilling multiple wells on a single pad. The wells were directionally drilled to reach the desired subsurface location while using a common surface site. This reduced the surface impact per well dramatically. Multiple wells from the same surface location have the dual benefit of reducing costs and mitigating environmental trade-offs.

In 2008, an organization was launched called the Environmentally Friendly Drilling (EFD) systems. The EFD works to advance environmental technology, which further reduces the environmental trade-offs of oil and gas development. EFD uses a systems approach in exploring how technologies can be combined to further reduce oil and gas environmental impact. The EFD has determined that with the combination of technologies, the "footprint" can be reduced by 90 percent from the typical original oil and gas development site. Some of the components that reduce the overall footprint for wells include: multi-well pads; drilling pad design; modular, compact drilling rigs; optimal hydraulic fracture footprint; low impact access roads; and green completion technology. Combining and optimizing environmental technology can dramatically reduce environmental trade-offs of development.

Role for Multi-Stakeholder Engagement

There is a growing role and need for multi-stakeholder approaches to address concerns related to oil and natural gas development. A multi-stakeholder effort brings industry, academics, non-governmental organizations, government, and other interested parties together to proactively and productively seek solutions to issues around the environmental or community trade-offs in oil and natural gas development. his approach has proven to be effective in addressing a number of concerns.

An example of this approach in practice is the EFD managed by the Houston

Advanced Research Center (HARC). The HARC EFD combines scientific research with advanced technologies to create systems that address environmental issues associated with petroleum drilling and production operations. The objective is to identify, develop and transfer critical, cost effective, new technologies that can provide policy makers and industry with the ability to develop reserves in a safe and environmentally friendly manner. The program continues to add participants from environmental organizations, academia, government agencies, government laboratories, and industry. Currently over 100 organizations support this effort. The HARC EFD is recognized as a leading resource for objective data concerning oil and gas operations by industry, environmental organizations and regulators. It also sponsors public perception studies which raised public awareness and understanding among all stakeholders.

Role of Government Regulation

The role of regulators is to ensure the protection of health, safety, and the environment. In oil and gas development, regulators also have a key role to ensure the conservation of the resource. In the United States, state governments began regulating the oil and gas industry long before the federal government. One of the earliest laws regulating oil and gas development was Indiana's 1893 statute, which was affirmed by the US Supreme Court in 1898. The great advantage of the State regulatory model for on-shore oil and gas development is that States can tailor regulatory programs to fit regional geology, topographic, other scientific factors, as well as social and community differences. One-size-fits-all approach of federal regulation does not provide for these key differences between areas of the country.

Regulation is intended to set a common denominator and common requirements for companies. Effective regulations should establish the minimum level of acceptable and required performance. By being performance oriented, rather than proscriptive, regulations allow for innovation and the development of best practices that may go beyond the minimum requirements.

Clearly articulating the minimum performance standards and expectations is essential for effective regulations. Without clear standards, the regulated companies do not know how to set their own standards, so they can meet the regulations. Providing a clear standard and allowing companies to find the best ways to meet that standard is essential for innovation and development of new technologies that improve processes. It is these evolving technologies that offer the opportunity to further reduce environmental impact and improve operating efficiency.

Role of Industry Best Practices

The oil and gas industry is most known for technology development that leads to greater oil and gas production, such as three dimensional seismic, horizontal drilling, and hydraulic fracturing. While these technologies have enabled new production, including shale oil and gas, the industry has also led the development of technologies that have reduced the environmental and social impact of oil and gas development. In fact, technology that lessens the environmental impact can also reduce long-term costs of production.

The continuous improvement of processes often leads to higher standards of environmental protection. In many cases the technology is developed to solve a problem in high cost, remote, and possibly sensitive environments. Once technology is developed and implemented successfully, the cost generally decreases and can then be cost effectively applied more broadly. As previously stated, the multi-well pads that are typical in shale gas development through the United States to minimize surface impact were developed in the Alaska Arctic during the 1980s.

A best practice system is a mechanism to catalogue effective practices and technology solutions, so that others can apply them for similar circumstances. From an environmental stewardship standpoint, industry best practices are an effective way to develop new and better processes for protecting the environment. The best practices are not a substitute for a comprehensive regulatory system, but a way to catalogue advances and raise the expectations for future performance. Once new best practices demonstrate capability to exceed current standards, regulations may be revised to higher standards. In this way best practices and regulations can be used together to reduce trade-offs and create a continuous improvement cycle.

An example of the opportunities of combining best practices and regulations is the success of the North Dakota Industrial Commission in reducing well construction failures. Over several years of shale oil well drilling in the Bakken formation, the Commission compiled information on a small number of well construction failures (less than 0.2 percent). While the construction failures did not result in contamination of ground water, they did result in significant financial loss to the well owner and presented a potential environmental problem, if left uncorrected. The state regulatory agency created a working group in collaboration with the industry to determine the root cause of the well construction failures. The group was able to recommend changes to the drilling process, which eliminated casing damage during the drilling process. The regulatory agency required these changes as part of the permit conditions. Over an eighteen month period following the implementation of these drilling process requirements, North Dakota has not identified any new well construction failures. This is a successful example of how the industry can develop best practices and regulators can use those best practices to advance regulations.

Implications for Non-Market Dynamics of US Shale Oil and Gas Development

Shale oil and natural gas development in the United States provide important economic and energy security benefits for the country. Industry, government, and other organizations are making progress by reducing the adverse environmental and social trade-offs of oil and gas development. Industry and state regulatory agencies have moved quickly to address concerns regarding hydraulic fracturing. Regulations and practices regarding ground and surface water protection and land use have been implemented. Understanding and protecting air quality is improving. Research to understand induced seismicity is underway. While more remains to be done, organizations that involve multi-stakeholder participation are addressing these issues in a way that builds public confidence.

The regulatory structure for overseeing oil and gas regulation is largely in place. Many states have increased staff and resources to ensure effective implementation, although an effective performance measurement system would prove useful. Several regional best management practices groups are under development. These best management practice systems will provide a process for cataloging effective new technologies to address environmental and social issues, setting the stage for raising standards and reducing trade-offs in the future.

Shale oil and natural gas provide an exciting opportunity for energy supply

and economic growth in the United States and around the world. Technology development to solve environmental and social trade-offs offers further opportunity.

Chapter 5.
Regulatory Standards and Industry Practices: Managing Externalities in Development of Unconventional Oil and Gas in the United States

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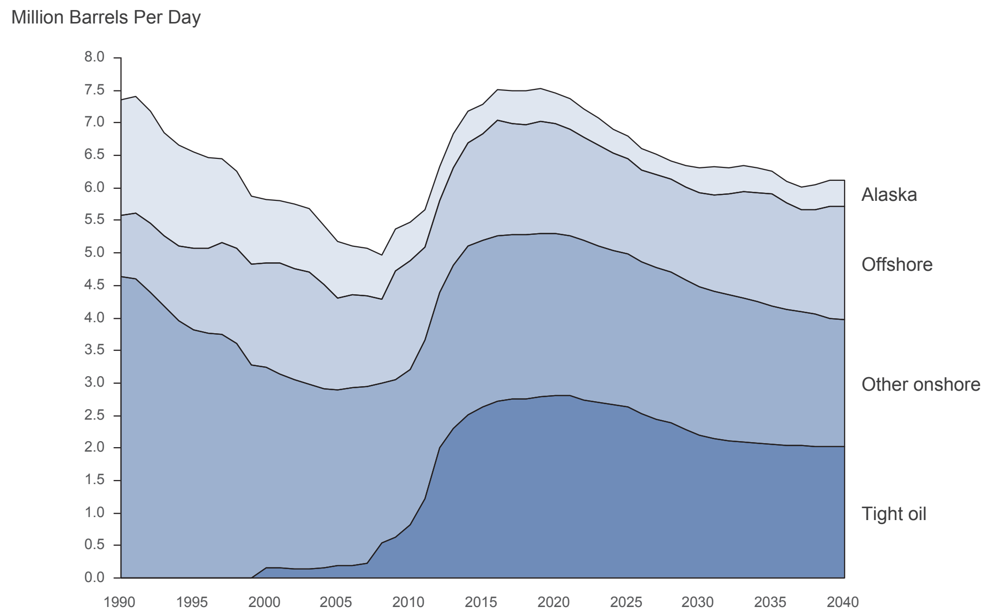
Development of unconventional oil and gas in the United States is well underway and moving along at a blinding pace. With potential economic gains mounting, total investment in shale plays exceeded US$133 billion during 2008-2012. According to most estimates, production and development looks to increase at an even faster rate as the share of natural gas and oil production coming from shale and tight formations is expected to rise into the future (See Figures 1.3 and 5.1). There are, however, several unknowns that may pose significant challenges to unconventional oil and gas development in the United States.

The factor we have focused on in this report is regulatory control. As concerns about the environmental and social impacts of fracking continue to grow, there is an increasing potential for the kind of regulatory intervention that may pose severe restrictions on unconventional oil and gas development. Discussions in the preceding chapters reveal several important lessons that may prove useful in estimating the likelihood for this kind of shift.

We know, for instance, that there are extensive regulatory controls on licensing, planning, leasing, development, and reclamation on federal lands, but we also know that these existing regulations may not be adequate given that

Figure 5.1: US Domestic Crude Oil Production by Source, 1990-2040



Source: EIA

drilling operations vary according to subsurface geology and technology. Secondly, we also know that public concerns about well-bore integrity, transparency, and water management have pushed various federal agencies, such as the BLM, to adapt new rules which themselves are subject to change depending on negotiations with various social interests. In short, what this suggests is that there is some room for uncertainty about the direction of regulatory controls as we speculate on the future of unconventional oil and gas development on federal parcels.

With respect to state-level regulation, we found significant variations in enforcement as well as pre-conditions on various drilling sites across different states. The single greatest challenge appears to be the lack of comprehensive regulatory framework as far as fracking is concerned; however, development of a one-size-fits-all policy with respect to unconventional gas and oil development is problematic given that geological specificity and variations in climate as well as topography largely determine the method and technology used to extract resources from tight formations. Given also that certain regulatory environments are more favorable for certain types of extraction methods and technology, the impact that more or less stringent regulation can have on overall productivity is likely to be cushioned by the variation in regulation, holding all else (i.e. recoverable supply) constant. However, spots of poor regulation can potentially be areas of risk whereby a single environmental or public health fallout can prove to be the basis for harsh regulatory backlash against the industry as was the case in the recent BP Deepwater Horizon drilling rig disaster and the restrictions on drilling that followed shortly thereafter.

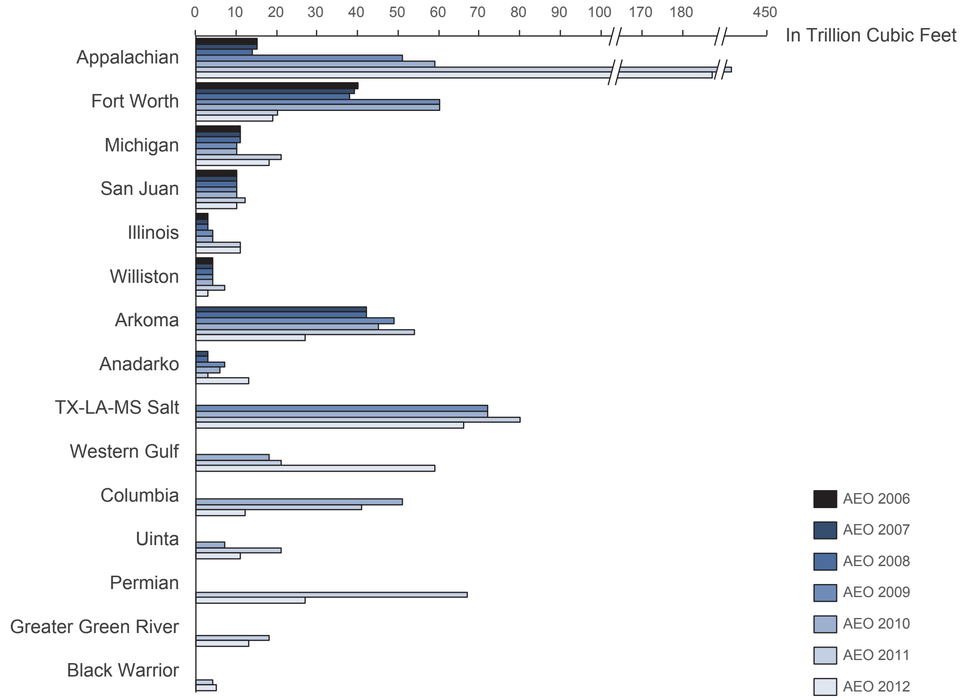
While the discussion suggests that state-level regulation, in conjunction with federal, regional, and local regulations, perform relatively well in addressing many concerns, it also appears to be the case that existing regulations are dated in relation to the change in technology and methods. Some potential problems point to a lack of adequate information about the state of regulations across different states as well as personnel resources to enforce existing regulations. Clearly, it seems to be the case that there is room for improvement on this front meaning this is an area in flux and much like federal regulation can change for better or worse.

The question about the kinds of regulation that we may see developing across different states may depend, in part, on how well the industry or the market may manage public concerns as well as the risks associated with drilling. The evidence from the above discussion suggests that there are improvements in at least two fronts in addition to changes in government regulation. One is on the technological front. Innovative approaches to managing water use

along with the utilization of multi-well pads and green completion technology have assuaged some environmental concerns. Second area is in inclusive cooperative engagement. Multi-stakeholder approach, which brings together players from the industry, academia, government, as well as other interest areas, have allowed for better problem identification, greater transparency and more effective solutions to potential problems in unconventional oil and gas development. Finally, we also see the emergence of best industry practice which incorporates all of these elements along with effective regulation in order to minimize well construction failures and other potential fallouts. Whether these market-based developments will be able to adequately address public concerns and thereby preclude the need for a comprehensive regulatory control remains to be seen.

Aside from the above non-market factors, there are other critical dimensions that cannot be overlooked. First and foremost is the supply of oil and gas in shale and other tight formations. According to the EIA, estimates of technically recoverable resource (TRR) are a function of land area, well spacing, percentage of area untested, percentage of area with potential, and estimated ultimate recovery (EUR) per well. Unproved TRR refers to estimates of resources that can be recovered using current technology without concern for additional economic or operating conditions. As wells are drilled and resources are extracted, unproved TRR become proved TRR and then ultimately catalogued as production. The problem is that the projection figure has a high degree of variance (See Figures 5.2 and 5.3). The EIA reasons that since the economics and timing of development can affect production, TRR does not necessarily reflect projected production. One of the criticisms against the development of shale and tight formations, however, is that the projected supply is grossly overestimated. Whatever may be the case, volatility in projected estimates of supply should be weighed in towards decisions about future invest-

Figure 5.2: Unproved Technically Recoverable Shale Gas Estimates Outlook by Basin

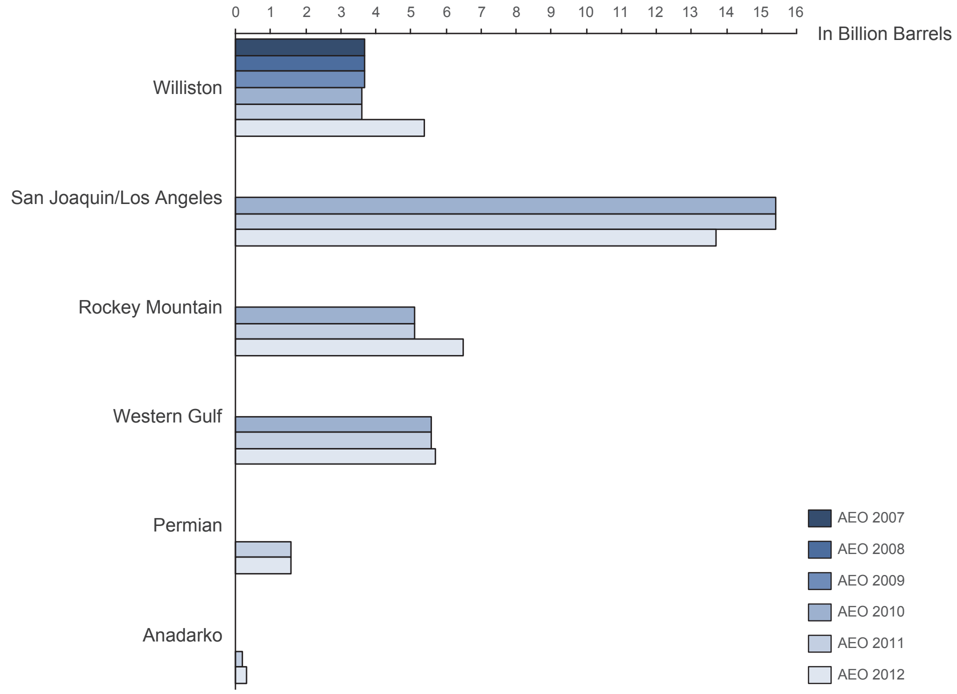


Source: EIA

ments in unconventional oil and gas.

Infrastructure conditions are also critical in processing and delivering natural gas for domestic as well as foreign consumption. LNG terminals and storage facilities as well as pipelines will be required to prevent bottlenecking and stranded supplies from areas that previously were not considered as a resource base for natural gas. Some estimates suggest that the cost of new natural gas transmission infrastructure and processing facilities will require about US$160 billion of infrastructure investment by 2035.[1] Of course, infrastructure development itself poses a whole new set of questions with respect to regulation and environmental as well as public health concerns.

Figure 5.3: Unproved Technically Recoverable Tight Oil Estimates Outlook by Basin



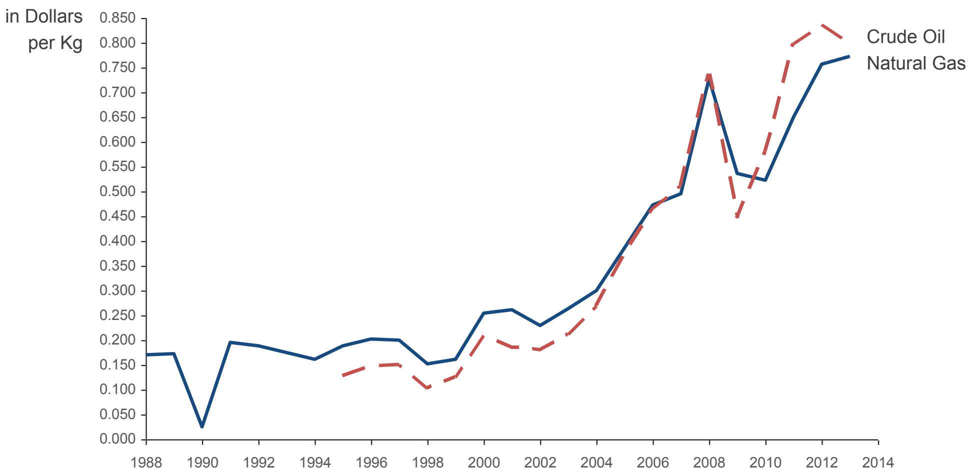
Source: EIA

Implications for South Korea

Short-term trends in US shale gas and tight oil should not be underestimated. Some recent estimates suggest that the exploitation of shale oil, for instance, will boost GDP of large net oil importers, such as Japan, by around 4 percent to 7 percent by 2035.[2] The impact on South Korea, which stands as the world's second largest importer of LNG and the seventh largest importer of oil, is significant. As shown in Figure 5.4, the price of crude oil and natural gas imports in South Korea has consistently increased over time. Similar to the Japanese counterparts, both the Korea National Oil Corporation (KNOC) and the Korea Gas Corporation (KOGAS) have responded by increasing their investment in US shale plays.

The Korean Ministry of Knowledge has long maintained that it will promote the expansion of shale gas imports to 20 percent of all natural gas imports by 2020. Private companies, such as the E1 Corporation and SK Innovation have announced that the import of LPG from US shale source will begin as early as 2014, timed to the Panama Canal expansion project. At the moment, the price of LPG produced from shale formations in the United States is 10 percent to 20 percent cheaper than the imports from the Middle East. As the number of stakeholders from other countries for unconventional oil and gas development in the United States grows, South Korea finds itself with a particular edge that some of these other players do not yet possess. As a recent signatory of the free trade agreement with the United States, South Korea has the ability to sidestep the time-consuming licensing process for US exports of natural gas and oil.

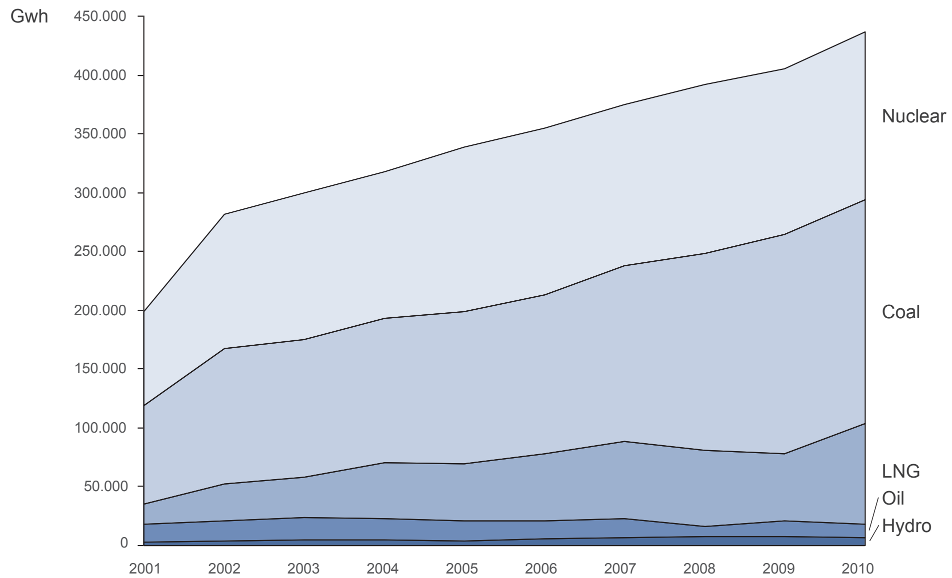
Figure 5.4: Import Price of Crude Oil and Natural Gas in South Korea, 1988-2014



Source: KITA

These conditions, however, do not necessarily imply unabashed optimism as far as energy prospects for South Korea are concerned. As discussed in the previous section, there are many risks and unknowns with respect to long-term outlook on unconventional oil and gas in the United States. Perhaps a more forward looking approach that problematizes risk management could prove useful. A step in this direction is strategic emphasis on optimal energy mix. As of today, nuclear power stands as one of the most important sources of electricity generation in South Korea and this is not likely to change into the future (See Figure 5.5).

Figure 5.5: Sources of Electricity Generation in South Korea, 2001-2010



Source: Korea Statistical Information Service

Dependence on coal, which currently stands to account for little over a third of electricity generation, will decrease into the future. In its place, LNG has emerged as an important alternative. As of 2001, only 8 percent of all electricity generated in South Korea came from LNG. This figure is more than doubled by 2010. Given that much of this energy source cannot be homegrown and the geopolitical risks associated with overdependence on Middle East sources have gone up, South Korea is likely to shift its attention to the development of unconventional oil and gas in North America. The exact measure of how much South Korea will rely on this energy source, however, should be tempered with the outlined risks as it forges ahead.

Notes

Executive Summary

1. See US Energy Information Administration (EIA), "Foreign Investors Play Large Role in US Shale Industry," *Today in Energy*, April 8, 2013, http://www.eia.gov/todayinenergy/detail.cfm?id=10711. There are other estimates. For instance, the Advanced Resources International (ARI) presents another estimate of about 48bb of recoverable shale oil and 1,161tcf of recoverable shale gas (EIA, 2013). CSIS (2010) presents other estimates that suggest a supply ranging from 274tcf to 616tcf. Just to provide some perspective, the total US residential use of natural gas during 2012 was about 4.2tcf while the total usage for electric power generation was 9.1tcf. As far as the consumption for oil is concerned, the United States consumed about 7 billion barrels of refined petroleum products and biofuels annually in 2010-2011.
2. US Energy Information Administration (EIA), "Energy in Brief: What is Shale Gas and Why Is It Important?" December 5, 2012, http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm.
3. IHS, "America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy," October 2012, http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx; IHS, "The Economic and Employment Contributions of Shale Gas in the United States," December 2011.
4. Ibid., 2012.
5. Marcellus Shale Education and Training Center (MSETC), "Economic Impacts of Marcellus Shale in Bradford County: Employment and Income in 2010," January 2012; Bill Powers and Art Berman, *Cold, Hungry and in the Dark: Exploding the Natural Gas Supply Myth* (Gabriola Island, BC: New Society Publishers, 2013); Richard Heinberg, *Snake Oil: How Fracking's False Promise of Plenty Imperils Our Future* (Santa Rosa, CA: Post Carbon Institute: 2013).
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7. Reuters, "South Korea's E1 to Import US Shale Gas LPG to Diversify Supplies," November 7, 2012, http://www.reuters.com/article/2012/11/08/lpg-korea-us-idUSL3E8M813Q20121108; Maeil Kyung-jae, "E1 Eui-uh SK Gas-do Mi Shale Gas Do-ip" January 6, 2013; Lefebvre Ben and Hiroyuki Kachi, "Tepco to Import US LPG from Enterprise Products," *Wall Street Journal*, February 27, 2013,

http://online.wsj.com/article/SB10001424127887323478304578330113264988492.html. The Nikkei Asian Review, "Shale Gas Boom Fueling Japan LNG Offensive," February 6, 2013.

8. US Environmental Protection Agency (EPA), "Study of the Potential Impacts of Hydraulic Fracturing in Drinking Water Resources: Progress Report," December 2012, http://www2.epa.gov/hfstudy/study-potential-impacts-hydraulic-fracturing-drinking-water-resources-progress-report-0; Alan J. Krupnick, "Managing the Risks of Shale Gas: Key Findings and Further Research," *Resources for the Future*, June 2013, http://www.rff.org/rff/documents/RFF-Rpt-ManagingRisksofShaleGas-KeyFindings.pdf; Sheila M. Olmstead, Lucia A. Muehlenbachs, Jhih-Shyang Shih, Ziyan Chu, and Alan J. Krupnick, "Shale Gas Development and Impacts on Surface Water Quality in Pennsylvania," *Proceedings of the National Academy of Sciences* 110, no. 13 (August 2012): 4392-4967; US Energy Information Administration (EIA), "Energy in Brief: What is Shale Gas and Why Is It Important?" December 5, 2012, http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm.
9. Sarah O. Ladislaw, David Pumphrey, Frank A. Verrastro, Lisa A. Hyland, and Molly A. Walton, *Realizing the Potential of U.S. Unconventional Natural Gas* (Washington, DC: Center for Strategic and International Studies, 2013).
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Chapter1.
Lessons and Implications from Non-Market Considerations in the Development of Unconventional Oil and Gas in the United States

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1. See US Energy Information Administration (EIA), "Foreign Investors Play Large Role in US Shale Industry," *Today in Energy*, April 8, 2013, http://www.eia.gov/todayinenergy/detail.cfm?id=10711. There are other estimates. For instance, the Advanced Resources International (ARI) presents another estimate of about 48bb of recoverable shale oil and 1,161tcf of recoverable shale gas (EIA, 2013). CSIS (2010) presents other estimates that suggest a supply ranging from 274tcf to 616tcf. Just to provide some perspective, the total US residential use of natural gas during 2012 was about 4.2tcf while the total usage for electric power generation was 9.1tcf. As far as the consumption for oil is concerned, the United States consumed about 7 billion barrels of refined petroleum products and biofuels annually in 2010-2011.
2. US Energy Information Administration (EIA), "Energy in Brief: What is Shale Gas and Why Is It Important?" December 5, 2012, http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm.

3. IHS, "America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy," October 2012, http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx; IHS, "The Economic and Employment Contributions of Shale Gas in the United States," December 2011.
4. Ibid., 2012.
5. Marcellus Shale Education and Training Center (MSETC), "Economic Impacts of Marcellus Shale in Bradford County: Employment and Income in 2010," January 2012; Bill Powers and Art Berman, *Cold, Hungry and in the Dark: Exploding the Natural Gas Supply Myth* (Gabriola Island, BC: New Society Publishers, 2013); Richard Heinberg, *Snake Oil: How Fracking's False Promise of Plenty Imperils Our Future* (Santa Rosa, CA: Post Carbon Institute: 2013).
6. US Energy Information Administration (EIA), "Foreign Investors Play Large Role in US Shale Industry," *Today in Energy*, April 8, 2013, http://www.eia.gov/todayinenergy/detail.cfm?id=10711.
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8. US Environmental Protection Agency (EPA), "Study of the Potential Impacts of Hydraulic Fracturing in Drinking Water Resources: Progress Report," December 2012, http://www2.epa.gov/hfstudy/study-potential-impacts-hydraulic-fracturing-drinking-water-resources-progress-report-0; Alan J. Krupnick, "Managing the Risks of Shale Gas: Key Findings and Further Research," *Resources for the Future*, June 2013, http://www.rff.org/rff/documents/RFF-Rpt-ManagingRisksofShaleGas-KeyFindings.pdf; Sheila M. Olmstead, Lucia A. Muehlenbachs, Jhih-Shyang Shih, Ziyan Chu, and Alan J. Krupnick, "Shale Gas Development and Impacts on Surface Water Quality in Pennsylvania," *Proceedings of the National Academy of Sciences* 110, no. 13 (August 2012): 4392-4967; US Energy Information Administration (EIA), "Energy in Brief: What is Shale Gas and Why Is It Important?" December 5, 2012, http://www.eia.gov/energy_in_brief/article/about_shale_gas. cfm.

Chapter3.

US Regulation of Unconventional Oil and Gas Development: Progress and Challenges

1. This paper draws from the author's papers. See Hannah Wiseman, "Risk and Response in Fracturing Policy," *University of Colorado Law Review* 84 (Summer 2013), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2017104; Hannah Wiseman and Francis Gradijan, "Regulation of Shale Gas Development, Including Hydraulic Fracturing," (unpublished; research initially funded by the Energy Institute, University of Texas), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1953547.
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4. See: US Energy Information Administration, "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays," July 8, 2011, ftp://ftp.eia.doe.gov/natgas/usshaleplays.pdf, 4 (describing federal involvement in research).
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6. See: Coastal Oil & Gas Corp. v. Garza Energy Trust, 268 S.W.3d 1, 2 (Tex. 2008) (describing the first commercial use of fracturing as occurring in 1949).
7. See J.A. Harper, "The Marcellus Shale – An Old 'New' Gas Reservoir," *Pennsylvania Geology* 38, no. 1 (2008), http://www.dcnr.state.pa.us/topogeo/pub/pageolmag/pdfs/v38n1.pdf, 12 (estimating that "[b]ased on information from the Barnett Shale play, a horizontal well completion might use more than 3 million gallons"); New York State Department of Environmental Conservation, "Revised Draft: Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program," September 7, 2011 ("It is estimated that 2.4 million to 7.8 million gallons of water may be used for a multi-stage hydraulic fracturing procedure in a typical 4,000-foot lateral wellbore"); Railroad Commission of Texas, *supra* note 5 ("Slick water fracking of a vertical well completion can use over 1.2 million gallons (28,000 barrels) of water, while the fracturing of a horizontal well completion can use over 3.5 million gallons (over 83,000 barrels) of water. In addition, the wells may be re-fractured multiple times after producing for several years.").
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13. See, e.g., Hannah Wiseman, "Risk and Response in Fracturing Policy," *University of Colorado Law Review* 84 (Summer 2013), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2017104; US Environmental Protection Agency, EPA 600/R-00/000, Draft, Investigation of Ground Water Contamination near Pavilion, Wyoming (2011), http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf. But see Susan Phillips, "Chesapeake Disputes EPA's Report on Pavilion, Wyo.," National Public Radio, Dec. 12, 2011, http://stateimpact.npr.org/pennsylvania/2011/12/12/chesapeake-official-disputes-epas-report-on-pavilion-wyo/.
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Chapter 4.
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Chapter 5.
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