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INTRODUCTION

In its annual World Energy Outlook,[1] released on November 12, 2012, the International Energy Agency (IEA)[2] issued projections that seemed unthinkable just a few short years ago: the United States is on the road to energy self-sufficiency. According to the IEA, the United States will become the world's largest oil producer within the next decade.[3] More remarkably, by 2035, North America will become a net exporter of oil, and the United States will increase its level of energy self-sufficiency from today's rate of approximately 80% to an astounding 97%.[4] By reducing

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1. INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2012 (2012).

2. The International Energy Agency (IEA) is an independent organization comprised of twenty-eight member nations: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. *Id.* at 2. Established in 1974, the goals of the IEA include the promotion of energy security within its membership and the provision of research and analysis promoting "reliable, affordable, and clean energy" for the world. *Id.*

3. The IEA projects that the United States will produce 11.1 million barrels of oil per day (mb/d) in 2020 while Saudi Arabia will produce 10.6 mb/d. The United States' dominance will be relatively short-lived as Saudi Arabia is projected to surpass the United States once again by 2030. United States oil production hit a modern low of 6.9 mb/d in 2008. By 2011, United States production had increased to 8.1 mb/d. Following the projected attainment of peak production in 2020, United States production will decline gradually to 10.9 mb/d in 2025, 10.2 mb/d in 2030, and 9.2 mb/d in 2035. Saudi Arabian oil production is projected to decline slightly until 2020 (11.1 mb/d in 2011, 10.9 mb/d in 2015, and 10.6 mb/d in 2020), at which point it will increase gradually through 2035 (10.8 mb/d in 2025, 11.4 mb/d in 2030, and 12.3 mb/d in 2035). Production from Russia, the world's third major oil nation, is projected to decline steadily from 10.6 mb/d in 2011 to 9.2 mb/d in 2035. *Id.* at 106–07, 115.

4. *Id.* at 75–76.

its dependence on foreign-sourced energy, the United States is moving in a different direction than much of the world as China, India, the European Union, and the Association of Southeast Asian Nations[5] all project to increase their relative energy imports.[6]

Due to the increasing connectedness of worldwide energy markets,[7] our nation's energy self-sufficiency does not necessarily equate to the long-sought promised land of "energy independence,"[8] but the impacts nonetheless will be profound. The reduced dependency on oil from the Middle East will change the United States' national security interests in this turbulent region.[9] Maintaining price stability in a worldwide market will remain important, but the United States will no longer be reliant on oil sourced from the Middle East. Conversely, exports of oil from the Middle East to China and India will increase dramatically to supply their growing energy demands.[10] These two diverging trend lines have the potential to fundamentally reshape the international geopolitical environment.[11]

The outlook for the United States' role in the global natural gas market is even brighter than that for oil. By 2015, the United States is projected to surpass Russia as the top global producer of natural gas.[12] As recently as 2006, the U.S. Energy Information

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5. The Association of Southeast Asian Nations is comprised of Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam. *Id.* at 649.

6. *Id.* at 75.

7. *See id.* at 24 (describing how price differences between regional markets will decline over time as well as how linkages between different energy commodities will increase).

8. *See* Daniel Yergin, *US Energy Is Changing the World Again*, FIN. TIMES, Nov. 16, 2012, http://www.ft.com/intl/cms/s/0/b2202a8a-2e57-11e2-8f7a-00144feabdc0.html (describing energy independence as having been a stated policy goal for the United States since the energy crisis of the early 1970s).

9. *See* Benoit Faucon & Sarah Kent, *IEA Pegs U.S. As Top Oil Producer by 2020*, WALL ST. J., Nov. 12, 2012, http://online.wsj.com/article/SB10001424127887323894704578114492856065064.html (quoting noted businessman T. Boone Pickens as questioning the rationale for a United States naval presence in the Middle East by stating, "[i]t's insane that we have the Fifth Fleet of the U.S. Navy tied up there to protect oil that ends up in China and Europe").

10. *Asia Could Account for 90% of Middle East Oil Exports in Future: IEA*, CHANNEL NEWS ASIA (Dec. 4, 2012, 10:05 PM), http://www.channelnewsasia.com/stories/marketnews/view/1241061/1/.html.

11. *See* Yergin, *supra* note 8 (discussing the implications of the changing energy marketplace upon the relationship between the United States and China).

12. The IEA projects that the United States will produce 679 billion cubic meters (bcm) of natural gas in 2015 while Russia will produce 675 bcm. According to IEA projections, both the United States and Russia will continue

Administration projected a future with the United States as a significant importer of liquid natural gas (LNG), reflecting the belief that there would be an insufficient supply of natural gas produced in North America to satisfy the national demand.[13] An infrastructure to accommodate projected LNG imports developed along the country's eastern seaboard, but the demand for imported LNG never fully materialized.[14] Today, as these facilities sit largely vacant, policymakers debate the ramifications of the United States exporting LNG and discuss the feasibility of converting an LNG import-based infrastructure to an export-based infrastructure.[15]

What will be responsible for this dramatic transformation in the United States' trade balance for energy commodities? The main protagonist is the so-called "Shale Revolution"[16] built on technology. While projected reductions in the domestic demand

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to gradually increase natural gas production through 2035. United States production will increase to 747 bcm in 2020, 765 bcm in 2025, 784 bcm in 2030, and 800 bcm in 2035. Russian production will increase to 704 bcm in 2020 and 737 bcm in 2025. By 2030, Russia will again surpass the United States as the world's leading natural gas producer with production of 808 bcm followed by 856 bcm in 2035. INT'L ENERGY AGENCY, *supra* note 1, at 138.

13. According to the 2006 projections, the United States would import 4.4 trillion cubic feet of liquid natural gas in 2030. U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2006 86 (2006).

14. Henry D. Jacoby et al., *The Influence of Shale Gas on U.S. Energy and Environmental Policy*, 1 ECON. ENERGY & ENVTL. POL'Y 37, 38 (2012); *see also Energy to Spare: America Is on Track to Produce All the Energy it Needs at Home*, ECONOMIST, Nov. 17, 2012, http://www.economist.com/news/business/21566694-america-track-produce-all-energy-it-needs-home-energy-spare (describing LNG import facilities as sitting "mainly idle").

15. *See generally* U.S. ENERGY INFO. ADMIN., EFFECT OF INCREASED NATURAL GAS EXPORTS ON DOMESTIC ENERGY MARKETS (2012) (comprising the first part of the LNG Export Study commissioned by the U.S. Department of Energy); NERA ECON. CONSULTING, MACROECONOMIC IMPACTS OF LNG EXPORTS FROM THE UNITED STATES (2012) (comprising the second part of the LNG Export Study commissioned by the U.S. Department of Energy). The Department of Energy invited public comment on these reports and indicated that it may use the reports as a basis for action in administrative proceedings. 2012 LNG Export Study, 77 Fed. Reg. 73,627 (Dec. 11, 2012).

16. *See* Robert Bryce, *America Needs the Shale Revolution*, WALL ST. J., June 13, 2011, http://online.wsj.com/article/SB10001424052702304432304576369140191493636.html# (arguing that the shale revolution has poised the United States for an industrial renaissance); *see also Fracking Here, Fracking There*, ECONOMIST, Nov. 26, 2011, http://www.economist.com/node/21540256 (opining that America's shale revolution is twenty years old even though its impact has been limited to the past five years).

for oil are important,[17] the use of technology to unlock energy resources contained within shale formations will be primarily responsible for reshaping the United States' energy economy.[18] From 2010 to 2035, the total volume of natural gas produced per year in the United States is projected to increase from 21.4 trillion to 31.4 trillion cubic feet per year, and by 2035, shale gas will comprise more than one half of all domestic production.[19] Without the development and adaptation of technologies in various natural gas and oil shale plays across the United States, the dramatic increase in domestic production of natural gas and oil would be impossible. The role of technology in the Shale Revolution, however, should not be limited to its past. The continued development of the technology that began the Shale Revolution is essential to fully realizing the benefits (and avoiding the adverse effects) of these resources.

I. The Role of Technology in the Rise of Shale Gas and Oil Development

The Shale Revolution has been unleashed not because of a geologic discovery, but rather because extraction technology finally has developed to the point where economical extraction of long-known resources has become possible.[20] For decades, scientists and drilling operators knew that hydrocarbons are present in shale formations.[21] In fact, natural gas has been produced from shale rock at some level since the earliest days of the natural gas industry. The nation's very first natural gas well, drilled in 1821, lit the streets of Fredonia, New York, using natural gas produced from the Devonian Shale formation.[22]

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17. *See* INT'L ENERGY AGENCY, *supra* note 1, at 24 (noting that increasing vehicle fuel-efficiency and increasing use of alternative fuels for transportation will reduce United States demand for oil after 2020).

18. According to the IEA, "[e]nergy developments in the United States are profound and their effect will be felt well beyond North America—and the energy sector. The recent rebound in US oil and gas production, driven by upstream technologies that are unlocking light tight oil and shale gas resources, is spurring economic activity . . . and steadily changing the role of North America in global energy trade." *Id.* at 23.

19. U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2013 EARLY RELEASE OVERVIEW 2, 15 (2012).

20. Susan L. Sakmar, *The Global Shale Gas Initiative: Will the United States Be the Role Model for the Development of Shale Gas Around the World?*, 33 HOUS. J. INT'L L. 369, 370–71 (2011).

21. *Id.* at 370.

22. ROBERT G. PIOTROWSKI & JOHN A. HARPER, PA. DEP'T OF ENVTL. RES., BLACK SHALE AND SANDSTONE FACIES OF THE DEVONIAN "CATSKILL" CLASTIC WEDGE IN THE SUBSURFACE OF WESTERN PENNSYLVANIA 2 (1979).

Until recently, however, the low permeability of shale made large-scale extraction of gas and oil trapped within it too difficult to be profitable. Permeability is a measurement of the ability of liquids or gasses to move within a geologic formation.[23] And given that shale rock has a very low permeability, hydrocarbons—oil and natural gas—cannot move freely within the pores of the rock.[24] They remain tightly held, virtually locked in place. Though conventional extraction technologies can be used to unlock these hydrocarbons to a small degree, this is usually too expensive to be worthwhile. The volume of hydrocarbons recovered using conventional techniques simply does not justify the development costs.[25] For example, in a 1980 report prepared by the U.S. General Accounting Office, one operator noted that it could recover its costs from the drilling of a conventional well in less than two years, while the pay-off period for a shale gas well—using then-available technology—was more than five years.[26] Thus, without cost-effective extraction technology, shale gas and oil would remain locked deep within the earth.

Through research funded by both the government and private entities, key technologies—including horizontal drilling and hydraulic fracturing (fracing or fracking)—have been developed or adapted to enable the commercial extraction of shale gas and oil. In the 1970s, the Department of Energy (DOE) began to support research investigating the viability of developing unconventional natural gas reservoirs, including those within shale formations.[27] One such project was the Eastern Gas Shales Project (EGSP), initiated by the DOE in 1976.[28] This project sought to determine the volume of natural gas contained in shale formations and to develop technology to increase production potential.[29] Projects like the EGSP laid the groundwork for technological breakthroughs including directional drilling, the use of multi-stage fracturing, and slick water hydraulic fractur-

23. HOWARD R. WILLIAMS & CHARLES J. MEYERS, MANUAL OF OIL AND GAS TERMS 700 (14th ed. 2009).

24. *See* U.S. GEN. ACCOUNTING OFFICE, HELP FOR DECLINING NATURAL GAS PRODUCTION SEEN IN THE UNCONVENTIONAL SOURCES OF NATURAL GAS 1, 5 (1980) (comparing the permeability of shale to that of formations containing conventional oil and gas reserves).

25. Sakmar, *supra* note 20, at 370–71.

26. U.S. GEN. ACCOUNTING OFFICE, *supra* note 24, at 6.

27. *See id.* at i–iv (describing federal government actions to increase development of natural gas from eastern shales, tight sands natural gas, coal bed methane, and the methane of geopressured zones).

28. *Id.* at 7–10.

29. PIOTROWSKI & HARPER, *supra* note 22, at 6–7.

ing—technologies that make modern shale gas and oil extraction possible.[30]

While this early research was a collaborative effort among state government agencies, universities, research laboratories, and private industry,[31] federal involvement was critical in focusing the collective research efforts. As noted by one industry official, "'[i]n the early 1980s, the industry as a whole did not have a clear vision for producing gas from shales and benefited from DOE involvement and funding . . . .'"[32] Another industry official echoed the vital role that the federal government played in advancing technology by stating, "'[t]he Department of Energy was there with research funding when no one else was interested and today we are all reaping the benefits.'"[33]

The foundation established by this federal investment in research was essential, but large-scale development of shale oil and gas resources also would not have occurred without private pioneers who applied and continued to develop necessary technologies. The most influential of these was George P. Mitchell.[34] In 1981, through his company, Mitchell Energy and Development Corporation, Mitchell began drilling numerous test wells in the Barnett Shale formation near Fort Worth, Texas.[35] Over time and with continued technological adaptation, Mitchell proved that shale gas could be extracted profitably.[36] By 1998, the volume of shale gas produced from the Barnett Shale play—from wells drilled by Mitchell and other operators—had reached ninety-four million cubic feet per day.[37] While this level of early production was noteworthy, it represented merely the tip of the

30. *See* NAT'L ENERGY TECH. LAB., U.S. DEP'T OF ENERGY, SHALE GAS: APPLYING TECHNOLOGY TO SOLVE AMERICA'S ENERGY CHALLENGES 1, 6 (2011) (quoting George E. King, Global Technology Consultant for Apache Corporation).

31. U.S. GEN. ACCOUNTING OFFICE, *supra* note 24, at 8.

32. *See* NAT'L ENERGY TECH. LAB., *supra* note 30, at 6 (quoting Dan Gleitman, Senior Director of Intellectual Asset Management with Halliburton).

33. *See id.* (quoting Fred Julander of Julander Energy).

34. *See* David Brooks, *Shale Gas Revolution*, N.Y. TIMES, Nov. 4, 2011, at A31 (describing George P. Mitchell as a "business genius" who provided the nation with a "wondrous" gift).

35. Terry W. Roberson, *Environmental Concerns of Hydraulically Fracturing a Natural Gas Well*, 32 UTAH ENVTL. L. REV. 67, 72 (2012).

36. *See id; see also* BREAKTHROUGH INST. ENERGY & CLIMATE PROGRAM, WHERE THE SHALE GAS REVOLUTION CAME FROM: GOVERNMENT'S ROLE IN THE DEVELOPMENT OF HYDRAULIC FRACTURING IN SHALE 8–9 (2012) (describing Mitchell's collaboration with the federal government in the ongoing technological adaptation).

37. ANTHONY ANDREWS ET AL., CONG. RESEARCH SERV., UNCONVENTIONAL GAS SHALES: DEVELOPMENT, TECHNOLOGY, AND POLICY ISSUES 5 (2009).

iceberg as production in the play continued to expand, reaching a level of three billion cubic feet per day within a decade.[38]

Other companies took note of the results in the Barnett Shale play and began drilling wells within other shale formations.[39] In 2002, Southwestern Energy Company began exploration of the Fayetteville Shale formation in Arkansas through the reworking of a well that had been drilled previously into a different formation.[40] The production from this, and other wells in the Fayetteville Shale play, confirmed that the technologies used in the Barnett Shale play could be applied successfully to other shale formations, and the industry as a whole continued to expand the scope of shale gas operations.[41] By 2003, development had begun in Oklahoma's Woodford Shale formation,[42] and by 2008, drilling booms were underway within Louisiana's Haynesville Shale formation and Pennsylvania's Marcellus Shale formation.[43]

This burgeoning Shale Revolution was not limited to natural gas production. The basic technologies that had been developed to extract natural gas from shale rock also worked to extract oil from shale rock. With rising oil prices in 2010 and 2011, some operators shifted their focus from shale gas to shale oil by undertaking extensive efforts to extract oil from the Bakken Shale formation in North Dakota and Montana.[44]

II. Debating the Benefits and Costs of Shale Development

The Shale Revolution began in the south-central United States in areas that, for the most part, already had active drilling

38. Production from the Barnett Shale play was three bcf/d by 1997. *Id.* By 2010, gas production in the Barnett Shale play had continued to increase, reaching a level of five bcf/d. Nat'l Energy Tech. Lab., *supra* note 30, at 3.

39. U.S. Energy Info. Admin., Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays 4 (2011).

40. Larry Taylor, *Fayetteville Shale*, Encyc. of Ark. History & Culture (last updated June 5, 2012), http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=6011.

41. U.S. Energy Info. Admin., *supra* note 39, at 4.

42. Thomas E. Kurth et al., American Law and Jurisprudence on Fracing 15 (2011), *available at* http://www.energyfromshale.org/sites/default/files/Fracking-Study-2011-Updated-Version-08-22-2011.pdf.

43. *See* Mark Schleifstein, *Haynesville Natural Gas Field Is the Most Productive in the U.S.*, Times Picayune, March 27, 2011, http://www.nola.com/politics/index.ssf/2011/03/haynesville_natural_gas_field.html (describing developmental activities within the Haynesville Shale play). *See generally* Ross H. Pifer, *What a Short, Strange Trip It's Been: Moving Forward After Five Years of Marcellus Shale Development*, 72 U. Pitt. L. Rev. 615 (2011) (describing developmental activities within the Marcellus Shale play).

44. Kurth et al., *supra* note 42, at 18.

industries.[45] Because of the extensive preexisting oil and gas development, the populations of these states presumably had a comfort level with, or perhaps simply an acceptance of, oil and gas operations. Although the manner and scope of drilling operations for shale gas and oil differ substantially in some respects from conventional operations, there was little public dialogue about shale extraction in these states. But as the Shale Revolution expanded into the northeastern United States, a geographic area whose populace had comparatively little experience with the contemporary oil and gas industry, a new debate ensued about the impact of the modern technologies involved with shale development.

The modern shale gas era commenced in the Appalachian Basin in 2005 when Range Resources began to extract natural gas from the Marcellus Shale formation through a well in Washington County, Pennsylvania.[46] The movement of the shale gas industry to the northeastern United States would have a major impact on the future development of the resource for two major reasons. First, it quickly became clear that the geographic footprint for the United States oil and gas industry was forever altered. Second, with an expanded geographic area of operation, the oil and gas industry would face heightened scrutiny about the impacts of drilling and other developments.

The Marcellus Shale formation is vast. One commentator described it as "truly enormous, a national wonder extending from New York to Tennessee along a swath of territory larger than Greece."[47] In addition to its huge size, the formation also contains an immense amount of natural gas. According to a 2010 report commissioned by the United States Energy Information Administration, the Marcellus Shale formation holds approximately 55% of the total undeveloped technically recoverable shale gas reserves in the United States.[48] The proximity of the Marcellus Shale formation to the cold-weather population centers in the Northeastern and Mid-Atlantic regions of the United States provides operators in the play with transportation-based cost advantages over operators in other United States shale

45. Using data from 2005, Texas led the nation with 5.255 trillion cubic feet (tcf), of natural gas production. Oklahoma was the nation's second leading natural gas producer with 1.670 tcf of production, and Louisiana ranked fifth nationally with 1.296 tcf of production. U.S. ENERGY INFO. ADMIN., NATURAL GAS ANNUAL 2005 3 (2005).

46. Pifer, *supra* note 43, at 620.

47. KURTH ET AL., *supra* note 42, at 10.

48. U.S. ENERGY INFO. ADMIN., *supra* note 39, at 4–5.

plays.[49] The large volume of available natural gas resources, when combined with the economic advantages of extracting in the Northeast, ensures that shale development, in the long run, will not be limited to the parts of the United States with traditional oil and gas operations. For the foreseeable future, shale resources will be developed in the northeastern United States.

While Pennsylvania and New York are the birthplaces of the oil and natural gas industries, respectively, the general public in these states was largely unfamiliar with modern oil and gas operations at the dawn of the twenty-first century. Upon becoming aware that shale development was taking place or was about to take place, many individuals and organizations began to raise questions about the potential adverse impacts to public health and the environment from this development.[50] The debate that ensued as Marcellus Shale drilling commenced was very impassioned and pitted those advocating the economic benefits of extensive shale gas development against those questioning the safety of the technologies that were being used in the resource extraction process.[51] Amongst the loud voices on both sides of the debate, everyone was considered to be either for resource development or for the environment, but not both. Of course, as with many issues that generate a polarizing debate, the best course for public policy lies somewhere in the middle ground. There are merits to the arguments of both sides of the shale development debate, and we should strive as a society to reach an appropriate balance so that we can realize the economic benefits of shale resources while also minimizing adverse impacts to public health and the environment.

Where shale gas activities have taken place in Pennsylvania, there undeniably have been positive economic impacts.[52] Landowners, local business owners, workers, and communities

49. Pifer, *supra* note 43, at 623.

50. *See generally* U.S. GOV'T ACCOUNTABILITY OFFICE, REPORT NO. GAO-12-732, OIL AND GAS: INFORMATION ON SHALE RESOURCES, DEVELOPMENT, AND ENVIRONMENTAL AND PUBLIC HEALTH RISKS (2012) (discussing environmental and public health risks arising from shale gas and oil development).

51. *See* TIMOTHY W. KELSEY ET AL., MARCELLUS SHALE EDUC. & TRAINING CTR., ECONOMIC IMPACTS OF MARCELLUS SHALE IN PENNSYLVANIA: EMPLOYMENT AND INCOME IN 2009 10 (2011) (noting the polarizing debate "between those who believe it is good for Pennsylvania and others who believe that it is not"); *see also* INT'L ENERGY AGENCY, *supra* note 1, at 141 (noting "vocal public concerns" expressed about shale development).

52. A study conducted by the Marcellus Shale Education & Training Center "suggest[ed] that the economic impact of Marcellus Shale in Pennsylvania during 2009 ranged between . . . $3.1 and $3.2 billion in that year." KELSEY ET AL., *supra* note 51, at 5.

throughout Pennsylvania have received financial benefits, directly or indirectly, from shale gas operations. Many landowners have benefited financially through the receipt of lease bonuses and gas royalties.[53] Depending upon when the oil and gas leases were signed, some Pennsylvania landowners reportedly received bonuses of more than six thousand dollars per acre.[54] As revealed by a reported rise in sales tax revenue, a variety of local businesses also have realized gains as a result of the influx of new customers and new business opportunities.[55] Additionally, the Marcellus industry has served as a large employment opportunity for workers in many fields.[56] Finally, the recently established Impact Fee is funding a variety of recreational, transportation, and conservation-related initiatives throughout Pennsylvania, to include those areas that do not overlay the Marcellus Shale formation.[57]

Increased natural gas production resulting from extensive shale development has also substantially lowered the price of natural gas.[58] This reduction has benefited homeowners who rely

53. *See id.* at 12 (describing the leasing environment and the payment of royalties in Pennsylvania).

54. Stephen W. Saunders, *Weighing the Risks and Rewards*, PA. LAWYER, Apr. 2012, at 18.

55. *See* CHARLES COSTANZO & TIMOTHY W. KELSEY, PENN STATE CTR. FOR ECON. & CMTY. DEV., MARCELLUS SHALE AND LOCAL COLLECTION OF STATE TAXES: WHAT THE 2011 PENNSYLVANIA TAX DATA SAY 2–3 (2012) (finding that "[t]he data indicate that sales tax collections in counties with much Marcellus activity continued to outperform collections in counties with less or no Marcellus activity").

56. While there are differing opinions regarding the number of jobs created by Marcellus Shale development, there is agreement that there has been some increase. *See* TIMOTHY J. CONSIDINE ET AL., THE ECONOMIC IMPACTS OF THE PENNSYLVANIA MARCELLUS SHALE NATURAL GAS PLAY: AN UPDATE iv (2010) (estimating that Marcellus Shale development generated 44,098 jobs in 2009 and that it would generate 211,909 jobs by 2020); STEPHEN HERZENBERG, KEYSTONE RESEARCH CTR., DRILLING DEEPER INTO JOB CLAIMS 1 (2011) (estimating the number of jobs created by Marcellus Shale development in 2009 as "no more than 10,000"); KELSEY ET AL., *supra* note 51, at 5 (estimating the number of jobs created by Marcellus Shale development in 2009 to be between 23,385 and 23,884).

57. *See* Mary Young, *County Basking in Money from Drilling Impact Fees,* READING EAGLE, Dec. 3, 2012 (noting that the county will soon receive $500,000 to fund bridge repairs and quoting the Berks County Parks Director as stating, "'[w]e got an early $349,067.68 Christmas present'" to upgrade parks in a county that does not contain any Marcellus Shale gas deposits).

58. In June 2008, the market price for natural gas was $12.70 per MMBtu. By September 2009, the market price had declined to $3.00 per MMBtu. After a brief increase, prices declined to approximately $2.00 by June 2012. TIMOTHY J. SKONE, NAT'L ENERGY TECH. LAB., ROLE OF ALTERNATIVE ENERGY SOURCES: NATURAL GAS TECHNOLOGY ASSESSMENT 5 (2012).

on natural gas to heat their homes, and it also has stimulated growth in those industries, such as the petrochemical industry, that rely on natural gas as a feedstock.[59] These economic benefits together with those that have accrued to those individuals and businesses more closely connected with drilling operations are certainly important, particularly in light of the grim economic climate experienced by the entire nation during the Great Recession.

But while many individuals and businesses have realized economic benefits, legitimate environmental concerns about shale gas development have been raised within Pennsylvania and elsewhere.[60] These concerns range from water quality, water quantity, and air quality, to habitat fragmentation.[61] In determining the manner in which future shale gas or oil development should occur, if at all, certainly policy makers must consider all of the purported benefits and alleged costs of development. Any potential negative impacts to public health or to the environment from shale development must be investigated. We cannot allow resource extraction that imperils our future, but we must nevertheless recognize that *all* activities carry some level of risk. In the establishment of sound public policy regarding shale development, we must consider the level of risk posed and the extent to which this risk can be minimized or managed.

As in other industrial operations, incidences of environmental harm have occurred during shale development. In the most widely reported incident of alleged water contamination in Pennsylvania, several landowners in Dimock Township, Susquehanna County, claimed that their water wells had been polluted by methane migration as a result of nearby drilling operations.[62] Other reported environmental harms in the Marcellus region have included the blowout of a well,[63] the quarantine of cattle

59. *See generally* Lindsey Bewley, *Petrochemicals: Shale Gas Restores U.S. Competitiveness,* CHEMICAL WEEK, Mar. 26, 2012, at 19 (discussing the role of shale gas in "rapidly transforming the North American petrochemical industry"); PRICEWATERHOUSECOOPERS LLP, SHALE GAS: RESHAPING THE US CHEMICALS INDUSTRY (2012) (discussing the role of shale gas in revitalizing American manufacturing).

60. *See generally* U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 50 (discussing environmental concerns arising from shale gas and oil development).

61. *Id.*

62. Pifer, *supra* note 43, at 639.

63. *See* Roberson, *supra* note 35, at 120 (describing an incident at an EOG Resources well site in Clearfield County, Pennsylvania where natural gas and wastewater were released into the air for sixteen hours).

that were exposed to spilled wastewater,[64] and minor earthquakes allegedly caused by the injection of frac wastewater into underground storage reservoirs.[65] Even though these and other instances of environmental harm have occurred, there has been no demonstration to date that the technological processes utilized in shale development are inherently dangerous. On the contrary, the available evidence suggests that any environmental concerns or impacts are manageable using existing regulatory authority.[66] This does not mean that we should not strive to improve the process, or that we should not seek to realize further benefits with fewer costs. We indeed should work to minimize any adverse impact from shale development. To do so, technology, again, must play a key role.

III. Moving Toward a Greener Shale Revolution

Prior to the shale revolution, natural gas enjoyed a wide reputation as an environmentally friendly energy source.[67] The phrase "clean-burning natural gas" has been used as a marketing slogan to tout the advantages that natural gas held over other competing fossil fuel energy sources.[68] There is no debate that

64. Press Release, Pa. Dep't Envtl. Prot., Cattle from Tioga County Farm Quarantined After Coming in Contact with Natural Gas Drilling Wastewater (July 1, 2010), *available at* http://www.prnewswire.com/news-releases/cattle-from-tioga-county-farm-quarantined-after-coming-in-contact-with-natural-gas-drilling-wastewater-97603614.html.

65. Henry Fountain, *Disposal Halted at Well After New Quake in Ohio,* N.Y. Times, Jan. 2, 2012, at A11.

66. *See* MIT Energy Initiative, The Future of Natural Gas: An Interdisciplinary MIT Study xiii, 15 (2011) (finding that "[t]he environmental impacts of shale development are manageable but challenging" and recommending coordination between research and regulation to minimize the environmental impacts of shale development). The U.S. Environmental Protection Agency is engaged in a multi-year study to evaluate the process of hydraulic fracturing including water usage, chemical usage, and the treatment of wastewater. Office of Research and Dev., U.S. Envtl. Prot. Agency, Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources (2011). An initial progress report was scheduled to be released in late 2012 with the final report to follow in 2014. *Id.* The results of this study likely will guide policymakers in addressing any risks posed to public health or the environment by shale development.

67. *See* MIT Energy Initiative, *supra* note 66, at 1 (noting that natural gas "has the lowest carbon intensity, emitting less carbon dioxide per unit of energy created than other fossil fuels" and that "[i]t burns cleanly and efficiently, with very few non-carbon emissions").

68. *See* Bill Siuru, *Clean Burning Natural Gas Vehicles,* Green Car (Oct. 1, 2007), http://www.greencar.com/articles/clean-burning-natural-gas-vehicles.php (describing "clean burning" natural gas as "one of the most promising alternative fuels"); *see also* Steven D, *Why Exxon Is Running Ads Saying Natural Gas*

natural gas burns more cleanly than other fossil fuels and is thus more environmentally friendly from a purely consumptive standpoint.[69] The recent focus on hydraulic fracturing, however, has raised questions about whether the extraction process for shale gas is more environmentally harmful than that used for other fossil fuels.[70] Most scientific studies that have analyzed the carbon footprint of shale development using a lifecycle approach—from production to consumption—agree that the overall carbon footprint of shale gas compares favorably to that of other fossil fuels.[71] Nonetheless, many environmental questions persist. Regardless of how one views shale resource extraction, technologies have been developed, and continue to be developed, that improve the environmental standing of the shale oil and gas extraction processes.

The Shale Revolution is still in its infancy. With the exception of the Barnett Shale play, all of the other shale plays are in their first decade of development. Despite its relative youth, shale development already has become a greener process through technological innovation. One component of the shale development process that has seen considerable advancement is the management of wastewater.[72] The hydraulic fracturing process that is necessary to economically extract shale gas or oil requires an extensive amount of water. On average, one- to five-million gallons of water are used to hydraulically fracture each

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Is Safe, DAILY KOS (May 14, 2011, 11:05 AM), http://www.dailykos.com/story/2011/05/14/976019/-Why-Exxon-is-Running-Ads-Saying-Natural-Gas-is-Safe (describing Exxon advertisements touting natural gas as "clean burning").

69. *See* Supporting Safe and Responsible Development of Unconventional Domestic Natural Gas Resources, Exec. Order No. 13,605, 77 Fed. Reg. 23,107 (Apr. 13, 2012) (describing natural gas as "a cleaner source of energy than other fossil fuels" provided "appropriate safeguards" are in place).

70. *See* Roberson, *supra* note 35, at 108–15 (reviewing six studies that have analyzed hydraulic fracturing).

71. *See* Michael Goldman, *Drilling into Hydraulic Fracturing and Shale Gas Development: A Texas and Federal Environmental Perspective,* 19 TEX. WESLEYAN L. REV. 185, 239 (describing various studies that have been completed comparing the greenhouse gas impact of shale gas compared to other fossil fuels); *see also* L.M. Cathles, *Assessing the Greenhouse Impact of Natural Gas,* GEOCHEMISTRY, GEOPHYSICS, GEOSYSTEMS, June 6, 2012 (concluding that substituting natural gas for coal reduces the impact on global warming by 40%). *But see* Robert W. Howarth et al., *Venting and Leaking of Methane from Shale Gas Development: Response to Cathles et al.*, SPRINGERLINK.COM (Feb. 1, 2012), http://www.eeb.cornell.edu/howarth/Howarthetal2012_Final.pdf (defending an earlier conclusion that "the GHG footprint of shale gas is greater than that of other fossil fuels").

72. The possible methods for dealing with frac wastewater include underground injection wells, treatment and discharge into surface waters, and reuse. *See* KURTH ET AL., *supra* note 42, at 11.

well.[73] For the fracking process, this water is combined with sand and a proprietary chemical mixture designed to maximize the production of hydrocarbons.[74] Depending on the geology of a particular area, 20% to 40% of the fluid will return to the well-head.[75] This flow-back fluid or produced water is a brackish mixture comprised of the fluid that was used for fracking as well as substances that were previously located within the geological formation, including naturally occurring radioactive materials.[76] Within the Barnett Shale and other early shale plays, most operators disposed of this flow-back fluid by injecting it into underground injection control (UIC) wells for permanent storage.[77]

As development began in the Marcellus Shale play, operators were faced with a potential problem as Pennsylvania's geology differed from that in Texas and was not suitable for widespread use of UIC wells.[78] Operators began to transport the flow-back fluid to municipal wastewater treatment facilities where the fluid was processed and ultimately released into the waters of the Commonwealth.[79] Questions were raised about the quality of the water that was being released by these municipal facilities, and the Pennsylvania Department of Environmental Protection acted to increase the standards for Total Dissolved Solids in released water.[80] During this time, many treatment facilities voluntarily agreed to refrain from accepting flow-back fluid for treatment.[81] In the search for disposal alternatives, many operators began reusing this flow-back fluid for future hydraulic fracturing operations.[82] While the reuse of flow-back fluid is more of a practical, rather than technological, solution to the problem, it

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73. *Id.*

74. *Id.*

75. *Id.*

76. U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 50, at 41–42.

77. *See* Roberson, *supra* note 35, at 125 (describing the geologic properties within Texas that allow for disposal of wastewater in underground injection wells); *see also* Sorell E. Negro, *Fracking Wars: Federal, State and Local Conflicts over the Regulation of Natural Gas Activities,* ZONING & PLANNING L. REP., Feb. 2012, at 1, 6 (characterizing underground injection as the "industry's preferred disposal method" in Western states).

78. Laura C. Reeder, Note, *Creating a Legal Framework for Regulation of Natural Gas Extraction from the Marcellus Shale Formation,* 34 WM. & MARY ENVTL. L. & POL'Y REV. 999, 1001 (2010).

79. *See* Press Release, Pa. Dep't Envtl. Prot., DEP Calls on Natural Gas Drillers to Stop Giving Treatment Facilities Wastewater (Apr. 19, 2011) (indicating that at least twenty-seven facilities treated frac wastewater).

80. 25 PA. CODE § 95.10 (2010).

81. Press Release, Pa. Dep't Envtl. Prot., *supra* note 79.

82. *See* Matt Blauch et al., *Technique Reuses Frac Water in Shale,* AM. OIL & GAS REP. (Sept. 2009) (discussing the reuse of wastewater).

resulted in the dual environmental benefits of eliminating permanent disposal as well as reducing the volume of freshwater that was needed in operations. Nationally, the search for an effective treatment of flow-back fluids has led to the development or adaptation of dozens of technological processes.[83] One such innovation is a thermal distillation process that allows for on-site treatment of flow-back fluid.[84] This AltelaRain® System was developed by Altela, Inc., as part of a demonstration project funded by the National Energy Technology Laboratory with the United States Department of Energy.[85]

In an effort to eliminate completely the issue of flow-back fluid treatment, significant research has been conducted to find an alternative to hydraulic fracturing.[86] Experimentation has been conducted using various methods of well stimulation involving foam fracturing, VES gel systems, carbon dioxide-based foams and fluids, methanol-based fluids, and nitrogen.[87] To date, none of these methods has been developed to the point of being used commercially, but efforts continue to develop a technological alternative that would have environmental advantages.

The specific contents of the hydraulic fracturing fluid also have been the subject of green innovation. Chesapeake Energy Corporation recently announced that it was developing a fracturing fluid that would be comprised entirely of green—environmentally harmless—substances.[88] In addition to the areas already discussed, environmentally beneficial technology also has

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83. *See* Colorado School of Mines, RPSEA Project 07122-12, An Integrated Framework for Treatment and Management of Produced Water (Apr. 14, 2009) (slide presentation), *available at* http://www.rpsea.org/attachments/contentmanagers/3447/07122-12_2009_Unconventional_Gas%20_Project_Review_Drewes.pdf (describing fifty-four technologies used for the treatment of flowback fluids).

84. Press Release, Nat'l Energy Tech. Lab., U.S. Dep't of Energy, New Wastewater Treatment Facilities to Open with DOE-Tested Technology: Marcellus Plants Employ Cost Effective, Energy Efficient AltelaRain® Technology (Oct. 3, 2012).

85. Press Release, Nat'l Energy Tech. Lab., U.S. Dep't of Energy, Water Treatment System Cleans Marcellus Shale Wastewater: DOE-Funded Field Demonstration Speeds Commercialization of Mobile Desalination System (Apr. 13, 2011).

86. D.V. Satya Gupta, Tomball Technology Center, Unconventional Fracturing Fluids: What, Where and Why, Presented at US EPA Technical Workshop for the Hydraulic Fracturing Study: Chemical & Analytical Methods, Arlington, Virginia (2010).

87. *Id.*

88. Joe Carroll, *Chesapeake Testing 'Green' Fracking Fluids in Shale Wells*, BLOOMBERG (Oct. 2, 2012, 4:23 PM), http://www.bloomberg.com/news/2012-10-02/chesapeake-testing-green-fracking-fluids-in-u-s-shale-wells.html.

developed or is developing with regard to well construction and maintenance,[89] microseismic monitoring,[90] the reduction of surface impacts from development,[91] and the reduction of air emissions.[92]

When green technology is available, it is likely that shale gas and oil operators will be receptive to incorporating it into their operations. They have a number of reasons to welcome new innovation, including regulatory compliance, public relations, and economics. The scope of oil and gas activity has evolved rapidly during the time of the Shale Revolution, and the regulatory agencies often have lagged behind. In many instances, the applicable statutory and regulatory frameworks were not developed with shale development in mind, and often they do not address all issues involved with these new developments. As new statutes or regulations that would impose heightened standards are under consideration, companies have an incentive to ensure that they will be able to continue to conduct operations in a seamless manner after the implementation of any new statutes or regulations. Early adoption of new technology ensures that operators will be able to act with this continuity.

Companies also may consider adopting new green technologies for public relations purposes. A shale development company that is viewed as environmentally responsible may acquire leases from wary landowners more easily, and also may be able to raise capital more easily from personal or institutional investors. Additionally, shale development companies, and the industry as a whole, have an incentive to demonstrate that they will be proactive in working to improve the extraction process, both to improve public relations and to demonstrate to policy makers that there is no need to heighten regulatory or statutory standards.

Some new technologies can provide economic benefits in addition to environmental benefits. The cost savings associated with adopting new technology may not be realized initially, but a company with a long view will recognize that an eventual economic return helps to justify the implementation of a new technology.

89. Andrew Jennings, *Shale Gas Development: Enabled by Technology,* 29 FIRST BREAK 127, 128 (2011).

90. NAT'L ENERGY TECH. LAB., U.S. DEP'T OF ENERGY, COMMERCIALIZED TECHNOLOGIES AND SIGNIFICANT RESEARCH ACCOMPLISHMENTS 2 (2012).

91. NAT'L ENERGY TECH. LAB., *supra* note 30, at 7 (2011).

92. Andrew Maykuth, *Natural Gas Producers Turn to 'Green Completion'*, PHILA. INQUIRER, Nov. 25, 2012, at D01.

IV. A Continuing Government Role in a Greener Shale Revolution

The federal government should play an important role in the advancement and implementation of green technology in the shale development industry. The brief history of development demonstrates the huge potential that is offered by shale development. Shale gas and oil have been proven to be a "game changer"[93] in moving the United States toward energy self-sufficiency. The economic benefits from development, both direct and indirect, are undeniable. Shale gas and oil are more environmentally friendly than competing fossil fuels, and renewable energy sources are not likely to be produced in a reliable and economical manner so as to reduce our reliance on fossil fuels for many years.[94] Because of these benefits, both in the advancement of economic interests and in the protection of environmental and national security interests, the federal government should be actively involved in the promotion of shale gas and oil as an important component of our movement toward energy self-sufficiency.[95]

The federal government, through the Department of Energy, has a history of supporting shale gas and oil research.[96] The Shale Revolution would not have occurred without this support. This historic support has continued to the present day and it must continue into the future for the benefits of shale development to be maximized.[97] While private industry certainly has played an important role in the development of technology for

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93. *See* Sakmar, *supra* note 20, at 370 (referring to shale gas as a "'game changer' that will 'revolutionize' global gas markets").

94. *See* U.S. Energy Info. Admin., *supra* note 13, at 3 (2012) (projecting the market share of renewable energy in the nation to grow from 10% to 15% by 2035).

95. During the 2012 Presidential election, both major political parties indicated that energy self-sufficiency should be a national priority. *See* Moving America Forward: 2012 Democratic National Platform 39, *available at* http://criticalmassprogress.com/wp-content/uploads/2012/09/2012-democratic-national-platform.pdf (advocating "an all-of-the-above approach to developing America's many energy resources, including wind, solar, biofuels, geothermal, hydropower, nuclear, oil, clean coal, and natural gas"); *see also* We Believe in America: 2012 Republican Platform 15–17, *available at* http://www.gop.com/wp-content/uploads/2012/08/2012GOPPlatform.pdf (advocating the promotion of "all forms of energy" to keep energy costs low and to ensure American competitiveness abroad).

96. *See* U.S. Gen. Accounting Office, *supra* note 24.

97. *See* U.S. Gov't Accountability Office, DOE Could Enhance the Project Selection Process for Government Oil and National Gas Research 1 (2008) (noting that industry may underinvest in research and development in all areas because the benefits do not all accrue to the one who bears the cost).

shale development as well as in the greening of this technology, the necessary investment for continued technology will not come from industry alone. The federal government must act to spur innovation and engage in partnerships with industry actors, universities, and state government agencies to leverage the federal research investment for the maximum benefit of the nation.