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# Four Questions About Fracking

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## Introduction

It is difficult to think of a more timely or important topic than horizontal hydraulic fracturing and its impact on the environment. It is especially useful to have an exchange of views on this subject now, before the statutes, regulations, and court decisions start to roll in. Law professors—I cannot speak for anyone else—have a strong proclivity for backward-looking analysis, dissecting what should have been done after the basic direction of the law is set and the courts have spoken. It is much more useful to weigh the pros and cons of different approaches at an early stage in the evolution of an issue, although admittedly, it is also more risky. So I congratulate the *Law Review* on organizing today's conference.

Before I begin, it is appropriate to say a few words by way of background about horizontal hyrdrofracturing, or "fracking" for short. This will be familiar to many of you, but there may be others in the audience who are relatively unversed in the subject, and some context may help in following the debates on the various panels to come.

What exactly is fracking and why is it different from ordinary oil and gas field production? I am not a petroleum engineer. But let me offer my understanding, expressed in lay terms, for what it is worth.

Traditional production of oil and gas involves drilling a vertical pipe from the surface to an oil or gas reservoir in the ground.[1] Because of the weight of the rock and soil above it, the oil or gas is under great pressure. Once the pipe penetrates the reservoir, that pressure causes the oil and gas to rise through the pipe to the surface, where it can be gathered for commercial use. Reservoir is a bit of a misnomer here.

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1. *See Energy in Brief: What Is Shale Gas and Why Is It Important?*, U.S. Energy Info. Admin., http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm (last updated Dec. 5, 2012).

Sometimes there is literally a pool of oil or gas trapped in a hollow space between sedimentary layers of rock in the ground. But often conventional oil and gas deposits are embedded in permeable rock. In order to extract it, however, the rock must be sufficiently permeable that oil and gas will flow through it, into the pipe and up to the surface, once the deposit is penetrated by the pipe.

Petroleum engineers have long known that there is a great deal of oil and gas in the ground that is trapped in rock that is not permeable, and hence cannot be extracted by simple drilling of a vertical pipe.[2] In the parlance of the industry, the fissures that contain the valuable material are too "tight" to flow. These engineers have long sought a way to open up these fissures to let the trapped oil and gas flow out.

One technology for doing this, known as hydraulic fracturing, has been around for about sixty years and is now routinely used to enhance the production from conventional oil and gas wells.[3] Hydraulic fracturing involves pumping a fluid, sometimes called "slick water," down into the well under great pressure. The fluid is mostly water mixed with some proppant like sand or small ceramic balls plus a small amount of lubricating chemicals.[4] The pressure from the water fractures the rock, and the sand props the fractures open. The fracturing fluid, or most of it at any rate, is then pumped out, and if all goes well the oil or gas flows out behind it.

The recent innovation, which is responsible for all the stir, consists of combining hydraulic fracturing with a relatively new technology, horizontal drilling. This consists, as the name suggests, of drilling down vertically and then, at some point, turning the drill bit and moving horizontally through a seam of rock.[5] Much of the oil and gas in the ground that is trapped in nonpermeable rock is found in relatively thin seams of coal or shale. A couple dozen years ago, a number of independent gas producers started fiddling around with the idea that you could combine horizontal drilling with hydraulic fracturing, and this might be a way to extract gas from these thin seams of coal or shale. They would drill down to the seam, turn the pipe horizontally and thread it through the seam, and then inject the

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2. *See* VIKRAM RAO, SHALE GAS: THE PROMISE AND THE PERIL 7 (2012).

3. Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115, 122–23 (2009).

4. HEATHER COOLEY & CHRISTINA DONNELLY, PAC. INST., HYDRAULIC FRACTURING AND WATER RESOURCES: SEPARATING THE FRACK FROM THE FICTION 21 (2012) (detailing the variations in the composition of fracking fluids to compensate for the specifics of local geology and individual wells).

5. *See* LEONARDO MAUGERI, OIL: THE NEXT REVOLUTION 42–44 (2012).

seam with fracturing fluid. After a long period of trial and error, an independent gas producer named George Mitchell, working in the Barnett Shale field near Fort Worth, Texas, figured out the right combination of horizontal drilling, pressure, and proppants to get the gas flowing out of shale.[6] Mitchell's breakthrough came in 1998. His success was observed by other producers, and they quickly emulated his methods.

What was the impact of Mr. Mitchell's successful innovation? It now appears that it means nothing less than an enormous expansion of the reserves of oil and gas in the United States. No one knows for sure by how much.[7] To some extent it depends on prices going forward. It could mean a doubling of reserves; it could mean more.

The impact of this sudden surge in reserves is somewhat different for gas and oil.[8] Gas is transported primarily by pipeline, which means the relevant market is regional or national. Gas, if you will, is a closed market. An expansion of U.S. reserves of gas means a reduction in the price of gas nationally.

Oil is bought and sold on a world market, so the impact is different. A surge in oil reserves in the United States will yield some stabilization of the price of oil in the United States, but not very much. An expansion of reserves basically means more wealth for the United States and less for the countries from which we currently import oil.

For both commodities, the sudden expansion of reserves means more jobs in the oil and gas extraction industries. Exactly how many more jobs is guesswork. President Obama, in his 2012 State of the Union address, said 600,000 additional jobs.[9] That is a big deal in a soft employment economy. The unemployment rate in North Dakota, where oil production using fracking technology is booming, is 3.7 percent, less than half the national average.[10] Workers on oil rigs in North Dakota can make $70,000 in five months.[11] Supervisors earn

6. Daniel Yergin, The Quest 325–32 (2011).

7. The exact amount of unconventional oil reserves remain uncertain, but recent estimates suggest the United States and Canada have a combined 1,301.7 billion barrels in total technically recoverable unconventional oil, that is, oil that may or may not be economically recoverable at present. In comparison, the proved reserves (oil that can be economically recovered at current prices) for the entire world is assessed at 1,354.2 billion barrels. Amy Meyers Jaffe et al., The Status of World Oil Reserves: Conventional and Unconventional Resources in the Future Supply Mix 17–19 (Oct. 2011).

8. Ernest J. Moniz, Henry J. Jacoby & Anthony J.M. Megs, MIT Study on the Future of Natural Gas 7 (2011).

9. President Barack H. Obama, State of the Union Address (Jan. 25, 2012).

10. Eric Konigsberg, *Kuwait on the Prairie,* New Yorker, Apr. 25, 2011, at 43.

11. *Id.* at 50.

$320,000 a year. Landowners in North Dakota who are lucky enough to own two square miles of land in the Bakken shale area get $1 million up front and $500,000 a year in royalties, estimated to last two decades.[12]

For gas there are other dramatic effects, because the closed market means a fall in natural gas prices.[13] This has lots of benefits. Home heating bills go down. Electric bills are either stable or go down. Chemical and fertilizer plants that consume lots of natural gas or gas byproducts begin to move back to the United States. Some heavy industry may move back or stay because of lower energy costs.

Other impacts of falling gas prices are of more ambiguous import. I suspect that the fracking revolution probably means the end of the nuclear power industry in the United States.[14] Nuclear power cannot compete against cheap gas as a source of combustion for power generation. The fracking revolution also has the coal industry on the ropes. The coal producers like to blame the Obama Administration for launching a "war on coal," but a bigger problem is that under longstanding environmental regulations coal is less attractive as a source of power generation than cheap gas. Perhaps more problematically, lots of cheap gas also means the solar power industry and the wind power industry will need continuing government subsidies if they are to stay afloat.[15] If budgetary stringencies mean those subsidies are curtailed, they too could be done in by cheap gas.

On the oil front, the surge in domestic reserves will have less impact, because the price of oil is fixed by supply and demand in the world market, and the price will likely remain relatively high due to rising demand in Asia and the developing world. But there will still be big effects. U.S. imports of oil are way down, from 60 percent of total oil consumption to about 40 percent. The recession and improvements in fuel efficiency are partly responsible.[16] But the surge in domestic

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12. *Id.* at 51.

13. *Natural Gas: An Unconventional Bonanza*, Economist (Special Report), July 14, 2012, at 1, 5–7.

14. *See* Brad Plumer, *Another Casualty of the Shale Gas Boom: Nuclear Power*, Wash. Post (Feb. 21, 2013), http://www.washingtonpost.com/blogs/wonkblog/wp/2013/02/21/another-casualty-of-the-shale-gas-boom-nuclear-power; David Biello, *Is Nuclear Power Doomed to Dwindle?*, Sci. Am. (Feb. 5, 2013), http://blogs.scientificamerican.com/observations/2013/02/05/is-nuclear-power-doomed-to-dwindle.

15. *See* Henry D. Jacoby et al., *The Influence of Shale Gas on U.S. Energy and Environmental Policy*, 1 Econ. Energy & Envtl. Pol'y 37, 49 (2012).

16. In addition to surging domestic production, U.S. energy consumption is holding flat or declining annually, magnifying the impact of decreased imports. *Short Term Energy Outlook*, U.S. Energy Info. Admin., http://www.eia.gov/forecasts/steo/report/us_oil.cfm (last visited May 15, 2013).

production, especially from North Dakota, is perhaps the biggest factor. North Dakota, almost overnight, now produces more oil than Alaska and is second only to Texas among U.S. states, all due to fracking technology.[17] The impact on the balance of payments is enormous—roughly $100 billion a year is now going to those lucky workers and landowners in North Dakota rather than to Saudi princes. The International Energy Agency in Paris estimates the U.S. will be the largest producer of oil in the world by 2020, surpassing Saudi Arabia.[18] Energy independence, which every President since Nixon has claimed to be a top national priority, suddenly is beginning to look like less of a pipe dream.

So that is a capsule summary of fracking and why it is a very big deal; a "game changer" to use the current cliché. To say that this has come as a surprise to energy experts, politicians, and economists would be an understatement. No one saw this coming.

As a startling and unforeseen development, the fracking revolution presents a number of interesting questions. I will address four. These are not the only significant questions presented by this surprise. But they are ones that resonate particularly with me, a property and environmental law teacher. Here, in brief summary, are the four questions.

First, why did fracking technology, perhaps the most important innovation in energy technology in a generation, emerge in the United States rather than somewhere else? Answering this question may provide some clues about the conditions that promote innovation in developing new sources of energy more generally.

Second, are there any novel environmental risks presented by fracking? Fracking undoubtedly poses environmental risks, but we need to ascertain whether they are the kinds of risks that can be addressed by ratcheting up existing regulatory regimes, or if something entirely new is needed.

Third, if there are novel risks, what is the best regulatory strategy for addressing those risks?

Fourth and finally, what should a concerned citizen anxious about the prospect of global warming think about fracking? Is fracking something to be opposed in order to promote a transition to alternative energy, or is it something to be embraced as a bridge to a greener future?

17. Current North Dakota production is over 720,000 barrels per day, behind only Texas, at approximately two million barrels per day. *U.S. Monthly Crude Oil Production Reaches Highest Level Since 1998*, U.S. Energy Info. Admin. (Dec. 4, 2012), http://www.eia.gov/todayinenergy/detail.cfm?id=9030; *see also* Russell Gold, *Oil and Gas Bubble Up All Over*, Wall St. J., Jan 3, 2012, at A7.

18. Int'l Energy Agency, World Energy Outlook 2012, at 23 (2012).

## I. Why Did the Fracking Revolution Happen Here?

On to the first question: why did the fracking revolution happen in the United States rather than somewhere else?

Let us start with the role of the federal government. One possible explanation can be easily eliminated. Current fracking technology was not developed by the federal government. Over the years, the U.S. Department of Energy has channeled billions of dollars in grants to promote new sources of energy, ranging from nuclear fusion, to synthetic fuels, to photovoltaic cells, to battery technology, to hydrogen cars. Yet comparatively little in the way of research dollars has been devoted to the development of new oil and gas extraction techniques.[19] The United States devotes more public money to energy research than any other country, but fracking did not emerge out of an Energy Department laboratory.

This does not mean the federal role was irrelevant. Although little grant money went to developing fracking technology, the federal government provided a valuable subsidy, in the form of a tax break.[20] Tucked away in a 1980 tax bill designed primarily to impose a windfall profits tax on oil and gas producers was a provision, known as section 29,[21] that provided a special federal tax credit for drilling for so-called unconventional natural gas. This special credit no doubt helped keep several competing gas producers going in the 1990s in their quest for technology to extract gas from the Barnett Shale in Texas. So the federal government did not invent fracking, but perhaps it kept the technology from dying before its time. Note, however, that the government support did not take the form of the government picking winners and losers. Rather, the primary form of support was a general

19. From 1978 to 2010, approximately $3 billion in Department of Energy Research and Development expenditures were focused on oil and gas. In this same period, the Department of Energy devoted approximately $26 billion to coal, $45 billion to nuclear, and, more recently, $20 billion to renewable energy generation. *See* U.S. Energy Info. Admin., Direct Federal Financial Interventions and Subsidies in Energy in Fiscal Year 2010, at 34 (2011).

20. Federal spending related to fracking research equaled roughly $137 million over three decades, primarily in the 1970s—well before the major successes of recent years. But tax breaks supporting fracking pioneers were substantial, totaling over $10 billion from 1980 to the present. Kevin Begos, *Early On, Fracking Got Injection of Federal Funding, Tax Breaks*, Wash. Times, Sep. 23, 2012, http://www.washingtontimes.com/news/2012/sep/23/early-on-fracking-got-injection-of-federal-funding.

21. Crude Oil Windfall Profit Tax Act of 1980, Pub. L. No. 96-223, § 231(a), 94 Stat. 229, 268 (formerly codified at I.R.C. § 29; now codified as amended at I.R.C. § 45k (2006)). *See generally* Mark A. Muntean, *Rebirth of a Tax Credit: An Overview of Code Section 29*, 27 S. Tex. L. Rev. 235 (1986).

tax credit, broadly available to anyone who could claim to be drilling for unconventional gas. In effect, the decision to take the subsidy was made unilaterally by individual producers, each of whom could choose, based on its own calculus, whether to take up the subsidy or leave it on the table.

What about industry structure? Another possibility that can be eliminated is that the innovation came from the research department of one of the major oil companies that continually advertise their commitment to energy innovation on TV. It is true that many of the majors are American, and that these companies invest huge sums of money searching for new sources of energy and new ways of extracting it. But the critical breakthrough in the development of fracking technology was not developed by a major. It was achieved in the late 1990s through a trial-and-error process doggedly pursued by George Mitchell's energy company, an independent gas producer.[22] Mitchell's company was not exactly a pipsqueak in the energy world; it sold for $3.5 billion to another independent firm once the potential value of fracking in the Barnett Shale area became apparent.[23] But Mitchell had nothing comparable to the resources or the engineering talent of the major oil companies.

I would emphasize several other factors about oil and gas production in the United States which I think were indirectly responsible for the fracking revolution. One is that mineral rights in the United States are predominantly privately owned. The United States follows the so-called *ad coelum* rule, by which the owner of land is deemed to own the air rights above the land and the subsurface rights below the land.[24] Ownership of the subsurface rights includes the right to extract "fugacious" minerals found by drilling down into the subsurface column below the land, including oil, gas, and groundwater. This is why, in the *Beverly Hillbillies*, the discovery of oil under the Clampett farm leads to the family moving to Beverly Hills. The United States is something of an outlier in this regard. Most other countries follow the rule that subsurface minerals belong to the state, and so permission from the government is required to engage in subsurface mineral development.

Why might private ownership of subsurface mineral rights translate into greater innovation in drilling technology? You might be thinking—"greed." But I am not sure the governments that control

22. *See* YERGIN, *supra* note 6, at 325–28.

23. Jesse Bogan, *The Father of Shale Gas*, FORBES (Jul. 16, 2009), http://www.forbes.com/2009/07/16/george-mitchell-gas-business-energy-shale.html.

24. 63C AM. JUR. 2D *Property* § 12 (2009); *see also* Thomas W. Merrill, *Trespass, Nuisance, and the Costs of Determining Property Rights*, 14 J. LEGAL STUD. 13, 16, 26–36 (1985); Peter M. Gerhart & Robert D. Cheren, *Recognizing the Shared Ownership of Subsurface Resource Pools*, 63 CASE W. RES. L. REV. 1041, 1045–46, 1048–50 (2013).

mineral rights development in other parts of the world are necessarily more public spirited than the landowners who agree to enter into leases of their mineral rights to oil and gas production companies. I would emphasize something else—decentralization of control. In a country like the United States that follows the *ad coelum* rule, ownership and hence control over subsurface minerals is fragmented among tens of thousands of separate owners. A production company that wants to experiment with an innovative technology can always find an owner sufficiently willing to take risks—or if you are more cynical, sufficiently ignorant of the risks—to convey the required rights. When mineral rights are owned by the government, access is necessarily controlled by a centralized bureaucracy. Bureaucracies tend to be slow and cautious. Promoting innovative extraction technologies that could easily end up a bust is difficult to explain to the boss.

A very rough and admittedly inconclusive empirical confirmation of this point is provided by looking at a map of the United States where fracking activity is underway, and comparing it to a map showing areas of land and associated mineral rights that are controlled by the federal government. There is very little overlap. It could be, of course, that it just happens that there are few promising shale deposits under federal lands. But this is almost certainly not the explanation. Oil and gas producers have simply concluded that dealing with private owners is far easier than dealing with the bureaucracy in the Department of the Interior[25]—or waiting for the lawsuits to be resolved if and when the Department agrees to start leasing.[26]

Another factor that helps explain the fracking revolution is that regulation of oil and gas production in the United States is largely a matter of state rather than federal law. The explanation for this is historical. Oil and gas production developed well before the 1970s, when federal environmental law came on the scene.[27] Oil and gas

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25. Rules for fracking on federal land have been repeatedly delayed, largely due to political pressures. While the Department of the Interior floated proposed rules for fracking on federal lands in May 2012, extensive public comments ensured there would be no final rules published before the 2012 presidential election. Ben Geman, *Interior Delays 'Fracking' Rules*, The Hill (Dec. 11, 2012, 5:16 PM), http://thehill.com/blogs/e2-wire/e2-wire/272307-interior-pushes-back-fracking-rule-timeline.

26. A harbinger of the future here may be *Center for Biological Diversity v. Bureau of Land Management*, No. C 11-06174 PSG, 2013 WL 1405938 (N.D. Cal. Mar. 31, 2013), in which a magistrate judge has held that the Interior Department cannot enter into leases that contemplate the use of fracking on federal lands until a full-blown Environmental Impact Statement is prepared that takes a "hard look" at the environmental risks associated with this technology. *Id.* at *6.

27. This dramatic expansion of the federal role in environmental protection largely began with the National Environmental Policy Act of 1969, declaring "a national policy which will encourage productive and enjoya-

regulation was traditionally a state matter, and was primarily oriented toward maximizing production, not controlling environmental harms.[28] Probably because regulatory structures were already in place at the state level when the environmental revolution got underway, federal environmental regulation has largely left this system of state regulation untouched.[29]

Why does state regulation help foster technological innovation? You may be thinking state regulation equals lax regulation. But not all federal regulation is strict, and not all state regulation lax. Again, the more apt significance of state regulation is that regulatory oversight of the oil and gas industry is decentralized. Different states have different approaches, meaning regulators in some states are more tolerant of experimental or innovative production technologies than regulators in others.[30] Again, this differs from other nations, where regulation of the oil and gas industry tends to be much more centralized.

Why does decentralized regulation promote innovation? The theory that explains this might go as follows. All regulators tend to be risk averse.[31] If things go well, they get no credit. If things go badly, they get blamed. But the degree of risk aversion of regulators falls along a spectrum. Some are more risk averse than others. Where regulation is decentralized, a new technology like fracking can find at least one or two states where it is allowed to get going. This sets in motion a natural experiment. If the results are good, and the risks do not seem too great, then risk-averse regulators in other states will give

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ble harmony between man and his environment." 42 U.S.C. § 4321 (2006). *See generally* Michael J. Graetz, The End of Energy 41–59 (2011).

28. Bruce M. Kramer, *Federal Legislative and Administrative Regulation of Hydraulic Fracturing Operations*, 44 Tex. Tech. L. Rev. 837, 838 (2012) ("[T]he decades of the 1930s and 1940s became ones where states responded to the lack of federal regulation with the enactment of state oil and gas conservation statutes that delegated to state agencies broadened powers to regulate the oil and gas industry.").

29. What federal regulation there is of the oil and gas industry tends to focus on specific incidents, such as oil spills, *see* 33 U.S.C. § 2712 (2006 & Supp. V. 2011), or on the types of activity that oil and gas companies happen to engage in, such as the transportation of chemicals. We do not see the form of cradle-to-grave regulations present for industries as in the Resource Conservation and Recovery Act. 42 U.S.C. § 6901–6992k (2006) (regulating the transportation, treatment, and disposal of hazardous wastes).

30. *See* Christopher S. Kulander, 63 Case W. Res. L. Rev. 1101 (2013) (describing current regulatory regimes in major fracking states).

31. *See* William W. Buzbee, *Remembering Repose: Voluntary Contamination Cleanup Approvals, Incentives, and the Costs of Interminable Liability*, 80 Minn. L. Rev. 35, 91–93 (1995) (discussing risk avoidance in bureaucracy, using the example of the EPA).

it the green light to go ahead there, too.[32] If the results are not so good, or the risks seem too large, then the regulators in other states will throw up roadblocks to the new technology, and the experiment will wither away. In a more centralized regulatory environment, which tends to be the norm in other parts of the world, the experiment is less likely to get off the ground in the first place. This is because the median regulator is risk averse. And being the only regulatory game in town, the risk aversion of the median regulator is likely to translate into hostility to technological innovation.

The last structural feature of the United States I will mention is the highly developed infrastructure of pipelines, and the practice of treating pipelines like common carriers open to all.[33] This allows small producers without their own pipelines or without significant economic or political clout to gain access to markets. Again, the situation in other parts of the world is very different, where pipelines are either owned by the government or are not regarded as common carriers accessible to all.[34] One could say the United States has an open infrastructure in energy markets, at least on this dimension, and that this allows experimentation by small firms to flourish.

So if I had to sum up the factors that explain why the United States developed fracking technology before anyone else, I would say in one word: decentralization. Specifically, decentralization of control over resource development. One case study does not prove the general

32. Critics of state regulation often raise the specter of industry capture at local or state levels, yet nothing at this point suggests those risks are greater than they would be at the federal level. David B. Spence, *Federalism, Regulatory Lags, and the Political Economy of Energy Production*, 161 U. PA. L. REV. 431, 507 (2013) ("There is no evidence to suggest that the states' varying approaches to [fracking] questions reflect industry capture; an equally likely explanation is that each state is balancing the costs and benefits of development differently.").

33. Interstate oil pipelines have been classified as common carriers since 1906. Hepburn Act, Pub. L. No. 59-337, 34 Stat. 584 (1906) (amending the Interstate Commerce Act's common carrier provisions to apply to "the transportation of oil or other commodity, except water and except natural or artificial gas, by means of pipe lines"); *see also* Christopher J. Barr, *Unfinished Business, FERC's Evolving Standard for Capacity Rights on Oil Pipelines*, 32 ENERGY L.J. 563, 567–68 (discussing the history and statutory basis for oil pipelines' common carrier status under the Interstate Commerce Act). Interstate gas pipelines were excepted from the common carrier requirements of the Interstate Commerce Act, but beginning in the 1980s, a series of Federal Energy Regulatory Commission regulations provided gas producers with open access to pipelines. *See* 18 C.F.R. pt. 284 (2012).

34. *See, e.g.*, Dylan Cors, *Breaking the Bottleneck: The Future of Russia's Oil Pipelines*, 7 DUKE J. COMP. & INT'L L. 597, 606 (1997) (comparing pipeline regulation in the United States with Russian and European legal regimes).

point. But the fracking revolution is at least a cautionary tale for those who assume that overarching federal energy policy is the key to innovation in energy. It may be that private property rights, entrepreneurialism, local control, and the absence of federal bureaucracy make a better recipe for the development of "game changing" technological breakthroughs.

## II. Does Fracking Present Any Novel Risks?

The second question I will address is whether fracking presents any novel environmental problems that warrant a change in our existing systems of environmental regulation. Why the emphasis on novel risks? The following thought experiment may be useful. Imagine a discovery in the United States of new conventional sources of oil and gas equivalent in magnitude to the additional reserves of oil and gas brought on line by fracking. In other words, imagine we discover a huge new deposit of oil and gas in some backwater area of the country that somehow had been overlooked all these years. How, if at all, do the risks posed by fracking differ from the kinds of risks that would be associated with an upsurge in oil and gas production using conventional techniques? This question is important because it tells us whether we need new laws and regulations to deal with fracking. To the extent fracking-generated production is no different than a surge in conventional production, the solution is presumably to ratchet up the existing regulatory framework for oil and gas production to meet the challenges of the new surge in production. If, however, fracking is associated with new risks that have no parallel under conventional production, then we have to start thinking about developing a new regulatory framework to deal with these new risks.

The environmental bill of indictment against fracking is a long one. Among the members of some environmental advocacy groups, I suspect that the most telling charge is that fracking, by giving us cheap gas, will delay the process of converting to renewables, and hence will compromise efforts to reduce the risk of climate change.[35] This issue is sufficiently important that I will postpone it to question four. For many landowners who own property in the vicinity of prospective fracking operations, the most critical concern is that fracking will contaminate groundwater aquifers, thereby jeopardizing water supplies and property values.[36] Fracking fluid contains a small percentage of chemicals, some of which, like arsenic, are known toxics and others of which, like benzene, are known carcinogens. If these chemicals find their way into the groundwater, they could pose a health risk or at the very least would seriously impair property values.

35. *See* Jacoby et al., *supra* note 15.

36. *See* Wiseman, *supra* note 3, at 131–32.

Other charges are that fracking operations will damage local roads due to heavy truck traffic, cause air pollution due to releases from poorly controlled wells or containment ponds, place unsustainable demands on local water supplies, damage wildlife habitat by requiring the construction of new pipelines, and even cause earthquakes.[37] The question is which if any of these risks requires the development of new regulatory systems.

Virtually all of these risks are matters of real concern. But many are the kinds of externalities that would be generated by an upsurge in conventional oil and gas production. Here I would include truck traffic, air pollution, and habitat destruction from pipelines. There is no reason to believe these problems cannot be addressed by adapting existing forms of regulation to meet the new challenges. Surges in truck traffic can be met by new limits on the weight or type of vehicles or by user fees on those that use heavy trucks on back country roads. Air pollution can be addressed by new types of stationary source controls on gas and oil wells—something that the EPA is already moving toward doing.[38] Habitat destruction can be controlled by applying local land use controls and the Endangered Species Act.[39]

Among the risks that are unique to fracking include its voracious consumption of water. But the demand for water used in fracking appears to be manageable in areas like Pennsylvania and Ohio where surface water, which is renewable, is used.[40] In areas like West Texas where groundwater must be tapped, existing permitting schemes can be used to allocate scarce local water supplies. Ideally, increased recycling of fracking fluid will reduce the demand on water supplies nearly everywhere.[41] Earthquake risks fall in the category of "more

37. *See* Hannah Wiseman, *Regulatory Adaptation in Fractured Appalachia*, 21 VILL. ENVTL. L.J. 229, 254–56 (2010) (detailing surface impacts of fracking operations).

38. In 2012, the EPA issued regulations aimed at curbing emissions from oil and gas production sites, specifically targeting fracking operations. *See* Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, 77 Fed. Reg. 49,490 (Aug. 16, 2012) (to be codified at 40 C.F.R. pts. 60, 63).

39. *See* Kalyani Robbins, *Awakening the Slumbering Giant: How Horizontal Drilling Technology Brought the Endangered Species Act to Bear on Hydraulic Fracturing*, 63 CASE W. RES. L. REV. 1143 (2013).

40. Local authorities in these areas have shown willingness to manage water usage by fracking operations by changing consumption rates or suspending usage. *See* COOLEY & DONNELLY, *supra* note 4, at 16 (describing state responses to water withdrawal for fracking operations).

41. States regulating fracking operations increasingly require or encourage wastewater recycling and reclamation. These requirements may become increasingly widespread, as they decrease pressure on local water sources

study required."[42] The most prominently discussed episode, from Ohio, involved injection of spent fracking fluid into deep geologic formations, not fracking operations themselves.[43] If deep injection of spent fluid causes earthquakes, then plans to require carbon sequestration by deep injection of $CO_2$ also need to be reexamined. So this may not be a problem, or may be a problem not unique to fracking.

The water contamination risks are the matter of greatest concern to local landowners and loom large in the public imagination. They are also a category of risk that presents a plausible claim to being novel or unprecedented. The matter is complicated by the variety of potential pathways of water contamination.[44] The pathway that has received the most attention is the prospect that fracking fluid injected into deep shale formations might migrate upward through fractures into groundwater aquifers. There is currently no documented instance of this happening,[45] and most experts think it highly unlikely.[46] The

and decrease the need to dispose of waste water. *See* Wiseman, *supra* note 37, at 267–68 & n.245.

42. As of yet, the connections between fracking operations and earthquakes are unclear. While it has long been known that oil and gas extraction generally may cause increased seismic activity, the only United States Geological Survey study on the question did not find that fracking presents a greater than normal risk for these events. *See* News Release, David J. Hayes, Deputy Sec'y, U.S. Dep't of Interior, Is the Recent Increase in Felt Earthquakes in the Central US Natural or Manmade? (Apr. 11, 2012) ("USGS's studies do not suggest that hydraulic fracturing, commonly known as 'fracking,' causes the increased rate of earthquakes. USGS's scientists have found, however, that at some locations the increase in seismicity coincides with the injection of wastewater in deep disposal wells."); *see also* Nat'l Research Council, Induced Seismicity Potential in Energy Technologies 156 (2012) (reaching similar conclusions).

43. *See* Mark Niquette, *Ohio Tries to Escape Fate as Dumping Ground for Fracking Fluid*, Bloomberg (Feb. 1, 2012, 12:01 AM), http://www.bloomberg.com/news/2012-02-01/ohio-tries-to-escape-fate-as-a-dumping-ground-for-fracking-fluid.html.

44. Moniz, Jacoby & Megs, *supra* note 8, at 7 ("Shale development requires large-scale fracturing of the shale formation to induce economic production rates. There has been concern that these fractures can also penetrate shallow freshwater zones and contaminate them with fracturing fluid, but there is no evidence that this is occurring.").

45. The most recent United States Geological Survey assessment of 127 sample wells in the Fayetteville Shale area of Arkansas found no evidence that fracking operations had contaminated local groundwater, despite over 4,000 drilling operations in the vicinity. Timothy M. Kresse et al., U.S. Geological Survey, Shallow Groundwater Quality and Geochemistry in the Fayetteville Shale Gas-Production Area, North-Central Arkansas (2011); *see also* Ayesha Rascoe, *No Contamination from Fracking Found in 2 Arkansas Counties-USGS*, Reuters (Jan. 9, 2013, 7:17 PM), http://www.

basic reason is that shale seams are typically very deep, up to a mile underground, and the enormous weight of rock and soil above these seams will compress any fractures that might otherwise allow fracking fluid to migrate upward.[47] Still, fracking involves the uncontrolled release of toxic chemicals—underground and out of sight. This makes people understandably nervous, and with good reason. We have had other experience recently with assurances from experts that complicated and novel activities—like buying and selling collateralized debt obligations—pose no risk, and we have lived to regret it. Another pathway of contamination might be from deep geologic formations where spent fluid is injected. Again, the depth of the injection, the lack of porosity in overlying rock, and the natural force of gravity make contamination of aquifers much closer to the surface unlikely. But the uncontrolled nature of the injection of waste chemicals causes apprehension.

Other potential pathways of contamination have elicited less public attention but may present greater risks. Improper sealing of vertical drilling pipes could allow fracking fluid to escape at depths

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reuters.com/article/2013/01/10/usa-fracking-arkansas-study-idUSL1E9C9FCZ20130110. A 2011 Duke University study of wells in the Marcellus Shale area of Pennsylvania found elevated methane levels, but no signs of fracking fluids or chemicals in the groundwater. Steven G. Osborne et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, 108 PROC. NAT'L ACAD. SCI. 8172 (2011). The Duke study's authors later theorized that methane may be moving through previously unknown, naturally occurring pathways, resulting in unforeseen migration. Nathaniel R. Warner et al., *Geochemical Evidence for Possible Natural Migration of Marcellus Formation Brine to Shallow Aquifers in Pennsylvania*, 109 PROC. NAT'L ACAD. SCI. 11961 (2012).

46. A 2011 Department of Energy study "share[d] the prevailing view that the risk of fracturing fluid leakage into groundwater sources through fractures made in deep shale reservoirs is remote." SHALE GAS PROD. SUBCOMM., U.S. DEP'T OF ENERGY, SECOND NINETY DAY REPORT 17 (2011).

47. Only one study has suggested that shale seams may be more permeable than previously estimated, and thus susceptible to fracking fluid migration. But this study relied entirely on computer modeling and no field data, drawing strong criticism from other experts. This illustrates one of the major difficulties in determining the risks of groundwater contamination—understanding the geology of shale formations more than a mile deep is limited, and the subject is difficult to research. *See* Tom Meyers, *Potential Contaminant Pathways From Hydraulically Fractured Shale to Aquifers*, 50 GROUND WATER 872 (2012); *see also* Abrahm Lustgarten, *New Study Predicts Frack Fluids Can Migrate to Aquifers Within Years*, PRO PUBLICA (May 1, 2012, 3:29 PM), http://www.propublica.org/article/new-study-predicts-frack-fluids-can-migrate-to-aquifers-within-years (reviewing the Meyers study and criticizing its methodology).

much closer to aquifers.[48] Improper lining of surface containments could lead to leaching of fluid into groundwater, as could unprotected blowouts. Accidental spills from trucks are always a possibility. It is also possible that fracking activity might disturb pockets of methane gas closer to surface aquifers, or could agitate sediment in the bottom of water wells, which would then contaminate the well water.[49]

Collectively, the water contamination risks are relatively novel and have elicited a fair degree of anxiety. Regulations of the "best practices" variety designed to minimize the risk of leaking from improperly sealed vertical pipes, or from blowouts, or from surface containment ponds, are both feasible and desirable. But there is no known technology to reduce the risks from many of the potential pathways of contamination—including the scariest, if the most remote, risks presented by injection of fracking fluid into deep shale seams or into geologic formations for disposal.

So I would conclude that the water contamination risks are novel and do not have any close parallel in conventional oil and gas production. The experts may be right that based on geology the risks of contamination from deep injection are close to zero. But only time will tell for sure. In the meantime, nearly everyone who draws water from an aquifer above or in the vicinity of fracking activity is a guinea pig. We need to put in place some regulatory system to address the risks of water contamination associated with the uncontrolled release or injection of fracking fluid. And since all pathways of contamination pose risks unique to fracking, we should adopt a regulatory structure broad enough to address those risks, too.

## III. How Should We Address Novel Fracking Risks?

The third question is, given that fracking presents novel issues of water contamination, what sort of regulatory system should be put in place to address those risks? David Schizer, my colleague and dean at Columbia Law School, and I are writing a paper about this.[50] Let me offer some of the highlights of our argument.

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48. *See* Osborn et al., *supra* note 45.

49. This problem of sediment disturbance may explain why numerous reported cases of alleged fracking contamination turn out to be incorrect. The drilling process has been found to agitate preexisting sediment, making water appear dirty or unsafe, without any evidence of fracturing chemicals in the water. Elizabeth W. Boyer et al., Ctr. for Rural Pa., The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies (2011) (comparing water wells before and after fracking; finding no change in methane, but finding an increase in sediment and iron in water).

50. Thomas W. Merrill & David M. Schizer, *The Shale Oil and Gas Revolution, Hydraulic Fracturing, and Water Contamination: A Regulatory Strategy*, 98 Minn. L. Rev. (forthcoming 2013).

The first issue is whether to adopt a system of ex ante or ex post regulation.[51] Ex ante regulation tries to head off harm before it occurs. Ex post regulation puts a price on harm after it occurs. In many contexts, ex ante is better, particularly if we have significant information about harms and how to prevent them.

We do not, however, have good information at present about the expected magnitude and incidence of water contamination caused by fracking. With respect to the central source of anxiety—the risks of migration of contaminants from shale rock formations to nearby aquifers—we have a classic he-said, she-said situation. The industry says the risk is basically nonexistent.[52] The environmentalists say the harm could be catastrophic.[53] Until we have more actual experience with horizontal fracking, we will not know for sure who is right.

Nor do we have good options for controlling the incidence of contamination, certainly not from all potential pathways of contamination. We know how producers can minimize the risks of contamination from surface activities, like leaky containment tanks or spills from trucks. But we are basically in the dark about how to minimize the risks from fracking activity itself. Again, over time some consensus views will probably emerge about best practices. But for the moment, producers are in a learning-by-doing mode. Without better information, it is impossible to design a sensible system of ex ante regulation.

The environmentalists would say, when in doubt apply the precautionary principle.[54] But the only type of ex ante regulation we

51. The factors differentiating ex ante and ex post regulation often parallel the arguments regarding rules and standards in law. *See generally* Louis Kaplow, *Rules Versus Standards: An Economic Approach*, 42 Duke L.J. 557 (1992); *see also* Robert Innes, *Enforcement Costs, Optimal Sanctions, and the Choice Between Ex-post Liability and Ex-ante Regulation*, 24 Int'l Rev L. & Econ. 29 (2004).

52. Recent statements by Rex Tillerson, CEO of Exxon Mobil, to Forbes magazine provide an example of this industry position: "[T]he precautionary principle will absolutely undermine the economy. . . . If you want to live by the precautionary principle, then crawl up in a ball and live in a cave." Brian O'Keefe, *Exxon's Big Bet on Shale Gas*, CNN Money (Apr. 16, 2012, 5:00 AM), http://tech.fortune.cnn.com/2012/04/16/exxon-shale-gas-fracking.

53. *See, e.g.*, Statement of Allison Chin, President of the Sierra Club (July 28, 2012), *available at* http://content.sierraclub.org/naturalgas ("No state has adequate protections in place. Even where there are rules, they are poorly monitored and enforced. Thanks to the multiple federal exemptions, we can't even count on the federal government to keep us safe."); Amy Mall, *Safe Fracking Is a Fairy-Tale—The Latest Science from Europe*, EcoWatch (Oct. 11, 2012), http://ecowatch.org/2012/safe-fracking-a-fairy-tale.

54. *See* Cass R. Sunstein, Worst Case Scenarios 119 (2009) ("When risks have catastrophic worst-case scenarios, it makes sense to take

could possibly adopt given the dearth of information about expected harms and control measures would be to impose a moratorium on fracking until further information is gathered about its potential adverse effects. You could call this the New York solution.[55] Sometimes moratoriums make sense, given what we know about the likely benefits and risks of an activity. For example, I would probably agree that it makes sense to put a moratorium on human cloning until we know more about the implications.

But with respect to fracking, a complete moratorium does not seem very sensible. For one thing, hydraulic fracturing has been used with conventional vertical wells for sixty years, without any notable adverse effects. For another, the scientific explanation for why upward migration of fracking fluids will not occur seems plausible and has been endorsed in principle by expert panels at the EPA and Energy Department.[56] To be sure, adding horizontal drilling to fracturing increases the risk of subsurface contamination. But it does not change the risk very much with respect to surface contamination, except insofar as the total amount of fracking activity goes up. In any event, it is too late to impose a moratorium on fracking where it is already underway, which is lots of places.

Under the circumstances, the only feasible way to regulate the novel water contamination risks presented by fracking is ex post. Practically speaking, that means some kind of liability rule for water contamination that can be causally linked to fracking activity after it occurs. David Schizer and I have an elaborate discussion of what an optimal liability regime would look like.[57] It would feature rules designed to encourage the development of and compliance with best practices regulations, mandatory baseline testing of water quality to help resolve causation questions, attorney fee shifting for successful claimants, and the posting of bonds or evidence of insurance to contend with insolvency risks. Ideally, it would be established by legislation, most likely at the state rather than the federal level. And such ideal legislation, we suggest, would provide for an expeditious and inexpensive administrative system for processing claims.

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special measures to eliminate those risks, even when existing information does not enable regulators to make a reliable judgment about the probability that the worst-case scenarios will occur.").

55. New York State has imposed an effective moratorium on all fracking activity in the state. While rules permitting fracking have been drafted by the state Department of Environmental Conservation, vocal opposition from environmental groups has led to a sort of regulatory paralysis. *See* Danny Hakim, *Shift by Cuomo on Gas Drilling Prompts Both Anger and Praise*, N.Y. Times, Oct. 1, 2012, at A1.

56. *See* Shale Gas Prod. Subcomm., *supra* note 46.

57. Merrill & Schizer, *supra* note 50.

Unfortunately, the ideal is almost certainly unattainable. The sad truth about environmental harms, recognized some years ago by Jim Krier in a little essay entitled *The End of the World News*, is that legislatures will not act until there is incontrovertible evidence of a link between some activity and a real, tangible harm.[58] Abstract demonstration of a risk will not do. I am reasonably confident this is true of fracking. Until there is an irrefutable demonstration that subsurface fracking activity has led to a water contamination disaster, we are not going to see legislation prescribing a liability regime, ideal or not.

Happily enough, all is not lost, because we have a nonideal liability regime that can be dusted off and applied to any water contamination episodes that may occur: the common law of torts. The common law of torts does not have all the features that Schizer and I recommend, such as fee shifting, the posting of bonds, and administrative adjudication. But it is not beyond the realm of imagination to think that the common law, when applied to alleged water contamination due to fracking, could be applied in such a way as to approach the kind of liability system we would consider desirable.

With respect to the standard of care for example, the common law has a number of doctrines that can be deployed to encourage the development and compliance with best practices regulations. Violation of a best practices rule should be negligence per se. Compliance with a rule should give rise to a regulatory compliance defense. And for harms that remain untouched by any best practices regulation, res ispa loquitur would be appropriate. Practically speaking, this last doctrinal move would be tantamount to a kind of strict liability. This, we argue, is appropriate, in part to create incentives for producers to adjust activity levels and to keep searching for innovative ways to minimize harms.

A somewhat similar story can be told about proof of causation. Ordinarily, the plaintiff has the burden of proving causation. This could prove to be an almost insuperable barrier in a water contamination case, without evidence about the quality of the water before fracking activity took place.[59] Thus, an ideal liability scheme

58. James E. Krier, *The End of the World News*, 27 Loy. L.A. L. Rev. 851, 852 (1994).

59. The complications of proving groundwater contamination are present in both litigation and scientific studies. Identifying the specific source of methane is difficult by itself, and litigants can rarely prove that methane contamination is not naturally occurring. At best, parties may show that methane contamination derives from a general area, such as the Marcellus Shale, which may not be sufficient to prove causation. An example of this issue has been seen in the disputes surrounding water contamination in Dimock, Pennsylvania. *See* Mark Drajem & Jim Efstthiou, *Cabot's Methodology Links Tainted Water Wells to Gas Fracking*, Bloomberg (Oct. 2, 2012, 12:01 AM), http://www.bloomberg.com/news/2012-10-02/cabot-s-methodology-links-tainted-water-wells-to-gas-fracking.html.

would require baseline testing, mandatory disclosure of fracking chemicals, and perhaps even the mandatory use of harmless tracer chemicals in fracking fluid, all of which would dramatically lower the barriers to establishing causation.[60]

A common law court obviously could not mandate all these things, certainly not before any suit was filed. But a clever court might be able to adopt some presumptions about causation, which would have the effect of creating salutary incentives for baseline testing. Thus, a court could create a presumption of causation if the producer did not obtain water samples before fracking begins. This would create an incentive to obtain and secure samples as part of the lease negotiation process. And if any landowner refused to cooperate in the taking of water samples, the court could create a counter-presumption of no causation, should that landowner later decide to sue for water contamination. So with a little creativity, the common law court might make some progress on the causation front.

The common law has the further virtue that any issue that is likely to come up in a liability regime will have come up in some form in the common law. Thus, questions about defenses based on plaintiff misconduct, joint and several liability, the measure of damages, the enforcement of judgments, and so forth, will all have some off-the-shelf answer under the common law. Any legislated liability rule would undoubtedly be incomplete, and would have to draw on the common law by analogy in any event.

Finally, it is also worth noting that state legislatures often legislate on discrete issues that arise in the course of common law adjudication, in an effort to facilitate better results. If I could single out one issue that I would have the legislature weigh in on, it would be to require baseline sampling of local water supplies before fracking begins. Of course, given the Krier rule—that no environmental legislation is forthcoming until harmful effects are established—even this may be too much to hope for.[61] But it would be worth trying to secure such legislation, and this might be something that both producers and local opponents could agree upon as a step toward alleviating uncertainty about the effects of fracking.

## IV. How Will Fracking Impact Climate Change?

My fourth question is: what should a concerned citizen worried about climate change think of fracking?

60. Chris Mooney, *The Truth About Fracking*, Sci. Am., Nov. 2011, at 80, 85 (describing the introduction of tracers into fracking fluid mixtures as "relatively easy," but facing industry opposition).

61. James E. Krier & Edmund Ursin, Pollution and Policy 1–3, 11 (1977).

Global warming is a global phenomenon. This means that what happens in one part of the world may not do much to stop global warming, if it is offset by an equal and opposite change in another part of the world. Let me offer an example: Europeans, who care quite a bit about climate change, have aggressively pushed alternative energy sources like solar and wind power. To pay for this, they have required ratepayers to subsidize solar and wind producers through higher rates on electricity.[62] Higher rates on electricity have accelerated the movement of industry from Europe to Asia, where operating costs are lower. But in Asia, electricity is predominantly produced by power plants that burn coal. So subsidizing alternative energy sources in Europe may lead to higher rather than lower greenhouse gas emissions on a global basis, as industrial activity shifts from Europe to Asia.

How does this relate to the fracking revolution in the United States? Let's start with the evidence about the trend in greenhouse gas emissions in the last seven years on three continents: Asia, Europe, and North America. In Asia, greenhouse gas emissions are up quite a bit, as China and other Asian countries rapidly industrialize and have built thousands of coal-burning power plants to generate the electricity needed to power this industrialization process.[63] In Europe, greenhouse gas emissions are at best stable or a bit worse.[64] Why is that? Gas is expensive in Europe, and is subject to uncertainty because much of it comes from Russia.[65] Nuclear is on the outs after

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62. Steven Ferrey et al., *Fire and Ice: Renewable Energy and Carbon Control Mechanisms Confront Constitutional Barriers*, 20 DUKE ENVTL. L. & POL'Y F. 125, 169–71, (2010) (describing the operation of the feed-in tariff system used by EU member states to subsidize renewable energy).

63. *See* Jonathan Kaiman, *China's Emissions Expected to Rise Until 2030, Despite Ambitious Green Policies*, GUARDIAN (London), Nov. 26, 2012, http://www.guardian.co.uk/environment/2012/nov/26/china-emissions-rise-green-policies.

64. *See* Fiona Harvey, *EU Greenhouse Gas Emissions Rise Despite Climate Change Policies*, GUARDIAN (London) May 30, 2012, http://www.guardian.co.uk/environment/2012/may/30/european-union-greenhouse-emissions-rise. Greenhouse gas emissions in the European Union are based on Kyoto Convention targets relative to base years set by member states, with most EU states using 1990 as their base year. Because general advances in fuel efficiency have driven down emissions since 1990, EU member states are considered on-target for reducing emissions, even as their year-to-year emissions rise and fall. *See EU Greenhouse Gas Emissions and Targets*, EU COMM'N, http://ec.europa.eu/clima/policies/g-gas/index_en.htm (last visited May 15, 2013). In contrast, the U.S. Energy Information Administration measures American emissions relative to 2005 levels, so reductions may be more statistically significant.

65. Natural gas prices in the United States have dropped as low as $3 per million British thermal units, but generally settle close to $4. In Europe, per unit prices have ranged from $8–$12 in recent years. *Global Natural*

Chernobyl and Fukishima. Renewables are expensive and as yet are a relatively small part of the picture. So for a variety of reasons, Europe is burning more coal to generate electricity.

The good news is the United States, where greenhouse gas emissions have fallen significantly in the last seven years.[66] This is a country with no comprehensive climate change policy, and yet it has seen better $CO_2$ reductions than many other Western nations. What gives? Some of the progress in the United States is due to the economic slump and improvements in fuel efficiency of cars. The most important contributor, however, is the big shift in power generation from coal to natural gas, spurred by the cheap gas generated by the fracking revolution.[67] Power plants that run on natural gas emit about 50 percent of the greenhouse gases emitted by plants generated by coal. So the displacement of coal plants by cheap natural gas fired plants in the United States has given us the winning report card in terms of recent progress in controlling greenhouse gas emissions.[68]

What if anything can we conclude from this? Not a great deal, unfortunately. If the United States gets a B+ for reducing greenhouse gas emissions because of a shift from coal to gas, this will matter not in the larger picture if the United States continues to outsource industrial production to China, which generates power using coal. In order for natural gas to make a truly significant contribution to greenhouse gas emissions on a global basis, it would be necessary to

*Gas Prices Vary Considerably*, U.S. ENERGY INFO. ADMIN. (Sep. 30, 2011), http://www.eia.gov/todayinenergy/detail.cfm?id=3310.

66. *See* Benoit Faucon & Keith Johnson, *U.S. Redraws World Oil Map*, WALL ST. J., Nov. 13, 2012, at A1 (quoting estimate of International Energy Agency). Greenhouse gas emissions in the United States have declined approximately 7 percent from 2005 levels. This decline is remarkable by itself, yet future trends are even more surprising: by current Energy Information Agency estimates, greenhouse gas emissions are expected to remain below 2005 levels through 2035. Joel Kirkland, *U.S. Greenhouse Gas Emission Decline Despite Political Gridlock*, SCI. AM. (Jan 25, 2012), http://www.scientificamerican.com/article.cfm?id=us-greenhouse-gas-emissions-decline-despite-political-gridlock.

67. *See U.S. Energy-Related* $CO_2$ *Emissions in Early 2012 Lowest Since 1992*, U.S. ENERGY INFO. ADMIN. (Aug. 1, 2012), http://www.eia.gov/todayinenergy/detail.cfm?id=7350.

68. This judgment is complicated by the fact that more gas production means more methane leaking into the atmosphere, and methane is itself a potent (but relatively more short-lived) greenhouse gas. Thus, it has been argued that on a "life cycle" basis it is not clear that the natural gas revolution will yield a reduction in greenhouse gases overall. Fortunately, producers have an economic incentive to minimize gas leaks, because it costs them money. This incentive, plus new EPA regulations designed to reduce fugitive gas emissions, will hopefully keep natural gas in the winning column in terms of climate effects. For a review of the empirical literature, see Merrill and Schizer, *supra* note 50.

replace the use of coal with natural gas in Europe, Asia, and the rest of the developing world, as well as in the United States. This could happen. One small step in the right direction would be for the United States to develop a robust export industry in liquefied natural gas.[69] This would help make a partial transition to gas possible in countries like Japan. Of course, the more we export gas, the higher the price of gas in the United States, which could slow down the transition to gas here. Longer term, other countries in Europe and Asia are likely to adopt fracking technology themselves, and expand their own gas reserves. A small step in this direction would be for the United States to encourage the export of fracking technology to countries on other continents. Twenty years from now, we could be seeing China switching from coal to gas based on the development of new gas reserves using fracking technology on shale deposits in China.

Another variable in all this is oil. If fracking technology in the United States and elsewhere expands the production of oil, this will tend to hold price increases in oil in check. Lower prices of oil, relatively speaking, will encourage more cars and more driving, which will add to the total volume of greenhouse gas emissions worldwide. Electric cars may provide a partial answer to this. But again, if the electric cars sold in China are recharged with electricity coming from new coal burning plants, little will be gained. So it all comes back to the coal plants in China.

A third variable to add to the mix is the impact of the fracking revolution on renewables. Cheap gas, as I said at the outset of these remarks, is poison for renewables. If we assume that technology stands still from now until the end of the twenty-first century, renewables will never be able to compete with cheap gas without massive government subsidies. And the lesson of history, at least in the United States, is that subsidies for alternative fuels are not politically sustainable.[70] In a static technological world, the best bet for heading off climate change risk would probably be to press ahead on all fronts to promote the use of fracking in generating cheap gas.

But of course, technology does not stand still. Over time, there is reason to believe we will achieve a technological breakthrough in renewables, analogous to the breakthrough achieved with fracking. Which brings me back to my first question—how to stimulate innovation in the production of energy. To promote innovation, the government should strive to create the conditions in which

69. Exporting liquefied natural gas is difficult technically, and further complicated politically. LNG export plants require approval from the Department of Energy, which has been withheld in recent years due to political pressures. Currently, only one out of over twenty potential LNG export terminals has received federal approval. *See Better Out Than In*, ECONOMIST, Mar. 2, 2013, at 13.

70. GRAETZ, *supra* note 27 at 153–54.

entrepreneurial ventures thrive. Another constructive form of government intervention here would be a carbon tax, which would seek to equalize the social costs of carbon fuels and renewables, and thereby put renewables on a level playing field with carbon fuels. When are countries most likely to adopt a carbon tax? When the price of carbon fuels is going down, not up.[71] And what is it that is most likely to bring the price of carbon fuels down in the foreseeable future? Fracking.

So I would conclude that a conscientious citizen concerned about global warming should support the fracking revolution. Cheap gas will upend nuclear and renewables at least temporarily, but more importantly it will displace coal. If this can be done on a global basis, big progress will have been made against global warming. Cheap gas and potentially cheaper oil also make it more likely that legislatures will agree to adopt a carbon tax, which could help stimulate innovation in renewables over the long term. Cheap gas is thus probably the best strategy on the horizon for reducing greenhouse gases, until we see a technological breakthrough in renewables. And the only way to get cheap gas is to support fracking.

71. *See* Thomas W. Merrill & David M. Schizer, *Energy Policy for an Economic Downturn: A Proposed Petroleum Fuel Price Stabilization Plan*, 27 Yale J. Reg. 1 (2010). This is partly a function of loss aversion or the endowment effect: imposing a tax when prices are stable or rising is experienced as a loss, whereas imposing a tax when prices are falling is experienced as forgoing a potential gain. *Id.* at 29.