National Regulatory
Research Institute

Hydraulic Fracturing: Placing What We Know Today in Perspective

Ken Costello, Principal

The National Regulatory Research Institute

October 2011

11-16

Acknowledgments

The author wishes to thank Mr. Tim Baker and Mr. Ben Jackson of the Oklahoma Corporation Commission, Mr. Robert Burns of The Ohio State University, Chairman Joshua Epel of the Colorado Public Utilities Commission, Mr. Joe Hecker of NRRI, Dr. Douglas Howe of IHS CERA, and Mr. Joseph Rogers of the Massachusetts Office of the Attorney General.

Online Access

The paper can be accessed online at http://www.nrri.org/pubs/gas/NRRI_Hydraulic_Fracturing_Oct11-16.pdf

Executive Summary

Hydraulic fracturing ("fracking") is a technique that releases natural gas trapped in shale by injecting at high pressure fluids, usually consisting of water, sand, and chemicals. Typically over 99 percent of the fracking fluid is composed of water and sand, although the total volume of potentially toxic materials, even below the 1 percent level, can be considerable. The high pressure of the fluid injected allows the cracking open of the otherwise impermeable shale, freeing trapped gas, which then flows through a horizontal bore into the well casing and up to the surface. Some of the fracking fluid flows with the gas to the surface, where it must be disposed of; the rest remains underground.

Fracking, along with horizontal drilling, has made it possible for the U.S. and other countries to recover large amounts of shale gas economically, which promises to power electric generating plants and fuel industries, businesses, and homes for decades. The potential benefits of recovering these recently discovered vast resources in terms of job creation, reduced energy dependency on foreign sources, and revenues for local, state, and federal governments are large and undeniable. The potential of having ample amounts of shale gas is a major positive development that promises to help our economy.

But there are environmental—and therefore political—concerns about fracking to recover shale gas that introduce uncertainty into this rosy picture. Opponents of fracking allege that fracking contaminates drinking water and releases methane—a highly concentrated greenhouse gas 20 or more times more potent than CO_2—into the air, as well as toxic and radioactive chemicals. There are problems with waste disposal of fracking fluid as well. The gas industry contends that the environmental risks are manageable and have been exaggerated by fracking critics.

What should utility regulators make of this situation? In general, utility regulators have no authority to decide whether fracking may proceed, as the gas industry argues it must, or should be restrained until proof of manageable environmental harm can be proven. Should utility regulators assume that substantial environmental questions will limit fracking—and, therefore, natural gas production—in a way that would cause today's relatively low gas prices to rise? Or should they assume that environmental concerns will be addressed sufficiently that fracking projects will be permitted and thereby release oceans of natural gas so as to keep gas prices low? The challenge for policymakers is to make good decisions while uncertainties remain over the possible hazards of fracking.

As of today, evidence about the safety and environmental risk of fracking is inconclusive. Many charges against fracking are exaggerated or misplaced; other concerns are more valid. As one example, no documented evidence supports the charge that fracking itself has contaminated groundwater. Contrary to the allegations of some critics, the best evidence shows that fracking in itself does not cause flaming tap water or damaging earthquakes. Incidents attributable to fracking are often found to result from problems relating to other aspects of drilling, although serious problems may occur indirectly from fracking. Gas migration ("stray gas") to drinking-water wells, for example, frequently derives from a high presence of gas near the surface that naturally occurs. The table on page v summarizes the state of knowledge on seven controversial aspects of fracking that so far have dominated the public-policy debate.

In spite of evidence weighing against these concerns, the political reality is that the public in many states is wary of fracking, especially when it occurs in their backyards. As a result, some states are raising the bar, at least until further studies of fracking's potential harm are completed. Since October 2010, more than 100 bills related to fracking have been introduced in 19 states. Many of these bills call for disclosure of the chemicals used in fracking fluids, while others would require additional studies before fracking can proceed, or for outright bans on fracking in that jurisdiction.

Weighing all that we know today, the cost to the country of not exploiting its abundant shale-gas resources appears high in relation to the risk that increased fracking production would pose. The U.S. Energy Information Administration projects that over the next two decades, a slow-growth scenario for shale-gas production could cost natural-gas consumers hundreds of billions of dollars. Under more optimistic scenarios, the EIA presumes two things: (1) that no major incident or rash of incidents will occur that would hinder production and lead to restrictive regulations, and (2) that future studies will show that fracking imposes no serious risks that would warrant limited development or, more seriously, a ban on production.

Given the current state of the literature and the fact that major studies of fracking and its potential harm will be completed within the coming year, this paper believes that utility regulators should assume that at least a limited number of additional fracking projects will soon go forward. Many of them will be conducted by major oil and gas companies with wide experience in the field, in contrast to some smaller firms that have engaged in irresponsible fracking practices in the past and caused environmental damage in doing so. Thus it is reasonable to assume, for resource-planning purposes, that the price of natural gas will remain low for the foreseeable future. Evidence from additional studies and those fracking projects that do go forward will yield information that justifies either continuation or modification of present price expectations.

For those regulators who wish to delve more deeply into the existing scientific literature about fracking and studies soon to be completed, the paper addresses and references these matters in some detail.

Table: Frequently Asked Questions about Fracking

Question	Comment
Does fracking cause earthquakes?	▪ Disposal wells can cause earthquakes. ▪ The US. Geological Survey (USGS) has documented cases of earthquakes in which fracking was a possible cause. ▪ The magnitude is probably too small to result in any damage.
Does the composition of fracking fluids affect the public health?	▪ Yes, to the extent that the fluids include toxic chemicals that for one reason or another leak into the groundwater or wells. ▪ The gas industry has started to experiment with fracking fluids that contain no chemicals.
Does fracking contaminate groundwater?	▪ There is little evidence of a cause-and-effect relationship between fracking and contaminated water. ▪ Many of the water-contamination incidents may not have come from fracking itself but have resulted from other causes; however, public concerns still persist. ▪ Critics of fracking, however, have argued that no scientific evidence exists conclusively showing that fracking does not cause groundwater contamination.
Can fracking cause flaming tap water?	▪ It is doubtful that fracking is the reason for these events. ▪ Before fracking, there were instances in which natural gas was known to seep into water wells; evidence points more to other sources for methane in water sources; much of the naturally forming methane lies near the surface.
Does fracking have a good safety record?	▪ Up to now, the industry has had a good safety record, although some observers would dispute this claim and also argue that past experiences aren't all that relevant. ▪ Unanswered questions remain about certain risks.
Does fracking consume large amounts of water?	▪ Relative to many non-energy activities, it is not large. ▪ Compared with other energy sources in terms of water use per MMBtu produced, it is much lower. ▪ Water use for shale gas drilling constitutes a minuscule portion of the total water use in an area; at the margin, however, especially in drought areas, it can pose challenges.
Does fracking pose a higher public-health risk than conventional drilling practices?	▪ Because of the fracking fluid and wastewater, fracking inherently poses a higher risk. ▪ With faulty well completions and other operational failures, the environmental and public-health consequences would be more serious.
Is shale gas more damaging than coal in emitting greenhouse gases?	▪ Other than the Cornell study, the evidence seems to point in the other direction. ▪ The DOE Advisory Board as well as IHS CERA recommends additional studies and better data to measure upstream methane emissions from shale-gas production.

Table of Contents

Hydraulic Fracturing: Placing What We Know Today in Perspective

Hydraulic fracturing ("fracking") has the potential, along with other processes, such as horizontal drilling and computerized well controls, to provide the U.S. and other countries around the world with natural gas for several decades into the future. Most new natural-gas wells around the world uses fracking techniques. Shale gas has been one of the few bright spots in the U.S. economy over the past four years.[1] We find reserves of shale gas in different regions of the country. (*See* the Appendix.) The current consensus is that shale gas will help to assure sufficient U.S. gas supplies over the next several decades.[2]

Studies measuring reliably the total risk of shale-gas production from the combination of horizontal drilling and hydraulic fracturing are lacking. We should expect better information over the next two years. In the meantime, as argued in the paper, waiting for new evidence does not justify banning fracking[3] or imposing major restrictions on shale-gas production—the cost to the country is ostensibly too great relative to the benefits.[4] Policymakers should beware of maneuvers to use studies as a means to suspend or curtail shale-gas production. Some groups might argue, for example, that shale-gas production should stop until we have better information on the public-health hazards. But it is likely that these studies will not provide the definite information that policymakers hope to obtain. Thus, they will still have to make decisions under uncertainty, although the degree of uncertainty should be lower as more scientifically based studies become available. Although such a policy appears reasonable as of today, new evidence

---

[1] As expressed by the U.S. Energy Information Administration:

> The combination of horizontal drilling and hydraulic fracturing technologies has made it possible to produce shale gas economically, leading to an average annual growth rate of 48 percent over the 2006-2010 period. (*Annual Energy Outlook 2011* at http://www.eia.gov/forecasts/aeo/chapter_executive_summary.cfm#domestic.)

[2] *See*, for example, U.S. Department of Energy and National Energy Technology Laboratory, *Modern Gas Shale Development in the United States: A Primer*, April 2009.

[3] From an international perspective, countries have taken different positions on fracking and shale-gas production. For example, France has banned fracking while Poland has moved ahead with shale-gas production; the United Kingdom intends, as of this writing, not to review shale-gas production, partially because of a report that concluded the existence of no major threat from fracking and production.

[4] The U.S. Energy Information Administration projects that over the next two decades a low-growth scenario for shale-gas production will cost natural-gas consumers hundreds of billions of dollars, compared to a reference or high-growth scenario. *See* http://www.eia.gov/forecasts/aeo/IF_all.cfm#prospectshale.

showing serious hazards from fracking and shale-gas production could justify tight restrictions. We should wait only until then to take such actions.

Fracking is not new—it goes back more than 60 years in this country;[5] what is relatively new is the combination of horizontal drilling and fracking. It is this combination that has come under fire over the past couple of years because of charges that it can pose environmental and public-health risks. In previous times, when fracking was used with vertical drilling, the adverse effect from an engineering or operational problem was potentially much less than that from horizontal drilling. The amount of fracking fluid that can backflow and cause damage, for example, is much greater with horizontal drilling.[6] Also, up until about four years ago, fracking occurred mostly in low-density areas with an accompanying low risk to public health. Since then, fracking has proliferated in densely populated states. One major reason for the increased attention on fracking is the potential risk that it can pose to larger population centers.

The U.S. Environmental Protection Agency and other groups are undertaking major studies that will examine the environmental and public-health risks that fracking poses. These studies will report their findings over the next couple of years. We should then know more about the risks of fracking. We will also know what aspects of fracking and shale-gas production pose the greatest public-health risk. This new information should allow policymakers at all levels of government to make better informed decisions on subsequent actions. Several states have already taken action, in some instances major initiatives, in spite of the absence of definitive information. These activities reflect the public's concern that fracking might pose a public-health threat.

Although the vast majority of state utility commissions do not regulate natural-gas drilling, they do have an interest in the fracking debate because of the effect on the future supply and price of natural gas.[7] When making important decisions, state utility commissions frequently must choose among competing natural-gas price forecasts. Natural-gas prices are critical to a range of regulatory decisions covering both electric and gas utilities.[8] Natural-gas prices are often a crucial variable in electric-generation capacity planning and in benefit-cost

---

[5] The first commercial application of hydraulic fracturing likely occurred in either the Hugoton field of Kansas in 1946 or near Duncan, Oklahoma in 1949. *See* http://fracfocus.org/hydraulic-fracturing-how-it-works/history-hydraulic-fracturing.

[6] I thank Robert Burns for this insight.

[7] Incidentally, in July 2009, NARUC passed a resolution entitled "Supporting State Regulation of Hydraulic Fracturing." The reader can access the resolution at http://www.naruc.org/Resolutions/Resolution%20on%20Hydraulic%20Fracturing.pdf.

[8] *See*, for example, the NRRI paper "Looking before Leaping: Are Your Utility's Gas Price Forecasts Accurate?" at http://nrri.org/pubs/gas/NRRI_gas_price_forecasting_may10-08.pdf.

calculations for demand-side and energy-efficiency programs. Gas-price forecasts will rely on the magnitude of shale-gas production, which in turn will hinge on the resolution of the fracking debate.

I. Purpose of the Paper

This paper will identify the different positions on fracking without making any assessment or recommendation as to "who is right." Both sides of the fracking debate are passionate, making it difficult to reach a consensus among different groups even if the scientific evidence points in one direction.[9] An example of the polarizing positions is a recent dialogue between CEO of Chesapeake Energy Aubrey McClendon and former governor of Pennsylvania Ed Rendell. McClendon has labeled some opponents of fracking extremists when they intentionally misinform the public and instill fear into people about the risk of fracking. He argues that fracking and shale-gas production have a good track record for safety. Rendell criticizes shale-gas producers for making serious mistakes in the past that have jeopardized the public's health and for putting profits ahead of safety. He has said that past negligence by gas producers is the reason for public opposition to fracking.[10]

The paper will use "consensus" information to show where the various groups seem to have understated or overstated fracking risks. It will attempt to distinguish fact from opinions and self-interested positions. The paper will not independently assess the scientific evidence and other information on those risks.

The paper will address the relevant policy question "What is the cost of making a wrong decision?" It will highlight the important policy topic "What is the cost of regulating fracking with erroneous information on the actual risk?" For example, tight regulation presumes high risk that may turn out to be wrong. The social cost is uneconomic costs to gas producers, loss of jobs, and higher prices to consumers. On the other hand, light regulation when actual risk is high could lead to serious environmental and public-health problems. How policymakers evaluate these two risks in their decisions depends in part on their aversion to each one. Two groups with the same information can arrive at different decisions because of differing value judgments on the relative importance of objectives. One group that values a cleaner environment more than another group would tend to favor stricter regulations. Groups might also stick to a position that

[9] Two polls taken in New York illustrate the division of citizens over the desirability of shale-gas production. One poll shows that 45 percent of respondents favor shale gas drilling while 41 percent oppose it. In a second poll, respondents indicated that they trust opponents of fracking more than supporters by a 51 percent to 33 percent margin. *See* SNL Energy, "Poll: NY Voters Believe Shale Gas Opponents More Than Industry," *Daily Gas Report*, September 29, 2011, 1, 10.

[10] *See* SNL Energy, "Blame Game: McClendon Rips Anti-Gas Groups; Rendell Blasts Industry," *Daily Gas Report*, September 9, 2011, 1, 12.

promotes their self-interest, no matter what the evidence says. Cheap gas, for example, will undermine some energy-efficiency efforts, stifle the development of renewable energy, make many research and development efforts no longer justifiable, and curtail the use of coal.

The paper will also present an overview of the concerns that different groups have expressed about fracking. It will refer to and cite studies on fracking. If there is a consensus, it is that we need better data and additional analyses to create more fact-based and scientific evidence. Better evidence can help close the gap between the scientific evidence and the public perception of fracking hazards. As of today, the gap is wide. Part of the reason may be poor dissemination of the scientific knowledge that exists. Non-scientific information, much of which is ideologically and self-interestedly motivated, may be dominating the scientific information in affecting public perceptions.

But even with the closing of the gap, polarizing views will likely prevail in the future because of some groups' mistrust of the evidence and their unwillingness to change their beliefs in spite of new evidence that contradicts those beliefs. Groups' resistance, in fact, might harden as they see the latest evidence threatening their position. This reaction can further deepen the partisan and ideological tone of groups' positions.

A statistical concept called Bayes' theorem relates people's prior beliefs to their later beliefs based on new evidence.[11] Assume that two groups of people today have vastly different views on the risks of fracking; the first group believes the risks are small while the second group believes the risks are large. If new scientific studies show potentially high risk, one would expect the first group to change its beliefs by assigning a higher risk to fracking than it did previously. But if this group finds changing its public position on fracking contrary to its economic interests, it might instead hire experts to rebut the new findings. The second group would tend to respond the same way if the new evidence showed small risks from fracking. Suboptimal decisions can result when the policymaker (a) disregards the new evidence, unless he can demonstrate that this evidence is incredible; or (b) overreacts to the evidence by ignoring his prior beliefs, which presumably had some reasonable rationale. People generally will give more plausibility to the evidence on fracking—or other things, for that matter—when it coincides with their prior beliefs.

Another reason for the likely differences of views is that scientific efforts, no matter how sophisticated and sound, often fail to give policymakers the unambiguous consensus they seek. How then should policymakers use scientific evidence when it is inconclusive and conflicting? This reality complicates matters, but policymakers can apply rational approaches, which this paper will discuss in Part V.

---

[11] *See*, for example, Sharon Bertsch McGrayne, *The Theory That Would Not Die: Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines and Emerged Triumphant from Two Centuries of Controversy* (New Haven, CT: Yale University Press, 2011).

Finally, the paper will attempt to clarify some of the confusion over fracking. For example, many of the problems associated with drilling do not relate to fracking itself, a fact that has not been reported as such. Overall, the paper hopes to provide state utility regulators with balanced information on fracking; namely, *what would a knowledgeable, disinterested person say today about fracking based on the scientific and other fact-based information? With this information, what actions should the state and federal governments take that they haven't yet taken? What are the minimum restrictions on fracking that seem appropriate given what we know about fracking today?*

II. Definition of Fracking and Its Benefits

A. What is fracking?

Fracking is a technique that releases trapped natural gas in shale by injecting at high pressure fluids usually consisting of water, sand, and chemicals.[12] Typically over 99 percent of the fracking fluid is composed of water and sand. The high pressure allows the cracking open of the otherwise impermeable shale, freeing the trapped gas, which then flows through the horizontal bore into the well casing and up to the surface. As the fracking fluid recedes, sand holds open the fractures, allowing natural gas to flow up the well. Some of the fracking fluid flows with the gas to the surface, where it is pumped away for disposal; the rest remains underground.[13]

Gas producers have three options for disposing of the wastewater after drilling: (1) storage in evaporative ponds on the well site, in a lined pit or in tanks; (2) disposal wells; and (3) reusing or recycling.[14] Wastewater consists of the fracking fluid plus in-situ formation water, which contains a high composition of salt[15] and often heavy metals and radioactive materials. A

---

[12] Much of the information in this subsection comes from the U.S. Environmental Protection Agency website at http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm; and U.S. Department of Energy and National Energy Technology Laboratory, *Modern Gas Shale Development in the United States: A Primer*, April 2009 at http://www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf.

[13] For a 3-D interactive graphic that takes the viewer underground step-by-step through the process of fracking and horizontal drilling, *see* the National Geographic website at http://news.nationalgeographic.com/news/2010/10/101022-breaking-fuel-from-the-rock/.

[14] This approach will likely become more common in the future for both environmental and economic reasons. Treating wastewater is costly and controversial because of past problems in removing all the toxic and other harmful contents before dumping it in waterways.

[15] The salt composition typically is about three times greater than seawater's.

major concern is that this wastewater can cause serious environmental and public-health problems if disposed of improperly. A relevant question relates to what constitutes adequate disposal of wastewater. Should wastewater be recycled or placed in disposal wells if treatment is found to be inadequate?

B. The benefits of fracking

Fracking, along with horizontal drilling, is critical in extracting large volumes of gas from shale that can supply the U.S. market for decades. Without fracking, shale gas would not be economical. The energy guru Daniel Yergin has called this development the biggest energy innovation of this century. The effect of shale gas on the U.S. and worldwide energy markets will be nothing short of remarkable. With an abundance of domestic natural gas, the U.S. will be able to rely much less on foreign sources of gas, such as liquefied natural gas. Predictions of lower and more stable natural gas prices, saving gas consumers hundreds of billions of dollars over the next two decades,[16] should improve the economics of natural gas for different uses, notably in the electric power and transportation sectors.[17] Shale gas also means lower operation of coal-fired generation facilities, resulting in potentially large environmental benefits. Shale gas has so far created about 200,000 new jobs (direct, indirect, and induced) at a time of severe economic challenges. Finally, it has generated additional revenues for different levels of government.[18]

III. What Are the Major Concerns with Fracking?

Different reasons exist for why fracking and shale-gas production in general can lead to public-health and environmental risks. They include:

1. *Normal problems with well drilling, such as faulty well completions, sloppy operational practices, and careless labor activities*: Evidence points to faulty well completions as a major cause of groundwater contamination from shale-gas

---

[16] *See* footnote 4.

[17] Most forecasters, for example the U.S. Energy Information Administration, have revised downward their long-term natural-gas price forecasts as the estimated amount of recoverable shale gas has continuously increased over the past three years.

[18] *See*, for example, Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-Gas Production Subcommittee Ninety-Day Report*, August 11, 2011, 7 at http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf; and Timothy Considine et al., *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*, Pennsylvania State University, College of Earth and Mineral Sciences, July 24, 2009 at http://www.alleghenyconference.org/PDFs/PELMisc/PSUStudyMarcellusShale072409.pdf.

production. Gas can escape from more shallow geological formations into the groundwater. The main protection against water contamination is the steel and cement casings that act as a separating wall. Other causes of contamination are the release of methane into aquifers, surface spills, and other operational failures.

2. *Inadequate treatment of surface wastewater*: Pennsylvania experienced this problem when producers sent wastewater to sewage-treatment plants that were ill-equipped to clean it properly. Some of the wastewater contained radioactive materials and carcinogens (e.g., benzene). The inadequately treated wastewater was then released into rivers and other waterways. The problem of wastewater disposal is more acute in the East, where the absence of disposal wells restricts gas producers to discharging their wastewater at treatment plants.
3. *Transport of waste and chemicals*
4. *Spills*
5. *Well blowout (explosions) during fracking*: A blowout can spill fracking fluid on surrounding lands and surface waters.
6. *Methane emissions into the air and nearby drinking-water wells*: Emissions can result from fracking or other aspects of natural-gas production. Fugitive methane results from leaks in the well components that can cause methane (a concentrated form of greenhouse gas) to flow into the air. Methane migration results from leaks that can cause methane to flow into water wells and contaminate the water.[19]

Any natural-gas well has inherent safety and environmental risks. The question becomes: To what extent does shale-gas production pose more risk than conventional gas production? Fracking itself is not the reason for many of the problems associated with shale-gas production. Policymakers should distinguish between problems caused by fracking itself and problems originating from other aspects of shale-gas production.

Critics of fracking have expressed a number of concerns:[20]

1. *Inadequate regulations*[21] *and lax enforcement of existing regulations at the federal level*: Two examples are the so-called "Halliburton loophole," in which wastewater

---

[19] A major cause of methane migration is flaws in the cementing and casing of the wells.

[20] One extreme position expressed by some fracking opponents is that no safe way exists to inject toxic chemicals into the ground and control them.

[21] Although federal regulation of fracking falls under the Clean Water Act, the Clean Air Act, parts of the Safe Drinking Water Act, and the National Environmental Policy Act, the underground injection of fracking fluids is subject only to state regulations. A current policy issue is whether it should be subject to federal regulation. The Energy Policy Act of 2005 excluded wells that are hydraulic fractures from being reclassified as injection wells, which

coming out of the ground from shale-gas drilling does not have to be tested; and the fact that no regulation of methane as a contaminant in public water systems exists. Those opposed to, or skeptical of, federal regulation have argued that the combination of competent state regulation, voluntary industry actions, and technological advances should sufficiently assure environmentally safe fracking. If in fact this combination of events fails to evolve or is deemed inadequate, then federal regulation would be more tenable.

2. *Some states lack regulatory experience with natural-gas production*: In contrast, other states, such as Texas, Oklahoma, and Louisiana, have much experience in regulating fracking, the handling of "produced water," and the release of methane near fracked well sites. Most states with newly producing shale sites, however, do not yet have such regulations and are in the process of establishing them.

3. *The potential effect of fracking on drinking water and groundwater, public health, and environmental impacts in the vicinity of gas wells*. Specifically, environmentalists and others have expressed concerns over (a) methane emissions transported to drinking-water wells and the atmosphere, (b) inadequate treatment of wastewater byproducts for release into rivers and other bodies of water, (c) radioactive materials in the wastewater from fracking appearing downstream, (d) well blowout spilling fracking fluid on surrounding land, and (e) the large amount of water required for each fracked well.

The biggest fear of the public is that the wastewater could get into the water supply. For example, fracking could leach dangerous chemicals into groundwater and contaminate it with methane gas and produced water and fracking fluids, which contain a mix of chemicals that gas producers often do not disclose.

BP's Deepwater Horizon disaster and other incidents of recent years have raised questions about the willingness and capability of the U.S. oil and gas industries to create a strong safety culture.[22] Do the industry and individual producers apply "best management" practices to ensure safe fracking? The industry faces the risk that safety slackers could cut corners, leading to incidents followed by tight regulations that impose a high cost on the industry.

---

would place them under the Safe Drinking Water Act. (One exception is the use of diesel fuel during fracking, which falls under the Underground Injection Control program.)

[22] A September 2011 report by the federal government concluded that BP took shortcuts that contributed to the blowout and oil spill. Specifically, it identified the biggest contributor to the explosion as the failure of the cement casing at the bottom of the well to contain oil and natural gas within the well bore. The report also concluded that the incident originated from different mistakes by multiple parties—a finding consistent with previous investigations of the incident. *See* John M. Broder, "BP Shortcuts Led to Gulf Oil Spill, Report Says," *The New York Times*, September 14, 2011.

It would be in the industry's own best interest to set its own standards to mitigate safety problems that could have a substantial financial effect on gas producers. Self-regulation can sometimes be a sufficient deterrent of bad behavior, especially when firms are able to detect behavior that can harm all firms in the industry.[23] Even with self-regulation, the states or the federal government would likely want to (1) set minimum standards[24] and (2) assure the public that the industry is enforcing its own standards. The same rationale exists for why the federal government might want to act as a safety net if states fail to ensure minimum protection of the environment and public health. One failure might come from the state regulatory agency's failure to monitor adequately and inspect gas drilling and production sites.

Self-regulation might be unacceptable to some readers, but it does represent one side of the regulation spectrum, with stringent governmental regulation on the other side. As an alternative, shale-gas producers could work with state regulators to establish regulations that the public perceives as adequate in mitigating fracking hazards.[25] As mentioned more than once in this paper, for its own sake if nothing else, industry should not oppose weak regulations and enforcement. If incidents occur, the expected fallout is first for the public to blame underregulation and then for the government to take actions that err on the side of overregulation—an outcome that the industry will learn to regret. Another factor that could jeopardize shale-gas production is litigation. Gas producers have already seen lawsuits filed against them for drinking-water contamination and other incidents. Although the topic is not addressed in this paper, the author recognizes the substantial adverse effect that lawsuits can have on shale-gas producers.

---

[23] The harm can come from costly regulations, which experiences in other contexts have shown frequently to reflect an overreaction to an incident caused by the laxity of just one firm.

[24] Some groups have argued for minimum federal standards, arguing that politics might dominate state or local efforts to regulate fracking and shale-gas production adequately. Federal standards do not preclude a state or locality from enforcing stricter regulatory rules if they are deemed to be in the public interest.

[25] One good example of cooperation was between the Texas legislature and the gas industry in creating a new law that requires gas producers to disclose the chemicals in their fracking fluid. The Texas Railroad Commission adopted a set of rules that met with approval by environmental organizations. *See* http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/6423262.

IV. Hard Facts, Half-Truths, and Nonsense about Fracking[26]

Much of the public information on the hazards of fracking is of dubious accuracy. This state of affairs reflects a combination of the absence of good scientific evidence and the ideological posturing and self-interested motives of various groups. Industry and others contend that fracking opponents have internationally disseminated misinformation to halt or hinder shale-gas production.[27] On the other side, fracking skeptics complain that industry is understating the risks of fracking to avoid stricter regulations and litigation.

Below, the author offers his comments on seven controversial aspects of fracking that so far have dominated the public-policy debate. (S*ee* also Table 1 for a summary of these comments.) The question here is: What does the balance of evidence suggest about the environmental and public-health risks of fracking?

A. Does fracking cause earthquakes?

While disposal wells can cause earthquakes, the magnitude is probably too small to cause any damage. Some observers attribute the earthquakes in Virginia and Colorado in August of this year to fracking.[28] The U.S. Geological Survey (USGS) has documented cases of earthquakes in which fracking was a possible cause.[29] On its website, the USGS has this explanation:

---

[26] The author adopted these terms from the title of the book *Hard Facts, Dangerous Half-Truths, and Total Nonsense: Profiting from Evidence-Based Management*, co-authored by Jeffrey Pfeffer and Robert Sutton (Cambridge, MA: Harvard Business School Press, 2006).

[27] Two culprits singled out by the gas industry are *The New York Times* and the documentary *Gasland*, which was nominated for an Oscar in 2011. The *Times* has been running articles highlighting the safety and environmental risks of fracking. One article reported that shale-gas drillers in Pennsylvania were flushing large quantities of contaminated wastewater into rivers that supply drinking water. The wastewater contained radioactive materials and carcinogens, such as benzene. Critics of *Gasland* were especially critical of the allegation that natural-gas drilling causes flaming tap water.

[28] New York, Oklahoma, and Texas have had small earthquakes that some experts attribute to fracking. The United Kingdom has also experienced instances in which fracking may have caused earthquakes. *See* "Earthquake Fears Halt Shale Gas Fracking" on the website of *The Financial Times* at http://www.ft.com/intl/cms/s/0/0577dda0-8c82-11e0-883f-00144feab49a,s01=1.html#axzz1XZdP5y3D.

[29] *See*, for example, the USGS website at http://pubs.usgs.gov/of/2002/ofr-02-0073/ofr-02-0073.html.

> Earthquakes induced by human activity have been documented in a few locations in the United States, Japan, and Canada. The cause was injection of fluids into deep wells for waste disposal and secondary recovery of oil, and the use of reservoirs for water supplies. Most of these earthquakes were minor. The largest and most widely known resulted from fluid injection at the Rocky Mountain Arsenal near Denver, Colorado. In 1967, an earthquake of magnitude 5.5 followed a series of smaller earthquakes. Injection had been discontinued at the site in the previous year once the link between the fluid injection and the earlier series of earthquakes was established. (*See* http://earthquake.usgs.gov/learn/faq/?faqID=1)

Although the evidence shows minimal damage from fracking-induced earthquakes, regulators might want gas producers to avoid geologically active areas and those areas with shallow faults that could cause vertical migration of the fracking fluid.[30] Regulations might include, for example, minimum distances between disposal wells and fracture treatments, and major faults.

B. Does the composition of fracking fluids affect the public health?

The answer is "yes" to the extent that the fluids include chemicals that for one reason or another could leak into the groundwater or wells. Even though fracking fluid typically contains less than one percent chemicals, they can cause substantial harm when leaked into the groundwater or drinking-water wells. Concerns over the hazards of fracking mainly originate from how high a percentage of chemicals the fracking fluid contains.[31] A U.S. Geological Survey document, for example, expressed that:

> Whereas the percentage of chemical additives in a typical hydrofrac fluid is commonly less than 0.5 percent by volume, the quantity of fluid used in these hydrofracs is so large that the additives in a three-million-gallon hydrofrac job, for example, would result in about 15,000 gallons of chemicals in the waste.[32]

C. Does fracking contaminate groundwater?

Contamination of drinking-water wells depends on several factors, including the toxicity of the fracking fluid and the produced water, the transport and disposal of wastewater, and the distance of the gas well to the drinking-water well. The produced water, for example, may contain salts, metals, and radioactive chemicals found thousands of feet below the surface.

---

[30] I thank Robert Burns for this insight.

[31] The gas industry has started to experiment with fracking fluids that contain no chemicals.

[32] *See* http://geology.com/usgs/marcellus-shale/.

The U.S. EPA has noted the following:

> Contaminants of concern to drinking water include fracturing-fluid chemicals and degradation products and naturally occurring materials in the geologic formation (e.g., metals, radionuclides) that are mobilized and brought to the surface during the hydraulic fracturing process.[33]

Based on more than one million wells drilled with fracking, however, there is little evidence that fracking directly causes groundwater contamination. The major explanation is that fracking typically occurs thousands of feet below the groundwater level. Reports of water-contamination incidents originating from fracking itself do not exist. Instead, reports show that these incidents resulted from surface spills, poor cementing jobs in wellbores, and other operational failures. Critics of fracking point to the lack of conclusive evidence that fracking does not cause groundwater contamination.[34] The gas industry and regulators, it seems, need to better educate the public on factors that can cause groundwater contamination and the extent to which fracking is a likely cause. Natural-gas producers have not helped their cause by refusing to disclose the chemicals used in their fracking fluid. The public, rightly so, perceives that producers are trying to hide something that they do not want exposed.

The contamination of drinking-water wells with methane and wastewater above ground has been a public concern. In some states, notably Pennsylvania, we have seen spills of fracking fluids and flowback into watershed areas. The state's environmental protection agency has imposed a large number of fines—for example, upon gas producers who spill thousands of gallons of used fracking fluids into waterways.[35] Fracking causes these above-ground spills because they involved fracking fluids. The problem, then, seems to lie with laxity in above-ground construction and enforcement.

A fundamental question relates to what happens to the wastewater once it releases the natural gas from the shale. The driller may store the "flowback" until disposal or reuse. But problems have caused spills into local drinking water. The evidence leans toward other factors

---

[33] See the U.S. EPA's webpage, "Hydraulic Fracturing Research Study," 2 at http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf.

[34] They point to complaints in several states, for example, where residents have reported changes in water quality following fracking operations at gas wells near their homes.

[35] An October 2010 report by the Pennsylvania Land Trust Association found that shale-gas producers in Pennsylvania violated the law 1,614 times between January 2008 and August 2010, including 1,056 violations that had or were likely to have an adverse environmental effect. Violations included improper well-casing construction, blowout prevention, improper construction of wastewater impoundments, and permitting violation. The data for the report came from the Pennsylvania Department of Environmental Protection. *See* http://switchboard.nrdc.org/blogs/amall/shocking_new_report_pa_natural.html.

largely accounting for those incidents. They include leaking storage pits, faulty well completion, and leaking production equipment. As of today, we are not 100 percent certain of the causes of spills. If these are the actual causes, however, then the solution is for drillers to take the necessary precautions by executing sound engineering methods and safety practices.

Knowing what causes water contamination is one example in which policymakers would benefit from more fact-based information. A related area of needed research is measurements of the health effects of methane-contaminated drinking water.

D. Can fracking cause flaming tap water?

The allegation that fracking causes flaming tap water was highlighted in the documentary *Gasland*. It is doubtful that fracking is the reason for these events; before fracking, there were instances in which natural gas was known to seep in water wells. Evidence points more to other causes of methane in water sources, including drilling through a geologically unstable formation, faulty well completion, and natural phenomena.[36] In many regions of the country, enough methane is in the ground to leak into people's well water. Much of the naturally forming methane lies near the surface. But so far the evidence is inconclusive. Here is another example in which policymakers need better fact-based and scientific evidence to identify the causes of flaming tap water.

E. Does fracking have a good safety record?

Up to now, most observers would say that the industry has had a good safety record, although other observers would dispute this claim. Unanswered questions still remain over the risks that fracking poses for the environment, especially when done on a much larger scale and under more varied circumstances than in the past. We should see answers to some of these questions from studies over the next two years. (*See* Part VI.)

The DOE Advisory Board mentioned that the past safety record may not be all that relevant:

> Advocates state that fracturing has been performed safely without significant incident for over 60 years, *although modern shale gas fracturing of two-mile-long laterals has only been done for something less than a decade*.[37] (Emphasis added)

---

[36] For a rebuttal of *Gasland*'s allegation that fracking causes contamination of water wells with methane, *see* the State of Colorado Oil and Gas Conservation Commission website at http://cogcc.state.co.us/library/GASLAND%20DOC.pdf.

[37] Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-Gas Production Subcommittee Ninety-Day Report*, August 11, 2011, 13.

F. Does fracking consume large amounts of water?

Compared to some non-energy-producing activities, such as farming and watering golf courses, fracking does not consume unusually large amounts of water. Also, water use per MMBtu produced is much higher for conventional oil production, coal production, nuclear power, diesel fuel, and gasoline than for shale-gas production. Water use for shale-gas drilling constitutes a minuscule portion of the total water use in an area. At the margin, however, especially in drought areas, it can pose challenges. The DOE Advisory Board report stated that:

> While water availability varies across the country, in most regions water used in hydraulic fracturing represents a small fraction of total water consumption. Nonetheless, in some regions and localities there are significant concerns about consumptive water use for shale gas development.[38]

A report by the National Conference of State Legislatures also expressed concern:

> Approximately 2 million to 4 million gallons of water are needed to drill and fracture a horizontal shale gas well. Although this volume can be relatively small for an area's overall surface water budget, using that much water in a short time period may challenge infrastructure and supplies. Significant water withdrawals could affect municipal water supplies, aquatic life, fishing and recreational activities, and industries such as power plants that depend on water use.[39]

G. Does fracking pose a higher public-health risk than conventional drilling practices?

Because of the fracking fluid and wastewater involved, fracking has a higher risk. If faulty well completions and other operational problems occur, the environmental and public-health consequences could be more serious. It therefore becomes even more imperative for gas producers that use fracking not to cut corners and to maintain a strong safety culture that has little tolerance for mistakes. Even in the absence of special fracking problems, gas drilling has inherent risks for public safety and the environment that policymakers cannot ignore.

H. Is shale gas more damaging to the environment than coal in emitting greenhouse gases?

The question relates to shale-gas production in general—not fracking specifically. Other than the Cornell study, the evidence suggests that coal emits more greenhouse gases than shale

---

[38] Ibid., 19.

[39] The National Conference of State Legislatures, "Regulating Hydraulic Fracturing: States Take Action," December 2010, 3 at http://www.ncsl.org/?tabid=22021.

gas. The DOE Advisory Board as well as IHS CERA recommends additional studies and better data to measure upstream methane emissions from shale-gas production.[40]

Industry and others have pointed out fundamental flaws in the Cornell study. Criticizing a study is much easier, however, than coming up with new evidence that passes scientific peer review. One criticism relates to the assumptions made about the "lost and unaccounted for" gas, or the gap between the amount of gas at the wellhead and the amount that gets to the retail market. The study did not attempt to measure how much of that gas goes into the atmosphere.

Results from the Cornell study suggest that natural gas might not be the clean source of energy the industry claims, especially in terms of greenhouse-gas emissions.[41] The study also showed methane emissions to be much higher from shale-gas production than from conventional gas production.[42]

V. Disagreement over Policy: Can We Reach a Consensus?

Assume that everyone has the same information about the public-health risk of fracking. Assume also that everyone agrees that shale-gas production has the same social benefits. Why, then, would we continue to see a wide divergence of viewpoints?

---

[40] See Parts VI.A and VII below for a summary of these studies. In its initial report, the DOE Advisory Board said that:

> Methane emissions from shale gas drilling, production, gas processing, transmission and storage are of particular concern because methane is a potent greenhouse gas: 25 to 72 times greater warming potential than carbon dioxide on 100-year and 20-year time scales respectively. Currently, there is great uncertainty about the scale of methane emissions…inadequate data are available about how much methane and other air pollutants are emitted by the consolidated production activities of a shale gas operator in a given area, with such activities encompassing drilling, fracturing, production, gathering, processing of gas and liquids, flaring, storage, and dispatch into the pipeline transmission and distribution network. (Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-Gas Production Subcommittee Ninety-Day Report*, August 11, 2011, 16.)

[41] Natural gas is mostly methane, which is a major source of greenhouse gas.

[42] The reason is the substantial amounts of methane emissions from flowback fluids that return to the surface. The study estimated that methane emissions from shale-gas production are 30-50 percent higher than those from conventional gas production.

A. Differences over credibility of the scientific evidence and interpretation of the evidence

One reason is disagreements over the credibility of scientific and other evidence (i.e., over the facts). People may disagree over the certainty of the evidence or the relevance of the evidence for each shale-gas basin.

Another explanation is the presence of differences over the interpretation of the scientific evidence for regulatory actions and policies. One group may interpret evidence of low probability of public-health risks to justify a precautionary ("better safe than sorry") approach;[43] another group may interpret the same evidence to justify no additional action. People assign differences to the social optimal trade-offs between the environmental risks and economic benefits of fracking (i.e., differences over the weights assigned to various societal objectives; namely, better economic conditions and less public-health risk). The gas industry has argued that experience and existing knowledge have shown minimal and manageable risks from fracking. Because the benefits from fracking and shale production are huge, the industry's argument is that any major regulatory actions would inevitably be harmful to society as a whole. The policy implication is the absence of a legitimate reason for additional federal regulation because state regulation, along with safe industry practices, has ostensibly protected the environment and public health.

Differences in trade-offs might stem more from the self-interests of different groups than from what is in society's best interest. For example, environmentalists are likely to assign a high weight to environmental and public-health effects that exceed what is socially optimal. For self-interest reasons, the gas industry is likely guilty of assigning excessive weight to economic benefits, relative to other social benefits, from shale-gas production. The job of the policymaker is to determine the socially optimal "weights." This is a difficult task, but one that is unavoidable for good decisionmaking that aspires to serve the public interest.

[43] S*ee* the next subsection on "the precautionary approach."

Table 1: Frequently Asked Questions about Fracking

Question	Comment
Does fracking cause earthquakes?	▪ Disposal wells can cause earthquakes. ▪ The US. Geological Survey (USGS) has documented cases of earthquakes in which fracking was a possible cause. ▪ The magnitude is probably too small to result in any damage.
Does the composition of fracking fluids affect the public health?	▪ Yes, to the extent that the fluids include toxic chemicals that for one reason or another leak into the groundwater or wells. ▪ The gas industry has started to experiment with fracking fluids that contain no chemicals.
Does fracking contaminate groundwater?	▪ There is little evidence of a cause-and-effect relationship between fracking and contaminated water. ▪ Many of the water-contamination incidents may not have come from fracking itself but have resulted from other causes; however, public concerns still persist. ▪ Critics of fracking, however, have argued that no scientific evidence exists conclusively showing that fracking does not cause groundwater contamination.
Can fracking cause flaming tap water?	▪ It is doubtful that fracking is the reason for these events. ▪ Before fracking, there were instances in which natural gas was known to seep into water wells; evidence points more to other sources for methane in water sources; much of the naturally forming methane lies near the surface.
Does fracking have a good safety record?	▪ Up to now, the industry has had a good safety record, although some observers would dispute this claim and also argue that past experiences aren't all that relevant. ▪ Unanswered questions remain about certain risks.
Does fracking consume large amounts of water?	▪ Relative to many non-energy activities, it is not large. ▪ Compared with other energy sources in terms of water use per MMBtu produced, it is much lower. ▪ Water use for shale gas drilling constitutes a minuscule portion of the total water use in an area; at the margin, however, especially in drought areas, it can pose challenges.
Does fracking pose a higher public-health risk than conventional drilling practices?	▪ Because of the fracking fluid and wastewater, fracking inherently poses a higher risk. ▪ With faulty well completions and other operational failures, the environmental and public-health consequences would be more serious.
Is shale gas more damaging than coal in emitting greenhouse gases?	▪ Other than the Cornell study, the evidence seems to point in the other direction. ▪ The DOE Advisory Board as well as IHS CERA recommends additional studies and better data to measure upstream methane emissions from shale-gas production.

B. The precautionary approach

The *precautionary approach* is used in setting environmental and safety policies across different industries and contexts. This approach says that even in the face of uncertainty, society should act today to avoid major problems in the future. Uncertainty in our discussion here refers to the lack of complete proof that fracking is seriously harmful to public health. The uncertainty can arise, for example, from unreliable evidence of a causal link between fracking and groundwater and surface-water contamination. The precautionary approach says that society takes an inordinate risk when it acts to prevent a potential harmful event only under scientific certainty. The approach errs on the side of caution in protecting the general public from risk.

The precautionary approach, therefore, reflects a "better safe than sorry" stance that assigns a benefit to prevention even with inconclusive risk. It acts as insurance against major future problems or catastrophic events. For fracking, the precautionary approach would recognize both (1) its possible threats to the environment and public health and (2) the inconclusive nature of the scientific evidence.

Measured precautionary actions might include mandatory water sampling (before and after drilling),[44] funding of risk studies on fracking, and disclosure of chemicals used in fracking.[45] These are relatively low-cost actions that are hard to oppose, even with the

---

[44] Some gas producers, like Chesapeake Energy in Pennsylvania, have voluntarily sampled drinking wells near their gas wells. One reason for this action is to protect themselves from liability. In Colorado, gas producers have agreed to do water samples before and after drilling and to submit the results to the Colorado Ground Water Committee. *See* SNL Energy, "Colorado Launches Water Sampling Program in Collaboration with Industry," *Daily Gas Report*, August 3, 2011, 1-2. The DOE Advisory Board recommended measurement of water quality of wells near shale-gas production sites:

> Availability of measurements in advance of drilling would provide an objective baseline for determining if the drilling and hydraulic fracturing activity introduced any contaminants in surrounding drinking water wells… the value of these measurements for reassuring communities about the impact of drilling on their community water supplies leads the [Advisory Board] to recommend that states and localities adopt systems for measurement and reporting of background water quality in advance of shale-gas production activity. (Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-gas production Subcommittee Ninety-Day Report*, August 11, 2011, 23.)

[45] A few states, as of the time of this writing, require gas producers to disclose the chemicals used in fracking fluid. They include Louisiana, Michigan, Texas, and Wyoming. Some gas producers have voluntarily agreed to disclose the chemicals they use; some states are moving toward requiring full disclosure of the fracking fluids. In April 2011, the Ground Water Protection Council (composed of state regulatory agencies) and the Interstate Oil and Gas Compact Commission created FracFocus to release lists of fracking chemicals for individual

inconclusive information that we have today on the hazards of fracking. To the author, they represent a reasonable approach in excluding high-cost regulatory actions unless new information shows, with a high degree of reliability, that fracking poses a major public-health risk. Some policymakers might consider these major actions as part of a precautionary approach, but it appears that these actions are unreasonable responses to a speculative problem. They would seem not to pass any cost-benefit test, as their high uncertainty would ostensibly discount the expected benefits to a value below the expected costs. In the meantime, states can take low-cost actions with transparent benefits such as mandatory disclosure of fracking fluid and water sampling.

This cautious approach recognizes that, given current information, we should only take major high-cost actions if new evidence indicates that fracking poses a higher risk than the scientific evidence shows today. One major action would be placing a moratorium on fracking. More information may confirm serious risks and large public-health hazards from fracking. But the cost to a state's or locality's economy would seem not to justify a moratorium as of today. Other actions, such as mandatory reduction of the chemicals used in fracking, mandatory recycling of wastewater, and strict federal regulations in general, are also harder to defend as of today because of their large more-certain costs relative to the benefits, which are highly uncertain in the absence of conclusive scientific evidence.[46]

An incremental version of the precautionary approach to policymaking, which this paper advocates, corresponds to the concept "real options theory."[47] According to this theory, policymakers would "hedge" by not requiring costly actions until they acquire more definitive information, in order to reduce the chances of making the wrong decision. This wait-and-see posture can, therefore, avoid serious mistakes. Policymakers would defer making a major decision until, for example, they know more about the risks of fracking. As discussed in the next subsection, policymakers make good decisions when they (1) attempt to quantify the risks of alternative options and then (2) choose the option consistent with the aversions they judge society has toward each risk.

---

wells, voluntarily provided by producers. FracFocus is a fracking registry website that the public can assess to locate wells and identify chemicals used in the fracking process. It also contains federal, state, and non-governmental reference material and data to help the public better understand fracking. *See* http://www.fracfocus.org.

[46] Regulation at both the federal and state levels could create more uncertainty and costs for the natural-gas industry. The industry may respond by investing less in shale gas, which in the long run could drive up natural gas prices, increase the use of "dirtier" energy, and increase foreign imports.

[47] For a discussion of real options theory and its application, *see* Lenos Trigeorgis, *Real Options: Managerial Flexibility and Strategy in Resource Allocation* (Cambridge, MA: The MIT Press, 1996); and *The Quarterly Review of Economics and Finance*, 38, Special Issue, 1998.

The precautionary approach is not devoid of controversy. Critics point to its shortcoming compared to a cost-benefit analysis that takes into account uncertainty and the risk aversion of the decisionmaker. How much money should society spend today to avoid a possible problem tomorrow? Should society spend $10 million or $1 million today to avoid a major incident? The precautionary approach provides little guidance. When people purchase insurance, they at least implicitly compare the premiums with the expected cost from a bad event. Shouldn't society have an idea of the benefits from spending money today to reduce fracking risk? In sum, the precautionary approach—especially when it involves society's spending large sums of money today—might not reflect an economically rational way to set socially desirable policy.[48]

C. Type I and Type II errors

Shale-gas production results in net economic benefits to the extent that its value in the marketplace—reflected by the price it sells for—is greater than the costs of drilling, transporting, and distributing the gas. But because production imposes a cost on society that lies outside the realm of the marketplace (e.g., community disruption, possible water contamination), policymakers must decide whether these external costs should affect the amount of production or the methods for production. Policymakers face the risk of making a decision based on erroneous information.

The preferred regulatory position on fracking comes down to the decisionmaker's risk aversion toward negative outcomes, given the available scientific and other fact-based information. One person may be more troubled by the possibility of an incorrect discovery that fracking has a high public-health risk when in fact it has a low risk—what we call here a *Type I error*. A Type I error results in society's expending excessive resources on safety because of overregulation. Another person may be more troubled by the possibility of an incorrect scientific discovery that fracking has a low public-health risk when in fact it has a high risk—what we call here a *Type II error*. A Type II error results in an unsafe condition because of underregulation.

Reasonable people can disagree over whether a Type I error or a Type II error is a more serious problem. They can have honest differences over whether overregulation or underregulation is a greater social concern. The natural-gas industry would argue that Type II error has a lower societal cost because it professes that the risk from fracking is minuscule. This view is consistent with saying that a Type I error is large because of the high cost of regulation relative to its benefits: (1) Society wastes resources to mitigate an exaggerated risk and (2) consumers have to pay more for natural gas.

Environmentalists, on the other hand, would implicitly assign a higher cost to a Type II error. Local community groups and politicians might also assign a higher cost to a Type II error.

---

[48] For critiques of the precautionary approach, see Richard A. Posner, *Catastrophe: Risk and Response* (New York: Oxford University Press, 2004); and Robert W. Hahn and Cass R. Sunstein, 2005, "The Precautionary Principle as a Basis for Decision Making," *The Economists' Voice*, vol. 2, no. 2 (2005), article 8.

From their perspectives, the public-health hazards of gas production would overwhelm any benefits to a locality or state.[49] Their view is that underregulation of fracking, which to them has high risk, is a more serious problem than overregulation. At the extreme, they may argue that the risks warrant the suspension of fracking until society has more information that it is safe (e.g., that fracking does not contaminate water wells and groundwater).[50] Cheap gas can significantly hinder energy-efficiency efforts, renewable-energy development, and the coal industry. These groups' advocates may push for heavy regulation just to drive up the price of natural gas artificially and make their causes more economically defensible. Publicly, they may argue that the public-health and environmental risks of fracking warrant heavy regulation. They are, in effect, assigning a higher cost to a Type II error, similarly to the environmentalists, but for strictly self-interested reasons.

A trade-off exists between a Type I and a Type II error: Reducing one type of error compromises the other. For example, reducing a Type II error means imposing "heavy regulation," which increases its risk when the actual public-health risk is small.

Because of the uncertainty over the right regulatory policy, along with differences in risk aversion, two people with the same information can advocate different actions. The first person in the previous discussion, for example, would tend to prefer light regulation, while the second person would favor heavy regulation. The first person implicitly assigns a higher value to gas production and the attendant economic benefits relative to environmental benefits from less production than the second person. The optimal decision today depends on how things turn out in the future—for example, light regulation is optimal when actual risk is low, and heavy regulation is optimal when actual risk is high. (*See* Table 2.)

The optimal policy decision would minimize the cost of error—namely, the additional cost to industry from heavy regulation when risk is actually low, or the public-health cost from light regulation when risk is actually high. Because of uncertainty over the actual value of error, any decision is vulnerable to criticism after the fact. The decisionmaker needs to assume the role of a risk manager. Over time, the costs of the two errors would likely change as society acquires better information about the actual risk levels and the effectiveness of regulation in mitigating those risks. Given what we know today, with the large economic benefits from fracking and shale-gas production, this paper argues that a rational policymaker would tend to tolerate more

---

[49] This is a symptom of the Not-In-My-Backyard (NIMBY) problem (*see* subsection E).

[50] Some environmentalists have contended that more regulation would actually help the industry by increasing public confidence that fracking is safe and not environmentally harmful. Thus, shale-gas production would less likely face interruptions because of incidents and vocal public opposition. *See*, for example, SNL Energy, "Gas Experts Argue Against 'One-Size-Fits-All' Fracking Rules," *Daily Gas Report*, April 29, 2011, 4-5.

easily a Type II error.[51] Given new information and incidents with fracking, however, in the future this balance could shift toward favoring a Type I error.

D. Good decisions require reliable information and sound judgment

The optimal decision requires both sound scientific evidence and good judgment by the decisionmaker. Although beliefs and risk preferences should not enter science, they do, in fact, affect public policies. The higher the cost a person assigns to a particular scientific error, the higher the standard of evidence he will demand. For example, the first person in our previous discussion would look more critically at the discovery that fracking has high risk;[52] the second person would look more critically at the discovery that fracking has low risk. Which of these standards is more valid is not strictly a scientific matter. Thus, when people have different opinions of scientific findings, often it is not because of differences in the credibility of the findings; instead, each person may have different concerns (i.e., value judgments).[53] Scientific discoveries can play a critical role, however, in debates that involve subjective social values, like the protection of public health from hazardous activities versus the protection of industry from overregulation.

With the denial of social values in any scientific discovery, debates often turn to interpretations and the reliability of data and findings. We have seen this phenomenon during the fracking debate: If a study comes out with findings contrary to the interests of certain groups, those groups will hire experts to dispute the findings. With much at stake economically, harsh

---

[51] This statement assumes that tight regulation would have a large cost for the economy because of less shale-gas production. Not everyone would agree with this assumption. Heavy regulation might have little cost effect on production or might actually increase production over time with greater public acceptability of the public-health risk from production.

[52] An example is a comment by a U.S. congressman who criticized the U.S. EPA study on fracking before it was even completed:

> The EPA is doing a study, and they are looking for whether there's been some contamination of drinking water. If I thought they could not be biased on a scientific study, I would sleep well at night. But there's nothing this EPA does that is scientifically based; it's all driven politically. (SNL Energy, "EPA Decisions 'All Driven Politically,' Says Texas Representative," *Daily Gas Report*, August 17, 2011, 1,10)

[53] This statement applies to a wide array of societal issues. One stark example is taxes: some groups find taxes repugnant, irrespective of the state of the economy or other conditions. So even if economic studies show convincingly that higher taxes would reduce the federal government's deficit, these groups would still oppose them for other reasons, such as loss of personal freedom. Other groups, for their own reasons, would use these studies to favor tax increases. They might assign a higher cost than the first group to a deficit relative to loss of personal freedom.

rebuttal of studies is not surprising. What is critically lacking at the moment, according to some observers, is definitive scientific evidence showing whether fracking poses more or less of an environmental and public-health threat than the public perceives today. The hope is that over the next two years policymakers will have better scientific evidence to make well-informed decisions.

In sum, two people can agree about the scientific findings but disagree over policy implications; for example, scientific findings might include the following: (1) Fracking is highly unlikely to contaminate wells or groundwater, (2) fracking and drilling can cause methane to enter waterways, (3) disposal wells can cause earthquakes but with minimal damage, (4) reduction of chemicals would make fracking safer, and (5) fracking fluids entering water wells or groundwater have serious environmental consequences. The trade-off of conflicting objectives requires a value judgment. Scientific analysis, however, can help identify and quantify the consequences of alternative ways for making those trade-offs. The question of what society should do in the face of uncertainty over the risk of fracking is ultimately a public-policy question, not a scientific one.

Table 2: Regulatory Policies under "High" and "Low" Public-Health-Risk Scenarios

Nature of regulation	**Actual public-health risk**	
	Low	High
Heavy	*Type I error*	Optimal
Light	Optimal	*Type II error*

E. The NIMBY problem: Don't drill in my neighborhood

Local opposition to production facilities falls under the label Not-In-My-Backyard (NIMBY). The local population may see an environmental or safety threat from a facility or production process. The fracking process in shale-gas production represents one such threat, especially in an urban environment or in areas with little previous experience in natural-gas production. Frequently, the fears are irrational; but the political reality remains that if the public is wary of a new facility or production process in their locality, the owner will need to address those fears or face strong opposition.

1. What causes it?

Three general problems underlie the NIMBY syndrome. NIMBY projects are facilities that increase overall social welfare but inflict net costs on the citizens living in the host locality. First, the risk perceptions of local citizens may be distorted because of faulty information. Better education of citizens can mitigate this problem. Both government and industry have a responsibility in this regard.

Second, the siting/political process may not mirror the consensus belief or position of a locality. An active minority of opponents to a facility can dominate the preference of a more passive majority at town meetings or in referenda. This intervention can lead to a decision not representative of the majority preferences in the community. The vocal group may be most affected by a facility or have ideological or self-interest reasons for opposing it. They may perceive no benefits, for example, but only environmental or safety threats from the facility.

Third, the aggregate benefits of a facility, some of which are external to a local area, may dominate local costs. For example, the local area bears the environmental costs while most of the benefits accrue to other areas, as with shale gas delivered to out-of-state consumers. In any event, a decision based on faulty information, a defective political process, or disregard for out-of-area effects is likely to lead to a NIMBY problem.

2. How to overcome it

Real-world experiences have shown the importance of local participation in every aspect of the siting process (for example, economic, safety, environmental). Not only should local individuals or groups have the opportunity to participate but government and industry should encourage them to do so. Industry acts as a good citizen when it is responsive to the concerns of local people over a facility that can potentially cause substantial harm. Education and public understanding are critical in subsiding opposition and gaining support for a facility. One often-suggested remedy to the NIMBY syndrome is to shift jurisdiction to a less local authority, such as the federal government.[54]

VI. Federal and State Activities

A. U.S. EPA study and DOE Advisory Board

The U.S. Environmental Protection Agency (EPA) is undertaking a congressionally mandated study[55] on the relationship between fracking and drinking water, applying the "best

[54] This is presumably the underlying rationale for granting FERC exclusive authority, under The Energy Policy Act of 2005, over the siting of LNG terminals.

[55] See EPA's "Draft Hydraulic Fracturing Study Plan" at http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm#curstud. The agency's Science Advisory Board reviewed the plan, submitting comments on August 4, 2011.

available science, independent sources of information, and conduct[ing] the study in consultation with others using a transparent, peer-reviewed process."[56] The study will examine the full life cycle of water in the fracking process, from the purchasing of water, to its mixing with sand and chemicals, to fracturing itself, to treating and disposing of the flowback and the produced water. The study will address how each of these phases affects groundwater and well water. The EPA expects to publish its initial findings in late 2012, with later findings expected in 2014.

The U.S. Department of Energy on May 5, 2011 announced the formation of an Advisory Board of the Shale Gas Subcommittee, composed of seven experts, to recommend ways to make fracking safer and cleaner. The Advisory Board's charge is to:

> Identify steps that can be taken to reduce the environmental and safety risks associated with shale gas development and, importantly, give the public concrete reason to believe that environmental impacts will be reduced and well-managed on an ongoing basis, and that problems will be mitigated and rapidly corrected, if and when they occur.[57]

The Advisory Board publicized its initial recommendation in August 2011 with further recommendations released later in the year.[58] It identified four major areas of concern: (1) possible pollution of drinking water from methane and chemicals used in fracturing fluids, (2) air pollution, (3) community disruption during shale-gas production,[59] and (4) cumulative adverse impacts that intensive shale production can have on communities and ecosystems.

The Advisory Board was struck by the wide gap in perceptions among various groups of the public-health hazards of shale-gas production. It recognized the need to narrow this gap through the combination of education, improved industry practices, and more definitive scientific evidence. The Advisory Board recognized that political action results more from public perception than from scientific evidence. If the general population feels threatened by fracking, regardless of the validity of those feelings, politicians will feel compelled to do something whether or not the beliefs are supported by facts and science.

---

[56] In a 2004 study, the EPA found no evidence of contamination of drinking water from fracking. Back then, however, much less fracking, especially in conjunction with horizontal drilling, occurred relative to today's and tomorrow's projected levels.

[57] Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-Gas Production Subcommittee Ninety-Day Report*, August 11, 2011, 11.

[58] The Advisory Board had 90 days to recommend immediate steps for making fracking safer and cleaner. It has an additional three months to recommend comprehensive safety and environmental policies for state and federal regulators.

[59] The Advisory Board recommends a "holistic" approach to the different aspects of drilling, production, and delivery activities (e.g., traffic on roads, noise, visual aesthetics, and air quality).

The Advisory Board acknowledged that making fracking safe and environmentally benign requires a combination of competent regulation, research and development efforts, and improvements in best practices by industry. It agrees that the gas industry can develop shale-gas production safely as long as it uses good practices and makes improvements over time. It places faith in the gas industry to make these improvements without strict regulations:

> Industry's pursuit of more efficient operations often has environmental as well as economic benefits, including waste minimization, greater gas recovery, less water usage, and a reduced operating footprint. So there are many reasons to be optimistic that continuous improvement of shale-gas production in reducing existing and potential undesirable impacts can be a cooperative effort among the public, companies in the industry, and regulators.[60]

The natural-gas industry has continuously made improvements in wastewater recycling and using fewer chemicals in fracking. Both of these actions will reduce the safety and environmental risks from fracking. Although these actions are mostly economically motivated, they reflect a response to the public's concern as well as possible future political actions. One rational government stance is to wait and see how far the industry goes in implementing these actions before contemplating tougher regulations.

The Advisory Board places little blame on fracking for past incidents at shale-gas production sites:

> Opponents point to failures and accidents and other environmental impacts, but these incidents are typically unrelated to hydraulic fracturing per se and sometimes lack supporting data about the relationship of shale gas development to incidence and consequences.[61]

Addressing the gas industry, the Advisory Board warns that a stance of merely pronouncing that fracking has proven safe over decades of experience without addressing the issues raised by the public and others "will not succeed." Even though the gas industry has used the fracking process for decades, it has only recently encountered more challenging and diverse conditions. For example, until the last four years fracking occurred mostly in areas with low populations with an accompanying low risk to public health. The Advisory Board believes that the industry needs to be responsive to the public's concerns, irrespective of their validity. For

---

[60] Shale Gas Subcommittee of the Department of Energy Advisory Board, *The SEAB Shale-Gas Production Subcommittee Ninety-Day Report*, August 11, 2011, 9.

[61] Ibid., 13.

example, it assigns top priority to gas producers' disclosing the chemicals they use in their fracking fluid.[62]

B. State activities

The states have actively engaged in the fracking debate. Since October 2010, more then 100 bills related to fracking have been introduced in 19 states.[63] Many of these bills call for disclosure of the chemicals used in the fracking fluid. Other provisions include the following: (1) outright bans on fracking, (2) additional studies, (3) prohibition of certain chemicals in the fracking fluid, (4) gas-producer liability for incidents, (5) permit requirements, (6) reporting requirements, and (7) location restrictions.[64]

Legislative action is more likely in states with little experience in natural-gas production. State activities reflect the public's view that fracking is high-risk, especially when it comes to contaminating sources of drinking water. Fracking, rightly or wrongly, has a conspicuous public-perception problem. The gas industry needs to address this problem if it hopes not to face the prospect of strict regulations. No matter what industry says and what the scientific evidence shows, if the public perceives fracking as highly risky, regulations and other restrictive government actions that threaten shale gas development will become more imminent. We have already seen this outcome in some states, which have imposed moratoria and strict regulations. Others have taken a more deliberate approach by requiring studies on the risks of fracking prior to any major actions.

In addition to the federal government, states face the tough challenge of balancing the benefits of shale-gas production with protection of the environment and public health. This trade-off is particularly difficult in today's tough economic times, as suspending, delaying, or banning shale-gas production would result in job losses and lost tax revenues.

---

[62] SNL Energy, "Chemical Disclosure, State Reviews of Fracking Regulations Urged at DOE Panel," *Daily Gas Report*, July 14, 2011, 1, 8.

[63] A survey of state activities is found in Edison Electric Institute, "Emerging Natural Gas Issues: Recent Environmental Concerns and Actions Surrounding Hydraulic Fracturing," Discussion Draft, June 2011 at http://www.eei.org/ourissues/ElectricityGeneration/Documents/Fracking%20June%202011_Web.pdf; and the National Conference of State Legislatures, "Regulating Hydraulic Fracturing: States Take Action," December 2010 at http://www.ncsl.org/?tabid=22021. View individual state regulations at http://fracfocus.org/regulations-state.

[64] *See* Edison Electric Institute, "Emerging Natural Gas Issues: Recent Environmental Concerns and Actions Surrounding Hydraulic Fracturing," Appendix C.

VII. Other Studies

Other major studies on fracking are either completed or underway. How policymakers will use their results, some of which will inevitably convey conflicting information—for example, lifecycle greenhouse-gas emissions from gas-fired plants relative to coal-fired plants—remains to be seen. Will policymakers assign a high or low uncertainty to the studies' findings? To what extent will they supplement the results from these studies with their own preconceived views? Part V addressed these questions.

The major studies include:

1. *Resources for the Future (RFF)*: This study "will be the first independent, broad assessment of expert opinion and public perception of the risks associated with the shale gas development process. The research team…will use that information to determine the most significant risks and the behaviors of industry and regulators that influence those risks. Matching these findings to an analysis of existing state and federal policies will lead to recommendations for how and where to improve regulation and encourage industry action." Unlike other studies, after identifying the major risks and their causes, the RFF study will recommend the most economical policies to mitigate those risks. The Alfred P. Sloan Foundation provided a $1.2 million grant to fund the study. The study will report its findings by the end of 2012. (*See* http://www.rff.org/news/press_releases/pages/rff-launches-new-initiative-on-risks-and-regulation-of-shale-gas.aspx)

2. *The Energy Institute at the University of Texas*: The motivation for the study is as follows: "The problem is that the development of…vast shale gas resources through 'fracking' has been accompanied by claims of damage to groundwater and surface water. To date, however, no independent research has been conducted to support or rebut these environmental concerns." The study will report its findings in early 2012. (*See* http://www.energy.utexas.edu/index.php?option=com_content&view=article&id=50&Itemid=160)

3. *Duke University*: This 2011 study found a correlation between methane levels in water wells and shale-gas drilling in the Marcellus region. Specifically, it found more methane in water wells located closer to shale-gas wells. The authors concluded that the most likely source of contamination is leaky gas-well casings.[65] The study emphasized the need for (a) additional research, (b) sampling and monitoring of water wells, and (c) a better understanding of reasons for high methane levels.[66] (*See* http://marcellusdrilling.com/2011/05/mdn-in-depth-duke-

[65] Other analyses, including those by state agencies, have also found that fracking was not responsible for drinking-water contamination.

[66] Critics of the study point to its lack of baseline data and data on the depth of methane.

university-study-links-marcellus-shale-gas-drilling-with-methane-contamination-of-water-wells/)

4. *Cornell Universit*y: This controversial study examined the methane emissions ("fugitive emissions") from shale gas. It presented evidence showing much higher methane emissions from unconventional drilling than from conventional drilling.[67] The most disputed finding was that natural gas contributes more to global warming than coal and its carbon dioxide emissions.[68] (*See* http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf) Along with surface and groundwater contamination, greenhouse gas emissions are currently the most disputable aspects of fracking.
5. *Carnegie Mellon University and National Energy Technology Laboratory*: The two studies showed that lifecycle greenhouse-gas emissions over a long period (e.g., over 100 years) are much greater from coal-fired power plants than from gas-fired plants fueled with shale gas. The results contradict the findings of the Cornell study. (*See* http://www.cmu.edu/piper/briefs/2011/august/aug-25/marcellusshalegas.html

   and http://www.postcarbon.org/reports/PCI-Hughes-NETL-Cornell-Comparison.pdf)
6. *IHS CERA* and the *Worldwatch Institute/Deutsche Bank Climate Change Advisors*: The IHS CERA study criticized both the U.S. EPA and the Cornell University study for using erroneous estimates of upstream methane emissions.[69] Their assumptions, as noted in its critique, neglected to reflect current industry practices. IHS CERA calls for better data to measure methane emissions from shale-gas production.[70] The Worldwatch Institute study also criticized the Cornell University study. It concluded that natural gas emits far smaller amounts of greenhouse gas than coal.

---

[67] The study reported between 30 and 50 percent higher methane emissions from shale gas wells than from conventional gas wells.

[68] According to the U.S. EPA, methane is 20 times more effective than carbon dioxide at trapping heat in the atmosphere.

[69] SNL Energy, "IHS: EPA and Cornell Misused, Distorted, and Overstated Shale Emissions Data," *Gas Utility Week*, August 29, 2011, 1, 15-16. The reader can access the IHS CERA paper, titled "Mismeasuring Methane," August 2011 at http://press.ihs.com/press-release/recent-estimates-greenhouse-gas-emissions-shale-gas-production-are-likely-significantl.

[70] The DOE Advisory Board, mentioned in the last section, also called for better data on upstream methane emissions.

But the study warns that the gas industry should reduce upstream methane emissions to lessen the greenhouse-gas footprint of shale-gas production.[71]

7. *Arkansas Geological Survey*: The study found a link between seismic activity and fracking wastewater disposal wells[72]; it found, however, no link between fracking itself and seismic activity.[73] (See http://www.theglobeandmail.com/report-on-business/international-news/shale-gas-fracking-halted-after-possible-quake-link/article2042598/) Other groups, like the U.S. Geological Survey, have also discovered a connection between disposal wells and earthquakes.

8. *State of New York*: In September 2011, the New York Department of Environmental Conservation released a comprehensive report on hydraulic fracturing.[74] The report proposed several recommendations for mitigating the risks of shale-gas production in the Marcellus and Utica shale gas regions. They include (a) disclosure of chemicals in the fracking fluid, (b) tighter air-quality control, (c) reduced greenhouse-gas emissions, (d) enhanced well casings, (e) prohibition of surface drilling under certain conditions, (f) tight monitoring of gas well operations, and (g) strict enforcement of regulations by state and local governments. These recommendations would still make "more than 80 percent of the Marcellus Shale where gas extraction is viable…accessible."[75] The report concluded that shale-gas production and fracking will have a substantial effect on the environment because

---

[71] SNL Energy, "Study: Upstream Emissions Narrow Natural Gas' Advantage over Coal," *FERC Gas Report*, August 29, 2011, 2-3. Another study, funded by the American Clean Skies Foundation, reported (using revised U.S. EPA data) that gas-fired electricity generation produces 50 percent fewer greenhouse gas emissions than coal-fired generation does. The reader can access the study at http://www.cleanskies.org/wp-content/uploads/2011/06/staple_swisher.pdf.

[72] Disposal wells handle the wastewater that is a byproduct of natural gas drilling. The U.S EPA regulates these wells, which fall in the Class 2 category. Disposal wells are more common in the West than in the East. In the absence of disposal wells, producers must first treat wastewater before dumping it into rivers and other waterways.

[73] *See* SNL Energy, "Arkansas Approves Disposal Well Ban; Fracking Not Linked to Seismic Activity," *Daily Gas Report*, July 28, 2011, 2.

[74] See New York Department of Environmental Conservation, *Oil, Gas and Solution Mining Regulatory Program: Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing in the Marcellus Shale and Other Low-Permeability Gas Reservoirs*, Revised Draft, September 2011 at http://www.dec.ny.gov/energy/75370.html.

[75] New York Department of Environmental Conservation, "2011 Recommendations for Permitting High-Volume Hydraulic Fracturing," September 2011, 1 at http://www.dec.ny.gov/energy/75664.html.

"such operations have the potential to draw substantial development into New York, which would result in unavoidable impacts to habitats (fragmentation, loss of connectivity, degradation, etc.), species distributions and populations, and overall natural resource biodiversity." A major purpose of the study was to find ways to reduce the adverse effects of shale-gas production on small towns and rural communities. One major recommendation is to issue permits only after the state regulators consult with gas producers and communities to "mitigate adverse impacts at the local and regional levels."[76] The report recognized the benefits of shale-gas production in creating new jobs and boosting incomes and local economies.[77] It concluded that production would increase local and state tax revenues but also would require an increase in government services.

VIII. Conclusion

With substantial economic benefits from shale gas, any policy action that hinders its development, such as tough federal regulations, should presume serious environmental and public-health risks from fracking. We lack evidence today to support the contention that such risks exist. Additional experience with fracking over the coming years, along with new scientific evidence, might justify more restrictions; but absent new information, any action that the federal or state government takes should not jeopardize shale-gas production. A major criticism against federal regulation is that it is incapable of taking into account the special conditions of gas production in individual states. In other words, a "one size fits all" policy is an ill-advised solution. Notwithstanding this criticism, the federal government could play a valuable role by funding studies, providing technical support to states, and acting as a backstop in the event that a state is unable or unwilling to establish and enforce even "minimum" regulations.

A policy against major restrictions today places the burden of proof on those who support a ban on shale-gas production or other major regulations that could hamper its development. Examples of major regulations are (1) inclusion of fracking as part of the Safe Drinking Water Act, notably the Underground Injection Control program; (2) mandatory use of certain technologies; (3) national standards for protecting drinking water near fracking sites and (d) stringent reporting requirements. Shale gas has demonstrated its benefits to the economy and natural gas consumers—few people would question the evidence. Opponents and skeptics of

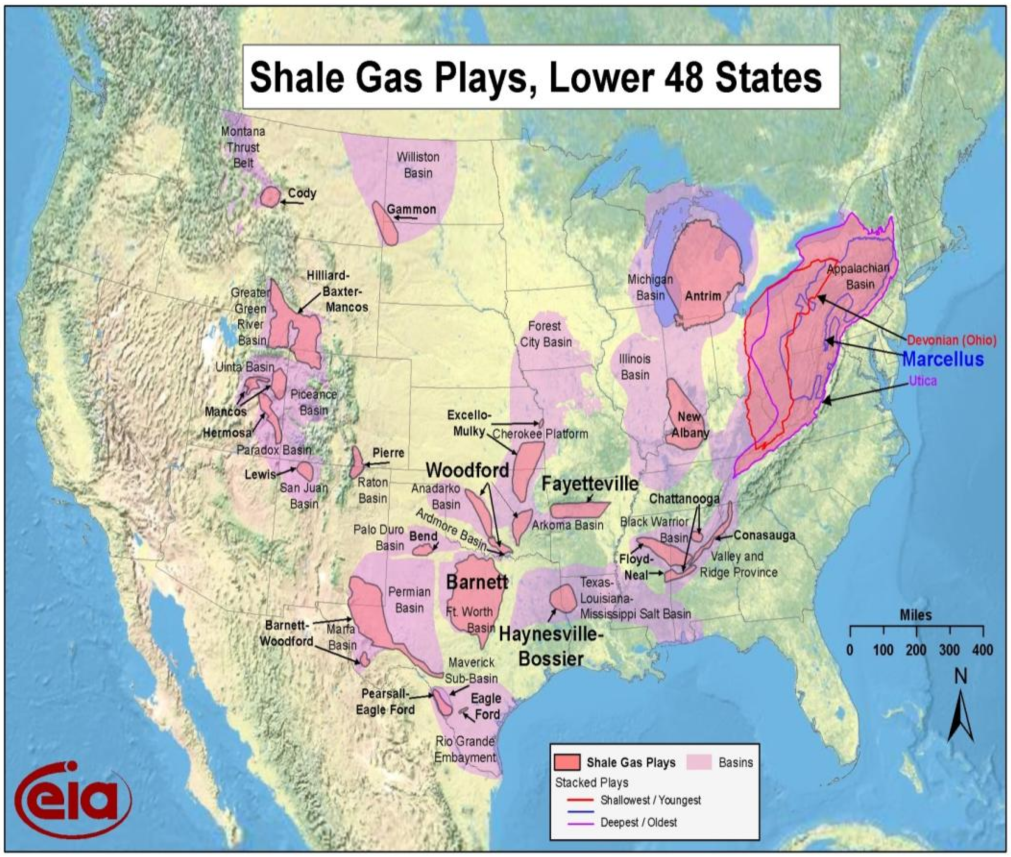
---

[76] The report also mentioned (*see* ibid., 1) that "permits will only be issued consistent with the [Department's] ability to review and oversee high-volume hydraulic fracturing activities and ensure compliance with permit conditions."

[77] The Department projected that shale-gas production in New York could add as much as $2.5 billion in annual wages to the state by the time production peaks. Job additions for the state, from both the direct and indirect effects of shale-gas production, could number as many as 54,000.

fracking have not yet offered conclusive information showing serious safety and environmental problems that warrant major restrictions on shale-gas production.

Appendix: Shale Gas Basins in the U.S.



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010