Environmental Concerns and Regulatory Initiatives Related to Hydraulic Fracturing in Shale Gas Formations: Potential Implications for North American Gas Supply

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ICF International's *2010 Natural Gas Market Review* identifies natural gas from unconventional shale formations as a "game changer" for North America, providing an increasing amount of the natural gas supply. By 2020, shale gas is predicted to account for over 30% of the natural gas used in North America, up from 13% in 2009.[1] The report specifically mentions that gas from the Marcellus shale plays a critical role in the overall supply outlook.[2]

Initially, gas extracted from the Marcellus shale formation, which spans parts of New York, Ohio, Pennsylvania and West Virginia, is not expected to meet a major portion of Ontario's natural gas needs. Rather, because of its location, it will be primarily destined for the Northeastern US market. ICF International (hereafter referred to as ICF) reports that Marcellus shale gas has already displaced Canadian natural gas exports in this market.[3]

As mentioned above, by 2020 it is predicted that shale gas will be supplying more than 30% (30 billion cubic feet or bcf per day) of the natural gas in North America, with 20% of that total (6.1 bcf/day) being produced from the Marcellus shale formation.[4] ICF projects that by 2020 "due to the anticipated increases in Marcellus production and anticipated decreases in flows from Western Canada, some Marcellus gas will flow into Canada at Niagara in the summer months, helping to fill gas storage in the Dawn area."[5]

ICF raises some of the uncertainties with its natural gas supply projections. One of ICF's key uncertainties is that "If the regulation of hydraulic fracturing becomes more stringent, this could slow the growth of shale gas production."[6]

The purpose of this paper is to provide some background information on hydraulic fracturing and its potential environmental impacts, and delve deeper into the question of whether or not more stringent fracturing regulations might affect gas development in the Marcellus shale. Additionally, the paper looks at some of the other regulatory initiatives pending in the Marcellus shale region, to see if they, too, might influence the pace or scope of development in the Marcellus shale.

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[1] ICF International. August 20, 2010. *2010 Natural Gas Market Review*. Prepared for the Ontario Enegy Board. p.7. http://www.oeb.gov.on.ca/OEB/_Documents/EB-2010-0199/ICF_Market_Report_20100820.pdf

[2] ICF, 9.

[3] ICF, 26.

[4] ICF, 51.

[5] ICF, 53.

[6] ICF, 75

This paper focuses on gas production in the Marcellus shale because ICF identified the Marcellus as being critical to the North American natural gas supply outlook. Moreover, if Marcellus shale gas supply does decline due to the regulation of hydraulic fracturing or other regulatory initiatives, the gas flowing into Ontario from the western provinces may simply pass through Ontario to meet the needs of the U.S. Northeastern states.[7]

Section 1 of the report provides a brief description of hydraulic fracturing and some of the environmental impacts related to this technique. Section 2 discusses various regulatory initiatives, including hydraulic fracturing legislation and regulations that have the potential to affect production that may lead to a change in the supply outlook of gas from Marcellus shale.

1. Overview of Hydraulic Fracturing and Potential Environmental Impacts

Hydraulic fracturing is technique used to stimulate the production of oil and natural gas from both conventional and unconventional formations. Typically, the process involves the injection of large volumes of water, sand and small volumes of chemical additives into the target formation. Eventually, the pressure from the fluid injection causes the formation to fracture. The sand remains behind to hold open the fractures and the injected fluids flow back out of the well, thus enabling the oil or gas to flow more freely from the formation into the gas well.

Hydraulic fracturing is necessary to unlock the gas held within dense gas shales. In the late 1990s, natural gas operators developed a technology known as "slickwater fracturing" for use in shale formations. Slickwater fracs were first used successfully on vertical wells in Texas. But it is the combination of horizontally drilled wells and the slickwater fracture treatment that are responsible for the shale gas boom.

The boom has not come without consequences. There are citizens, politicians, public interest groups, landowners and mineral owners from the Barnett Shale to the Marcellus Shale voicing concerns about the impacts of shale development on their health and on their lives.

As mentioned above, the purpose of this report is to round out the picture of the environmental impacts related to hydraulic fracturing. The ICF report lists three major environmental concerns related to hydraulic fracturing mentioned in:

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[7] As pointed out on p. 9 of the ICF report, "Much of the gas that currently flows on TCPL is destined for the Northeast U.S. Gas production in the Marcellus Shale displaces the need for exports to the Northeast U.S. Therefore, even if the flows on TCPL decrease over time, more of the gas that does flow can stay in Ontario rather than being exported to U.S. markets."
If there is a decline in Marcellus shale gas production, there will be a void in the U.S. Northwest that will need to be filled.

water requirements, chemical exposures, and contaminated water management. These are discussed below.

Water Requirements

> *Wells need substantial amount[s] of water to pump into the deep underground shale formation for hydraulic fracturing. The demand for water competes with other water resource needs.*
>
> *--ICF, p. 55*

In the late 1990s, natural gas operators developed a technology known as "slickwater fracturing" for use in shale formations. Compared to conventional fracturing jobs, these operations use much higher volumes of water. For example, a Marcellus Shale well fracturing operation requires from 1 to 10 million gallons of water[8] compared to the 50,000 gallons reportedly used to fracture conventional natural gas wells in the Western Canadian Sedimentary Basin.[9] It has been reported that shale wells in BC's Horn River Basin may require as much as 26 million gallons of water to hydraulically fracture a single horizontal well.[10]

The transportation of a million gallons of water to fracture a well is estimated to require 200 truck trips,[11] so a 5-million-gallon hydraulic fracturing operation would require 1,000 truck trips. Not only does this create the potential for local air quality concerns, the level of heavy truck traffic also creates road repair issues and safety concerns if the trucks are driving through residential neighborhoods.

The cost of water haulage increases with the distance between the source-water and the gas well. Consequently, shale gas operators prefer to extract water from

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[8] Hazen and Sawyer estimate 3 – 8 million gallons; Vidic estimates 1 – 8 million and Kargbo et al. estimate that 2-10 million gallons are required.
Sources: Hazen and Sawyer, December 22, 2009. Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed. p.5.
http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/12_23_2009_final_assessment_report.pdf
Vidic, Radisav. 2010. Sustainable Water Management for Marcellus Shale Development. Slide 5. http://www.temple.edu/environment/NRDP_pics/shale/presentations_TUsummit/Vidic-Temple-2010.pdf. Kargbo, D.M., Wilhelm, R.G. and Campbell, D.J. "Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities," *Environmental Science and Technology*. 2010, 44 (15). pp 5679–5684. http://pubs.acs.org/doi/pdf/10.1021/es903811p

[9] Campbell, K. and Zaluski, W. "Hydrogeology and Management of Water Issues in the Development of Shale Gas in the Horn River Basin in northeastern British Columbia." http://www.geocanada2010.ca/uploads/abstracts_new/view.php?item_id=785

[10] Campbell, K. and Zaluski, W. "Hydrogeology and Management of Water Issues in the Development of Shale Gas in the Horn River Basin in northeastern British Columbia." http://www.geocanada2010.ca/uploads/abstracts_new/view.php?item_id=785

[11] Vidic, Radisav. 2010. Sustainable Water Management for Marcellus Shale Development. http://www.temple.edu/environment/NRDP_pics/shale/presentations_TUsummit/Vidic-Temple-2010.pdf

nearby streams or underground water supplies.[12] The most appropriate locations for water withdrawals from the public or regulatory agency perspective may not be in close proximity to the hydraulic fracturing location. In these cases, water transportation may add substantial costs to shale gas operations.[13]

According to Radisav Vidic, professor of civil engineering at the University of Pittsburgh, water transportation costs for Marcellus producers "can be significant." He cites a range in costs from $0.10 a barrel (42 gallons) to $2 a barrel.[14] Based on Vidic's number, hauling water for a 5 million gallon hydraulic fracturing operation would cost the operator between $12,000 and $240,000.

Concerns about the ecological impacts to aquatic resources resulting from huge water withdrawals have been raised throughout the Marcellus shale region. Potential impacts include aquifer depletion, stream flow depletion and disruption of natural flow regime, and interference with flows to wetlands and other water dependent ecosystems. In turn, aquatic life, fish, wildlife and plant life can be affected, and drinking water supplies can be depleted.

Chemical Exposures

> *Hydraulic fracturing fluid is a mixture of water, sand and chemicals that includes friction reducers, biocides, surfactants and scale inhibitors, acids. The principal concern, however, is whether these chemicals could come in contact with groundwater and water supplies.*
>
> *- ICF, p. 55.*

Data supplied to the New York Department of Environmental Conservation by companies hoping to develop Marcellus shale wells in that state included 200 different chemicals that may be found in fracturing fluids.

Exposure to these chemicals can occur in a variety of ways. Hydraulic fracturing fluids can spill, posing health hazard to workers or others who come into contact with the chemicals. For example, an emergency room nurse in Colorado was exposed to a fracturing fluid called ZetaFlow while treating a gasfield worker whose clothes had been splashed by the chemical. She immediately lost her sense of smell and developed a headache, and within a couple of days her liver, heart and lungs began to shutdown.[15]

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[12] Kargbo, D.M., Wilhelm, R.G. and Campbell, D.J. "Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities," *Environmental Science and Technology*. 2010, 44 (15), pp 5679–5684. http://pubs.acs.org/doi/pdf/10.1021/es903811p

[13] New York State Water Resources Institute. "Water withdrawals for hydrofracking." http://wri.eas.cornell.edu/gas_wells_water_use.html

[14] Vidic did not explain under what scenarios these costs estimates were derived.

[15] Lustgarten, A. November 13, 2008. "Buried Secrets: Is natural gas drilling endangering U.S. water supplies?" *ProPublica*. http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113

Spills of fracturing fluids and wastes into watercourses can expose aquatic organisms to toxic compounds. For example, in 2009 two spills at a Cabot Oil and Gas well in Pennsylvania entered a stream and resulted in a fish kill.[16]

There are a growing number of cases in the Marcellus shale of people being exposed to high concentrations of methane, the major component of natural gas, either through leaks from improperly constructed wells, or communication between hydraulic fractures and other geological conduits. In Washington County, Pennsylvania a hydraulic fracture communicated with an abandoned well, which allowed methane to flow to the surface and contaminate private water supplies.[17] Methane is not toxic to humans, but it is flammable and can build up to explosive levels. For example, in 2004, about a month after a well was fractured, natural gas was discovered bubbling out of West Divide Creek in Colorado.[18] One nearby resident, Steve Thompson, said that, "I came down with a funnel and scooped some of the biggest bubbles with it. . . I lit the bubbles with a match, and they burned like gas. It even melted my funnel."[19]

Increasingly in Pennsylvania, companies are constructing large pits or impoundments the size of football fields to hold millions of gallons of hydraulic fracturing fluid wastes, called "flowback." The concentration of such large pools of waste has the potential to create serious air pollution problems due to the release of volatile organic compounds from these wastes.[20] Already citizens living close to the flowback recycling ponds have experienced "odors like that of gasoline and kerosene."[21]

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[16] Pennsylvania Department of Environmental Protection. September 23, 2009. "DEP Issues violation notice to Cabot Oil and Gas - Company Must Properly Clean Up Susquehanna County Gel Spill." Press Release.
http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=2373&typeid=1

[17] DEP draft report. *Stray Gas Migration Associated with Oil and Gas Wells.* Alexander Investigation, Washington County –September, 2006.
http://www.google.com/url?sa=t&source=web&cd=1&ved=0CBIQFjAA&url=http%3A%2F%2Fwww.uppermon.org%2FMarcellus_Shale%2FPA-DEP-Stray%2520Gas%2520Migration%2520Cases.pdf&rct=j&q=Stray%20Gas%20Migration%20Associated%20with%20Oil%20and%20Gas%20Wells&ei=Rv6YTJGMIoG0lQef--HgDw&usg=AFQjCNE72Cm9X9cnIEnixN_taz-mICJseQ&sig2=2EE6kYPN2d8njlK-GYZRxw&cad=rja

[18] Heiman, J. Monday, April 19, 2004. "Well comes under suspicion in West Divide Creek gas seep." Glenwood Springs Post-Independent.
http://www.postindependent.com/article/20040419/VALLEYNEWS/40418010

[19] Chakrabarty, Gargi. April 13, 2004. "Toxic Bubbles Trouble Silt; Divide Creek Tainted by Natural Gas Leak, Toxic Benzene," *Rocky Mountain News.* 1B.

[20] Volz, C., Michanowicz, D., Christen, C., Malone, S., Ferrer, K. August 24, 2010. Potential Shale Gas Extraction Air Pollution Impacts - How Organic Compounds Contained in the Shale Layer Can Volatilize Into Air, Become Hazardous Air Pollutants and Cause Ozone Formation. Fractracker.org http://www.fractracker.org/2010/08/potential-shale-gas-extraction-air.html

[21] Legere, L. June 22, 2010 "Wastewater recycling poses risks of odors, leaks and spills," *The Daily Review*. http://thedailyreview.com/news/wastewater-recycling-poses-risks-of-odors-leaks-and-spills-1.858825

An air modeling study conducted for New York State looked at the potential emissions from fracturing flowback wastes stored in a centralized impoundment. Based on industry-reported concentrations of methanol in fracturing fluids, the authors were able to calculate that an impoundment receiving 50 million gallons of flowback per year could have an annual emission of 32.5 tons of methanol.[22] The U.S. Environnmental Protection Agency reports that "chronic inhalation or oral exposure to methanol may result in headache, dizziness, giddiness, insomnia, nausea, gastric disturbances, conjunctivitis, visual disturbances (blurred vision), and blindness in humans."[23]

Contaminated Water Management

> *Wells produce significant amounts of water along with the gas; this occurs mostly in the early stages of production. The produced water will have the fracking chemicals in it as well as other contaminants from the shale. One of these is a class of materials referred to as [naturally] occurring radioactive materials (NORMs) which collect in the holding tanks. Management of produced water including reprocessing and removal to keep it out of streams and water sources is required by environmental law and regulations.*
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> *–ICF, p. 55*

There are two types of fluid wastes that must be managed by natural gas operators. The first hydraulic fracturing fluids flowback. It's been estimated that 50% of the injected fracturing fluids return to the surface over a period of a few weeks. The volume of flowback can be anywhere from 500,000 to 5 million gallons.[24]

After the initially large pulse of flowback, the wells continue to generate lower volumes of wastewater or 'produced water' on the order of 100 – 1,200 gallons per day.[25] These wastes are also known as brine because of their typically high salt content.

Environmental concerns with both flowback and brines stem from the fact that these wastes may contain a variety of chemicals. Recent chemical analyses of flowback from Marcellus wells in Pennsylvania revealed high concentrations (i.e., at levels exceeding water quality standards) of volatile organic compounds

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[22] New York State Department of Environmental Conservation. Sept. 30, 2009. Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs. p. 6-56. http://www.dec.ny.gov/docs/materials_minerals_pdf/ogdsgeischap6.pdf

[23] U.S. Environmental Protection Agency web site. "Methanol Hazard Summary." Created in April 1992; Revised in January 2000. http://www.epa.gov/ttn/atw/hlthef/methanol.html

[24] This is 50% of the amount of water used to fracture the well.

[25] Vidic, Radisav. 2010. Sustainable Water Management for Marcellus Shale Development. Slides 9-11.
http://www.temple.edu/environment/NRDP_pics/shale/presentations_TUsummit/Vidic-Temple-2010.pdf

like benzene and toluene; semi-volatile compounds such as naphthalene; glycols; metals; salts; and radioactive substances such as radium.[26]

During the fall of 2008, the disposal of large volumes of flowback and produced water at municipal water treatment facilities in Pennsylvania contributed to high levels of total dissolved solids (TDS) in the Monongahela River and its tributaries.[27] Subsequent studies showed that in addition to the Monongahela River, many of the other rivers and streams in Pennsylvania had a very limited ability to assimilate additional TDS, sulfate and chlorides, and that the high concentrations of these constituents were harming aquatic communities.[28] The PA Department of Environmental Protection quickly took measures to address the high TDS levels, ordering all treatment plants discharging wastewater into the Monongahela or its tributaries to reduce the volume of gas drilling wastewater accepted at their plants to one percent or less of their daily flow.[29]

2. Regulatory Initiatives May Affect Development of Marcellus Shale

The Marcellus shale lies beneath parts of four states: New York, Pennsylvania, West Virginia and Ohio. Not surprisingly, the different states have had different regulatory responses to the mad dash for shale gas.

According to a study published by the American Petroleum Institute, tax and regulatory policies at local, state, and federal levels have an important bearing on the costs and returns from drilling.[30] The following section presents several examples of proposed regulatory initiatives that may influence the pace and scope of gas produced from the Marcellus shale.

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[26] The Pennsylvania Department of Environmental Protection (PADEP) is undertaking a program to study the chemical makeup of flowback water produced from hydraulically fractured Marcellus Shale wells in Pennsylvania. Preliminary results are available through the Palmerton Group. "Frac Flow-Back Water Study."
http://www.palmertongroup.com/services/marcellus-shale-gas.asp Data were reviewed and by Lisa Sumi.

[27] U.S. Department of Energy web site. "Sustainable Management of Flowback Water during Hydraulic Fracturing of Marcellus Shale for Natural Gas Production." DE-FE0000975.
http://www.netl.doe.gov/technologies/oil-gas/Petroleum/projects/Environmental/Produced_Water/00975_MarcellusFlowback.html

[28] Pennsylvania Department of Environmental Protection. April 11, 2009. "Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges."
http://www.portal.state.pa.us/portal/server.pt/document/754458/high_tds_wastewater_strategy_041109_pdf

[29] Michaels, C., Simpson, J. and Wegner, W. (Riverkeeper) September, 2010. *Fractured Communities.* p. 13. http://www.riverkeeper.org/wp-content/uploads/2010/09/Fractured-Communities-FINAL-September-2010.pdf

[30] IHS Global Insight. 2009. *Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing*. Report prepared for the American Petroleum Institute.
http://www.api.org/policy/exploration/hydraulicfracturing/upload/IHS-GI-Hydraulic-Fracturing-Natl-impacts.pdf

Hydraulic Fracturing Moratorium in New York

Currently, there are no wells being drilled in the New York portion of the Marcellus shale reservoir. And if a bill presently before the New York Assembly passes, there won't be any Marcellus gas wells in New York for at least another seven months. The Senate version of the bill passed on August 3, 2010. The bill included a measure to ban hydraulic fracturing in deep, horizontal gas wells in the state until May 15, 2011. The moratorium would provide the state's Department of Environmental Conservation more time to finish its review of the potential impacts of shale gas drilling, and develop new permitting guidelines. The *Associated Press* reports that the measure is expected to pass the Assembly in the fall.[31]

In its draft review, the New York DEC stated that prohibition of drilling would contravene Article 23-0301 of the Environmental Conservation Law.[32] So it is not likely that the department would support a long-term ban on drilling.

But it is possible that state legislators could continue to propose and pass legislation that would put development on hold across the entire state or within specific regions. During the 2010 Assembly there was a bill moving through the Assembly that proposed a moratorium on the issuance of drilling permits in the Catskill region until 120 days after the U.S. EPA completes its study on the potential impacts of hydraulic fracturing on water.[33]

Even if the statewide moratorium does not last, the New York City watershed is not likely to see any drilling because in April, 2010, NY State DEC announced strict regulations on shale gas drilling in the upstate area that supplies most of the City's drinking water. The regulations require companies to conduct an environmental impact review for every proposed well in the Catskills and Skaneateles Lake watersheds, making it highly unlikely that any drilling will be done there.[34]

A study conducted by Tim Considine for the American Petroleum Institute looks at three potential scenarios for gas development in the Marcellus shale states (NY, PA and WV). In the low development scenario there are no wells drilled in New York, in the medium scenario 340 wells are drilled in the state per year, and in the high scenario 502 wells are drilled annually. Under the low scenario, gas production from the Marcellus shale in 2010 is 4 billion cubic feet (bcf) per day, and this rises to 9.5 bcf/day and 13 bcf /day for the medium and high

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[31] August 4, 2010. "Natural gas drilling moratorium passes New York Senate." *Syracuse.com.* http://www.syracuse.com/news/index.ssf/2010/08/gas_drilling_moratorium_passes.html

[32] Draft SGEIS 9/30/2009, Page 9-2

[33] Oliva, Z. June 8, 2010. "Hydro-Fracturing Bill Advancing Through NYS Assembly," *HarrisonPatch*.
http://harrison.patch.com/articles/hydro-fracturing-bill-advancing-through-nys-assembly

[34] Navarro, M. April 23, 2010. "State decision blocks drilling for gas in Catskills," *New York Times*.
http://www.nytimes.com/2010/04/24/science/earth/24drill.html

development scenarios.[35]

Considine concludes that under the medium and high scenarios the Marcellus region would eventually become the largest natural gas field in North America, which he says could occur if New York lifts its drilling moratorium and Pennsylvania does not impose a severance tax. But if tax and regulatory policies are adopted that increase the costs of production or if natural gas prices remain low for an extended period, then the odds favoring the low development scenario increase substantially.

In the low scenario, Marcellus gas production is 4 bcf/day in 2010, which is 2 bcf/day lower than what is projected for the Marcellus in the ICF Natural Gas Market Report.[36]

If the drilling moratorium in New York is continued, and gas prices remain low, it's possible that the flow of gas from the Marcellus will not reach the levels anticipated in the ICF report.

Pennsylvania Severance Tax

Although not an environmental regulation per se, a severance tax could help local and state officials deal with the cost of some of the impacts related to Marcellus Shale gas development in Pennsylvania. The Governor's tax plan is similar to the severance tax imposed on the oil and gas industry in West Virginia. The tax levied on gas operators would be 5 percent at the wellhead, plus 4.6 cents per 1,000 cubic feet of gas produced. Such a tax is projected to raise $280 million in 2011.

The Governor Rendell said a severance tax could help to fund road damage, environmental protection, and the training for emergency workers in case of a disaster related to from natural gas drilling.[37]

A report prepared for the American Petroleum Institute suggests that the absence of a severance tax in Pennsylvania and New York helps to offset higher gas development costs in the Marcellus that result from regulations, climate conditions, topography, labor markets, and other structural factors. The authors point out the fact that currently Marcellus drilling is soaring in Pennsylvania and falling in West Virginia, and suggest that while other factors may account for this stark difference, the absence of a severance tax in Pennsylvania may account for a significant share of this difference. They conclude by saying that imposition of

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[35] Considine , T.J. July 14, 2010. *The Economic Impacts of the Marcellus Shale: Implications for New York, Pennsylvania, and West Virginia.* Prepared for the American Petroleum Institute. p. 34. http://www.api.org/policy/exploration/hydraulicfracturing/upload/API%20Economic%20Impacts%20Marcellus%20Shale.pdf

[36] ICF International, 2010. p. 51.

[37] Foster, K. Sept. 13, 2010. "Battle begins to place severance tax on Pa. Marcellus Shale drillers," *The Farm and Dairy*. http://www.farmanddairy.com/uncategorized/battle-begins-to-place-severance-tax-on-pa-marcellus-shale-drillers/15753.html

any significant severance tax on Marcellus gas could induce a redirection of investment flows to other shale plays or other profitable investments.[38]

These sentiments have been echoed by many others in the gas industry who warn that adopting West Virginia's tax structure could prompt some to send rigs, jobs and money for compressor stations and pipelines to shale formations in other states.[39]

Consequently, if a severance tax is passed in Pennsylvania this year, or in years to come, there may be a decline in growth of gas production from the Marcellus shale. Similarly, if New York chooses to allow drilling, but imposes a severance tax, gas production in that state might not be as robust as predicted.

New Pennsylvania Water Discharge Standards

In August of 2010, Pennsylvania state enacted new rules limiting the discharge of wastewater from gas wells to 500 milligrams per liter of total dissolved solids (TDS) and 250 milligrams per liter for chlorides. All new and expanding facilities that treat Marcellus shale wastewater are required to meet these discharge limits.[40]

The problem is, there is a severe shortage of treatment facilities that can process flowback and brine to meet these new standards. A facility run by Fountain Quail can meet the new limits, but only has the capacity to treat 200,000 gallons per day,[41] a second facility can handle 400,000 gallons of flowback per day,[42] and a third, under construction, is expected to have the capacity to treat one million gallons per day.[43]

That means there are still more than 7 million gallons/day of flowback and brines that are not being treated.[44]

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[38] Considine , T.J. July 14, 2010. *The Economic Impacts of the Marcellus Shale: Implications for New York, Pennsylvania, and West Virginia.* Prepared for the American Petroleum Institute. p. iv. http://www.api.org/policy/exploration/hydraulicfracturing/upload/API%20Economic%20Impacts%20Marcellus%20Shale.pdf

[39] Levy, M. September 12, 2010. "Marcellus Shale tax front and center in Capitol," Times Herald. http://www.timesherald.com/articles/2010/09/12/news/doc4c8d7ced6e626784380824.txt

[40] Beveridge, S. August 26, 2010. "DEP sets drilling rules for water protection." *Washington County Observer-Reporter*. http://www.observer-reporter.com/or/localnews/08-26-2010-Gas-drilling-water-regs

[41] Fountain Quail. July 8, 2010. "Fountain Quail already exceeding 2011 Treatment targets for flowback, produced water from shale gas drilling in Pennsylvania," Press Release.

[42] February 12, 2010. "DEP approves gas drilling wastewater treatment permit," SunGazette. http://www.sungazette.com/page/content.detail/id/539249.html?nav=5011

[43] Pennsylvania Department of Environmental Protection. June 11, 2010. "Pennsylvania DEP Secretary: New Treatment Plant Showcases Technology to Meet Stronger, Greatly Needed Water Quality Standards." Press Release. http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=12047&typeid=1

[44] In 2009, wastewater from fracturing flowback and brines produced by the natural gas industry in Pennsylvania was estimated by the industry to be 9 million gallons/day, and this figure was

DEP Secretary John Hanger estimated that treating the water will cost natural gas operators between 12 and 25 cents per gallon,[45] which amounts to additional costs of between $120,000 and $250,000 to treat a million gallons of flowback.

Disposal wells are not an option available in Pennsylvania,[46] although some operators are shipping their wastes to Ohio and possibly West Virginia where there are disposal wells. But transporting and disposing of wastes at injections wells is expensive,[47] and could become even more costly if Ohio passes a proposed bill that would create a $0.20-per-barrel disposal tax on wastes shipped from other states.[48]

The least expensive method of dealing with flowback is to reuse it to fracture another well. The wastewater is reconditioned with an additive and then blended with fresh water. The flowback water cannot be reused "as is" because the chloride levels create the potential for well casing corrosion, and bacteria in the flowback may also create downhole problems.[49]

Reusing flowback is not without its problems. There are concerns that even diluted flowback water may adversely impact a well's production capabilities.[50] Also, reusing flowback cannot be done indefinitely - a time will come when the wastewater is no longer fit to be used, or there may not be another well ready to be fracked. At that point in time, the waste is taken to a facility where the solids are separated out and the water can be reused for hydraulic fracturing.

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expected to increase to 19 - 20 million gallons/day in 2011 (**Source:** PA Department of Environmental Protection. April 11, 2009. "Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges." http://www.portal.state.pa.us/portal/server.pt/document/754458/high_tds_wastewater_strategy_041109_pdf)

[45] Trowbridge, E. June 18, 2010. "Marcellus drillers face stringent wastewater regulations," *Pittsburgh Post-Gazette.* http://www.post-gazette.com/pg/10169/1066449-454.stm#ixzz0zvDeFZaF

[46] Thompson, D. February 1, 2010. "Scientists search for the best treatment - Industry needs effective way to handle frac water." *Sun Gazette.* http://www.sungazette.com/page/content.detail/id/538767.html?nav=5011

[47] ALL Consulting report that in Arkansas it can cost upwards of $6/barrel ($0.14/gallon) to transport and dispose of wells in an independently owned disposal well. This works out to be about $140,000 to ship one million gallons. If Pennsylvania operators are shipping out of state, the transport distances may be greater than in the Arkansas example, so costs are likely higher. **Source:** Arthur, D., Bohm, B., Coughlin, B.J. and Layne, M. 2008. ALL Consulting. Hydraulic Fracturing onsiderations for Natural Gas Wells of the Fayetteville Shale. p. 18. www.aogc.state.ar.us/ALL%20FayettevilleFrac%20FINAL.pdf

[48] Hunt, S. January 10, 2010. "Gas wells' leftovers may wash into Ohio – Experts fear brine from Pennsylvania may end up here." Columbus Dispatch. http://www.dispatch.com/live/content/local_news/stories/2010/01/10/gas-wells-leftovers-may-end-up-here.html.

[49] Vidic, Radisav. 2010. *Sustainable Water Management for Marcellus Shale Development*. Slide 18. http://www.temple.edu/environment/NRDP_pics/shale/presentations_TUsummit/Vidic-Temple-2010.pdf

[50] http://www.sungazette.com/page/content.detail/id/538767.html?nav=5011

The new wastewater discharge rule has only been in effect for two months, so it's too early to determine whether the regulation may put a damper on Marcellus gas production in PA. The industry has suggested that it will. The president of a coalition of gas operators in the Marcellus said, " The new TDS limit is unique to Pennsylvania and could put oil and gas producers at a disadvantage, causing an investment shift to other states."[51]

Regulations Related to Hydraulic Fracturing

The regulatory initiatives concerning the development of the Marcellus shale are not unique, and growing public concern regarding the environmental and public health impacts from hydraulic fracturing is spurring similar initiatives wherever shale gas development is taking place.

Public concern with hydraulic fracturing has been steadily mounting since the early 1990s, when natural gas companies began fracturing in shallow geological formations such as coal beds. The primary concern at that time was over the potential injection or migration of toxic fracturing fluids into water aquifers located near or in the coalbed methane formations.

In 2004, EPA published a study that said hydraulic fracturing posed little or no threat to drinking water supplies in coalbed methane producing areas. While many critiqued the agency's results,[52] EPA declined any further study of the issue.

Over the past two years there's been a groundswell in public concern about hydraulic fracturing. The potential environmental impacts from hydraulic fracturing, especially on water resources, have come under intense scrutiny ever since natural gas companies started fracturing the Marcellus Shale formation. This is due in no small part to the fact that the Marcellus underlies watersheds that serve as New York City's drinking water.

Public concern has also intensified because more information has become available regarding the potential environmental and health effects related to hydraulic fracturing fluids and wastes. For example, for the past five years Dr. Theo Colborn has been collecting a wealth of data regarding chemicals used during hydraulic fracturing of natural gas wells. She has also researched the potential health effects related to exposure of these fracturing chemicals. Her

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[51] Campbell, C. June 11, 2010. "Proposed TDS levels split environmentalists, gas industry." *Observer-Reporter.* http://www.observer-reporter.com/or/mostread/06-11-2010-new-water-regulations

[52] E.g., Weston Wilson, EPA Whistleblower. Wilson, W. October 8, 2004. "Letter to Senators Allard, Campbell and Representative DeGette." http://earthworksaction.org/publications.cfm?pubID=372 And the Oil and Gas Accountability Project. Sumi, L. April 7, 2005. *Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know About Hydraulic Fracturing*. 64 pp. http://earthworksaction.org/pubs/DrinkingWaterAtRisk.pdf

most recent summary, includes chemical and health-related data on 201 chemicals used during the hydraulic fracturing process.[53]

Colborn found that 94% of the hydraulic fracturing fluid chemicals in her database are associated with skin, eye ad respiratory harm, 93% with harm to the gastrointestinal system, and 83% with brain and nervous system effects.

Colborn's research, which also includes analyses of chemicals found in waste pits and chemicals used during the drilling process, was groundbreaking because it was the first time citizens living amidst oil and gas operations had access to a body of scientific data on the potential health effects related to hydraulic fracturing fluids and chemicals used in natural gas development.

Chemical Disclosure

The increased awareness of the potential environmental and health impacts posed by hydraulic fracturing fluids and wastes have led to initiatives at the local, state and federal level to require companies to disclose the chemicals used during hydraulic fracturing.

In 2008, Colorado was the first state in the nation to require companies to disclose the chemicals that it was using in its hydraulic fracturing operations.[54] The rule requires companies to disclose the chemicals in fracturing fluids to health officials and regulators, but not the public. And disclosure was required only for chemicals stored in 50 gallon drums or larger.[55]

Two years later, Wyoming passed a much stronger disclosure rule as part of a package of revamped oil and gas rules. The Wyoming disclosure rules went into effect in September, 2010. It requires companies to submit a full list of the chemicals they plan to use during fracturing operations for each individual well. And once the fracturing operation is completed, companies must report the concentrations of each chemical used.[56]

At the federal level, in two separate initiatives, members of Congress[57] and EPA[58] have been pressing companies for more information about chemicals in fracturing fluids.

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[53] February, 2009. The Endocrine Disruption Exchange. Products and Chemicals Used in Fracturing.
http://www.endocrinedisruption.org/files/ProductsandChemicalsUsedinFracturing2-16-09.pdf
[54] Lustgarten, A. November 13, 2008. "Buried Secrets: Is natural gas drilling endangering U.S. water supplies?" *ProPublica*. http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113
[55] Lustgarten, A. November 13, 2008. "Buried Secrets: Is natural gas drilling endangering U.S. water supplies?" *ProPublica*. http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113
[56] Kusnetz, N. Septebmer 14, 2010. "Wyoming Fracking Rules Would Disclose Drilling Chemicals," *ProPublica.*
http://www.propublica.org/article/wyoming-fracking-rules-would-disclose-drilling-chemicals
[57] February 18, 2010. "Energy & Commerce Committee Investigates Potential Impacts of Hydraulic Fracturing."

And in Congress, two bills - the Fracturing Responsibility and Awareness of Chemicals (FRAC) Act by Rep. Dianne DeGette of Colorado, and Clean Energy Jobs and Oil Company Accountability Act[59] would require all oil and gas operators to disclose the chemicals used to fracture its wells. The FRAC Act would also amend the Safe Drinking Water Act to include hydraulic fracturing in its definition of underground injection.[60]

The Independent Petroleum Association of America (IPAA) claims that if hydraulic fracturing is regulated under the Underground Injection Control (UIC) provisions of the Safe Drinking Water Act that there would be an incremental cost of approximately $100,000 per unconventional well.[61]

The American Petroleum Institute puts the regulatory burden placed on shale operators at $47,333, and states state that hydraulic fracturing regulation would also lead to delays in well completion. According to API, experience suggests that a 20% reduction in the number of wells completed each year due to increased regulation is a valid assumption due to the additional time needed to file permits, push-back of drilling schedules due to higher costs, increased chance of litigation, injunction or other delay tactics used by opposing groups and availability of fracturing monitoring services.[62]

Both the IPAA and API estimates of "regulatory burden" are what those organizations have calculated to be the cost to ensure that gas wells that undergo hydraulic fracturing meet the standards required by Class I Underground Injection Control (UIC) wells. This requirement isn't part of any of the hydraulic fracturing regulations currently under consideration at the federal or state level. Although if the FRAC Act passes, it would open the door for this type of requirement in the future.

It is not possible to know whether or not federal fracturing legislation will go be successful this year or not. But when asked "Is a change in the law coming?" one

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http://energycommerce.house.gov/index.php?option=com_content&view=article&id=1896:energy-a-commerce-committee-investigates-potential-impacts-of-hydraulic-fracturing&catid=122:media-advisories&Itemid=55

[58] U.S. Environmental Protection Agency. September 9, 2010. EPA Formally Requests Information From Companies About Chemicals Used in Natural Gas Extraction / Information on hydraulic fracturing chemicals is key to agency study of potential impacts on drinking water. http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/ec57125b66353b7e85257799005c1d64!OpenDocumenthttp://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/HFvoluntaryinformationrequest.pdf

[59] Govtrack.us. S. 3663: Clean Energy Jobs and Oil Company Accountability Act of 2010. http://www.govtrack.us/congress/billtext.xpd?bill=s111-3663

[60] Govtrack.us. S.1215:Fracturing Responsibility and Awareness of Chemicals (FRAC) Act http://www.govtrack.us/congress/bill.xpd?bill=s111-1215

[61] Advanced Resources International. April 24, 2009. *Bringing Real Information on Energy Forward – Economic Considerations Associated with Regulating the American Oil and Natural Gas Industry.* Prepared for Independent Petroleum Association of America and the Liaison Committee of Cooperating Oil and Gas Associations. p. 17, Table 3.

[62] IHS Global Insight, p. 10.

Washington, DC analyst who tracks political developments in the energy sector replied, "Probably."

Exxon, who recently acquired XTO to get into the Marcellus shale gas play is apparently concerned enough about federal hydraulic fracturing legislation that the company included a clause with XTO that allows it to walk away from the deal "if Congress bans hydraulic fracturing or makes it prohibitively expensive."[63]

If the federal government doesn't regulate fracturing, other states can still follow Colorado's and Wyoming's lead and write their own rules requiring the disclosure of chemicals in hydraulic fracturing fluids.

Conclusions

The Marcellus shale gas play is blessed and cursed by its location. It has the benefit of being located in close proximity to major markets for natural gas. But it also lies beneath some major river basins that provide drinking water to millions of citizens.

The discovery and exploitation of natural gas from shale formations has been dubbed a "game changer" for natural gas supply in North America.[64] Indeed, the size of the resource is extremely large, although as pointed out by ICF in its *2010 Natural Gas Market Review*, there are many factors that could affect the amount of gas ultimately extracted from shales.

The extraction of natural gas from shales has not only been a game changer with respect to the North American natural gas supply outlook, it's raised public awareness with respect to natural gas drilling. This has spurred regulations that may ultimately slow the growth of shale gas development.

There are several regulatory initiatives currently being considered at the state and federal level that have the potential to influence the rate and extent of gas production from the Marcellus shale. The status of at least three of these – federal hydraulic fracturing regulations, the Pennsylvania severance tax and the drilling moratorium in New York State – may be resolved in the next several months, or they may linger for some time, creating uncertainty for the natural gas operators in the Marcellus region.

This report does not offer a detailed economic analysis of the potential compliance costs associated with present regulatory proposals. Rather it

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[63] Hargreaves, S. December 23, 2009. "Exxon's drilling juggernaut," CNNMoney.com http://money.cnn.com/2009/12/23/news/economy/exxon_drilling/index.htm

[64] For example: Medlock, K.B. Oct. 6, 2009. "Shale Gas: A game-changer with global implications." (James Baker Instititue for Public Policy, Rice University.) http://www.bakerinstitute.org/publications/EF-WWT-MedlockShaleGas-100609.pdf and Wynn, G. and Hirschler, B. January 28, 2010. "Shale gas is U.S. energy "game changer" - BP CEO," *Reuters.* http://www.reuters.com/article/idUSLDE60R1MV20100128

provides a qualitative overview of the potential for such regulations to significantly slow the production of Marcellus shale gas.

- If the ban on hydraulic fracturing in New York continues, and gas prices remain low, the American Petroleum Institute has calculated that Marcellus shale production might only be 4 billion cubic feet (bcf) per day. ICF's projected development scenario is that the Marcellus shale will produce 6 bcf/day in 2020. A 2 bcf/day shortfall would most likely mean that Marcellus gas would not be available to meet the winter demand at Dawn.
- The natural gas industry in Pennsylvania is in agreement that a severance tax would drive them out of Pennsylvania. They the West Virginia severance tax as being responsible for that state's lower drilling figures. It's unclear, however, how much of an exodus would occur, since so much investment has been made in leasing the Marcellus shale.
- To access the gas in the Marcellus shale, as well as other shale gas reservoirs, hydraulic fracturing is required. The hydraulic fracturing process uses massive quantities of water and creates massive quantities of wastewater. In Pennsylvania, there is not adequate capacity to dispose of or treat hydraulic fracturing flowback and brines. The expense of wastewater disposal or treatment can add significant costs on to the development of a Marcellus gas well. These costs may be too burdensome for some operators.
- If federal regulation of hydraulic fracturing occurs, the ramifications would be felt in every natural gas producing basin in the country. At this point in time, however, the disclosure provisions being proposed federally are not onerous, and should not affect any natural gas producer's bottom line. If more stringent regulations are proposed at some point in the future, then there may be costs that force some operators out of the Marcellus (or any other) shale gas play

Given the incipient state of U.S. regulatory controls over shale gas development, the seriousness of the environmental consequences arising from this development, and mounting public concern, projections for dramatic growth in production from shale formations may be significantly overstated.