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CHALLENGES OF UNCONVENTIONAL SHALE GAS DEVELOPMENT: SO WHAT'S THE RUSH?

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INTRODUCTION

Exploitation of previously inaccessible shale gas deposits is beginning to have a major impact on energy utilization in the United States. U.S. shale gas production increased from 1.0 trillion cubic feet in 2006 to 4.8 trillion cubic feet in 2010.[1] Shale gas accounted for 23% of U.S. natural gas production in 2010 and is projected to increase to 49% of production by 2035.[2] Similar growth is predicted in many other countries, with China believed to have the largest shale gas reserves.[3]

The advancing technology for shale gas extraction from previously inaccessible sites has resulted from research and development funded by the U.S. Department of Energy (DOE) and by the individual companies, and is being adopted globally in the many countries which have shale gas reserves.[4] Increased natural

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1. U.S. ENERGY INFO. ADMIN., REVIEW OF EMERGING RESOURCES: U.S. SHALE GAS AND SHALE OIL PLAYS 4 (2011), *available at* http://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf.

2. U.S. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2012 3 (2012), *available at* http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.

3. U.S. ENERGY INFO. ADMIN., WORLD SHALE GAS RESOURCES: AN INITIAL ASSESSMENT OF 14 REGIONS OUTSIDE THE UNITED STATES 4 (2011), *available at* http://www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf.

4. ALEX TREMBATH ET AL., BREAKTHROUGH INST. ENERGY & CLIMATE PROGRAM, WHERE THE SHALE GAS REVOLUTION CAME FROM (2012), *available at* http://thebreakthrough.org/blog/Where_the_Shale_Gas_Revolution_Came_From.pdf.

gas production in the U.S. is projected to cause significant job growth and to have positive national security implications.[5] Natural gas production is also viewed as environmentally advantageous, primarily because it replaces coal in power plants, thereby reducing emissions of sulfur oxides, particulates, and mercury.[6] The greater efficiency of burning natural gas in power plants results in less carbon dioxide emissions than does coal, but the value of unconventional shale gas development (UGD)[7] in avoiding climate change is unclear as methane is itself a potent greenhouse gas and the extent to which it will leak into the atmosphere during the drilling and distribution process is under debate.[8] Also of concern is the extent to which the plentiful availability of natural gas will slow down movement toward a low-carbon world. Both major U.S. political parties support shale gas development.[9]

Stepping back from this predominantly positive picture, we ask what might be the appropriate speed to extract the nation's shale gas. We suggest considering the risks and benefits of unconventional shale gas extraction in much the same way that we would consider the risks and benefits of the marketing of a new chemical agent or a new drug in which costs and benefits are

5. *Natural Gas from Shale: Unlocking Energy from Shale Gas Formations*, CHEVRON, http://www.chevron.com/deliveringenergy/naturalgas/shalegas/?utm_campaign=shale&utm_medium=cpc&utm_source=google&utm_term=hydraulic_Fracturing (last updated May 2012).

6. *See generally id.*

7. Unconventional shale Gas Drilling (UGD) differs from conventional shale gas drilling by its reliance on the techniques of horizontal drilling and hydrofracturing to release gas tightly bound to shale. Conventional shale gas drilling is usually aimed at large pools of underground gas.

8. *See, e.g.*, Robert W. Howarth et al., *Methane and Greenhouse-Gas Footprint of Natural Gas from Shale Formations*, 106 CLIMATIC CHANGE 679 (2011); Mohan Jiang et al., *Life Cycle Greenhouse Gas Emissions of Marcellus Shale Gas*, ENVTL. RES. LETTER, Aug. 5, 2011, at 1; Nathan Hultman et al., *The Greenhouse Impact of Unconventional Gas for Electricity Generation*, ENVTL. RES. LETTER, Dec. 15, 2011, at 1; CHEVRON, *supra* note 5. The consensus is that the Howarth paper overstates the extent of methane loss. If so, UGD provides a net benefit in terms of global climate change. However, it is still true that any methane loss will contribute to global climate change, and that the lessening of methane loss to the atmosphere is to industry's benefit as it is the product that they sell.

9. *See, e.g.*, Barack Obama, U.S. President, *Remarks by the President in State of Union Address* (Jan. 24, 2012), *available at* http://www.whitehouse.gov/the-press-office/2012/01/24/remarks-president-state-union-address (discussing natural gas, stated "America will develop this resource without putting the health and safety of our citizens at risk"); *see also America's Natural Resources*, REPUBLICAN PLATFORM, http://www.gop.com/2012-republican-platform_America/ (last visited Jan. 20, 2013). They both do so with expected caveats about the need to protect human health and the environment.

carefully considered prior to approval. The time element provides an additional reason to proceed slowly with respect to shale gas. Shale gas is a limited resource. The supply of natural gas in identified tight shale deposits in the U.S. will last perhaps two to five decades before it runs out. It is not a new surgical technology or wonder drug that once deployed will always be available, nor is it a newly developed chemical product with socially valuable uses that may continue for an indefinite time. We all recognize that it is tragic for people to die just before the cure for their disease becomes available. But will it be a tragedy if the window for exploitation of shale gas is delayed by a few years and simply extends that much longer?

We approach the subject by providing overviews of three different areas which are among those for which we believe more consideration of short-term issues would help maximize the benefits of UGD: direct health and environmental risks related to toxicology and safety issues; indirect effects on communities, including social disruption and attendant health impacts; and inefficiencies due to lack of clarity in the laws pertinent to the potential adverse consequences of shale gas drilling on the environment—particularly at the local level. For all three we will be describing paths forward. Our focus will be on the state of Pennsylvania, which has aggressively exploited its tight shale gas deposits. We begin by providing an overview of UGD and proceed to describe the confusion generated by industry's success in steering the debate to focus on the wrong questions. We also briefly consider the precautionary principle and sustainability in relation to shale gas development. We conclude by briefly comparing the current situation with UGD to the approach to drugs and medical devices under the Food, Drug, and Cosmetic Act (FDCA), and to new chemicals under the Toxic Substances Control Act (TSCA).

I. Overview of Unconventional Shale Gas Development[10]

The target for UGD is gas trapped within hydrocarbon-rich shale beds. In contrast to underground pools of natural gas which can be brought to the surface through a vertical well,

10. For overviews of UGD see FracTracker, www.fractracker.org (last visited Jan. 20, 2013); Sarah K. Adair et al., *Considering Shale Gas Extraction in North Carolina: Lessons from Other States*, 22 Duke Envtl. L. & Pol'y F. 257 (2012); Chevron, *supra* note 5; Office of Fossil Energy & Nat'l Energy Tech. Lab., U.S. Dep't of Energy, Modern Shale Gas Development in the United States: A Primer (2009), *available at* http://www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf.

retrieving shale gas requires breaking up the relatively impermeable source rock.[11]

Developing technology is particularly notable for increasing the ability to drill vertically deep underground; to bend the pipe horizontally within the shale layer; to blow open holes in the pipe within the shale gas layer; to inject water under pressure to break open the shale; and to include in the water a variety of hydrofracturing chemicals which help release the gas from the shale and otherwise increase gas yield.[12] Drilling operations typically occupy two to ten acres with perhaps eight separately hydrofractured wells; average about a thousand truckloads of water and other materials per well; often use poorly surfaced and relatively unsafe rural roads; involve noisy compressors; bring an influx of workers who are not part of the community; and have been accompanied by socially disruptive activities.[13]

Not surprisingly, much controversy has resulted from this sudden burst of industrial activity in rural and semi-rural areas. A majority of those testifying against UGD before a federal panel cited health concerns among the reasons for their opposition.[14] The opposition to UGD has affected the tempo of development in a number of the sixteen states now believed to have exploitable shale gas reserves. Pennsylvania, for example, has had over 9000 wells permitted since 2000, and over 6000 of those wells are drilled and/or producing.[15] The state of New York, however, has proceeded more slowly, only recently ending its formal moratorium and exempting critical watershed areas from UGD. Other states, such as Maryland and North Carolina, are still debating whether to proceed with drilling.[16]

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11. *See, e.g.*, OFFICE OF FOSSIL ENERGY & NAT'L ENERGY TECH. LAB., *supra* note 10, at 84.

12. *See generally id.*

13. *See, e.g.*, NAT'L ASS'N OF DEV. ORG. RES. FOUND., NATURAL GAS DRILLING IN THE MARCELLUS SHALE: ECONOMIC OPPORTUNITIES AND INFRASTRUCTURE CHALLENGES (2010), *available at* http://www.ruraltransportation.org/uploads/naturalgas.pdf.

14. Bernard D. Goldstein et al., *Missing from the Table: Role of the Environmental Public Health Community in Governmental Advisory Commissions Related to Marcellus Shale Drilling*, 120 ENVTL. HEALTH PERSP. 483 (2012).

15. Sean D. Hamill, *Powdermill Compiles List of Pa. Shale Wells*, PITT. POST-GAZETTE, May 25, 2012, http://www.post-gazette.com/stories/local/marcellus shale/powdermill-compiles-list-of-pa-shale-wells-637445/; *see also Carnegie Museum of Natural History Pennsylvania Unconventional Natural Gas Wells Geodatabase*, CARNEGIE MUSEUM OF NAT. HIST., http://www.carnegiemnh.org/powdermill/gis-wells.html (last updated May 2012).

16. *See* Editorial, *Md. Fracking Study Loses Ground*, BALT. SUN, Apr. 23, 2012, http://articles.baltimoresun.com/2012-04-23/news/bs-ed-fracking-20120423_1_fracking-study-fee-natural-gas (advocating for further study before

Shale gas from different locations differs in the extent to which hydrocarbons larger than methane (CH_4) are present.[17] The term "dry gas" is used for gas that is predominantly methane while a gas having more of the higher molecular weight compounds is called "wet gas."[18] Methane is not considered a toxic pollutant in the usual sense of direct effects of a chemical, although it is a potent greenhouse gas and at high levels is explosive and can cause asphyxiation.[19] However, the larger molecular weight wet gas components include agents that are of concern, such as benzene, a known cause of human leukemia.[20] Upwards of five million gallons containing between 0.5% and 1.5% hydrofracturing additives are used for each well.[21] Literally hundreds of different chemical and physical agents have been used in hydrofracturing. These agents range from sand to prop open the microfractures, to antimicrobial compounds to prevent against fouling.[22] Approximately 15% to 40% of the hydrofracking fluid is returned to the surface in a relatively short time.[23]

Flowback fluids returning to the surface can contain the known fracking fluids and naturally occurring chemicals from within the earth's surface, including hydrocarbons, dissolved

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deciding on UGD, stating ". . . given the industry's track record in neighboring Pennsylvania, it would seem foolhardy not to conduct one.").

17. *See, e.g.*, WORLD ENERGY COUNCIL, SURVEY OF ENERGY RESOURCES: SHALE GAS - WHAT'S NEW 5 (2012), *available at* http://www.worldenergy.org/documents/shalegasupdatejan2012.pdf.

18. *What's the Difference Between Wet and Dry Natural Gas?*, STATEIMPACT.ORG, http://stateimpact.npr.org/pennsylvania/tag/natural-gas-prices/ (last visited Jan. 20, 2013). The latter is more valuable, particularly now with oil being much higher in price than gas. Wet gas is also a source of chemical feedstock leading to plans for locating chemical plants in wet shale gas areas such as southwestern Pennsylvania.

19. *Basic Information on Methane*, CAN. CTR. FOR OCCUPATIONAL HEALTH & SAFETY, http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/methane/basic_met.html (last updated Dec. 11, 2006); *see also* Stephen G. Osborn et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, 108 PROC. NAT'L ACAD. SCI. U.S. 8172 (May 17, 2011), *available at* http://www.pnas.org/content/108/20/8172.full.pdf+html (stating that the presence of methane derived from shale in water or air can be considered to be an indicator of the probable presence of non-methane hydrocarbons).

20. ENVTL. & ENERGY STUDY INST., SHALE GAS AND OIL TERMINOLOGY EXPLAINED: PRODUCTS AND BYPRODUCTS (2011), *available at* http://files.eesi.org/fracking_products_120111.pdf.

21. *Shale Shock: Hydraulic Fracturing*, NATURALGAS.ORG, http://www.naturalgas.org/shale/shaleshock.asp (last visited Jan. 20, 2013).

22. *See What Chemicals Are Used*, FRACFOCUS.ORG, http://fracfocus.org/chemical-use/what-chemicals-are-used (last visited Jan. 20, 2013) (listing the chemicals used).

23. *Flowback Water*, WIKIMARCELLUS, http://waytogoto.com/wiki/index.php/Flowback_water (last updated Dec. 15, 2011, 11:24 AM).

minerals and metals, brine constituents, and radioactive materials.[24] From January through June 2012, more than twelve million barrels of unconventional waste were reported, including over four million barrels of drilling and flow back fluids.[25] Human exposure to these constituents can occur through ground water contamination via surface spills, faulty well casing over time, loss of integrity of containment ponds or structures, and hydrogeologic connections. During the first eight months of 2011, sixty-five wells in the Marcellus Shale formation were cited by the state of Pennsylvania for faulty casing and/or cement.[26]

Sources of air emissions include diesel trucks and machinery, compressor stations, storage tanks and condensate tanks. Volatile organic chemicals (VOCs) emitted from many parts of the drilling operations are of particular concern. VOCs are also ozone precursors as are oxides of nitrogen which are emitted from diesel sources and from other combustion processes associated with drilling. Other activities associated with a UGD site that raise concerns include heavy truck traffic and noise from compressors.

II. Managing the Advisory Process

Controversy about UGD led in 2011 to the formation of advisory committees by President Obama, Governor Corbett of Pennsylvania and Governor O'Malley of Maryland.[27] In their executive orders, all three specifically mention concern about public health and the environment. However, none of the fifty-two members appointed to these three committees has any background in health, even in the broadest sense of the term—e.g., no toxicologists or risk assessors, let alone physicians with environmental health expertise or other health care providers. None of the total of eight state agencies involved in the two states

24. Envtl. & Energy Study Inst., *supra* note 20.

25. Matt Kelso, *Pennsylvania Unconventional Waste Data*, FracTracker.org (Sept. 7, 2012), http://www.fractracker.org/2012/09/pennsylvania-unconventional-waste-data/.

26. Laura Legere, *DEP Inspections Show More Shale Well Cement Problems*, Times-Tribune, Sept. 18, 2011, http://thetimes-tribune.com/news/dep-inspections-show-more-shale-well-cement-problems-1.1205108#axzz1YPDNCmnB.

27. Goldstein et al., *supra* note 14; *Blueprint for a Secure Energy Future*, Whitehouse.gov (Mar. 30, 2011), http://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf; Pa. Exec. Order No. 2011-01 (Mar. 8, 2011), http://www.portal.state.pa.us/portal/server.pt/gateway/PTARGS_0_2_785_708_0_43/http%3B/pubcontent.state.pa.us/publishedcontent/publish/global/files/executive_orders/2010___2019/2011_01.pdf; Md. Exec. Order No. 01-01-2011-11 (June 6, 2011), http://www.governor.maryland.gov/executiveorders/01.01.2011.11.pdf.

includes those responsible for health. Similarly, the lead for the federal advisory committee was given to the DOE with input specified from the Environmental Protection Agency (EPA) and the Department of Interior—but not from the Department of Health and Human Services. None of the civic organizations represented on these committees has been among those that traditionally focused on human health aspects of the environment, such as the Children's Environmental Health Network, Group Against Smog and Pollution, or the American Lung Association.

Evaluation of the potential impact of UGD on non-human biota has fared only slightly better. Of the fifty-two members, only one has a scientific background related to ecosystems, although some of the environmental groups with leaders on the committees are primarily associated with ecological issues (e.g., Trout Unlimited; The Nature Conservancy). Not surprisingly, support for health-related research resulting from these advisory processes has been minimal or delayed until the future.

III. Managing the Information Related to Health and Environmental Research Needs: Contradiction and Confusion

In view of the relative lack of health and ecosystem expertise in the advisory process, it is perhaps understandable that three misleading statements downplaying the importance of health or ecosystem research are dominating the discussion of research needs. Each is arguably accurate at first glance. First, we are told that there is no need to worry because hydrofracturing to increase oil and gas yield has been used for many decades. This is contradicted by the repeated claim that hydrofracturing of shale gas is an exciting new technology that permits us to obtain previously untapped natural gas resources. Both of these claims cannot be true. In fact, while hydrofracturing began close to fifty years ago, technology has developed such that instead of using perhaps 50,000 gallons of water in relatively shallow vertical wells, the process now uses upwards of five million gallons in wells bent horizontally in shale layers more than 1.5 kilometers underground.[28] The chemical and physical agents used for hydrofracturing are also changing. Claiming that there is no need to worry because the basic technology is unchanged is akin to argu-

28. *Compare Hyrdaulic Fracturing: The Process*, FracFocus, http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process (last visited Jan. 20, 2012) *with A Historic Process*, FracFocus, fracfocus.org/hydraulic-fracturing-how-it-works/history-hydraulic-fracturing (last visited Jan. 20, 2013).

ing that there is no more risk from a hand grenade than from a firecracker because they are both explosives.

A second misleading statement seemingly aimed at limiting health research is that there is no proof that hydrofracturing leads to groundwater contamination. This statement may well be true if the term "hydrofracturing" is restricted to the successful release of chemicals at depths more than a thousand meters below natural groundwater aquifers. But it is also true that groundwater contamination from hydrofracturing chemicals has occurred, and that communities have been told not to drink from their polluted wells. The cause of the contamination from hydrofracturing chemicals has included the rupture of well casings and loss of containment of the hydrofracturing chemicals above ground. In terms of research, the strong industrial and political support for a thorough evaluation of the issue of whether hydrofracturing chemicals released deep underground reaches groundwater can be seen as a cynical attempt to focus research on a question whose answer is highly likely to be favorable to those who advocate drilling.

Thirdly, there is a misleading focus on only the hydrofracking agents that are intentionally added to water, rather than on those chemical and physical agents that come to the surface and need to be disposed of carefully. The chemicals used in the hydrofracturing process have been withheld from the public, but we are told that the secrecy issue has been solved. Recent laws in Colorado, Pennsylvania and elsewhere are a step forward. These laws require that the names of the hydrofracturing agents used locally be released, except if claimed to be confidential business information.[29] However, the language very specifically exempts drilling companies from disclosing information about compounds brought up to the surface, such as arsenic, barium, radionuclides, and brine components. Exemptions also exist for compounds that are caused by chemical reactions or that are incidental or unintentional.[30] A far greater concern than what is injected deep underground is the mixtures of hydrofracturing chemicals, natural gas hydrocarbons and natural underground

29. *See also* 58 PA. CONS. STAT. § 3222.1 (2012). The loophole for Confidential Business Information (CBI) does not preclude a physician from obtaining this information for the purpose of treating a patient. But it would require the physician to sign a legally binding non-disclosure form which would be chilling in itself, and would likely violate Pennsylvania's laws for physician reporting of health threats. *See generally* Act 13 of 2012, 2012 Pa. Laws 1, *available at* http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/2012/act13.pdf (last visited Jan. 20, 2013).

30. *Id.*

constituents that are brought back to the surface and must be disposed of safely. Of the upwards of five million gallons forced underground during the hydrofracturing process, perhaps 15% to 40% returns to the surface relatively quickly as flowback water. Produced water, which has the hydrocarbons and natural underground constituents similar to flowback water, refers to water that comes to the surface more slowly during the perhaps decade or longer lifetime of the extraction process. Disposal of this large volume of water from the many thousands of wells that are to be drilled is challenging. Even without the presence of toxic chemicals and radionuclides, the water's brine content far exceeds that of seawater or of wastes that can be readily disposed of safely.

Note that each of these misleading statements has the intended or unintended impact of diminishing the need for health research. Research is unnecessary if we have decades of experience with allegedly no reported health problems; it is unnecessary if the only question is whether the hydraulic fracturing chemicals released many thousands of feet underground percolate up to groundwater; and it is unnecessary if the only possible concern is with disclosed chemical and physical agents that are individually well-studied and of no particular toxicological concern at low concentrations.[31]

IV. Health Impacts of UGD

Information about the potential health impacts of UGD has begun to develop, albeit relatively slowly.[32] A number of studies

31. Unfortunately, there has been a tendency for politicians who are unhappy with scientific findings to resort to ad hominem attacks on scientists. One example is that of the Pennsylvania Secretary of Environmental Protection Michael Krancer, whose Congressional testimony gratuitously attacked Cornell University scientists who had estimated the global climate effects of methane leaks, and Duke University scientists who reported methane in water wells. *See Natural Gas Drilling: Pennsylvania's Perspective, the State's Regulation of the Natural Gas Industry*: *Hearing Before the Subcomm. On Water Res. and Env't of the H. Comm. on Transp. and Infrastructure*, 112th Cong. (2011) (testimony of Michael L. Krancer, Sec'y Pa. EPA), *available at* http://files.dep.state.pa.us/AboutDEP/AboutDEPPortalFiles/RemarksAndTestimonies/MLK-Testimony-111611.pdf.

32. *See, e.g.*, Madelon L. Finkel & Adam Law, *The Rush to Drill for Natural Gas: A Public Health Cautionary Tale*, 101 Am. J. Pub. Health 784 (2011); Theo Colborn et al., *Natural Gas Operations from a Public Health Perspective*, 17 Hum. Ecological Risk Assessment 1039 (2011); Bernard D. Goldstein & Jill Kriesky, *The Public Health Implications of Unconventional Natural Gas Drilling*, *in* Contemporary Technologies for Shale-Gas Water and Environmental Management 33 (Water Env't Fed'n 2012); Roxana Witter, Assistant Research Professor, Colo. Sch. of Pub. Health, Community Impacts of Natural Gas Development and Human Health at the Workshop on Health Impact Assessment of New

have documented the fact that people are concerned about their health, and have reported on these concerns. They include a variety of non-specific symptoms, such as nausea and headaches, as well as symptoms that are traceable to specific body organ systems, such as the respiratory and gastrointestinal tracts.[33]

A. *Water Pollution*

Water pollution has been a central concern. There has been no comprehensive attempt to gather pre-drilling information about water quality. In Pennsylvania, the new Marcellus Shale Act (Act 13) increases the likelihood that industry will obtain baseline water quality data through holding companies liable for any nearby water quality problems unless it can show that the problems were pre-existing.[34] Three major potential sources of water pollution are the hydrofracturing chemicals intended to be introduced into the well; hydrocarbons, such as methane, that can infiltrate into nearby groundwater; and the flowback water that comes up from the well as a result of the hydrofracturing processes, and which brings with it agents naturally present underground.[35]

Energy Sources: Shale Gas Extraction (Apr. 30, 2012); ROXANA WITTER ET AL., HEALTH IMPACT ASSESSMENT FOR BATTLEMENT MESA, GARFIELD COUNTY COLORADO (2010), *available at* http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf); ROXANA WITTER ET AL., POTENTIAL EXPOSURE-RELATED HUMAN HEALTH EFFECTS OF OIL AND GAS DEVELOPMENT: A WHITE PAPER (2008), *available at* http://docs.nrdc.org/health/files/hea_08091702a.pdf13 (issue of health effects raised or summarized in peer reviewed literature).

33. *See* WILMA SUBRA, EARTHWORKS' OIL & GAS ACCOUNTABILITY PROJECT, HEALTH SURVEY RESULTS OF CURRENT AND FORMER DISH/CLARK, TEXAS RESIDENTS (2009), *available at* http://www.earthworksaction.org/library/detail/health_survey_results_of_current_and_former_dish_clark_texas_residents/; WILMA SUBRA, EARTHWORKS' OIL AND GAS ACCOUNTABILITY PROJECT, COMMUNITY HEALTH SURVEY RESULTS, PAVILLION, WYOMING RESIDENTS (2010), *available at* http://www.earthworksaction.org/files/publications/PavillionFINALhealth Survey-201008.pdf (work by Subra has described these symptoms) (cataloguing symptoms among those who are complaining or in a potentially biased sample of the population can be valuable in pointing toward the need for more thorough studies and the dimensions of such additional studies); *see also* Kyle J. Ferrar et al., Assessment and Logitudinal Analysis of Health Impacts and Stressors Perceived to Result from Unconventional Shale Gas Development (submitted for publication) (on file with authors) (Our unpublished work in Pennsylvania has shown similar findings in individuals concerned about the impact of shale gas drilling on their health and demonstrated that the findings persist in the same population over time.).

34. *See also* 58 PA. CONS. STAT. § 3222.1 (2012). *See generally* Act 13 of 2012, 2012 Pa. Laws 1.

35. *See supra* Part II.

B. *Air Pollution*

Air pollution is of concern both locally and regionally. While not well-studied, emissions are expected to be highest during the two to six week period that hydrofracturing is occurring at any one well.[36] Several researchers have reported that air pollution levels during hydrofracturing at a local site in Colorado exceeded various federal health risk guidelines.[37] Currently, multiple wells are drilled at each drill pad and hydrofracturing may be repeated at any one well, so air pollution from hydrofracturing may be a recurring exposure issue for those living in the immediate locality of a drilling pad.[38] With thousands of wells planned in regions with natural gas resources trapped in the shale, this also becomes a regional issue. Ozone is a particular concern as its precursors are both hydrocarbons and oxides of nitrogen—the latter potentially emitted in large quantities from the many diesel trucks, diesel compressors, and other combustion sources that are part of the UGD process. Many areas of the Northeast are struggling to meet the national ambient standard for ozone, particularly as recent scientific findings are leading to a push for more stringent ozone standards.[39] There is a potential irony here in that exceeding the ozone standard usually leads to curtailing industrial activity—the opposite of the major sales pitch for UGD.[40]

C. *Worker Health*

Drilling of oil or gas wells is a relatively hazardous operation requiring particular care.[41] The National Institute for Occupational Safety and Health (NIOSH) has found that oil and gas workers are at high risk for fatalities with a rate approximately

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36. Lisa M. McKenzie et al., *Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources*, 424 SCI. TOTAL ENV'T 79, 80 (2012). Also, note that there is a growing body of evidence linking social stress to susceptibility to the adverse health effects of air pollutants. *See, e.g.*, Jane E. Clougherty & Laura D. Kubzansky, *A Framework for Examining Social Stress and the Susceptibility to Air Pollution in Respiratory Health*, 117 ENVTL. HEALTH PERSP. 1351 (2009).

37. *See* McKenzie, *supra* note 36.

38. *See id.*

39. Jesse D. Berman et al., *Health Benefits from Large Scale Ozone Reduction in the United States*, 120 ENVTL. HEALTH PERSP. 1404 (2012).

40. *See supra* Parts I–III.

41. Scott J. N. McNabb et al., *Injuries to International Petroleum Drilling Workers, 1988 to 1990*, 36 J. OCCUPATIONAL MED. 627 (1994); Ctr. for Disease Control & Prevention, *Fatalities Among Oil and Gas Extraction Workers—United States, 2003-2006*, 57 MORBIDITY & MORTALITY WKLY. REP. 429 (2008) [hereinafter CDC].

seven times higher than the fatality rate for all U.S. workers.[42] Close to half of all fatalities were related to motor vehicle accidents or heavy machinery or equipment.[43] Drilling muds and vapors are also hazardous.[44] Hydrofracturing adds additional burdens, including safety hazards related to bringing water and hydrofracturing agents to and from the often crowded drill site, as well as the toxicity of the hydrofracturing agents. NIOSH has been evaluating the potential health issues related to exposure to silica which is used as a proppant to keep open the underground shale fractures.[45] Exposure to silica is an issue not only on the site but also for the workers in mines which have been opened to provide silica for UGD.

D. *Radiation Issues*

Relatively high background levels of naturally occurring radioactive agents are a feature of seabeds, including the ancient seabeds that are now shale layers. Two issues have been raised. First is the potential for high radon levels in natural gas delivered to consumers. One researcher has pointed out that natural gas to the New York metropolitan area now comes from the Gulf Coast.[46] The travel time is sufficiently long that there will be natural decay of radon, which has a half-life of only 3.8 days, thereby lessening its radioactivity when it reaches the consumer.[47] Presumably, this travel time would be greatly shortened if the natural gas began its journey to New York City from the Marcellus Shale areas of northeastern Pennsylvania, thereby resulting in

42. *See* CDC, *supra* note 41.

43. *Id.*

44. Kjersti Steinsvag et al., *Effect of Drilling Fluid Systems and Temperature on Oil Mist and Vapor Levels Generated from Shale Shaker*, 55 ANN. OCCUPATIONAL HYGIENE 347 (2011).

45. *See* OSHA-NIOSH, HAZARD ALERT: WORKER EXPOSURE TO SILICA DURING HYDRAULIC FRACTURING (2012), *available at* http://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.pdf (stating that exposure to silica causes lung damage and chronic lung disease).

46. MARVIN RESNIKOFF, RADIOACTIVE WASTE MGMT. ASSOC., RADON IN NATURAL GAS FROM MARCELLUS SHALE: EXECUTIVE SUMMARY (2012), *available at* http://www.nirs.org/radiation/radonmarcellus.pdf. Reznikoff has had to make many assumptions in his calculations, again reflecting the absence of relevant data needed to address this significant potential problem. He has also calculated that there will be an additional 1,182–30,448 excess lung cancer deaths due to radon from the Marcellus Shale. *Id.* at 2. Marvin Resnikoff, *Radioactivity in Marcellus Shale Challenge for Regulators and Water Treatment Plants*, *in* CONTEMPORARY TECHNOLOGIES FOR SHALE-GAS WATER AND ENVIRONMENTAL MANAGEMENT, *supra* note 32, at 45.

47. *See* RESNIKOFF, RADON IN NATURAL GAS FROM MARCELLUS SHALE, *supra* note 46.

higher levels of radioactivity and a greater lung cancer risk in homes with gas appliances. The second issue is that of technically-enhanced, naturally-occurring radioactive materials (TENORM), a problem that is not unusual in the oil and gas industry. TENORM refers to the higher levels of radioactivity that may result from concentrating radioactive agents as a result of technology, such as scales of radioactive particles that may develop in pipes that have transmitted large volumes of natural gas.[48]

E. *The Particular Problem of Mixtures*

One of the issues of greatest toxicological concern raised by UGD is that of the potential impact of untested mixtures of chemicals. Traditionally, both drugs and environmental agents have been evaluated one at a time. Untoward experiences with drug mixtures are a staple of medical pharmacology. For environmental agents, there has been a longstanding challenge to understand and predict the effects of the mixtures. This challenge can be met when we actually test the mixture, such as gasoline, or have sufficient human experience to gather epidemiological evidence, such as with coffee.[49] Advances in basic biological research and in informatics are now being applied to understanding and predicting the impact of external agents on humans.[50] It is imperative that they also be brought to bear on mixtures of toxicological concern, including the mixtures of chemicals associated with UGD.

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48. *See* Resnikoff, *in* CONTEMPORARY TECHNOLOGIES FOR SHALE-GAS WATER AND ENVIRONMENTAL MANAGEMENT, *supra* note 46, at 45.

49. *See* Jane V. Higdon & Balz Frei, *Coffee and Health: A Review of Recent Human Research*, 46 CRITICAL REV. FOOD SCI. & NUTRITION 101 (2006).

50. For an example, see Robert Kavlock et al., *Update on the EPA's ToxCast Program: Providing High Throughput Decision Support Tools for Chemical Risk Management*, 25 CHEMICAL RES. TOXICOLOGY 1287 (2012). Computational toxicology in which computer programs are used to rapidly and efficiently predict the impacts of small changes in chemical structure is routinely used by the pharmaceutical industry in developing new drugs. The U.S. EPA and National Institute of Environmental Health Sciences are cooperating in using similar technology for predicting the toxicity of chemical compounds. Advances in molecular biology also have provided avenues for improved predictability of chemical toxicity. *See* COMM. ON TOXICITY TESTING & ASSESSMENT OF ENVTL. AGENTS & NAT'L RES. COUNCIL, TOXICITY TESTING IN THE 21ST CENTURY: A VISION AND A STRATEGY (2007); *see also* NAT'L INST. OF ENVTL. HEALTH SCI., ADVANCING RESEARCH ON MIXTURES: NEW PERSPECTIVES AND APPROACHES FOR PREDICTING ADVERSE HUMAN HEALTH EFFECTS (2011), *available at* http://www.niehs.nih.gov/about/visiting/events/pastmtg/2011/mixtures/pdf_supporting_materials.pdf (applying these approaches to chemical mixtures is being considered).

V. SURPRISES

It is hubristic to assume that we can completely understand and control all aspects of a complex and evolving technology, much of its operation occurring deep underground, with upstream and downstream ramifications that are still unclear. About the only certainty is that there will be surprises. Two surprises related to the disposal of flowback and produced water have already occurred. The discovery of bromine in the effluent coming out of Publicly Owned Treatment Works (POTWs) in southwestern Pennsylvania led to a "voluntary moratorium" on using POTWs for such wastewater.[51] Much of the waste was then trucked to Ohio for injection into deep disposal wells, a process that was hastily suspended when it was found, unexpectedly, to cause local earthquakes.[52]

More unexpected consequences of this evolving technology can be anticipated. Avoiding adverse consequences of surprises requires expecting the unexpected. The likelihood of surprises increases when shortcuts are taken. Several historical technological disasters, including the Titanic and extending to the recent Deepwater Horizon and Fukushima incidents, have a key element of lack of adequate preparation for the unexpected coupled with an erroneous belief that all was safe.[53] Avoiding surprises requires vigorous regulatory oversight and transparency. It also requires avoiding undue haste. Every technological option related to the drilling process or to upstream or downstream activities should be carefully considered and subject to pilot testing before being used.

VI. PRECAUTIONARY PRINCIPLE

In the context of UGD, the precautionary principle argues for a "go slow" approach. This controversial and variously defined principle was developed in Europe and has been adopted as a cornerstone of EU environmental policy.[54] Its key

51. Scott Detrow, *Explaining Pennsylvania's Link to Ohio Earthquakes*, STATEIMPACT.ORG (Apr. 4, 2012), http://stateimpact.npr.org/pennsylvania/2012/04/04/pennsylvanias-link-to-ohio-earthquakes/.

52. *Id.*

53. Note that we use the term incident rather than accident. In public health we distinguish between accidents, which we define as occurring by chance (e.g., a meteor hitting an off-shore oil rig) and incidents which are preventable, such as the Deepwater Horizon event).

54. Press Release, European Comm'n, Commission Adopts Communication on Precautionary Principle, IP/00/96 (Feb. 2, 2000), *available at* http://europa.eu/rapid/press-release_IP-00-96_en.htm?locale=en. The precautionary principle is also seen as having been manipulated by the EU to provide a basis

elements include shifting the burden of proof for safety to industry, taking preventative action in the face of uncertainty, exploring alternatives including avoidance, and fostering public participation in decisions.[55]

Definitions of the precautionary principle have been divided into "strong" and "weak," with the stronger providing more of an imperative on protecting the environment irrespective of economic benefits.[56] Adherents of a "strong" version of the precautionary principle would argue for a complete moratorium on shale gas drilling until all of the issues were resolved, and the burden for satisfactorily resolving the issues would fall completely on industry.

In the U.S., the precautionary principle has been adopted by a number of municipalities, ranging in size from San Francisco, California to Lyndhurst, New Jersey.[57] However, it has not achieved the status of a guiding principle enshrined in laws and constitutions as it has in the EU.[58] Overall, however, U.S. environmental law has been judged to be similar to EU law in its

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for erecting trade barriers to protect its agriculture, a reason why it has fallen into some disrepute among EU trading partners, including the U.S., Canada, and much of the developing world. *See* Bernard D. Goldstein, *Problems in Applying the Precautionary Principle to Public Health*, 64 OCCUPATIONAL & ENVTL. MED. 571, 571 (2007); *see also* James K. Hammitt et al., *Precautionary Regulation in Europe and the United States: A Quantitative Comparison*, 25 RISK ANALYSIS 1215 (2005). Note that evaluation by Hammitt of the extent to which precaution is used in U.S. and EU environmental regulations suggests that there is little difference. *Id.* at 1227. *See generally* Bernard D. Goldstein & Russellyn S. Carruth, *Implications of the Precautionary Principle to Environmental Regulation in the United States: Examples from the Control of Hazardous Air Pollutants in the 1990 Clean Air Act Amendments*, 66 LAW & CONTEMP. PROBS. 247 (2003) (evaluating the Hazardous Air Pollutants provisions of the 1990 Clean Air Act Amendments in relation to the precautionary principle).

55. David Kriebel et al., *The Precautionary Principle in Environmental Science*, 109 ENVTL. HEALTH PERSP. 871, 871 (2001); Rudi H. Nussbaum et al., *Community-Based Participatory Health Survey of Hanford, WA, Downwinders: A Model for Citizen Empowerment*, 17 SOC'Y & NAT'L RESOURCES 547, 552 (2004).

56. Nicholas A. Ashford et al., *Implementing the Precautionary Principle: Incorporating Science, Technology, Fairness, and Accountability in Environmental, Health, and Safety Decisions*, 5 INT. J. RISK ASSESSMENT & MGMT. 112 (2005); United Nations Conference on Environment and Development, *Final Declaration, Principle 15* (1992).

57. *See The Precautionary Principle in Action*, TAKINGPRECAUTION.ORG, http://www.takingprecaution.org/inact_bayarea.html (last visited Jan. 20, 2013); *Town of Lyndhurst, N.J. Adopts the Precautionary Principle*, PRECAUTION.ORG, http://www.precaution.org/lib/08/prn_lyndhurst_passes_pp_law.081111.htm (last visited Jan. 20, 2013).

58. LA CONSTITUTION Oct. 4, 1958, Charter for the Environment, art. 5 (Fr.). *See European Commission Adopts Precautionary Principle*, *supra* note 54 (discussing EU policy).

incorporation of precaution.[59] The 1990 U.S. Clean Air Act Amendments are an example of this similarity.[60]

VII. SUSTAINABILITY

The concept of sustainability is growing in importance as a means to approach complex local and global issues. The classic definition of sustainable development is development "that meets the needs of the present without compromising the ability of future generations to meet their own needs."[61] Sustainable development is based upon three pillars: economic, environmental, and social. Achieving the appropriate balance between these three is both the essence of sustainability, and its challenge.[62]

In our opinion, the precepts of sustainability are being violated by the current rush to UGD in two major ways. First, there has been very little consideration of the long-term consequences of UGD, let alone the multigenerational aspects of drilling that are central to sustainability. Many of the rural and semi-rural areas in which shale gas development is occurring have depended in the past on ecosystem services, including tourism, hunting, fishing, hiking, and natural beauty for their income. Many of these ecosystem services depend upon clean water. Will the land retain its attraction after the drilling is over?[63] Will retirees or others looking for a second home in a natural area still be attracted to these rural or semi-rural communities?

The second sustainability issue concerns the fact that shale gas is a limited resource. What would be the consequences if, for instance, one were to slow down shale gas extraction so that it began and ended two years later? This raises two issues. The long-term policy issue is whether it is more advantageous to have

59. Hammitt et al., *supra* note 54, at 1227.

60. Goldstein & Carruth, *supra* note 54, at 253.

61. The Bruntland Commission, *Report of the World Commission on Environment and Development: Our Common Future*, 16 (1987), http://www.un-documents.net/our-common-future.pdf.

62. COMM. ON INCORPORATING SUSTAINABILITY IN THE U.S. ENVTL. PROTECTION AGENCY, NAT'L RESEARCH COUNCIL, SUSTAINABILITY AND THE U.S. EPA (2011) (responding to a request from the EPA and providing a partial framework for sustainable action).

63. Pennsylvania now requires that drilling companies obtain bonds to ensure complete cleanup of sites ranging in size from $4,000 for up to fifty wells with total well bore lengths of less than 6000 feet and up to $600,000 for more than 150 wells with total well bore lengths of greater than 6000 feet. *Act 13 Frequently Asked Questions*, PA. DEP'T OF ENVTL. PROT. (Mar. 9, 2012), http://files.dep.state.pa.us/OilGas/OilGasLandingPageFiles/Act13/Act_13_FAQ.pdf. This hardly seems adequate to deal with surface restoration, let alone any substantial cleanup of water resources that might be needed.

the natural gas now or perhaps a few decades from now. Uncertainties in responding to this question include how quickly non-fossil fuel sources become available in relation to natural gas, as well as price and unpredictable future national security issues.[64] But the second issue more predictably argues in favor of a delay. The continual improvement in hydrofracturing-related technology leads to extracting an ever greater percent of the natural gas trapped in tight shale formations. In other words, less and less gas in the underground shale layer is being left behind after hydrofracturing. Those states, such as Pennsylvania and West Virginia, which have moved more quickly to develop shale gas resources will end up with less economic benefit in royalties than those states which will reap the benefit of the improved technology based upon lessons learned from current hydrofracturing activities. Similarly, there is ongoing improvement in recycling of hydraulic fracturing fluids, stability of cement casings, and other approaches to minimize environmental and occupational health risks based upon the experiences of early adopters.

VIII. Socioeconomic and Public Health Impact of Shale Gas Drilling

"Every single Pennsylvanian has more money in their pocket today—to save, invest and help make ends meet—as a result of plentiful natural gas development from the Marcellus Shale."[65]

At best, this statement by the leader of Pennsylvania's natural gas coalition is hyperbole designed to grab newspaper headlines. At worst, it is an indicator of an industry strategy designed to obfuscate the complex set of both positive and negative economic, social, and health impacts experienced in the largely rural Pennsylvania communities in which drilling has occurred to date. Indeed, the published analyses of the factors contributing to these impacts are limited and at this time do not provide a comprehensive conclusion regarding the full benefits and costs

64. It seems plausible that the value of natural gas will be greater in the future than it is now, but we note that we are not experts in this area. *See generally* Austin L. Mitchell & Elizabeth A. Casman, *Economic Incentives and Regulatory Framework for Shale Gas Well Site Reclamation in Pennsylvania*, 45 Envtl. Sci. & Tech. 9506 (2011) (analyzing environmental impact of rapid well expansion despite two-thirds price drop in three years).

65. Kevin Begos, *AP: Pa. Gas Drilling Brought $3.5 Billion in 2011*, Huffington Post (May 5, 2012, 12:05 PM), http://www.huffingtonpost.com/huff-wires/20120505/us-gas-drilling-value/ (quoting Kathryn Klaber, President of the Marcellus Shale Coalition. This membership organization includes representatives of shale gas drilling companies and ancillary industries. Established in 2008, it is the leading advocate for the rapid development of the industry in Pennsylvania.).

of shale gas drilling. The existing evidence of economic, social, and health impacts is considered in turn below.

Individuals who have negotiated leases for extraction of the shale gas beneath their property have experienced financial gains described anecdotally. But the actual size and distribution of such income have not been measured systematically. In 2009, a Penn State survey of 501 landowners living within 1000 feet of active Marcellus wells in Bradford and Tioga Counties found that 82% (412 of the 501 respondents) had signed natural gas leases.[66] Eighty-five percent had received a one-time lease payment, based on per acre prices ranging from one dollar to $5,750.[67] Reported royalties ranged from less than $25,000 (73%) to more than $250,000 (2%) with a total reported income of about $2.4 million.[68] A study by Jeffrey Jacquet and Richard Stedman of the efforts of landowners in the Southern Tier counties of New York (just north of the Pennsylvania border) to form coalitions to jointly bargain agreements indicates lease payments of approximately $2,500 per acre and royalties of 15%.[69] But the size of these earnings was not measured as part of the study.

The most commonly cited benefit beyond that to leaseholders is the increase in jobs brought by the Marcellus Shale. Here, a debate rages over the numbers cited by industry and its supporters, state government, and independent researchers. The Marcellus Shale Coalition website claims that the industry supported more than 200,000 jobs in the region in 2011.[70] Pennsylvania Governor Tom Corbett, a strong supporter of the industry, announced in September 2012 that "nearly 240,000 Pennsylvanians are now employed in the natural gas industry or ancillary businesses."[71] However, the Pennsylvania Center on Budget and Policy points out that this estimate, based on a gener-

66. TIMOTHY W. KELSEY ET AL., MARCELLUS SHALE EDUC. & TRAINING CTR., ECONOMIC IMPACTS OF MARCELLUS SHALE IN PENNSYLVANIA: EMPLOYMENT AND INCOME IN 2009 21 (2011), *available at* http://marcellus.psu.edu/resources/PDFs/Economic%20Impact%20of%20Marcellus%20Shale%202009.pdf.

67. *Id.* at 22.

68. *Id.*

69. *See* Jeffrey Jacquet & Richard C. Stedman, *Natural Gas Landowner Coalitions in New York State: Emerging Benefits of Collective Natural Resource Management*, 26 J. RURAL SOC. SCI. 62, 75 (2011).

70. *Production Processes*, MARCELLUS SHALE COAL., http://marcelluscoalition.org/marcellus-shale/production-processes/ (last visited Jan. 20, 2013).

71. *ICYMI: Shale Gas Insight Highlights*, MARCELLUS SHALE COAL. (Sept. 25, 2012), http://marcelluscoalition.org/2012/09/icymi-shale-gas-insight-highlights/.

ous definition including core and ancillary industries, represents only 4.2% of total state employment.[72]

Other economic benefits to consider include how the price of natural gas has fallen and its impact on household incomes, contributions to local and state governments through tax collections, including the most recent user fees, and the benefits that may accrue to Pennsylvanians as a result. Although estimates for the former are not available, the Pennsylvania Public Utility Commission reported that the first quarterly payment of user fees generated under the recently enacted comprehensive natural gas extraction legislation, Act 13, reached nearly $206 million, exceeding expectations by $25 million.[73] The revenue will be distributed between the state, thirty-seven counties, and 1500 municipalities where drilling and extraction occurs.[74] In addition, a 2012 study by Charles Constanzo and Timothy Kelsey concludes that "[s]tate tax collections in counties with significant activity related to Marcellus Shale drilling witnessed, on average, larger percentage increases in sales, personal income, and smaller declines in realty transfer tax collections than did other Pennsylvania counties," with three counties—Susquehanna, Greene, and Bradford—showing greater than 25% increases in 2011.[75] However, the authors note that the revenues vary significantly with the amount of drilling activity and that costs for state, social services, and impacts on the environment have not been considered in these calculations.

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72. Stephen Herzenberg, *Fact Checking the Corbett Jobs Record. . .and Some Unsolicited Advice*, THIRD & STATE (Sept. 21, 2012, 6:53 AM), http://thirdandstate.org/2012/september/fact-checking-corbett-jobs-recordand-some-unsolicited-advice.

73. *New Marcellus Shale Fee "Yields Higher-Than-Expected Revenue"*, MARCELLUS SHALE COAL. (Sept. 11, 2012), http://marcelluscoalition.org/2012/09/new-marcellus-shale-fee-yields-higher-than-expected-revenue/. Act 13 is the comprehensive legislation regulating shale gas development passed by the Pennsylvania General Assembly and signed into law by Governor Tom Corbett in February 2012. It addresses a wide range of topics including setbacks from residences, businesses, streams, etc. for drilling, local governments' ability to regulate drilling activities in their jurisdictions, chemical disclosures by companies, and the collection and distribution of user fees paid on a per well basis. Two provisions of the legislation—one related to local governments' regulatory rights and a second related to non-disclosure agreements required for medical professionals requesting information on proprietary chemicals when treating patients—are currently under appeal to the state Supreme Court.

74. *Id.*

75. CHARLES CONSTANZO & TIMOTHY W. KELSEY, PENN STATE CTR. FOR ECON. & CMTY. DEV., MARCELLUS SHALE AND LOCAL COLLECTION OF STATE TAXES: WHAT THE 2011 PENNSYLVANIA TAX DATA SAY 6 (2012), *available at* http://www.marcellus.psu.edu/resources/PDFs/MSTax2012.pdf.

However, economic costs also result from the drilling process, many of which emerge as negative externalities or costs not absorbed by the industry that creates them. Residents in drilling-intensive communities are most directly impacted when the process goes awry and well water is contaminated, requiring use of (and payment for) water trucked to the site. Data on the total cost of water across the state has not been calculated. Officials from Cabot Oil and Gas reported spending more than $200,000 on methane removal systems, vent stacks to prevent future methane build-up, and potable water for the residents of the fourteen homes in which wells were found to be contaminated in Dimock, Pennsylvania in 2010.[76] While this outlay was costly, it pales in comparison to the estimated $11.8 million for the permanent solution of extending municipal water to neighborhoods.[77]

Residents living close to shale gas drilling sites frequently express concerns about the loss of property value resulting from actual or perceived water, air, and soil contamination. A single study of housing prices in a limited geographic area in Washington County, Pennsylvania, an active drilling county, found short-term negative and very localized impacts.[78]

The influx of temporary and permanent residents to fill gas extraction jobs has also affected those who do not own homes or property. As Williamson and Kolb document in their research based on seventy stakeholder interviews in six Pennsylvania counties with active Marcellus Shale drilling, housing shortages are greatest where industry growth is large relative to the county population size and existing resources.[79] For example, Bradford and Lycoming Counties are among the most developed drilling sites in the state, and both are now regional headquarters for major gas producing companies. Doubling or tripling of rents in such communities is not uncommon.[80] In some cases, it is difficult to calculate the growth since virtually no rental market existed prior to the gas boom. The greatest burdens fall on residents living on

76. TONY DUTZIK ET AL., PENNENVIRONMENT RES. & POLICY CTR., THE COSTS OF FRACKING: THE PRICE TAG OF DIRTY DRILLING'S ENVIRONMENTAL DAMAGE 1 (2012), *available at* http://pennenvironmentcenter.org/sites/environment/files/reports/The%20Costs%20of%20Fracking%20vPA_0.pdf.

77. *Id.* at 14.

78. H. Allen Klaiber & Sathya Gopalakrishnan, Panel at the Agricultural & Applied Economics Association's 2012 AAEA Annual Meeting: The Impact of Shale Exploration on Housing Values in Pennsylvania (Aug. 12, 2012).

79. JONATHAN WILLIAMSON & BONITA KOLB, CTR. STUDY OF CMTY. & ECON., MARCELLUS NATURAL GAS DEVELOPMENT'S EFFECT ON HOUSING IN PENNSYLVANIA (2011), *available at* http://www.marcellus.psu.edu/resources/PDFs/housingreport.pdf.

80. *Id.* at 5.

the economic margins. Low-income residents eligible for Section 8 housing vouchers are unable to find landlords who will accept them or affordable rents even after applying the voucher.[81] Action Housing, a non-profit social service agency based in Pittsburgh, is reportedly scrambling to develop homeless shelters in Greene and Washington Counties to keep up with the need.[82]

Businessmen and women whose industries rely on clean air, water, and soil likewise suffer loss when contamination occurs or even when it is merely expected. Bamberger and Oswald report on the loss of farm animals in heavily drilled regions (including Pennsylvania), but do not assign a dollar value to this loss.[83] Cornell University researchers estimated that the economic cost suffered by a farmer (not specifically identified as in Pennsylvania) who lost seventy cows from exposure to a hydraulic fracturing wastewater overflow into his pasture and pond was a minimum of $112,000.[84] The estimate did not include the potential loss that was likely to result from decreased reproduction by surviving cattle. In a separate study of the five most heavily drilled counties in Pennsylvania, Penn State researchers reported an 18.5% decrease in milk production between 2007 and 2010.[85] The authors could not conclude from their data whether farmers were exiting dairy farming in favor of other agricultural activity because of the health of herds raised near shale gas drilling operations, or because of consumer perceptions about food produced near those operations.[86]

As companies have established drilling operations in state forests and other areas of recreational and environmental tourism, estimates of the loss of visitors and the dollars they spend have not yet been systematically measured. Dutzik and his colleagues report that just one tourism-related industry—fishing—generated an estimated economic impact of $1.6 billion in Pennsylvania, an average of $119 per fishing trip.[87] They also note that pipe ruptures in Washington County in 2009 were responsible for fish kills in a high-quality watershed and a public park,

81. *Id.* at 15.

82. *Id.* at 38–39.

83. Michelle Bamberger & Robert E. Oswald, *Impacts of Gas Drilling on Human and Animal Health*, 22 NEW SOLUTIONS 51, 61 (2012).

84. DUTZIK ET AL., *supra* note 76, at 30–31.

85. RILEY ADAMS & TIMOTHY W. KELSEY, PENN STATE EXTENSION, PENNSYLVANIA DAIRY FARMS AND MARCELLUS SHALE, 2007–2010 (2012), *available at* http://pubs.cas.psu.edu/FreePubs/PDFs/ee0020.pdf.

86. *Id.* at 4.

87. DUTZIK ET AL., *supra* note 76, at 19.

and that two other southwestern Pennsylvania streams were the sites of excessive water withdrawals by the industry that resulted in fish kills.[88] In a statewide study, The Nature Conservancy and other Pennsylvania conservation organizations estimated that 38,000 to 90,000 acres of forest may be cleared for drilling by 2030.[89] The resulting loss of ecosystem services—provision of scenic beauty and recreational opportunities, wildlife habitat and air and water purification—may reach $27 million per year.[90]

Perhaps the most frequently noticed impact of UGD in its early stages is the increased traffic volume and the wear and tear on local roads it brings. Estimates of 400 to 500 diesel truck trips carrying water, chemicals, and equipment to hydrofracture a single well far outstrips the capacity of many rural roads in Pennsylvania. Further, with evidence that as many as half of the industry-related vehicles were carrying overweight loads, the Pennsylvania State Police, Department of Environmental Protection, Public Utility Commission, and the Federal Motor Carrier Safety Administration launched Operation FracNet over three weekends in 2010, inspecting nearly 3500 trucks, and writing 2600 citations.[91] Although the state has instituted bonding requirements to pay for the cost of road damage, no study has established that they are sufficient to cover total damage costs. Nowhere have there been attempts to measure the number of traffic accidents specifically attributable to shale gas-related activities and costs in vehicle and property damage, human injury, and increased use of local emergency medical services or law enforcement associated with them. Health and social impacts described below also generate economic costs which likewise have not been systematically measured.

The economic impact data provided here, although limited, looks surprisingly complete when compared with that available on related social impacts, many of which are more difficult to quantify. In defense of shale gas drilling's impact, anecdotal evidence suggests that individuals from rural Pennsylvania commu-

88. *Id.* at 20.

89. *Id.* at 23.

90. In communities with fast-growing shale gas activities, even small businessmen and women are impacted. A typical concern they express is their inability to retain their long-time, dependable employees who are bid away by natural gas companies that are able to pay higher wages and benefits. Jill Kriesky, Notes from Charting the Future of Our Community Meeting (November 30, 2011) (on file with authors); *see also* DUTZIK ET AL., *supra* note 76, at 19.

91. CJ Randall, *Hammer Down: A Guide to Protecting Local Roads Impacted by Shale Gas Drilling* 8 (Cornell Univ., Working Paper, 2010), *available at* http://www.greenchoices.cornell.edu/downloads/development/marcellus/Marcellus_Randall.pdf.

nities who either left the region in search of work or who feared that they or their children would have to do so are finding shale gas industry-related work that allows them to return to or remain in the area that they are committed to see thrive.[92] However, estimates of the population flow to the region and of individuals and families able to remain as a result of the growing shale gas industry would be difficult to calculate and it does not appear that such efforts have been undertaken.

As reports from the Marcellus Shale Coalition suggest, individual shale gas drilling companies are generous in their contributions to a wide range of social organizations in the communities where they drill. Local United Way chapters, 4-H clubs, public schools, athletic programs, and charities are among the financial beneficiaries.[93] These contributions undoubtedly strengthen the opportunities for social networking and cohesion and are welcome in towns that have seen a drop in contributions to civic organizations during the recent economic decline.

Social costs have likewise proven difficult to measure, though they are often described in media accounts of communities that find themselves hosts to shale gas drilling.[94] The most comprehensive analysis of such costs comes from sociologist Simona Perry's ethnographic study of the impact of Marcellus Shale drilling in Susquehanna County, Pennsylvania from 2009 through 2011. Among the impacts she documents are pressures on social service agencies, hospitals, schools, and other social infrastructure brought about by homelessness, and the arrival of new workers and their families.[95] Losses that elude quantification but nevertheless are acknowledged by opponents and supporters of drilling alike are diminished connection to family history, to places in the community, and even to neighbors as differing opinions on gas industry development increase friction among families.[96]

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92. *See* Natural Gas Subcommittee of the Sec'y of Energy Advisory Bd., *Video of Public Meeting at Washington and Jefferson College*, SHALEGAS.ENERGY.GOV (June 13, 2011), http://prod-mmedia.netl.doe.gov/video/Schale_gas_Meeting 1.wmv.

93. *Community Coalition Members*, MARCELLUS SHALE COALITION, http://marcelluscoalition.org/marcellus-shale/community/community-coalition-members/ (last visited Jan. 20, 2013).

94. Ian Urbina & Jo Craven McGinty, *Learning Too Late of the Perils in Gas Well Leases*, N.Y. TIMES, Dec. 2, 2011, at A1.

95. Simona L. Perry, *Energy Consequences and Conflicts Across the Global Countryside: North American Agricultural Perspectives*, FORUM PUB. POLICY (Aug. 2011), http://forumonpublicpolicy.com/vol2011.no2/archivevol2011.no2/perry.pdf.

96. *Id.*

Other published studies based on interviews with key informants in Pennsylvania likewise identify community changes, especially increased truck traffic, social disorganization, and crime created by the influx of residents, as negative social externalities associated with the shale gas drilling process.[97] Survey-based research from twenty-one Pennsylvania counties confirms concern over these social impacts. One study, for example, found that a majority of mail survey respondents were more likely to expect a decline in social services as drilling increased, and a significant minority worried about worsening road conditions and a rising cost of living.[98]

Interestingly, published research on potential costs and benefits to human health is extraordinarily thin given the responsibility to protect human health accepted by both federal and state governments.[99] No health professionals sat on the Pennsylvania governor's Marcellus Shale Advisory Commission, the group upon whose recommendations Act 13 was developed.[100] The few health-related recommendations accepted by the Commission did include the establishment of a health registry which might have been used for preliminary analysis of health impacts.[101] But initial funding for it in the proposed legislation was withdrawn before its passage. Thus, the Pennsylvania Department of

97. Kathryn J. Brasier et al., *Residents' Perceptions of Community and Environmental Impacts from Development of Natural Gas in the Marcellus Shale: A Comparison of Pennsylvania and New York Cases*, 26 J. RURAL SOC. SCI. 32, 36 (2011); Jeffrey Jacquet, *Energy Boomtowns & Natural Gas: Implications for Marcellus Shale Local Governments & Rural Communities* (Ne. Reg'l Ctr. Rural Dev., Working Paper No. 43, 2009), *available at* http://nercrd.psu.edu/Publications/rdppapers/rdp43.pdf; Jeffery B. Jacquet, *Landowner Attitudes Toward Natural Gas and Wind Farm Development in Northern Pennsylvania*, 50 ENERGY POL'Y 677 (2012).

98. TED ALTER ET AL., INST. FOR PUB. POLICY & ECON. DEV., BASELINE SOCIOECONOMIC ANALYSIS FOR THE MARCELLUS SHALE DEVELOPMENT IN PENNSYLVANIA (2010), *available at* http://www.institutepa.org/PDF/Marcellus/MarcellusShaleStudy08312010.pdf.

99. *See* Goldstein et al., *supra* note 14.

100. *See* Bernard D. Goldstein & Jill Kriesky, *The Pennsylvania Gas Law Fails to Protect Public Health*, PITTSBURGH POST-GAZETTE, Mar. 11, 2012, http://old.post-gazette.com/pg/12071/1215612-109.stm. In September 2012, Joe Scarnati, President Pro Tempore of the Pennsylvania Senate, announced in a memo to his Senate colleagues that he would soon introduce legislation to establish the health registry and invited them to become co-sponsors.

101. *Id.; see* Letter from Joe Scarnati, President Pro Tempore of the Penn. Senate, to all Penn. Senators (Sept. 19, 2012) (on file with the Office of the President Pro Tempore of the Senate of Penn.). The letter did not explain why the measure was excluded from Act 13 or why the other health-related recommendations from the Commission such as physician and public education about potential health impacts, would not be part of his bill.

Health, the organization best positioned to oversee and fund health impacts research, does not have the resources to do so.[102]

The single argument associating shale gas drilling with health benefits is that insofar as higher income is associated with better access to health and better health outcomes, one can expect improvements in health in Marcellus Shale drilling regions. However, this claim has not been tested in Pennsylvania or elsewhere. Scant evidence emerges from a Texas survey-based study in which one researcher found that respondents in Johnson County, where drilling is well-established, were significantly more likely to believe that medical and healthcare services were improving when compared to responses from Wise County, where the industry is relatively new.[103]

Given the potential contact that Marcellus Shale gas workers have with hydraulic fracturing chemicals and sand, and contaminated air, water and soil at work sites, it is their health and safety that would seem to merit the most study. However, to date there has been only one occupational health study of the industry. In 2012, NIOSH analyzed 116 air samples from drilling sites in eleven states, including Pennsylvania. Forty-seven percent of the samples exceeded the legal workplace exposure limit set for silica by the Occupational Safety and Health Administration (OSHA).[104] Nine percent of samples contained silica at levels ten or more times the legal limit, which is a concentration beyond which half-face respirators can provide workers protection.[105] Breathing silica dust can lead to the breathing difficulties and coughing associated with silicosis and lung cancer.[106] Based upon these findings, NIOSH has recommended that the industry find safer, alternative proppants for fracking, provide appropriate respirators to workers, inform workers of the health impacts of working with silica, and monitor exposure levels.[107]

Based on newspaper stories and a widely-circulated "List of the Harmed" posted on the website of the Pennsylvania Alliance for Clean Air and Water, Pennsylvanians living near hydraulic fracturing sites clearly have experienced symptoms they believe

102. *See* Goldstein & Kriesky, *supra* note 100.

103. *See* Gene L. Theodori, *Paradoxical Perceptions of Problems Associated with Unconventional Natural Gas Development*, 24 SOUTH. RURAL SOC. ASS'N 97, 97 (2009).

104. *OSHA-NIOSH*, *supra* note 45, at 3.

105. *Id.*

106. *Id.* at 4.

107. *Id.* at 4–6.

are caused by the activity.[108] However, health-related research conducted within Pennsylvania to date includes only two published studies. Bamberger and Oswald's 2012 case study and survey study of farm animals and humans included some subjects from Pennsylvania communities.[109] Their research identifies upper respiratory (burning nose and throat), gastrointestinal (vomiting and diarrhea), dermatological (rashes), and vascular (nosebleed) problems as the perceived health impacts most frequently associated with living near drilling sites. A team of researchers surveyed in 2010, and then again twelve to eighteen months later, individuals who self-identified as having health problems that they believed resulted from drilling near their homes.[110] They found that the most frequently reported symptoms included problems with the integumentary, central nervous, and digestive systems. Psychological symptoms, especially stress, were the most frequently reported. All symptoms either increased or remained (statistically) unchanged over the time period examined.

It should be noted that none of these studies actually monitored exposures through air or water to specific chemicals used in the hydraulic fracturing process. The most definitive study in this regard monitored emissions a half-mile and further from shale gas drilling sites in Colorado over a three-year period.[111] It concluded that within a half-mile of drilling, there is an increased risk of both cancer and subchronic conditions including headaches, and throat and eye irritation based on the composition of the air samples analyzed. Similarly, another study found that some levels of exposures to chemicals used in fracking fluids can result in cancer, endocrine disruption, and immune system and neurological impacts on humans, although both studies are careful to note that their research did not measure the actual exposure of individuals in shale gas drilling regions.[112]

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108. *See, e.g.*, *Pipeline*, PITTSBURGH POST-GAZETTE, http://pipeline.postgazette.com/ (compiling news stories regarding Marcellus Shale); *see also List of the Harmed*, PA. ALLIANCE FOR CLEAN WATER & AIR, http://pennsylvaniaalliance forcleanwaterandair.files.wordpress.com/2012/05/list-of-the-harmed23.pdf/ (last updated Oct. 21, 2012).

109. *See* Bamberger & Oswald, *supra* note 83.

110. Kyle J. Ferrar et al., *Assessment and Longitudinal Analysis of Health Impacts and Stressors Perceived to Result from Unconventional Shale Gas Development*, (unpublished manuscript) (on file with authors).

111. *See* Lisa M. McKenzie et al., *supra* note 36.

112. MICHAEL S. COBURN, SUBLETTE CMTY. P'SHIP, COMMUNITY SATISFACTION AND QUALITY OF LIFE SURVEY OF LONG-TERM RESIDENTS OF SUBLETTE COUNTY (2008).

A final research focus which bears mention in an assessment of the economic, social, and health costs to communities that find themselves home to shale gas drilling is the "boom-bust cycle" associated with many forms of energy extraction, especially in the western U.S. One scholar's review of literature on this topic in the early years of Marcellus drilling led him to conclude that the applicability of the model to Pennsylvania would depend upon several factors related to the diversity of population, demography, geography, government, land ownership, and the legacy of coal extraction in the region.[113] The boom-bust cycle seems especially likely to take hold in communities with small populations and few community resources available to absorb the population influx, with small local governments with few ways to affect the pace and scope of industry development, and with a large number of landowners who do not own their mineral rights, for whom the potential income from leases overrides other considerations, or who believe that Marcellus Shale drilling will be no more disruptive than previous coal and gas extraction. The boom will cause the negative economic, community, environmental, and health impacts described above. The bust will occur when the gas runs out, employment and economic development associated with it declines, and residents and their families struggle to remain in communities with potentially contaminated air, water, and soil.

So far, a comprehensive study within this boom-bust framework has not been completed. It is too early to know if areas with boomtown characteristics can somehow avoid the bust. However, Johns Hopkins public health researchers David Schwartz and Cindy Parker note a connection between the economic bust and poor health outcomes which bears notice:

> Our work in Pennsylvania shows that abandoned coal mines are associated with a legacy of worse community socioeconomic deprivation (CSD). Higher levels of CSD have been associated with worse health outcomes across a wide range including diabetes, obesity, asthma, heart disease, mental health problems, and destructive health behaviors. The significant changes in communities related to shale gas drilling have also been associated with more crime and drug use in some cases. What the shale gas drilling industry leaves behind (e.g., environmental and ecological degradation, industrial development), could also lead to higher levels of CSD in these communities. Degradation, deprivation, and unhealthy individuals are possible

113. *See* Jacquet, *Energy Boomtowns & Natural Gas, supra* note 97.

long-lasting legacies in communities with extensive shale gas drilling.[114]

Recent survey-based research of two adjacent southwestern Pennsylvania counties, one with extensive drilling and one with only a few wells, provides some insight into residents' support or opposition to drilling. Major support comes from individuals who hold shale gas leases, others who believe that the industry promises economic opportunity, and those who think the environmental and health threats associated with drilling are minimal.[115] It is important to note that these respondents have only perceptions of the economic opportunities and of the potential health and environmental costs on which to base their support or opposition. For Pennsylvania residents and the policymakers who represent them to make truly informed decisions about the appropriate level and pace of shale gas development, the path forward must include three important steps.

First, the industry must acknowledge that drilling has significant negative consequences. It must admit that there are unmeasured and potentially considerable costs to individuals' homes, businesses, and health that could minimize or outweigh the benefits that accrue to them from lower energy prices, and that whole communities suffer from the changes to the quality of life ranging from increased traffic to disagreement among neighbors with opposing positions on shale gas drilling. The industry must also concede that the data simply does not yet exist to determine if the revenue gained by state and local governments under Act 13 is sufficient to cover the costs of infrastructure repair and remediation and to relieve the stress placed on government social services as a result of drilling activities.

Second, with all parties to the debate recognizing these costs, immediate steps must be taken to limit them. Regarding health impacts, the Heinz Endowments have taken the lead in establishing the Southwest Pennsylvania Environmental Health Project, whose mission is "to respond to individuals' and communities' need for access to accurate, timely and trusted public health information and health services associated with natural gas extraction."[116] But more must be done to ensure that those

114. BRIAN S. SCHWARTZ & CINDY PARKER, POST CARBON INST., WILL NATURAL GAS FUEL AMERICA IN THE 21ST CENTURY? SUPPLEMENTAL ARTICLES 11–15 (2011).

115. Jill Kriesky et al., *Differing Opinions on Natural Gas Drilling in Two Adjacent Counties with Different Levels of Drilling Activity* (2012) (unpublished manuscript) (on file with the Energy Policy Journal).

116. *About*, SW. PA. ENVTL. HEALTH PROJECT, http://www.environmentalhealthproject.org/about/ (last visited Jan. 20, 2013).

whose homes have become unlivable, whose housing options have disappeared, whose livelihoods have been diminished by drilling, and who perceive that their health or their family's health has been affected, are not forced to absorb negative externalities created by the industry.

Third, much more comprehensive research is needed to fully understand the economic, social, and health costs and benefits created by this industry. Getting the full picture requires far more transparency by the industry than currently exists. A full understanding of the economic impacts requires that companies provide data on the dollar value of leasing agreements and bonus payments, out-of-court settlements to families and businesses harmed, and in-state and out-of-state employment levels and wages. State government, through reporting from local governments, must carefully measure and report the increased use of social and physical infrastructure, from schools and hospitals to roads and wastewater systems. The state must also begin a broad epidemiological study of changes in health status associated with exposure to air, water, and soil contaminated by hydrofracking chemicals and a broad sociological study that characterizes the social impacts experienced across communities. Only with these three elements can a truly informed decision about the pace and extent of shale gas development be made in a way that incorporates the needs of all Pennsylvanians.

IX. An Approach to Understanding the Regulatory and Statutory Landscape Related to Shale Gas Drilling

Before choosing a path forward, it is essential to understand the current landscape of regulatory and statutory provisions governing the oil and gas industry, particularly with respect to the hydraulic fracturing of Marcellus Shale. A team of legal experts at Pittsburgh Public Health, supported by an advisory committee comprised of scientists (i.e., engineers, geologists, environmental medicine experts), representatives from the Pennsylvania Departments of Environmental Protection and Health, public health professionals, community advocates, and business and industry representatives, studied the question, "Do Pennsylvania laws protect groundwater during well site preparation and natural gas extraction?" This topic is particularly important to Pennsylvanians since approximately 56% of groundwater (i.e., the water that seeps below the land surface into empty spaces and

cracks)[117] pumped in the Commonwealth is used for domestic drinking by about 3,000,000 people (or approximately one-quarter of its citizens).[118] Groundwater is a vast resource estimated to be twice as abundant as the amount of water that flows annually into the Commonwealth's streams.[119]

A previous commission, convened by Governor Corbett, analyzed Marcellus Shale drilling and published a report of its findings in July 2011;[120] however, the report was incomplete in two respects. First, the Governor's commission focused on surface water rather than groundwater. Second, it did not look at water contamination from a public health perspective emphasizing the *prevention* of problems that could be associated with hydraulic fracturing.

Given that the study question was narrowly construed, the legal search had to be structured accordingly. The legal team constructed a search of those laws relevant to groundwater contamination which has or could occur under three different scenarios: (1) from deficiencies of the well itself; (2) from surface spills of chemicals used in fracturing on or around the well site; and (3) from leakage of contaminated flowback contained in surface impoundments or frack tanks. Other restrictions were used as well. For example, laws pertaining to public water systems, the municipal water supply, and surface mining were not examined. An analysis of the laws pertaining to water supplies on non-private lands (i.e., lands under the control of the Department of Conservation and Natural Resources (DCNR) was not performed since the DCNR acts as a leasing agent. The responsibilities for permitting and oversight activities vest with the Pennsylvania Department of Environmental Protection (PADEP).

Broad search terms such as "groundwater," "water table," and "aquifer" were used to ensure that a comprehensive listing of laws was obtained. Once these discrete laws were identified, entire acts and complete chapters of regulations were read to ensure that all laws relevant to the study question were analyzed. A listing of these provisions is contained in Figure 1 below.

After the laws were identified, a legal coding methodology was applied which distilled complex legal text into manageable

117. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT 93-643: WHAT IS GROUND WATER? (2001), *available at* http://pubs.usgs.gov/of/1993/ofr93-643.

118. BRYAN SWISTOCK, PENN STATE COLLEGE AGRIC. SCI., A QUICK GUIDE TO GROUNDWATER IN PENNSYLVANIA 7 (2007).

119. *Id.*

120. GOVERNOR'S MARCELLUS SHALE ADVISORY COMM'N, REPORT (2011), *available at* http://www.mde.state.md.us/programs/Land/mining/marcellus/Documents/MSAC_Final_Report.pdf.

components.[121] The components were assigned numeric representations in eight different categories: Acting Entity (the individual, company, governmental agency or other entity performing an Action that is the object of the law); Partner Entity (the individual, company, governmental agency or other entity with which the Acting Entity has a relationship); Prescription (whether the Acting Entity was performing pursuant to a mandate or whether the activity was discretionary); Purpose (whether the law is for prevention, remediation, or liability); Action (the verb characterizing what the Acting Entity does); Goal (the noun which is the objective of the Action); Timeframe (the period during which the Action is to be performed); and Condition (any precipitating event prompting the Action). A code book containing the numeric representations was provided to each of the legal analysts.

The benefits of applying a coding methodology to legal text are numerous. First, a coding methodology allows for the compartmentalization of complex scientific and legal concepts into manageable components. Second, it encourages greater uniformity by removing some of the subjectivity inherent in traditional legal analysis. Our study question was limited to Pennsylvania laws only and a review of these laws reveals marked inconsistencies. For example, there is a need to standardize terminology. "Water" and "person" are defined differently under different acts, and left undefined under others. Laws pertaining to groundwater under our three scenarios are spread over at least seven Acts and multiple sets of implementing regulations found in Pennsylvania Statutes, Pennsylvania Consolidated Statutes, and seven Chapters of the Pennsylvania Code.[122] This morass of laws is confusing at best and contradictory at worst. A third benefit of using a coding methodology is that it allows for comparisons between jurisdictions. Laws are written differently in each state. By using coding methodology, direct comparisons of legal mandates can be made even if state legislatures draft laws using different terminology. Similarities and differences are easily discovered, and gaps identified, allowing for best practices in all areas of the oil and gas industry.

Further study is needed before a definitive answer can be obtained to the question of whether the laws in Pennsylvania are

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121. This methodology was initially developed by Pittsburgh Public Health in its Public Health and Adaptive Systems grant funded by the Centers for Disease Control and Prevention (cooperative agreement 5P01TP000304). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention.

122. *See* Appendix, Figure 1.

adequate to protect the state's groundwater; however, a preliminary examination reveals deviation from oil and gas drilling mandates in other states and even from industry best practices. For example, in Pennsylvania the required casing depth is fifty feet below the water table.[123] In Maryland and Arkansas, the requirement is 100 feet.[124] Industry best practices also adopt the 100 feet requirement.[125] Wyoming extends the requirement to 120 feet.[126] Unlike some other states such as Colorado, Pennsylvania restricts health care professionals from sharing proprietary chemical information with other health care professionals.[127]

Pennsylvania's laws are silent with respect to some liability issues. Unlike other states such as Maryland,[128] Pennsylvania does not require the oil and gas industry to obtain insurance to compensate individuals who suffer personal and property losses due to hydraulic fracturing. Although the oil and gas industry is arguably one of the most potentially hazardous industries in Pennsylvania, the state's laws do not address the issue of strict liability.[129]

Moving forward, an analysis of other states' laws using the legal methodology developed at Pittsburgh Health would allow for an objective comparison of inter-jurisdictional oil and gas laws, and would help to establish best practices.

X. Balancing Risks and Benefits: The Food, Drug, and Cosmetic Act (FDCA) and the Toxic Substance Control Act (TSCA)

Our nation's laws governing the manufacture and use of chemical and physical agents in commerce vary greatly in their balancing of potential risks and benefits. Certain laws, such as the Clean Air Act and the Safe Drinking Water Act, are primarily concerned with protecting the public and are less concerned with potential benefits of commercial activity. However, for our

123. 25 Pa. Code § 78.83(c) (2011).

124. Md. Code Regs. 26.19.01.10(O) (2012); 178.00.10-004 Ark. Code R. § B-19(e) (LexisNexis 2011).

125. Am. Petroleum Inst., Hydraulic Fracturing Operations—Well Construction and Integrity Guidelines §7.3 (2009).

126. Oil & Gas Conservation Comm'n 3 Wyo. Code R. §22(a)(i) (West 2012).

127. Colo. Code Regs. § 404-1:205A(b)(5) (LexisNexis 2012); 52 Pa. Code §5.423 (2008).

128. Md. Code Regs. 26.19.01.06(c)(4).

129. *See* Berish v. Sw. Energy Prod. Co., 763 F. Supp. 2d 702 (M.D. Pa. 2011); Fiorentino v. Cabot Oil & Gas Corp., 750 F. Supp. 2d 506 (M.D. Pa. 2010).

present purpose, we have chosen to briefly review the cost and benefit approaches of the FDCA and TSCA. Both are acts in which Congress' concern is clear with respect to its goal of retaining the beneficial effects of drugs and products of the chemical industry while also protecting the public from adverse effects.

Under the FDCA, the Food and Drug Administration (FDA) primarily regulates the pharmaceutical industry, manufacturers and processors of foods, manufacturers of dietary supplements, and cosmetic companies.[130] Its major tools are premarket testing and review of drugs, labeling, and gathering of information, including reports of adverse incidents. The FDA is constantly involved in controversy about the appropriate speed at which it approves a new drug or medical device.[131] Its goal is to achieve an appropriate balance between the risks of an overly rapid approval process permitting a harmful agent or device to be marketed and the benefits of bringing a beneficial agent to the public as early as possible.

Pharmaceutical companies seeking approval of a new drug or medical technology are responsible for providing sufficient scientific evidence to demonstrate safety and efficacy.[132] This often requires millions of dollars for a series of rigorous studies, including clinical trials, all of which can take years to complete.[133] The rules governing the production of new chemicals also require a balancing of the potential for the beneficial social effects of new chemicals with their potential for producing adverse effects to environmental or human health.[134]

There is an unavoidable tension between the desire to make promising drugs available as soon as possible and the need to protect consumer safety. The FDA is highly precautionary with

130. Federal Food, Drug, and Cosmetic Act 21 U.S.C.A. § 301 et seq. (West 2012). It also was recently given the role of regulating the tobacco industry, but as there is no redeeming value to smoking we will not consider it here.

131. *See White House Urges FDA to Speed Up Pharmaceutical Sales Process*, MEDREPS CAREER CTR. (Sept. 26, 2012), http://www.medreps.com/pharmaceutical-sales-news/white-house-urges-fda-to-speed-up-pharmaceutical-sales-process/; Doug Bandow, *End the FDA Drug Monopoly: Let Patients Choose Their Medicines*, FORBES (June 11, 2012), *available at* http://www.forbes.com/sites/dougbandow/2012/06/11/end-the-fda-drug-monopoly-let-patients-choose-their-medicines/); Thomas J. Moore & Curt D. Furberg, *The Safety Risks of Innovation: The FDA's Expedited Drug Development Pathway* 308 JAMA 869 (2012).

132. *How Drugs are Developed and Approved*, U.S. FOOD & DRUG ADMIN., http://www.fda.gov/Drugs/DevelopmentApprovalProcess/HowDrugsareDevelopedandApproved/default.htm (last visited Jan. 20, 2013).

133. *Conducting Clinical Trials*, U.S. FOOD & DRUG ADMIN., http://www.fda.gov/Drugs/DevelopmentApprovalProcess/ConductingClinicalTrials/default.htm (last visited Jan. 20, 2013).

134. *See id.*

respect to drugs, choosing to err on the side of safety. Even if existing scientific data is very promising, FDA cannot approve a new drug until it is satisfied that data adequately demonstrates safety and efficacy.[135] While patient advocates sometimes become understandably impatient, such precautions have often prevented tragic outcomes.[136]

Similarly, TSCA provides a process that attempts to strike a balance between the benefits and risks of new chemicals. The legislative language acknowledges the presence of risk and uses a standard of "unreasonable risk" in pursuit of this balance.[137] It attempts to achieve balance through a process in which the chemical structure must be reviewed and approved by the EPA in advance of manufacture and release. Any significant new use, particularly one that involves increasing the extent of exposure, is subject to further review by the EPA.[138]

No such careful review has been applied to shale gas development, despite its rapid expansion into areas of much greater population and different geography. Yet it is shale gas development for which it is plausible to infer that the later we start, the longer the gas will last.[139] Our thesis is that during the relatively short lifetime of shale gas production, the proper balance favors minimizing the risks of moving too quickly, and that this balance is not currently being achieved.

XI. CONCLUSION

There is a history of technology implementation that we thought had taught us how to most sustainably blend environmental concerns and economic development with human health. The pattern has been that potentially harmful societal and industrial activities occur before the necessary health and safety information is available; adverse environmental and health outcomes are observed that are potentially associated with the industrial activity or new technology; major public concern devel-

135. *See* CTR. FOR DRUG EVALUATION & RESEARCH, U.S. DEPT. OF HEALTH & HUMAN SERVS., IMPROVING PUBLIC HEALTH THROUGH HUMAN DRUGS UPDATE 7 (2007), *available at* http://www.fda.gov/downloads/AboutFDA/CentersOffices/OfficeofMedicalProductsandTobacco/CDER/WhatWeDo/UCM121704.pdf.

136. *Id.*

137. *Making a Finding on Unreasonableness of Risk*, U.S. ENVTL. PROT. AGENCY, http://www.epa.gov/oppt/newchems/pubs/unrerisk.htm (last visited Jan. 20, 2013).

138. *Id.*

139. From the local viewpoint, there is indirect evidence suggesting that the later the start, the better the economic benefit.

ops, fueled by newspaper stories and litigation; and there is a frustrating inability to establish cause and effect relationships in large part because of inadequate exposure and outcome information. It is only when we recognize that research about health and safety impacts of new activities must occur before moving full speed ahead in using technology that the downward spiral into the frustrating inability to establish cause and effect relationships will end. Unfortunately, this has not happened with respect to shale gas drilling. To date, there are no comprehensive epidemiological studies planned (much less underway) that will conclusively verify or deny that the full hydrofracturing process, from site preparation through reclamation, harms humans, animals, or the environment. As discussed above, exposure studies of air pollutants and issues such as noise levels near drilling sites, as well as the major psychosocial impacts, indicate the dangers of drilling.

Today, as research slowly emerges around the complex issues of water, air, soil, and social degradation from shale gas drilling which may affect human health, there are only three certainties. The first is that there will be surprises in the form of threats to human health and safety that were unforeseen as the UGD accelerated. Indeed, since we began to track drilling and its outcomes in the Marcellus Shale region in 2009, we have already witnessed one dramatic surprise. On New Year's Eve 2011, residents in the Youngstown, Ohio area experienced an earthquake of 4.0 magnitude. Youngstown is not in Marcellus Shale drilling territory, but the geology that underlies it seemed appropriate for injecting fracking flowback water. Though the intensity of this quake was not sufficient to seriously frighten or hurt residents, Ohio regulators are not taking any chances, and are proposing regulations to place limits on the geologic formations into which waste can be pumped.[140]

We also can readily predict that clusters of adverse health effects will occur in shale drilling regions whether or not they are causally related to the drilling activities. A cluster is a geographical and temporal grouping of an adverse health effect, such as cases of autism, leukemia, or any other disease. Clusters often come to a community's attention when it notices a significantly higher occurrence of a specific disease during a given time period. Many similar hurdles to "scientifically" defining a cluster exist, but patterns of illness among neighbors are enough to raise

140. Ajay Makan, *Fracking Water Linked to Earthquakes*, FIN. TIMES, Apr. 14, 2012, http://www.ft.com/cms/s/0/e268a268-84f6-11e1-a3c5-00144feab49a.html#axzz1vXC4Lyd2.

significant concern in a community—and will often lead to questions or blame being assigned to a visible environmental threat such as an UGD site.[141] The resultant media coverage, loss in property values, and other untoward consequences are inevitable.

Finally, we are virtually certain that the UGD industry will find ways to pollute less over time. Depending on its corporate culture, a company may or may not want to "do the right thing" to avoid potential negative environmental and health impacts. The economic imperative of every corporation to maximize profits ensures that every ounce of hydrofracturing fluid that is not recycled, or every cubic inch of methane or other hydrocarbons that cannot be kept from escaping through pipes, represents a cost to the company. Under these circumstances, what is good for stockholders is also good for the health of residents close to drilling sites and the environment in which all of us live. But vigorous oversight is required.

President Obama, in his 2012 State of the Union Address, spoke glowingly about the value of shale gas development to our country, but stated: "America will develop this resource without putting the health and safety of our citizens at risk."[142] This will not happen unless we take our heads out of the shale and forthrightly explore the many issues raised by the explosive growth in UGD.

141. Clusters are frequent causes of toxic tort litigation. This complicates attempts to determine a cause and effect relationship, as scientific information gets tied up in the litigation process.

142. Obama, *supra* note 9.

APPENDIX:

FIGURE 1

Statute/Regulation	**Citation**
Act 13	P.L. 87, No. 13, as amended, 58 Pa. C.S. 2301 *et. seq.*
Oil and Gas Act	P.L. 2240, No. 223, as amended, 58 P.S. 601.101 *et. seq.*
Oil and Gas Conservation Law	P.L. 825, No. 359, as amended, 58 P.S. 401-419
The Clean Streams Law	P.S. 1987, as amended, 35 P.S. 691.1, *et. seq.*
The Solid Waste Management Act	P.L. 380, as amended, 35 P.S. 6018.101 *et. seq.*
Act 14 – Section 1905-A of the Administrative Code	P.L. 1093, No. 219, 52 P.S. 3301 *et. seq.*
The Hazardous Sites Cleanup Act	P.L. 756, No. 108, as amended, 35 P.S. 6020.101 *et. seq.*
PADEP	25 PA. CODE, Chapter 78
PADEP	25 PA. CODE, Chapter 79
PADEP	25 PA. CODE, Chapter 91
PADEP	25 PA. CODE, Chapter 92a
PADEP	25 PA. CODE, Chapter 93
PADEP	25 PA. CODE, Chapter 95
PADEP	25 PA. CODE, Chapter 96

FIGURE 2

58 P.S. § 601.204

(b) The owner or operator of any well granted inactive status shall be responsible for monitoring the mechanical integrity of such well to insure that the requirements of subsection (a)(1) and (2) are met and shall report the same on an annual basis to the department in a manner and form as the department shall prescribe by regulation.

Citation	**Entity**	**Presc.**	**Action**	**Goal**	**Entity**	**Time Frame**	**Condition**	**Purpose**
58 P.S. 601.204(b)	1	2	6	1	0	0	6	1
	Well Operator	Must/ Shall	Monitor	Well	—	—	When granted inactive status	Prevention
58 P.S. 601.204(b)	1	2	7	7	10	2	6	1
	Well Operator	Must/ Shall	Report/ Notify	Integrity of Well	PA. Dept. of Environmental Protection	Annually	When granted inactive status	Prevention