Energy Policy 82 (2015) 1–11

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Shale gas operator violations in the Marcellus and what they tell us about water resource risks

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HIGHLIGHTS

- We examine trends in violations issued to natural gas operators over 6.5 years.
- Analyzed 3267 unconventional and 9784 conventional violations.
- Decreased unconventional violation rates after 2011.
- Decrease best explained by shifting regulatory policy and inspector productivity.
- Differences in risks associated with conventional and unconventional development.

ARTICLE INFO

Article history:
Received 5 May 2014
Received in revised form
25 February 2015
Accepted 26 February 2015

Keywords:
Fracking
Shale gas
Water resources
Compliance
Violations

ABSTRACT

Development of shale gas entails environmental risk, particularly with respect to water resources, and stakeholders are keen to assess such risks before making development decisions. We focus on Pennsylvania, USA and the Marcellus Shale, the most productive shale play in the country. We examine compliance data recorded by the state regulatory agency in order to assess environmental risks and their trends and drivers over time. Overall, we track 3267 shale gas violations, noting that environmental violation rates increase from 2007 to 2009, remain high through 2010, and then drop in 2011 and thereafter. Violations related to spills and erosion were most commonly issued. A single change in policy resulted in a 45% decrease in environmental violation rates. Furthermore, for every 1% increase in wells drilled per inspections conducted, there was a 0.56% decrease in environmental violation rates. Similar effects were not found for administrative violations. Operator identity, price of gas, and other major policies were not significantly correlated with violation rates. In comparing conventional and shale gas extraction compliance we found that shale gas development entails more risk related to spills and solid waste management, while conventional development entails more risk associated with cementing and casing issues, and site restoration.

1. Introduction

Unconventional natural gas extraction is the subject of concern and interest from policy makers, energy and natural resource managers, environmental organizations, and the general public. Globally, estimates of natural gas technically recoverable from unconventional shale reserves has grown from 6622 Tcf in 2011 to 7299 Tcf in 2013, representing 32% of worldwide natural gas resources (U.S. Energy Information Administration, 2013). In this context the International Energy Agency (2012) has claimed, "natural gas is poised to enter a golden age." In the United States (US), where a large majority of current shale gas development is underway, five shale plays provide nearly 40% of total natural gas production in the country, and include the Barnett and Eagle Ford in Texas, the Haynesville in Louisiana and Texas, and the Fayetteville in Arkansas (USEIA, 2014). The Marcellus Shale, which exists below the states of Pennsylvania, New York, West Virginia, and Ohio is currently the largest producing gas shale in the United States, generating upwards of 14,000 Mmcf per day. Together, these plays have helped to make the United States the largest producer of natural gas in the world.

Shale gas development in the Marcellus, like elsewhere, brings

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http://dx.doi.org/10.1016/j.enpol.2015.02.033
0301-4215/

both economic benefits and environmental costs, particularly with respect to water resources. Activities that do, or have the potential to, impact water resources include: the withdrawal of water from surface and ground water sources; the treatment of wastewater for reuse, disposal, or discharge; the storage and handling of wastewater and other chemicals and fluids on well pads; storm-water runoff as a result of land use changes associated with well pad, access road, and pipeline construction; and well bore casing and sealing designed to isolate the well from shallow groundwater. These activities and the water resource risks they entail have been discussed in depth elsewhere, and have been identified as among the most important environmental and human health issues associated with shale gas extraction (Kappel et al., 2013; Kargbo et al., 2010; New York State Department of Environmental Conservation, 2011; Olmstead et al., 2013; Rahm and Riha, 2012, 2014; Vidic et al., 2013). In part because of these risks, many governments (e.g. France; Bulgaria; Quebec, Canada; New York, USA) have chosen to ban unconventional shale gas extraction or delay it until environmental risks are better assessed.

Conventional gas development, generally understood to mean vertical well drilling targeting relatively permeable and porous reservoirs, has been occurring in the US for over 100 years. In states that have experienced historical gas development, regulations and policies have been established that deal with at least some of the water resource risks outlined above (Kulander, 2013). However, the pace and scale of recent unconventional shale gas development has meant that many states, as well as the federal government, are reviewing their policies and regulatory frameworks. A recent survey of expert groups comprised of representatives from government, industry, NGO's and academia identified 12 consensus risk pathways of concern related to unconventional gas development. Seven of these pathways involved risks to surface water, while two involved risks to groundwater, highlighting the importance of water resource management with regard to shale gas drilling and production (Krupnick et al., 2013). In response to these water resource risks, states have taken a wide range of actions and approaches. Some states have moved forward with development quickly and have added regulations as management challenges dictated. Other states have been more cautious, enacting temporary or permanent moratoria while environmental and public health reviews are conducted. A review of how states regulate key aspects of shale gas development found differences in both the elements regulated and the stringency of such regulations (Richardson et al., 2013). Interestingly, only relatively few relationships could be found between the heterogeneity in state shale gas regulations, and more than 50 environmental, demographic, and political variables, suggesting that policy approaches were somewhat arbitrary.

The recent unconventional gas boom, combined with existing conventional development, has made Pennsylvania the most productive state in the Appalachia region by a wide margin, and one of the top five gas producing states in the US overall (USEIA, 2015). Pennsylvania has also moved toward greater transparency with respect to oil and gas activities. State regulatory agencies monitor and inspect gas development activities and assess operator compliance with existing rules and regulations. Compliance data related to both conventional and unconventional gas activities can be found on-line so that the public can stay informed of industry performance and regulatory oversight efforts. To our knowledge, this is the most accessible, complete, and up-to-date data set of its kind. Conventional wisdom suggests that there is some relationship between environmental compliance violations and environmental risks associated with the regulated activity. It is reasonable to also expect that compliance depends on the policies that exist, and the way in which those policies are enforced. For this reason, previous researchers have used available compliance data not just to raise public awareness of the variety and frequency of violations (Pennsylvania Land Trust Association, 2010), but also to quantify risks of natural gas development to the environment (Considine et al., 2011). Controversially, some researchers claimed that environmental impacts from events receiving violations had been "almost completely" mitigated by the industry, and that regulation and improved industry practice were reducing the incidence of environmental events still further (Considine et al., 2012). However, such work looked at only a relatively small time period (2.5–3.5 years), making it difficult to discern trends and their drivers. Naturally, such claims raise questions about the relationship between policy, industry practice, and environmental risks.

Here, we address these relationships by examining the recent compliance history of gas development operators in Pennsylvania. We analyze violations from unconventional shale gas operators since the boom in development of the Marcellus Shale, and compare them with violations issued to conventional operators to provide contextual information on risks and impacts of natural gas recovery that may have already existed. Our goals are to: 1. analyze trends in violations over time to determine the most common environmental risks that occur, and whether they are changing; 2. evaluate factors that might drive compliance trends; and 3. Compare violations issued to unconventional versus conventional operators to help ascertain whether risks associated with each activity are different from each other.

This analysis examines a longer time period (6.5 years) of gas development compliance than attempted previously, and uses a quantitative framework in which we control for key variables. We also include a wider variety of unconventional violation types than previously analyzed, and include a comparison with conventional violations. Following the analysis, we comment on the value of compliance databases for providing quantitative information that might inform broader risk assessment frameworks, adaptive policy making and strategic management of shale gas.

2. Methods

2.1. Data

Data on violations issued to unconventional gas operators was initially collected from the Pennsylvania Department of Environmental Protection (PADEP) Oil and Gas Compliance Report (Pennsylvania Department of Environmental Protection, 2013), and compiled as part of the Carnegie Geodatabase of Pennsylvania Marcellus Shale Natural Gas Wells (Whitacre, 2013). "Unconventional" gas wells are defined by PADEP as those drilled into a shale formation below the base of the Elk Sandstone or its geologic equivalent, where natural gas can generally not be produced except through hydraulic fracturing. Data on violations issued to conventional gas operators was collected directly from the PADEP Oil and Gas Compliance Report. We analyzed both Administrative and Environmental Health & Safety violations that resulted in either a blank enforcement code, a Notice of Violation or, for conventional wells only, a Consent Assessment of Civil Penalty, for the time period including 2007 through June 31st, 2013. The data was broken down into monthly time intervals for analysis. In some instances we aggregate data in six-month intervals for illustration purposes, with the first six months of each calendar year denoted as "a" and the second six months denoted as "b." We note here that the designation of either "Administrative" or "Environmental Health & Safety" within the PADEP Compliance Report was misleading, as violations of either type could signify an environmental event of interest. Therefore, we caution against ignoring violations labeled by PADEP as Administrative when trying to assess the full