9-2017

Measuring Environmental Performance for Oil and Gas Development

John A. Pendley
Susquehanna University

Measuring Environmental Performance for Oil and Gas Development

John A. Pendley
Associate Professor
Susquehanna University
Sigmund Weis School of Business
514 University Avenue
Selinsgrove, PA 17870
570-372-4533
pendley@susqu.edu

August 2017

Measuring Environmental Performance for Oil and Gas Development

Abstract

This study documents environmental performance for firms that extract oil and gas using hydraulic fracturing (fracking) technologies. Environmental performance is measured using public regulatory data for unconventional oil and gas development in the State of Pennsylvania. Using the performance measure, I show considerable variation in environmental performance for companies in the study. Of particular interest is that 'independent' oil and gas companies – smaller companies that specialize in exploration and production – performed better on average than the 'majors' – the large, international oil companies. The data and methods presented in the study should prove useful to researchers and stakeholders who find the lack of transparency in regulatory systems and environmental reporting a stumbling block to furthering research on environmental performance for firms that employ hydraulic fracturing.

Keywords Environmental Performance, Petroleum Industry, Hydraulic Fracturing

1. Introduction

The purpose of this study is to examine the environmental performance of oil and gas companies' upstream operations. Upstream operations involve all of the activities necessary to develop oil and gas properties and to extract the raw petroleum products. The environmental performance of this segment of the industry has not been studied adequately because upstream activities are regulated in the U.S. by the individual states instead of the Environmental Protection Agency (EPA). Being excluded from centralized oversight makes environmental data on drilling and crude oil production difficult to obtain and consolidate. Unlike other heavy industries, such as chemicals, steel, and paper, pollution produced by oil and gas drilling is not tracked by consolidated, single-source databases such as the Toxics Release Index (Patten, 2002; Clarkson *et al*., 2008; Cong and Friedman, 2011), the Council on Economic Priorities (CEP) indices (Wiseman, 1982; Ilinitch *et al*., 1998; Hughes *et al*., 2001) or KLD Research and Analytics (Cho and Patten, 2007). Instead, researchers interested in the environmental performance of oil and gas drillers would be required to understand the separate regulatory environments and gain access to the disparate computer systems of the individual states where drilling occurs.

This study addresses the lack of research in the area by quantifying the environmental performance of companies operating in a major onshore oil and gas play in the United States. The study concentrates on unconventional oil and gas development which employs horizontal drilling and hydraulic fracturing (fracking). Environmental threats from unconventional development include ground and surface water pollution, toxic solid waste, CO_2 emissions, and surface disturbances in environmentally sensitive areas (Liroff *et al*., 2015). In addition to the potential environmental effects, hydraulic fracturing is at the center of the massive shift in the

economics of oil and gas production. Oil and gas production has surged in the U.S., making the country a major petroleum producer. With the evolutionary shifts occurring in the industry and the associated increase in environmental risk, it is especially important to establish a literature of environmental assessment in this area.

In this study, environmental performance is measured using public regulatory data – production volume and well inspections. The study uses data for natural gas development in the state of Pennsylvania. Oil and gas development in Pennsylvania taps the Marcellus Shale, a highly productive tight-gas shale formation in the Appalachian basin. Pennsylvania has experienced considerable unconventional development due to a friendly political environment, favorable geologic conditions, and historical experience with petroleum development. Currently, over 7,000 fracked wells exist in the state (Amico *et al.*, 2016). The oil and gas industry is highly regulated – requiring the detailed tracking of drilling stages and oil and gas production. State law requires drilling sites, wells, and well pads to be inspected on a regular and systematic basis.

Production and compliance data are assembled for the period 2006-2014 (2006 being the beginning of the shale boom). This data is parsed, matched, and summed to create an environmental performance metric at the corporate parent level. Results indicate a wide variation in environmental performance for firms in the study. The most significant result of the study concerns systematic variation based on company size, complexity, and structure. In particular, smaller, less complex firms (called independents within the industry) exhibited better environmental performance scores compared to extremely large, integrated oil companies (called majors). Thus, corporate characteristics, such as size, operational integration, structural

complexity, and geographic dispersion may play important roles in determining environmental performance.

Many stakeholder groups would find the rankings and other findings of the study interesting and useful. Individuals living near drilling operations could use the information for leasing decisions. Communities might find the rankings helpful in creating zoning regulations and regulators could use the metric for inspection planning. Environmental performance metrics could be useful to the oil and gas companies themselves, as a benchmark against competitors or as a performance indicator in an environmental management system (EMS) (Albelda, 2011).

The environmental metric developed in this paper would be useful in studies of accounting and reporting. Environmental performance has long been used in accounting scholarship, particularly in the study of incentives underlying environmental reporting (Hughes *et al*., 2001; Patten, 2002; Cho and Patten, 2007; Clarkson *et al*., 2008). Typically, prior research has used broad-based indicators of environmental performance (such as Toxics Release Inventory) that are calculated for a large number of companies in many industries. The metric in this study is created differently – detailed environmental performance data is assembled for one high-risk industry. The homogeneity of the population of companies would allow more precise inferences and stronger conclusions. In addition, the data for the study are derived from public regulatory systems that are relatively stable and consistent. This differs considerably from many performance measures used in the past, such as CEP indices (Wiseman, 1982; Ilinitch *et al*., 1998; Hughes *et al*., 2001) and ratings by KLD Research and Analytics (Cho and Patten, 2007) – those measures were produced for a few years and then significantly modified or discontinued altogether.

The study is presented as follows. Sections 2, 3, and 4 provide background, describe the creation of the metric, and report the rankings. Section 5 more completely evaluates firm characteristics in relation to the performance rankings. Section 6 contains a discussion of the limitations and future research possibilities. Section 7 concludes the study.

2. Background

Land-based oil and gas development involve a number of complex steps, beginning with the acquisition of drilling rights, continuing with the preparation of the site and construction of the drilling pad, followed by the drilling and hydraulic fracturing of the wells. The drilling process involves the drilling of deep vertical wells until a particular hydrocarbon-holding geologic formation is reached, then one or more usually horizontal wells are created within the formation. Water mixed with sand and other chemicals are forced under high pressure in order to open small fissures and free the oil and gas. The wells thus created enter a period of production as oil and gas flow, over a period of months or years, to the surface.

Natural gas development has skyrocketed in the state of Pennsylvania. From 2006 through 2014, over 7,000 hydraulically fractured gas wells have been developed within the state of Pennsylvania (StateImpact Pennsylvania, 2014; Amico *et al*., 2016). Based on data collected by the Energy Information Administration (2016), natural gas production in 2007, in the very earliest stages of the shale boom, was 182,277 million cubic feet (mmcf), produced predominately through conventional processes – very little produced at that time through fracking. Seven years later, in 2014, the state produced 4,214,643 mmcf, virtually all produced from hydraulically fractured wells. This massive surge in natural gas production has placed Pennsylvania as a major natural gas producing state, now producing more natural gas than Colorado, Oklahoma or Louisiana (Energy Information Administration, 2016). A build-up of

industrial capacity is not, in itself, remarkable. But, in the case of natural gas production in Pennsylvania, it is the speed with which the productive infrastructure has been created, as well as the environmental dangers that are inherent in its development, which is singular and noteworthy.

The escalation of drilling has polarized many communities and groups of individuals. If you are against drilling, your opinion is that development harms public health and the environment; if you support drilling, your belief is that development is safe and represents prosperity to rural communities and economic advancement for the state. Unfortunately, the extremes in attitude (either good or bad in its entirety) have overshadowed a discussion of differential environmental performance records for drilling operators (and their corporate parents). In other words, it seems logical and reasonable that some gas companies are more careful that others. Despite the possibility that companies differ along an environmental performance continuum, little substantive work has been performed on the topic.

That is not to say that there has not been funded research on drilling violations in the Marcellus shale. One in particular (Considine *et al.*, 2012) has been heavily tinged with ideological bias to the point of being publicly discredited and, ultimately, forcing the closure of the research center that produced the research (DellaContrada, 2012). Thus, one immediate need is for objective and independent research on the environmental performance of firms operating in the major oil-rich shale regions.

3. The environmental performance metric

The state of Pennsylvania has an established system of regulatory oversight over the drilling and operation of oil and gas wells. Part of the regulatory oversight involves the periodic inspection of wells, the determination of violations, and the assessment of fines, all performed by

the state environmental regulatory authority, the Pennsylvania Department of Environmental Protection (PADEP). PADEP data is used to construct the study's environmental performance metric.

Number of compliance violations arising from site and well inspections is used as a base for the metric. A simple list of the top violators, while interesting, is insufficient for an environmental performance indicator. The problem with this simple method is that production activity is not accounted for. For example, a company with many violations may have many producing wells and extract a great deal of oil and gas. The large company may indeed be very cautious, but have many violations because they are, quite simply, large.

Thus, what is proposed in this study is to construct an environmental performance measurement based on regulatory violations but sensitive to the amount of operating activity subject to regulatory oversight. The metric is constructed as follows:

$$\frac{Hydrocarbon\ Production\ for\ Company\ q\ during\ Period\ i}{Number\ of\ Violations\ Assesed\ Against\ Company\ q\ during\ Period\ i} \quad (1)$$

Equation 1 yields a standardized measure of violation frequency per production unit. Data to estimate equation 1 were collected from inspection and production data from 2006 to 2014. For the metrics reported below, period *i* is defined as this entire time period. Time period *i* could, of course, be altered to suit the needs of the research question. Issues on defining the meaning of company identifier *q* are discussed in a separate section below.

3.1. Hydrocarbon Production

Pennsylvania has collected data about the production of oil and gas from unconventional wells since the inception of the gas boom in 2006. This information is available on the PADEP website, [1] first on an annual basis, then as laws were altered to require more frequent reporting,

on a semiannual basis. Excel files, one per year for 2006-2010 and two per year for 2011 through 2014, were downloaded from the state's web site (PADEP, 2015b).

The raw data contain not only production data, but other drilling events (date of spudding, or inception of drilling, date of extension of a well, date of plugging, etc.). Non-production events were stripped out of the Excel files, so that the remaining spreadsheet rows, representing oil and gas production, could be imported into an Access database for easier manipulation. Table 1 reports the production totals from the detail production records.

(Table 1 about here)

As shown in Table 1, petroleum production can yield multiple types of hydrocarbons. The production data for this study reflects three raw petroleum products: natural gas, measured in cubic feet; condensate, a liquid hydrocarbon measured in barrels; and crude oil, also measured in barrels. Since natural gas is in a gaseous state and other products are in a liquid state, the oil and gas industry uses simple equivalencies in business reports that allow a company to quantify its total petroleum output. Firms can choose either cubic feet equivalent (CFE) or barrels of oil equivalent (BOE). Both equivalencies utilize a conversion factor of 6,000 cubic feet of natural gas to 1 barrel of oil. In this study, BOE is used. To produce a total petroleum quantity in BOE, natural gas production is converted to BOE by using the conversion factor of 6,000 to 1, then added to the sum of condensate and crude oil produced (condensate and crude oil are already measured in barrels). In the remainder of the paper, total hydrocarbon production is reported in in thousands or millions of BOE.

3.2. Inspection Violations

In the United States, the authority to regulate the drilling and development of oil and gas wells falls to the individual states. In this capacity, all oil and gas producing states have enacted

laws designed (using variously worded phraseology) to protect the health and safety of citizens, monitor and control the development process so as to minimize environmental impacts, address landowner rights and responsibilities, and provide a minimum level of tolerances and construction practices to protect workers and other individuals in the immediate vicinity of the rig. As an integral part of the regulatory process, all oil producing states have a permitting and inspection system. Permits are issued to control where development takes place and, once construction of a well begins, inspectors visit the site to ensure that work complies with regulations to ensure the safety of workers, communities in the vicinity, and the environment.

As with production data, the PADEP website is used to obtain the raw violation data used in this paper (PADEP, 2015a). The state of Pennsylvania maintains a comprehensive dataset of inspections, violations, and enforcement actions. Compliance data was also obtained for the period January 1, 2006 through December 31, 2014.

The PADEP compliance reporting website contains a sophisticated data query engine, designed to deliver very specific results, as opposed to the creation of large comprehensive datasets. For example, if a user wishes to know the inspections (with violations) for a given drilling operator in a specific county for a particular time period, the search engine can deliver immediate results. Lengthy searches (such as the one performed for this study) cannot be manipulated within the search engine window. To create the data for this study, multiple queries were used to obtain a complete census of all compliance records (in a flat-file format). The flat-file download from the PADEP website was loaded into a Microsoft Excel worksheet, the records were then formatted, and moved into an Access database with linked tables for inspections, violations and enforcements. It is from this Access database that the data for this paper were derived.

For the period under study, the PADEP conducted 2,767 inspections that resulted in 5,044 violations.

3.3. Entity Definition

Most studies in governance, reporting, or public policy will target the corporate parent – the reporting entity controlled by a board of directors and responsible for public reporting to outside stakeholders. The PADEP does not track corporate parents. Instead, consistent with industry practice, the PADEP tracks 'operators.' In an oil and gas partnership, one entity must be designated the 'operating partner' or 'operator.' The operating partner coordinates operating activity on a well (or drilling unit). An operator is responsible for coordinating sub-contractors, obtaining permits, and keeping all records. In the day to day working of a drilling rig, the operator is a critical entity.

However, operating partners are usually subsidiaries of larger organizations. Therefore, in this study, it was necessary to link operators per the PADEP records to their corporate parent. The first step in identifying corporate parents of operating partners was to analyze permits. The PADEP permit reports (PADEP, 2012) were used in early stages of the project to link operating partners to corporate parents. These reports give specific information about permits issued (operator, location of the well, type of well to be drilled, etc.) and were used to create an initial operator list. Then, internet searches were then conducted using the operator name to identify the corporate parent. Some public records (for example, newspaper stories about public takeovers and buyouts) directly identified the corporate parent. For most operators, however, a thread of several web sources were required to confirm the parent. After the basic searches, if the link between operator and parent was not unequivocal, filings with the Securities and Exchange Commission were examined. Certain filings with the Securities and Exchange

Commission (the 10-K was used in this study) often disclose operating units of public corporations.

The corporate entity that controls the operator per the regulatory records was identified for all except the very smallest producers. These very small producers were excluded from the lists, (the cutoff used is explained further below). All oil and gas companies reported in the tables below represent consolidated corporate entities.[2]

4. Rankings

Table 2 reflects the rankings for production and inspection violations. The rankings, as shown, reflect the top 20 companies in terms of hydrocarbon production. These 20 companies account for 97.25% of production during the period under study and, as such, these companies represent substantially all of the unconventional drilling and production activity in the state.

(Table 2 about here)

Table 3 shows the same 20 firms ranked by the environmental performance metric (equation 1). Exxon Mobil Corporation is the poorest performer at one violation for every 118,700 BOE produced. CONSOL Energy Inc. is the best performer at one violation per 923,000 BOE produced.

(Table 3 about here)

The list in table 3 includes some of the largest international oil companies (called 'majors') and smaller oil and gas companies (called 'independents'). Majors engage in all aspects of the oil and gas value chain, while independents operate primarily in oil and gas development (upstream operations).[3] Majors are larger than independents, but the distinction is more complex than size. Because major oil and gas firms operate in more segments and in more diverse geographic circumstances, operating strategies (Sharma, 2001), capital allocations (Ernst &

Young, 2013), and regulatory responses (Sharma, 2001) may differ greatly from independents. Further, because of their size and notoriety, majors receive much greater public and political exposure and scrutiny (‘Wokoro, 2009). Given the importance of the distinction between majors and independents, an evaluation of the two groups is contained in Table 4. In Table 4, the firms are partitioned into majors and independents and a natural log transformation is applied to the metric values in order to reduce the skewness in the distribution and improve the variable’s statistical properties.

(Table 4 about here)

Three majors are included in the list: Chevron, Royal Dutch Shell, and ExxonMobil. The mean environmental performance for these three companies is lower than the independents in the study (t-value of 2.441, p=0.025, two tailed). Thus, for oil and gas development in the Marcellus Shale, the smaller, independent oil and gas companies have a better environmental performance record than extremely large, integrated oil and gas companies.

There could be several plausible reasons that the smaller independents have a better environmental records compared to big oil companies. Independents, being smaller, could have a more localized focus by specializing in a restricted set of geographic regions. Some independents may be specialists in onshore engineering methods and technologies, particularly those methods related to horizontal drilling and hydraulic fracturing. In addition, there may be a social-community effect since some of the independents are based in Pennsylvania and others, while not based in the state, operate almost entirely within its borders. On the other hand, majors operate in diverse geographic, geologic, and geo-political situations. Those development scenarios require very different engineering and technological systems. Further, major oil companies operate refineries, a dissimilar industrial sector, one that is subject to vastly different

strategic, operating, and regulatory requirements. It is conceivable that because of the size and complexity of these organizations, majors may direct investments in environmental controls and environmental systems toward the company's riskier operations, off-shore drilling for example, and away from domestic, on-shore, development. In addition, a major's risk tolerance may be higher than the smaller independents, resulting in an attitude of "pay the fine" as opposed to investing in costly environmental controls that would improve regulatory compliance. While the results of the study suggest that large, integrated oil companies have poorer environmental performance than smaller firms, more research is needed into the precise reasons for the this difference.

5. Further Analysis of Operating Characteristics and the usability and applicability of the metric

For a local purpose, such as a Pennsylvania landowner considering leasing of land for drilling, the metric is useful without further analysis. In the landowner's case, the size or operating structure of the parent companies would not likely be a major factor in the leasing decision. However, for broader research contexts other considerations may be necessary. The purpose of this section is to provide some perspective on the usefulness of the metric in future accounting, finance, and management research.

Specifically, this section examines the percentage of operations that are subject to Pennsylvania regulatory inspections. As described in the previous section, many of the companies are large multinational companies. Conversely, the metric is based on oil and gas development in one geographic region: the Marcellus Shale in Pennsylvania. If Marcellus development is only a small part of an organization's activities, the potential strength of the

metric as an entity-level measure may be reduced. Table 5 contains data from 2014 that is useful in assessing this issue.

(Table 5 about here)

The companies in table 5 are grouped depending on whether they are classified as independents (Panel A) or majors (Panel B). Three privately held companies are omitted since data for these companies were unavailable for the analysis. Unless otherwise noted, the data for the table were obtained from the firms' 2014 10-K filing with the SEC. The first two columns of Table 5 report lines of business (upstream, midstream, and downstream) and annual consolidated revenues. Independents, by definition, do not operate refineries. Thus, there are no traditional downstream (refinery) activities for the independents in Panel A.[4] The majors are well-known organizations that manage world-wide operations across all aspects of the petroleum value chain. These organizations are immense – mean revenues in 2014 for the majors is $351.8 billion compared to mean revenues of $5.8 billion for the independents.

The next set of columns report proved reserves, for the company as a whole (across all oil and gas properties), and for the Marcellus region[5] only. Proved reserves are geologic estimates of untapped oil and gas that are economically recoverable within a reasonable period of time (the SEC uses a 5-year time frame for the recoverability of proved reserves). The quantity of proved reserves is critical in the analysis of oil and gas companies, since current production must be replaced, and constantly replenished, in order to preserve the future cash flow prospects of the firm (Wright and Gallun, 2008). Of importance in this analysis is the percentage of proved reserves in the Marcellus region, as shown in Table 5. This percentage reflects the firms' long-term operating commitment to the region. For the independents in the study, mean percentage of reserves held in the Marcellus region is 46.0%. The independent oil and gas companies have a

significant investment in oil and gas holdings in the region which suggests that most of the independents will continue operating in the area for some time to come and that significant revenue streams will be produced from production in the area. Because of the size of the major oil and gas firms (Panel B), proved reserves in the Marcellus regions were not separately disclosed (generally, they were lumped in with other North American properties). Thus, their investment in the region could not be calculated.

The final set of columns reflects 2014 oil and gas production, also in total, for Pennsylvania only, and the percent represented by Pennsylvania production. Not surprisingly, much of the independents' current production is obtained from the Marcellus shale. On average, the independents obtained 40.9% of their oil and gas from the Marcellus. Marcellus production is a material part of the current operating structure for the independents in this study. This means that a significant proportion of oil and gas was produced under the purview of the regulators from which the study's compliance data was obtained. The collective evidence from Table 5 suggests that the study's metric should be a reliable indicator of the environmental performance of the independent oil and gas firms.

The mean proportion of the majors' 2014 operations attributable to Marcellus operations is 2.5%. This means that the study only examined the regulatory compliance of 2.5% of their oil and gas production. Given the small size of this proportion, how reliable is the metric with respect to the majors? Prior research documents certain elements of environmental management that can be considered "pervasive," in the sense of applying to the organization as a whole. Environmental governance mechanisms (Peters and Romi, 2015) and environmental management certifications (EMAS, 2009; ISO, 2015) are examples. If such mechanisms existed, they might apply to all oil and gas production, meaning that performance measured for a small

amount of production would apply to the firm as a whole. But, it is unknown whether such mechanisms were in place (and effective) for the majors in the study. Further complicating the issue is the sheer size and complexity of these organizations. Therefore, without further research, care should be taken when using this study's metric for the major oil and gas firms shown in Panel B.

6. Limitations and possibilities for future research

There are a number of important limitations, many of which suggest projects that would improve the specificity of the environmental indicator developed in this paper:

- A major finding of the study is that smaller independent oil and gas companies exhibit better environmental performance than big integrated oil companies. The fact that the structure of a company – it's complexity and integration across operating areas – impacts environmental performance is important. More research is needed to evaluate this relation. Several reasons for this result are suggested, including independents being more knowledgeable in the market or geophysical area and a community effect brought about by many independents being headquartered in communities affected by the drilling. However, these suggestions need empirical validation.
- Even after partitioning into 'independents' and 'majors,' a large size disparity continues to exist within the group of independent producers. Chesapeake, ranked first in production for the period under study, produced 360.4 million BOE, compared with 17.6 million BOE for the 20th ranked firm (EOG Resources). The exact effect of size within the independent group is not immediately known. Indeed, size may

constitute such a significant factor that it needs to be accounted for in more meaningful ways. More work is needed in this area.

- The metric developed in the study is a compliance-based measure. Compliance is only one aspect of environmental performance and, as such, other important aspects of environmental management are not explicitly captured, such as governance aspects (EMAS, 2009), strategic planning considerations (Ilinitch *et al*., 1998), operational integration (EMAS, 2009; Albelda, 2011), and information disclosure (Ilinitch *et al*., 1998; EMAS, 2009). This limitation does not diminish the usefulness of the metric for specific purposes, as outlined earlier in the paper. Regulatory compliance is extremely important to oil and gas companies and the compliance component is weighted much heavier in the petroleum industry than in many other industries (Sharma, 2001). In oil and gas, compliance systems are critical – operations are focused on engineering and geophysical sciences and all aspects of these operations are subject to environmental regulations (Sharma, 2001). Nonetheless, a relevant extension of the study would be to study other aspects of environmental management in conjunction with regulatory compliance. For example, does the existence of a chief sustainability officer (Peters and Romi, 2015) or a board of directors' committee directly charged with environmental oversight (Peters and Romi, 2015) help improve compliance rates for oil and gas companies? Or, do oil and gas companies with better environmental performance metrics publicly disclose more information about their environmental efforts?
- By using regulatory data, it is assumed that the state-run system of inspections functions properly: that the management and oversight of inspections is not overly

politicized; that there is sufficient funding of the inspection system; that there are sufficient numbers of inspectors and that they are not overworked; that inspectors are sufficiently compensated and trained. There is some evidence that this may not be the case. In 2014, a Pennsylvania state auditor's report was issued that severely criticized the PADEP for understaffing which could cause poor inspection results (DePasquale, 2014). The fact that questions have been raised about the quality of the regulatory system, calls into question the usefulness of the underlying data.

- The metric is developed over a relatively long period of time (2006-2014). Shifts in conditions during this time period could have affected environmental performance. For example, drilling technologies could have changed or engineering controls could have improved resulting in better environmental performance in recent periods compared to earlier periods in the fracking boom. Additional research is needed to address this possibility.

7. Conclusion

During the last decade, natural gas production has undergone an industrial renaissance, particularly in states like Pennsylvania where deployment of hydraulic fracturing technologies have caused the production of natural gas to skyrocket. The public policy issues, both pro and con, are numerous. For example, the ability to obtain large quantities of oil and gas from previously unobtainable deposits has the potential to reduce the United States' reliance on foreign sources of energy. On the negative side, the new drilling technologies pose significant risk of environmental degradation in the areas where drilling is conducted. Despite the economic benefits, fracking is still a very controversial process.

In this study, an environmental performance metric is created for oil and gas exploration firms that are at the center of the shale gas boom. The metric is created from publicly available violation and production data and the process of creating the components that make up the metric is illustrated in the study. The ranking of environmental performance based on the metric indicates a wide variation in environmental performance for firms that drill for and extract natural gas in the region.

Results indicate that there is a difference in environmental performance between major oil companies and the smaller independent oil companies, with major oil companies performing significantly worse than smaller independent companies. Characteristics that might correlate with this difference was beyond the scope of this particular study and referred to future research. But, several possibilities are discussed, including operating complexity, relative amount of onshore production in natural gas, and specialization in horizontal drilling.

This study contributes to understanding in this area by examining the environmental performance of individual oil and gas firms. In particular, the metric could be used:

- By oil and gas companies for internal use.
- In policy studies.
- To study governance and financial reporting.
- To examine auditing and assurance levels or the possibility to expand assurance practice.
- By communities and individuals.

The metric is derived independently without direct involvement of industry groups or the companies themselves. While the measure may be one-dimensional, the central focus on regulatory violations means that the metric directly addresses issues that lead to or cause

environmental degradation, an important issue for many stakeholder groups. For academics, the existence of such a metric could help foster more research in the environmental performance of oil and gas drilling, a topic that has been under-examined.

ENDNOTES

1. The escalation in drilling activity caused numerous changes in oil and gas regulation, and resulting reporting.

2. For example, the metric for ExxonMobil is calculated from production and violations for two natural gas operators which are wholly-owned subsidiaries of ExxonMobil (these operator are Philips Exploration and XTO Energy). Similarly, CONSOL Energy is parent to two operators as well (CONSOL Gas and CNX Gas)

3. Oil and gas operating activities fall into three major sectors: upstream activities (exploration, drilling, and production), midstream activities (distribution and transport), and downstream activities (refining). If an oil and gas company conducts primarily upstream activities it is termed an "independent" (AICPA, 2012). An independent may own or have interests in gathering facilities and pipelines but its primary focus is in procuring and developing mineral interests. Independents tend to focus on specific geographic of geologic formations and specialize in particular technologies. They also are smaller entities. On the other hand, large vertically integrated oil and gas operations are called "majors" (AICPA, 2012). Majors operate in all three areas. They explore and drill for oil, maintain extensive gathering and transport facilities and operate refineries.

4. CONSOL Energy originally produced coal, recently branching out into natural gas development. CONSOL still has significant coal holdings.

5. The Marcellus shale formation underlies the northern portion of the Appalachian Mountains in the eastern U.S. Oil and gas from this formation are recoverable from the states of Ohio, Maryland, Pennsylvania, Virginia, and West Virginia. Hydrocarbons are recoverable in the state of New York (the northern most regions of the Marcellus shale), however, the state of New York has instituted a complete ban on hydraulic fracturing. Consistent with SEC guidelines, oil and gas companies report reserves and production by geologic regions (oil and gas plays). Firms do not report a state-by-state analysis. However, of the states that allow Marcellus development, investment in wells and production of oil and gas are far larger in Pennsylvania than the other states – production in West Virginia, the no. 2 production state, was 25% of Pennsylvania's (Energy Information Administration, 2016).

REFERENCES

Albelda, E. (2011), "The role of management accounting practices as facilitators of the environmental management: Evidence from EMAS organisations", *Sustainability Accounting, Management and Policy Journal*, Vol. 2, No. 1, pp. 76-100.

AICPA. (2012), *Audit and Accounting Guide: Entities with Oil and Gas Producing Activities*, American Institute of Certified Public Accountants, New York, NY.

Amico, C., DeBelius, D., Detrow, S. and Stiles, M. (2016), "Shale play: Natural gas drilling in Pennsylvania", available at http://stateimpact.npr.org/pennsylvania/drilling (accessed 26 May 2016).

Cho, C. and Patten, D. (2007), "The role of environmental disclosures as tools of legitimacy: A research note", *Accounting, Organizations, and Society*, Vol. 32 No. 7-8, pp. 639-647.

Clarkson, P. M., Li, Y., Richardson, G. D. and Vasvari, F. P. (2008), "Revisiting the relation between environmental performance and environmental disclosure: An empirical analysis", *Accounting, Organizations, and Society*, Vol. 33 No. 4-5, pp. 303-327.

Cong, Y. and Freedman, M. (2011), "Corporate governance and environmental performance and disclosures", *Advances in Accounting*, Vol. 27 No. 2, pp. 223-232.

Considine, T., Watson, R., Considine, N., and Martin, J. (2012), *Environmental impacts during Marcellus shale gas drilling: Causes, impacts, and remedies*, Corrected version, June 6, 2012, University at Buffalo Shale Resources and Society Institute (now closed), Buffalo, N.Y., available at http://cewc.colostate.edu/2012/05/environmental-impacts-during-marcellus-shale-gas-drilling-causes-impacts-and-remedies/ (accessed 30 May 2014).

DellaContrada, J. (2012), "UB closes shale resources and society institute", University at Buffalo, State University of New York, available at http://www.buffalo.edu/news/releases/2012/11/13822.html/ (accessed 19 November 2012)

Delmas, M. and Blass, V. (2010), "Measuring corporate environmental performance: The trade-offs of sustainability ratings", *Business Strategy and the Environment*, Vol. 19 No. 4, pp. 245-260.

DePasquale, E. A. (2014), *Special Performance Audit of the Department of Environmental Protection (DEP): DEP's performance in monitoring potential impacts to water quality from shale gas development, 2009-2012*, Department of the Auditor General, Bureau of Special Performance Audits, Commonwealth of Pennsylvania, Harrisburg, PA, available at www.paauditor.gov/Media/Default/Reports/speDEP072114.pdf (accessed 18 August 2014).

Eco-Management and Audit Scheme (EMAS). (2009), Regulation (EC) No. 1221/2009 of the European Parliament and of the Council allowing voluntary participation by

organisations in a Community Eco-Management and Audit Scheme (EMAS) (O.J.E.U. 22 December).

Energy Information Administration. (2016), Natural Gas Gross Withdrawals and Production, available at www.eia.gov/naturalgas/ (accessed February 21, 2016).

Ernst & Young. (2013), *US Oil and Gas Reserves Study*, available at www.ey.com/oilandgas (accessed .3 June 2016).

Hughes, S., Anderson, A. and Golden, S. (2001), "Corporate environmental disclosures: Are they useful in determining environmental performance?", *Journal of Accounting and Public Policy*, Vol. 20 No. 3, pp.217-240.

Ilinitch, A. Y., Soderstrom N. S. and Thomas, T. E. (1998), "Measuring corporate environmental performance", *Journal of Accounting and Public Policy,* Vol. 17, pp. 383-408.

ISO. (2015), Environmental management systems – Requirements with guidance for use (ISO 14001:2015 15 September).

Liroff, R., Fugere, D. and Heim, S. (2015), *Disclosing the Facts 2015: Transparency and Risk in Hydraulic Fracturing*, available at www.disclosingthefacts.org/2015/DisclosingTheFacts_2015.pdf (accessed 15 February 2016).

Olsthoorn, X., Tyteca, D., Wehrmeyer, W. and Wagner, M. (2001), "Environmental indicators for business: A review of the literature and standardization methods", *Journal of Cleaner Production*, Vol. 9, No. 5, pp. 453-463.

Patten, D. M. (2002), "The relation between environmental performance and environmental disclosure: a research note", *Accounting, Organizations, and Society*, Vol. 27, pp. 763-773.

Pennsylvania Department of Environmental Protection (PADEP). (2012), *Oil and Gas: Permits Issued Detail Report*, available at http://depweb.state.pa.us (accessed 26 July 2012).

PADEP. (2015a), *Oil and gas: Oil and Gas Compliance Reports*, available at http://depweb.state.pa.us (accessed 28 June 2015).

PADEP. (2015b), *Oil and Gas Production Reports: Statewide Data Downloads*, available at http://depweb.state.pa.us (accessed 12 June 2015).

Peters, G. F. and Romi, A. M. (2015), "The association between sustainability governance characteristics and the assurance of corporate sustainability reports", *Auditing: A Journal of Practice & Theory*, Vol. 34 No. 1, pp. 163-198.

Scott, E. M., Cocchi, D. and Gemmell, J. C. (2014), "Designing a fit for purpose statistically reliable sustainability indicator", *Sustainability Accounting, Management and Policy Journal*, Vol. 5 No. 3, pp. 262-267.

Sharma, S. (2001), "Different strokes: regulatory styles and environmental strategy in the North-American oil and gas industry", *Business Strategy and the Environment*, Vol. 10, pp. 344-364.

StateImpact Pennsylvania. (2014), *Shale Play: Natural Gas Drilling in Pennsylvania*, available at http://stateimpact.npr.org/pennsylvania/drilling/ (accessed 26 January 2014).

Wiseman, J. (1982), "An evaluation of environmental disclosures made in corporate annual reports", *Accounting, Organizations, and Society*, Vol. 7 No. 1, pp. 53-63.

'Wokoro, J. (2009), "Beyond petroleum production to community development: international oil companies as proxy government", *Texas Journal of Oil, Gas & Energy Law*, Vol. 5, No. 2, pp. 323-356.

Wright, C. and Gallun, R. (2008), *Fundamentals of Oil and Gas Accounting*, 5th ed., PennWell Corporation, Tulsa, OK.

Table 1
Production totals for unconventional (hydraulically fractured) wells in Pennsylvania, 2006-2014

Year	Natural Gas (millions of cubit feet)	Condensate[a] (barrels)	Crude oil (barrels)
2006	748.1	0.0	604.2
2007	1,901.2	0.0	25,034.0
2008	9,770.8	0.0	85,260.8
2009	78,417.4	0.0	301,961.8
2010	271,501.2	319,890.0	41,674.0
2011	1,064,275.6	684,272.8	384,806.2
2012	2,042,099.1	1,786,612.0	65,160.4
2013	3,103,419.3	2,948,440.8	205,800.7
2014	4,051,427.0	3,982,720.7	380,166.3
Total	10,623,559.6	9,721,936.3	1,490,468.4

a. Condensate is a light, high-API hydrocarbon that is typically associated with natural gas production. Condensate is in a gaseous state underground, but, unlike natural gas, liquifies when it reaches the surface.

Table 2
Total production and violation count, top 20 producers in the State of Pennsylvania, 2006-2014

	Production		Inspection Violations	
Company Name	Total (thousands of BOE)[a]	rank	Number of Violations	rank
Chesapeak Energy Corp	360,391.6	1	556	2
Cabot Oil & Gas Corporation	235,124.3	2	565	1
Range Resources Corporation	165,321.3	3	329	6
Chevron Corporation	131,790.2	4	501	3
Talisman Energy (Repsol S.A.)	128,216.6	5	347	5
EQT Corporation	117,254.5	6	134	12
Anadarko Petroleum Corporation	97,026.6	7	201	8
Southwestern Energy Company	93,538.0	8	123	13
Royal Dutch Shell PLC	62,609.6	9	358	4
National Fuel Gas Company	62,562.9	10	170	9
CONSOL Energy Inc.	47,994.3	11	52	17
Rice Energy LLC	34,963.5	12	44	19
Pennsylvania General Energy Company	29,374.6	13	163	10
Exco Resouces. Inc.	28,452.4	14	147	11
Exxon Mobil Corporation	27,304.3	15	230	7
WPX Energy, Inc.	25,610.4	16	102	16
Carrizo Oil & Gas, Inc.	23,851.5	17	106	15
Citrus Energy Corporation	18,359.5	18	40	20
Energy Corporation of America	17,722.9	19	46	18
EOG Resources, Inc.	17,557.7	20	111	14
Mean	86,251.3		216.3	
Median	55,278.6		155.0	
Standard deviation	87,477.3		169.6	

a. BOE = Barrels of oil equivalent. BOE is a method used by the oil and gas industry to consolidate all hydrocarbon products (gas and liquids) into a single measure. Natural gas is converted to BOE at a rate of 6,000 cubic feet per barrel. Liquids (condensate and crude oil) are already stated in barrels. Liquid measurements are simply added to BOE for natural gas to obtain total BOE. A barrel of oil equals 42 US gallons or approximately 159 liters.

Table 3
Environmental performance for the top 20 producers in the State of Pennsylvania, 2006-2014

Company Name	Metric	Rank (best to worst)
CONSOL Energy Inc.	923.0	1
EQT Corporation	875.0	2
Rice Energy LLC	794.6	3
Southwestern Energy Company	760.5	4
Chesapeak Energy Corp	648.2	5
Range Resources Corporation	502.5	6
Anadarko Petroleum Corporation	482.7	7
Citrus Energy Corporation	459.0	8
Cabot Oil & Gas Corporation	416.1	9
Energy Corporation of America	385.3	10
Talisman Energy (Repsol S.A.)	369.5	11
National Fuel Gas Company	368.0	12
Chevron Corporation	263.1	13
WPX Energy, Inc.	251.1	14
Carrizo Oil & Gas, Inc.	225.0	15
Exco Resouces. Inc.	193.6	16
Pennsylvania General Energy Company	180.2	17
Royal Dutch Shell PLC	174.9	18
EOG Resources, Inc.	158.2	19
Exxon Mobil Corporation	118.7	20
Mean	427.5	
Median	377.4	
Standard deviation	251.9	

Table 4
Comparison of environmental performance metric (transformed) for independent versus major oil companies

	Independents	Majors
CONSOL Energy Inc.	6.828	
EQT Corporation	6.774	
Rice Energy LLC	6.678	
Southwestern Energy Company	6.634	
Chesapeak Energy Corp	6.474	
Range Resources Corporation	6.220	
Anadarko Petroleum Corporation	6.179	
Citrus Energy Corporation	6.129	
Cabot Oil & Gas Corporation	6.031	
Energy Corporation of America	5.954	
Talisman Energy Inc. (Repsol S.A.)[a]	5.912	
National Fuel Gas Company	5.908	
Chevron Corporation		5.573
WPX Energy, Inc.	5.526	
Carrizo Oil & Gas, Inc.	5.416	
Exco Resouces. Inc.	5.266	
Pennsylvania General Energy Company	5.194	
Royal Dutch Shell PLC		5.164
EOG Resources, Inc.	5.064	
Exxon Mobil Corporation		4.777
Mean values	6.011	5.171
t statistic	2.441	
p value (2 tailed)	0.025	

Note: For this table, a natural log transformation is applied to the raw values of the environmental performance metric (equation 1).
The group designation (i.e., independent versus major) was determined through news and industry reports, including the SIC codes that were assigned to each company by analysts, and if needed reference to corporate financial reports (such as the annual report or management's discussion and analysis in SEC form 10-K).

a. Repsol S.A., a very large integrated oil and gas firm, acquired Talisman Energy Inc. early in 2015. However, the amounts reported in this table are for Talisman alone since the merger had not become effective at December 31, 2014. Talisman was considered an independent, and is reported as such in this paper.

Table 5
Financial and production characteristics of the companies under study, by type of oil and gas firm

Panel A. Independent Oil and Gas Firms

			Proved Reserves 2014			Oil and Gas Production 2014		
Company name	Production Segments[e]	2014 Consolidated Revenues (millions US$)[a]	Total Oil and Gas Reserves (millions of BOE)[a]	Reserves in the Marcellus Shale region (millions of BOE)[a,b]	% in Marcellus Region	Total Production (millions of BOE)[a]	2014 Pennsylvania Production (millions of BOE)[c]	% Subject to Pennsylvaina Regulators
Anadarko Petroleum Corporation	US, MS	16,375.0	2,858.0	65.7	2.3%	312.5	34.2	10.9%
Cabot Oil & Gas Corporation	US, MS	2,173.0	1,233.5	1,097.8	89.0%	89.2	93.8	105.2% [c]
Carrizo Oil & Gas, Inc.	US, MS	710.2	151.1	22.4	14.8%	12.0	3.2	26.7%
Chesapeake Energy Corp	US, MS	20,951.0	2,469.1	765.4	31.0%	257.8	131.7	51.1%
CONSOL Energy	US, other	3,726.8	1,137.9	705.5	62.0%	39.3	20.1	51.1%
EOG Resources, Inc.	US, MS	17,473.5	2,497.3	NA	NA	36.3	3.7	10.2%
EQT Corporation	US, MS	2,469.7	1,789.8	1,379.9	77.1%	81.4	47.2	58.0%
Exco Resources. Inc.	US	660.3	210.6	44.9	21.3%	22.6	10.1	44.7%
National Fuel Gas Company	US, MS	2,113.1	319.0	307.8	96.5%	26.8	26.4	98.5%
Range Resources Corporation	US, MS	1,912.0	1,718.4	1,477.8	86.0%	70.7	55.4	78.4%
Rice Energy	US, MS	390.9	217.8	217.8	100.0%	16.3	17.2	105.5% [c]
Southwestern Energy Company	US, MS	4,038.0	1,790.7	949.1	53.0%	128.0	49.1	38.4%
Talisman Energy (Repsol S.A.)[d]	US, MS	3,763.0	827.4	NA	NA	134.7	30.9	22.9%
WPX Energy, Inc.	US, MS	3,493.0	726.6	49.6	6.8%	71.4	7.9	11.1%
Mean values		5,732.1	1,281.9	590.3	46.0%	92.8	37.9	40.9%

Table 5 continues on the next page.

Table 5, continued

Panel B. Major Oil and Gas Firms

Company name	Production Segments[e]	2014 Consolidated Revenues (millions US$)[a]	Proved Reserves 2014: Total Oil and Gas Reserves (millions of BOE)[a]	Proved Reserves 2014: Reserves in the Marcellus Shale region (millions of BOE)[a,b]	Proved Reserves 2014: % in Marcellus Region	Oil and Gas Production 2014: Total Production (millions of BOE)[a]	Oil and Gas Production 2014: 2014 Pennsylvania Production (millions of BOE)[c]	Oil and Gas Production 2014: % Subject to Pennsylvaina Regulators
Chevron Corporation	US,MS,DS	211,970.0	11,102.0	NA	NA	938.4	59.9	6.4%
Exxon Mobil Corporation	US,MS,DS	411,939.0	25,269.0	NA	NA	1,498.0	19.4	1.3%
Royal Dutch Shell PLC	US,MS,DS	431,344.0	12,849.3	NA	NA	1,143.7	10.3	0.9%
Mean values		351,751.0	16,406.8	NA	NA	1,193.4	29.9	2.5%

Note: Three privately held companies are omitted from this table (Citrus Energy, Energy Corporation of America, and Pennsylvania General) because they lacked data necessary for inclusion.

a. Obtained from information in the companies' 10-K filing for fiscal year 2014.

b. In most cases, the extent of reserves in the Marcellus region (i.e., the Appalachian basin) is disclosed in the companies' 10-K filing. When disclosure is absent in the 10-K, other information was accessed including company websites and investor presentations. NA is used to denote the failure to locate any quantification of the extent of reserves in the region.

c. The "2014 Pennsylvania Production" column represents hydrocarbon production reported to the Pennsylvania Department of Environmental Protection (PADEP). The amounts in this column were obtained from the study's databases. These amounts are wellhead amounts -- gross extractions of raw hydrocarbons. Production quantities that appear in finanancial reports (e.g., the 10-K) can be smaller than the wellhead amounts for a number of reasons. For example, shrinkage can occur, extracted gas can be used for various production processes such as repressuring a well, and extracted gas can be consumed internally. All of these gas uses are deducted from gross extractions to produce accounting quantities.

d. Repsol S.A., a very large integrated oil and gas firm, acquired Talisman Energy Inc. early in 2015. However, the amounts reported in this table are for Talisman alone since the merger had not become effective at December 31, 2014.

e. Production segment codes are: US = upstream operations (drilling and production); MS = midstream operations (pipelines, shipping, and other transportation modes); DS = downstream operations (refineries).