RFF REPORT

WHIMBY (What's Happening in My Backyard?): A Community Risk-Benefit Matrix of Unconventional Oil and Gas Development

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Laura Zachary, and Daniel Raimi

This report was produced as part of **The Community Impacts of Shale Gas and Oil Development**, *an RFF initiative.*

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Introduction

The Community Risk-Benefit Matrix illustrates and summarizes our findings characterizing the state of the literature on the community impacts of unconventional oil and gas development based on extensive literature reviews in areas of concern—local public finances, [1] education, [2] health, [3] seismicity, [4] economic impacts, [5] and housing[6]—as well as a number of RFF research projects.[7]

First, the matrix identifies areas of concern in the table headings. The impacts covered in these tables, the leftmost column, were driven by what we found in published literature reviews and/or in RFF research. Some impacts, such as crime, air quality, and groundwater quality are not included in the matrix because we did not conduct a literature review or original research on that impact.

Second, the matrix indicates the quality of the literature regarding these impacts, with green indicating a higher-quality literature, blue indication a medium-quality literature, and orange indicating a relatively poor quality literature (as shown in the matrix key, Figure 1). Impacts not studied in the literature reviews that were addressed by other RFF research are marked gray, indicating that the impact was not reviewed. Quality was judged subjectively, but the following considerations were important.

- A study is considered higher quality if we trust the results of such studies, including their accuracy, magnitude, and direction. We trust the results of studies when they have no major flaws, such as exposure metrics that we believe bias estimates to a large degree or inadequate methodology for assessing counterfactuals and controlling for unobservables. We recognize that few economic studies are able to access perfect data, and do not want to diminish the importance of papers that address topics that are difficult to study quantitatively. This standard, therefore, is not seeking a perfect study. Rather, we look for a lack of major flaws. Qualitative studies that conduct surveys or structured interviews, for example, may fall into this category as well if, due to satisfactory methodology, we trust the results.
- A study is considered medium quality if it is not of high or low quality. A study is therefore medium quality if it has any such major flaw or if either the methodology, data, focus, or study design lead to questionable results for a number of reasons. Generally, we find the magnitude and direction of these results to be informative, but question the precision.
- A study is considered lower quality if it has fatal flaws or a few major flaws, if the methodology, data, focus, or study design are inadequate to estimate any outcomes. A study that lacks any controls for unobservables, a study design that inherently produces biased results, or a time frame that would not capture observations regarding the outcome in question are examples of characteristics that would lead us to categorize a study as one of lower quality. Generally, we do not trust the magnitude, direction, or statistical significance of these studies.

[1] Local Government Impacts of Unconventional Oil and Gas Development

[2] Public Education Impacts of Unconventional Oil and Gas Development

[3] Health Impacts of Unconventional Oil and Gas Development

[4] Induced Seismicity Impacts of Unconventional Oil and Gas Development

[5] Economic Impacts of Unconventional Oil and Gas Development

[6] Housing Market Impacts of Unconventional Oil and Gas Development

[7] See the list of RFF projects studying the community impacts of shale development here: http://www.rff.org/research/collection/community-impacts-shale-gas-and-oil-development.

FIGURE 1. RISK-BENEFIT MATRIX KEY

	Higher quality: The majority of studies reviewed for an impact are of higher quality. Where there is one study of higher quality, it is marked as such.
	Medium quality: The majority of studies reviewed for an impact are of medium quality. Where there is one study of medium quality, it is marked as such.
	Lower quality: The majority of studies reviewed for an impact are of lower quality. Where there is one study of lower quality, it is marked as such.
	Not reviewed: Research on an impact was not reviewed.
↑	Increase: Studies show a positive, robust association with an impact (an increase in incidence or magnitude).
↓	Decrease: Studies show a negative, robust association with an impact (a decrease in incidence or magnitude).
↑↓	Heterogeneous: Across regions or areas, studies report robust results that differ.
Ø	No association: Studies report results that showed no association.
~	Inconsistent: Studies report differing (contradictory) results.

These categories are to be seen as rough averages of the quality of the studies on a particular impact. If the majority of studies for an impact are of a certain quality, they are marked with that color (e.g., if three studies are higher quality and one is lower or medium, it is marked as higher quality). In the few cases where the literature is split evenly between an impact, it is given the lower-quality color (e.g., two higher-quality and two medium-quality studies would be medium quality).

Third, the matrix indicates the relationship between oil and gas development and each impact, as reported across the literature using the symbols shown in the bottom half of the matrix key (Figure 1). If the vast majority of literature shows a statistically significant increase or decrease in an effect, that is marked by the up (↑) or down (↓) arrow (or null symbol (Ø) if the studies show no effect). These arrows are not value judgments—the up arrow does not mean it is a good outcome. An up arrow, rather, indicates an increase (in terms of incidence or size) of an impact. If the literature shows heterogeneous effects across regions or areas (e.g., if there is an increase in education expenditures in the Marcellus region but a decrease in North Dakota associated with increased unconventional oil and gas activities) and these findings are, for the most part, consistent across studies, that impact is marked with both arrows (↑↓). Where studies have findings that are inconsistent, in that the studies contradict one another (e.g., some find an increase whereas others find no effect or a decrease for an impact, say in the same state or context), that impact is marked with a tilde (~). The last element in each section of the matrix is some brief text further explaining the colors or symbols (or both) in the chart.

Local Government Effects

Local governments in municipalities and counties across the United States as well as school districts can benefit from oil and gas production in their regions through a number of revenue streams, including local taxes, greater property taxes, and enhanced economic development. Many states also share revenues with local governments from severance taxes as well as state and federal leases. At the same time, costs to local governments are likely to increase—mainly associated with road damages or expansion of sewer and water systems and sometimes more crime—and local areas can suffer if new revenues do not keep pace with needs. Even if revenues offset local government operating expenses (e.g., staff costs), localities can go into debt due to increased infrastructure spending to support increased populations and economic activity.

Some counties and municipalities reach agreements with industry to fix road damages directly (or pay to fix them), as well as build recreation or education infrastructure in order to mitigate costs to the community overall, help balance the impacts of oil and gas production more broadly in a region, and generate goodwill. Education outcomes can likewise be affected by changes to the composition and size of student populations, school finances, and the market for teachers and administrators, each of which may impact teacher effectiveness and student performance. Overall, how a local government or school district might be affected by an increase in unconventional oil and gas development is largely driven by local conditions and, in particular, state and local fiscal policies.

Tables 1 and 2 below summarize the findings from our literature review of the local government impacts of unconventional oil and gas development. We examined several studies that conduct surveys of and/or interviews with local government officials as well as analyze some financial data, such as tax revenue, in order to assess the changes in various cost and revenue sources for local governments, as well as any other challenges associated with unconventional oil and gas development. We additionally analyze two studies that assess effective tax rates across oil and gas producing states using two different methods. Several of these studies focus on Pennsylvania, while the rest focus on oil and gas producing areas across the United States.

- In all, we review 19 studies. Eight studies focus on the impacts of unconventional oil and gas development on local public finances, specifically, with one study analyzing financial effects as part of a larger study and another looking at stated gas tax rates as part of a larger study. Nine studies assess truck traffic impacts, including surveys, traffic, road damages, and accidents.
- The majority of the local public finance studies are qualitative in nature, with two studies conducting statistical analysis. The majority of the truck traffic studies reviewed conduct statistical analysis.
- The findings of these studies show that local areas, even within the same state, can see a wide variety of effects related to unconventional oil and gas development, often depending on preexisting local factors and capacity. The studies assessing effective tax rates show that this rate varies widely as well.
- The truck traffic literature shows that development increases the number of accidents as well as road damages, which become quite costly to local areas, as revealed by the local finance literature and as measured by the truck traffic literature.
- Overall, the literature shows that municipalities and counties are generally able to meet the increased demand for services and increased costs related to shale development (including costs associated with truck traffic), though some regions—particularly rural areas with rapid development—are less able to effectively respond to these changes.

TABLE 1. FISCAL IMPACTS RISK-BENEFIT MATRIX

Fiscal Impacts and Infrastructure for Counties and Cities		
Impact	**Findings**	**Results**
State revenue sharing	↑	Several studies note that in most states, allocation of state severance taxes, state lease revenues, and federal lease revenues to local governments increases.
Local tax receipts	↑Ø	Several studies find increases in local sales taxes and property taxes in jurisdictions that collect them. Large variation exists across regions.
Donations	↑Ø	Several studies note collaboration between operators and local governments in select regions, notably on road repair.
Water and sewage infrastructure	↑Ø	One higher-quality study finds that particularly in rural regions, increased population can strain existing infrastructure.
Expenditures	↑	Several studies note that increased demand for government services requires higher expenditures. Increased revenues allows higher expenditures and improved services.
Debt	↑↓	Studies note that in rural regions experiencing rapid growth, debt loads have increased. In other regions, increased revenues have allowed debt to be paid off, while some studies note no changes.
Government staffing	↑	Several studies note staff growth in law enforcement, fire and emergency services, social services, and clerk/recorder. Increased compensation is often required to grow/retain staff.

TABLE 2. TRUCK TRAFFIC RISK-BENEFIT MATRIX

Truck Traffic		
Impact	**Findings**	**Results**
Traffic congestion	↑	Several studies note increased vehicle traffic, particularly in regions with limited pipeline infrastructure.
Road damage	↑	Two studies measure increased road damage, while several find concern in interviews with local officials. Damage in some regions is offset with donations or increased local revenues.
Accidents	↑	Two studies note increases in accident rates for heavy-duty trucks and all traffic, with increased rates of injuries and fatalities in accidents.

In Table 3, we summarize our findings of the impacts of unconventional oil and gas development on public education.[8] That report reviews the economics literature examining the effect of unconventional oil and gas development on public education via three main channels—student population, school finances, and the labor market.

- In all, 15 studies were reviewed, covering the following education impacts: student enrollment and demographics, student-teacher ratios, school finances (changes to revenue and expenditure streams), and educational attainment (graduation rates, completion rates, and dropout rates).
- A limited number of studies specifically examine the relationship between unconventional oil and gas development and public education outcomes.
- Existing literature that pools data across many plays masks interpretation of the impacts that clearly vary substantially across states; research that distinguishes across individual states appears far more telling.
- This literature review finds diverging trends in student enrollment in boom districts: western states such as Texas, North Dakota, and Montana experienced increases in student enrollment, whereas eastern states such as Pennsylvania, Ohio, and West Virginia saw a decrease in student numbers.
- Funding per student and the resulting impacts on education vary based on the ability for districts to tax oil and gas based on production, how these taxes interact with state education funding formulas, local pressures on how to spend revenue windfalls and the spending and saving restrictions for school districts within a state.
- Substantial revenue coming in relatively rapidly due to resource booms leads to volatility and uncertainty in school finances that further impacts the ability of districts to strategically use increased funding to improve student outcomes. Without knowing if increased revenues would continue in the future, districts cannot commit to permanent expenditures such as increases to teacher salaries.

To draw conclusions about the net effect of unconventional oil and gas development on educational outcomes as well as inform decisions to help mitigate and harness, respectively, the potential negative and positive impacts on public education, policymakers need more research and analysis that employ a combination of statistical and qualitative methods.

[8] Read the full report: Public Education Impacts of Unconventional Oil and Gas Development

TABLE 3. EDUCATION RISK-BENEFIT MATRIX

K-12 Education		
Impact	**Findings**	**Results**
Student-teacher ratio	↑↓	Large variation exists across regions. Increase in number of students per teacher found for Texas and North Dakota, yet significant decreases found in the Marcellus region. Appears to be led by change in student numbers and does not indicate a change in teachers.
Revenue	↑↓	Several higher-quality studies report large variation across regions with varying tax policies. One study found an increase in total revenue per pupil in the Marcellus, but a decrease in North Dakota.
Education expenditures	↑↓	Several higher-quality studies report large variation across regions. Increase in the Marcellus region, but decrease in North Dakota and Texas.
Capital expenditures	↑Ø	Several studies analyzing different regions report differing results. One higher-quality study found increases for Texas and several studies found an increase for capital spending per pupil in North Dakota. However, no statistically significant association found for other regions.
Educational attainment	~	Two studies with data-related limitations (particularly for rural areas) report decreases. One study found no evidence of increased dropouts in the Marcellus region, Bakken region, or Colorado.
Performance	~	One study finds a number of mixed results across grades and subjects. One study finds slight decrease in student achievement in Texas.

Health and Safety

Of particular concern to communities experiencing or making the decision to allow unconventional oil and gas development has been the potential for adverse health effects and seismicity-related safety impacts (and damages) from such development. Since 2009, the central and eastern regions of the United States have seen a dramatic increase in the rate of earthquakes, with Oklahoma surpassing California (historically the most seismically active region in the United States) in the number of magnitude 3+ earthquakes per year in 2014. This increase has been tied to underground injection of wastewater, enhanced oil recovery activities, and (more recently) fracking itself. The literature on health concerns is less conclusive. Local air pollution related to engines used in drilling and stimulation phases of development as well as truck traffic are areas of potential concern, and noise and light pollution could be associated with a number of health impacts, such as stress or disturbed sleep. Public discussions often reflect concerns about cancer or adverse birth outcomes as well, though which development activities are to blame, if any, is less clear. While such concerns are understandable for local communities, the literature has been unable to either definitely prove or disprove any health impact studied.

Tables 4, 5, and 6 summarize the findings of our literature review[9] on the health impacts of shale development. In all, we reviewed 32 studies covering the following health impacts: birth outcomes, cancers, asthma, and other health effects such as migraines and hospitalization. Occupational health studies also addressed exposure to certain pollutants (such as silica and volatile organic compounds), and a number of hypothesis-generating studies analyzed burdens and concentrations (such as water and air samples) in order to assess the potential for health impacts. The tables presented below indicate the relationship between an impact, as reported across the literature, and unconventional oil and gas development as well as the quality of the body of research assessing each impact.

- We found that though many epidemiological studies used robust statistical methods to estimate changes in health outcomes associated with unconventional oil and gas development, all had shortcomings that were most often significant.
- These studies furthermore reported contradictory results for each impact. Some studies, for example, found increases in preterm birth, while others found decreases or no association. As is illustrated by the risk matrix, this was the case for all outcomes, save for the impacts analyzed by only one study. Where the results of these studies did not contradict each other, the impact was only analyzed by a single study.
- Furthermore, only one study spans the full range of damage function elements; due to the nature of the data and research methodologies, the studies are unable to assess the mechanisms of any health impacts (i.e., whether a certain impact is caused by air pollution, stress, water pollution, or another burden). Those that do assess burdens or concentrations do not measure changes in health outcomes or assess the potential for such changes (save for one study). (See the span chart in the full report linked in the footnote for more details).
- As a result, even where good evidence is offered for a link between unconventional oil and gas development and health, the causal factor(s) driving this association are unclear.

Though we do not see strong evidence of changes in health outcomes associated with unconventional oil and gas development in the literature, a lack of data or a lack of rigorous studies do not rule out the potential for these effects.

[9] Read the full report: Health Impacts of Unconventional Oil and Gas Development

TABLE 4. BIRTH OUTCOMES RISK-BENEFIT MATRIX

Birth Outcomes		
Impact	**Findings**	**Results**
Birthweight	~	Studies of mixed quality find positive, negative, and null associations with birthweight.
Low APGAR	~	One study finds a positive association, while a high-quality study finds no association.
Preterm birth	~	Several studies report no association with development, while one higher-quality study and another lower-quality study find an increase in premature births.
Small for gestational age	~	Two studies report an increase in babies who are small for their gestational age, while another higher-quality study reports no association.
Birth defects	↑	One flawed study finds evidence of an increase in some birth defects, but no association with one defect.

TABLE 5. CANCER IMPACTS RISK-BENEFIT MATRIX

Cancer		
Impact	**Findings**	**Results**
CNS Tumors	↑	One study finds evidence of positive association.
Childhood cancers	Ø	One lower quality study finds no association.
Leukemia and lymphoma	~	Studies report evidence of an increase or no association. One risk assessment finds an elevated risk of leukemia and other cancers based on air measurements of benzene, though another study finds air measurements of pollutants to be below a threshold of concern.

TABLE 6. OTHER HEALTH IMPACTS RISK-BENEFIT MATRIX

Other Health		
Impact	**Findings**	**Results**
Asthma	↑	One study reports increases in asthma hospitalizations, ER visits, and prescriptions for asthma medications.
Hospitalization	↑	One study finds an increase in hospital rates for some types of inpatient cases, but no associations for most cases.
Migraines	~	Two medium-quality studies report no association, while one lower-quality study reports an increase; all are self-reported symptoms.
Multiple symptoms	↑	One study finds positive and no associations for different types of self-reported symptoms.

Table 7 summarizes our findings on induced seismicity. Our literature review[10] on this topic provides an overview of the existing state of research on induced seismicity related to both unconventional and conventional oil and gas development in the United States. We discuss the causes of induced seismicity, the hazards associated with induced seismicity, what makes an area more likely to experience induced seismicity, and monitoring and mitigation potential. We also review several economic studies assessing the valuation of earthquake risk in the residential housing market, with one study focused on induced seismicity specifically, and one survey on the acceptability of seismicity that discusses induced seismicity.

- The large majority of studies are retrospective, concerned with establishing association with oil and gas activities for specific events or changes in the rate of seismic events regionally. This literature finds that the change in the rate of seismic events in the central and eastern United States is largely attributable to oil and gas operations, namely wastewater injection. A number of seismic events in Texas, Oklahoma, Ohio, and other areas that have been studied have been attributed to oil and gas operations.
- Only recently have studies attempted more forward-looking analyses—such as building and testing simulation models, with two studies establishing methods to predict the probability of future induced seismic events and a third proposing monitoring methods.
- Three studies analyzing oil- and gas-related induced seismicity assess above-ground impacts, including on the Oklahoma housing market, the acceptability of earthquakes (via a survey), and shaking intensity.
- Though the literature specifically addressing above-ground impacts is sparse, given the robust literature connecting seismicity to oil and gas activities as well as the robust literature on natural earthquakes, we feel comfortable saying there is an increase in phsyical damage related to the increase in shaking with higher magnitdue earthquakes. The literature connecting oil and gas activities to seismicity is large and of high quality, and as large magnitude earthquakes have been linked to these activities through the literature, we are able to infer that there is an increase in damage to buildings.
- Almost none of the literature, however, addresses how induced seismicity related to oil and gas development affects the stress of residents experiencing this seismicity. One survey begins to address this by touching on the acceptability of induced seismicity, but the survey is not directed at those experiencing this seismicity.

[10] Read the full report: Induced Seismicity Impacts of Unconventional Oil and Gas Development

TABLE 7. SEISMICITY IMPACTS RISK-BENEFIT MATRIX

Seismicity		
Impact	**Findings**	**Results**
Damage to buildings	↑	Increase in seismicity associated mainly with wastewater injection and also hydraulic fracturing operations, depending on geological conditions and land use patterns.
Stress and anxiety	~	Only one survey includes questions about the acceptability of induced seismicity as part of a larger study.

Economic Impacts

The localized impacts of shale gas and tight oil development are often framed in terms of income, employment, and economic development. These impacts may take various forms: royalty payments to mineral rights owners, the potential for increased direct and indirect job opportunities, increased sales for local businesses, and possible growth in wages for both extraction-related sectors and others due to an increase in the demand for labor. All of these benefits then have indirect and induced benefits to other sectors and the regional economy.

Landowners with active leases earn royalties, but their neighbors and other landowners who do not own their mineral rights may receive no compensation, experience negative externalities, and even see property values drop. Workers see new opportunities but, at least initially, much of the workforce comes in from outside the community, particularly in areas that do not have prior experience with oil and gas development. Likewise, local businesses that support oil and gas operations see increased demands and income growth, but residents may see higher prices for goods and housing. The overall economic changes to a local area are therefore not necessarily clear cut, though the literature generally finds an overall increase in employment and income.

Tables 8, 9, and 10 summarize the findings from our literature review on employment, income, and economic development, respectively.[11]

- We examine 32 studies, focusing on studies that analyze the effects at a local level, such as townships and counties, as oppoed to national changes, though a few studies look at state-wide effects. with many analyzing these local impacts
- Twenty-two of these studies analyze wages and earnings in some capacity, and fewer (17) analyze other sources of income such as lease payments and royalties. Three-quarters of the studies assess employment changes, while over one-third address the potential for a resource curse. Few studies assess the distributional effects of shale development, and those that do measure these impacts indirectly, such as through analysis of rental rates and other metrics.
- We conclude that there is strong evidence for local employment gains during a growth period of unconventional oil and gas development, though the magnitude of these benefits varies from study to study. Particularly, we find that some studies overestimate the employment effects of oil and gas development. Furthermore, the size of

[11] Read the full report: Economic Impacts of Unconventional Oil and Gas Development

the estimates in these studies can depend on the source of data. For example, some employment estimates include out-of-state or out-of-county workers.

- We also find that there is strong evidence of an increase in wages (though a few studies find that this increase may be temporary), and increases in royalty income, though the share of local residents that own the mineral rights varies greatly by area, with royalty benefits to the community varying accordingly.
- The literature on long-term development effects provides less consistent evidence, with several studies finding evidence of a "resource curse," where a jurisdiction with abundant resources (in this case oil and gas) experiences stagnant or even decreased growth and others finding no evidence of such an effect. The reason for these inconsistent outcomes is possibly related to the large number of socioeconomic variables that affect resource dependence locally as well as the difficulty inherent in measuring resource dependence on a local level, an outcome that is less concrete than, say, a change in employment. This literature reports conflicting evidence for the resource curse related to earlier oil and gas booms as well, though with more time the longer term effects of shale development may become more clear.

TABLE 8. EMPLOYMENT IMPACTS RISK-BENEFIT MATRIX

Employment		
Impact	**Findings**	**Results**
Local	↑	Several studies see increases, with large variation in magnitude across studies. Limited growth for local workers in regions without existing oil and gas workforce.
Regional	↑	Several studies see modest increases at the state- or shale play-levels; variation across studies, with some finding only short-term effects.

TABLE 9. INCOME IMPACTS RISK-BENEFIT MATRIX

Income		
Impact	**Findings**	**Results**
Wages	↑	Most studies see increases, some find no association; large variation in magnitude across studies
Other income	↑	Several studies note increases in bonuses and royalties prior to and during production for those with mineral rights.

TABLE 10. ECONOMIC DEVELOPMENT

Economic Development		
Impact	**Findings**	**Results**
Long-term growth	~	A number of studies report evidence for and against the resource curse.

Table 11 addresses home value changes specifically. Changes in housing prices as a result of unconventional oil and gas development are useful indicators of community perceptions about the benefits and damages of such development, as they aggregate and monetize preferences of home buyers and sellers. In our literature review, we look at 16 studies of the housing market impacts of unconventional oil and gas development, focus our discussion on the studies that assess changes in home prices related to proximity to unconventional oil and gas development (using hedonic analysis). A few studies reviewed also focus on lease clauses, rental rates, farm values, and tax base changes. The largest number of studies (six) use data from Pennsylvania, with two of these comparing Pennsylvania housing prices with New York's, exploiting the moratorium on drilling in New York. Two focus on Tarrant County, Texas, and one looks at the Barnett shale in Texas, while two analyze data for Weld County, Colorado. A few examine multiple regions.

- As a whole, we consider the literature on the nearby housing market impacts of unconventional oil and gas development to be reasonably conclusive, meaning several high-quality studies report comparable findings.
- The studies show strong evidence for decreases in value, up to –$33,843, or –26.6 percent, for groundwater-dependent homes within 2 kilometers (km) of a well pad, though this number varies by distance to well or well pad and across studies. The studies also show strong evidence for increases in housing value for those close-in homes with piped water, up to $4,802, or 3.4 percent, again dependent on distance to well or well pad and study. This range reflects anxieties about the potential for groundwater contamination. A few studies find smaller magnitude impacts, with one study finding none.
- Almost all of these studies are unable to account for mineral rights ownership (which would lead to an underestimate of housing price discounts from groundwater-dependent homes), though one study is able to analyze the effects of unconventional oil and gas development near Weld County homes with split estates. This study finds a decrease of over –$60,000, or –35 percent of average home value, for homes without mineral rights.
- The findings of these studies vary in terms of the persistence of these effects (the temporal nature of these impacts) as well as the relationship between these impacts and specific phases of drilling.

TABLE 11. PROPERTY VALUES RISK-BENEFIT MATRIX

Property Values		
Impact	**Findings**	**Results**
Homes near wells, piped water	↑	Several studies find modest increases in value (depending on distance to unconventional oil and gas development as well as other factors).
Homes near wells, groundwater	↓	Several studies find large decreases in value (depending on distance to unconventional oil and gas development as well as other factors).
Homes without mineral rights	↓	One study finds that homes without mineral rights see large, negative decreases in their price from nearby unconventional oil and gas development.

Social License to Operate

The RFF project is focused on community engagement practices and protocols that are used by oil and gas companies and local communities to address community interests and concerns in the development process, relying primarily on qualitative interviews with representatives from companies, governments, local groups, NGOs, and academic institutions

Table 12 highlights the social license to operate by oil and gas operators, an issue addressed by RFF research.

TABLE 12. SOCIAL LICENSE TO OPERATE RISK-BENEFIT MATRIX

Social License to Operate		
Impact	**Findings**	**Results**
Social license to operate		One study analyzes the relationship between oil and gas companies and local communities in which they operate.

Environmental Impacts

Though no literature review was conducted for environmental impacts as part of this initiative, RFF experts have published and are in the process of conducting a number of studies that address some of these impacts, including those to water quality and land use. Tables 13 and 14 highlight RFF research conducted in these areas.

TABLE 13. WATER QUALITY RISK-BENEFIT MATRIX

Water Quality		
Impact	**Findings**	**Results**
Water use		One study examines the spatial and temporal patterns of water withdrawals and consumption for natural gas development in the Susquehanna River Basin, finding that Susquehanna River Basin Commission policies for gas companies have been more binding than what has been suggested.
Surface water quality		Two studies address this endpoint. One finds no systematic effects of spills on Pennsylvania streams but does find effect of sedimentation from well sites and roads as well as effluent from treatment plants. One study finds that pits and tanks both present risks of spillage, but does not examine stream impacts.

TABLE 14. LAND USE RISK-BENEFIT MATRIX

Land Use		
Impact	**Findings**	**Results**
Solid waste/Landfills		One study finds that toxicity levels in solid wastes from Pennsylvania wells are generally below benchmarks (though uses a small sample).
Leasing		Two studies are forthcoming on this topic.
Agricultural land use		One study uses geospatial analysis to assess the short- and medium-run effects of increased oil and gas development on agricultural land use in North Dakota, finding that well construction and subsequent operation are correlated with a reduction in crop acreage.
Fragmentation		One study develops an optimization approach to incorporate environmental objectives into shale gas pipeline development. The authors illustrate model usage by estimating the trade-offs between costs and environmental externalities using data from northeastern Pennsylvania.

Conclusion

In 2013, we set out to characterize the literature on the impacts of unconventional oil and gas development, and the following year published a literature review on a number of outcomes (including, but not limited to, community impacts).[12] Then, much was unknown about the impacts of the unconventional oil and gas boom—the report listed 24 "critical questions." Of the nine questions that dealt directly with community impacts, seven have been addressed by a newer literature that we reviewed as part of this current initiative and that is summarized in the Community Risk-Benefit Matrix presented above.

One area that has seen a lot of work since the publication of this last review is the local economic impacts of unconventional oil and gas development. Many new studies have been published, and almost all show positive impacts on communities in terms of employment and income, though the literature studying other economic impacts, such as long-term growth and development, is less conclusive. And though there have been few local public finance studies conducted, we find these studies to be generally of high quality, with most showing that many local governments saw positive or neutral fiscal impacts, though a few faced increased debt for a number of reasons. Several local public finance studies are furthermore very comprehensive in terms of both the geographical focus and the various issues addressed.

The property value literature offers intriguing findings of how homeowners and those desiring a home might value a boom in unconventional oil and gas development, but a better understanding of the effects of split estates is important. And the seismicity literature has likewise provided many answers

[12] Read the full report:
Krupnick, Alan J., Raymond J. Kopp, Kristin Hayes, and Skyler Roeshot. 2014. *The Natural Gas Revolution: Critical Questions for a Sustainable Energy Future*. Washington, DC: Resources for the Future.

regarding whether oil and gas development caused specific seismic events and larger seismic rate changes in the central and eastern United States. This literature has furthermore moved toward probabilistic modeling that will likely aid in the development of mitigation strategies.

One area that stands out in its need for better data and higher-quality research (as well as more focus generally) is the health impacts literature. For each health impact, few studies have been conducted, and, for most of these impacts, the studies report inconsistent findings. Even though the seismicity linkages are better understood, the willingness to pay to avoid preventable earthquakes needs study to help guide the policy response.

It is important to note that much of this literature is place-based in that the studies generally look at one or a few counties or one state, meaning the generalizability of such findings is uncertain. Thus, studies conducted in additional states.

Overall, the literature has come a long way in addressing many of the “known unknowns” highlighted in the 2014 RFF report, though more work is still needed to fully understand the implications of the boom (and particularly the bust) in unconventional oil and gas development.