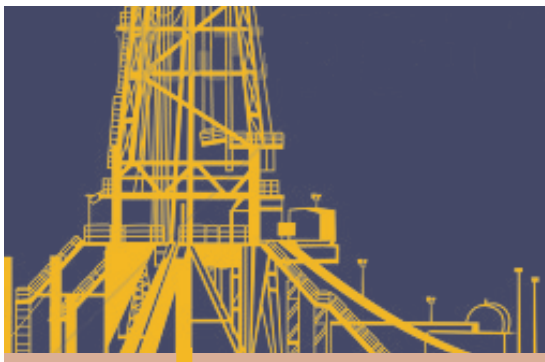
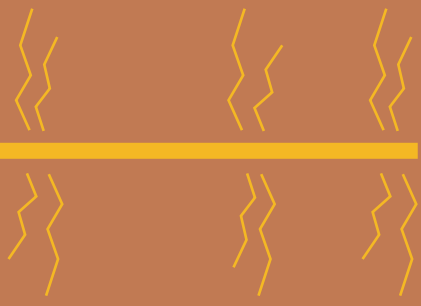


UNIVERSITY OF MICHIGAN

Public Perceptions Technical Report



HYDRAULIC FRACTURING IN THE STATE OF MICHIGAN

ABOUT THIS REPORT

This document is one of the seven technical reports completed for the **Hydraulic Fracturing in Michigan Integrated Assessment** conducted by the University of Michigan. During the initial phase of the project, seven faculty-led and student-staffed teams focused on the following topics: **Technology**, **Geology/Hydrogeology**, **Environment/Ecology**, **Human Health**, **Policy/Law**, **Economics**, and **Public Perceptions**. These reports were prepared to provide a solid foundation of information on the topic for decision makers and stakeholders and to help inform the Integrated Assessment, which will focus on the analysis of policy options. The reports were informed by comments from (but do not necessarily reflect the views of) the **Integrated Assessment Steering Committee**, expert peer reviewers, and numerous public comments. Upon completion of the peer review process, final decisions regarding the content of the reports were determined by the faculty authors in consultation with the peer review editor. These reports should not be characterized or cited as final products of the Integrated Assessment.

The reports cover a broad range of topics related to hydraulic fracturing in Michigan. In some cases, the authors determined that a general discussion of oil and gas development is important to provide a framing for a more specific discussion of hydraulic fracturing. The reports address common hydraulic fracturing (HF) as meaning use of hydraulic fracturing methods regardless of well depth, fluid volume, or orientation of the well (whether vertical, directional, or horizontal). HF has been used in thousands of wells throughout Michigan over the past several decades. Most of those wells have been shallower, vertical wells using approximately 50,000 gallons of water; however, some have been deeper and some have been directional or horizontal wells. The reports also address the relatively newer high volume hydraulic fracturing (HVHF) methods typically used in conjunction with directional or horizontal drilling. An HVHF well is defined by the State of Michigan as one that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid. The reports indicate if the text is addressing oil and gas development in general, HF, or HVHF.

Finally, material in the technical reports should be understood as providing a thorough hazard identification for hydraulic fracturing, and when appropriate, a prioritization according to likelihood of occurrence. The reports do not provide a scientific risk assessment for aspects of hydraulic fracturing.

Participating University of Michigan Units

Graham Sustainability Institute
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University of Michigan Energy Institute

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HYDRAULIC FRACTURING IN THE STATE OF MICHIGAN

Public Perceptions of High-Volume Hydraulic Fracturing & Deep Shale Gas Development

SEPTEMBER 3, 2013

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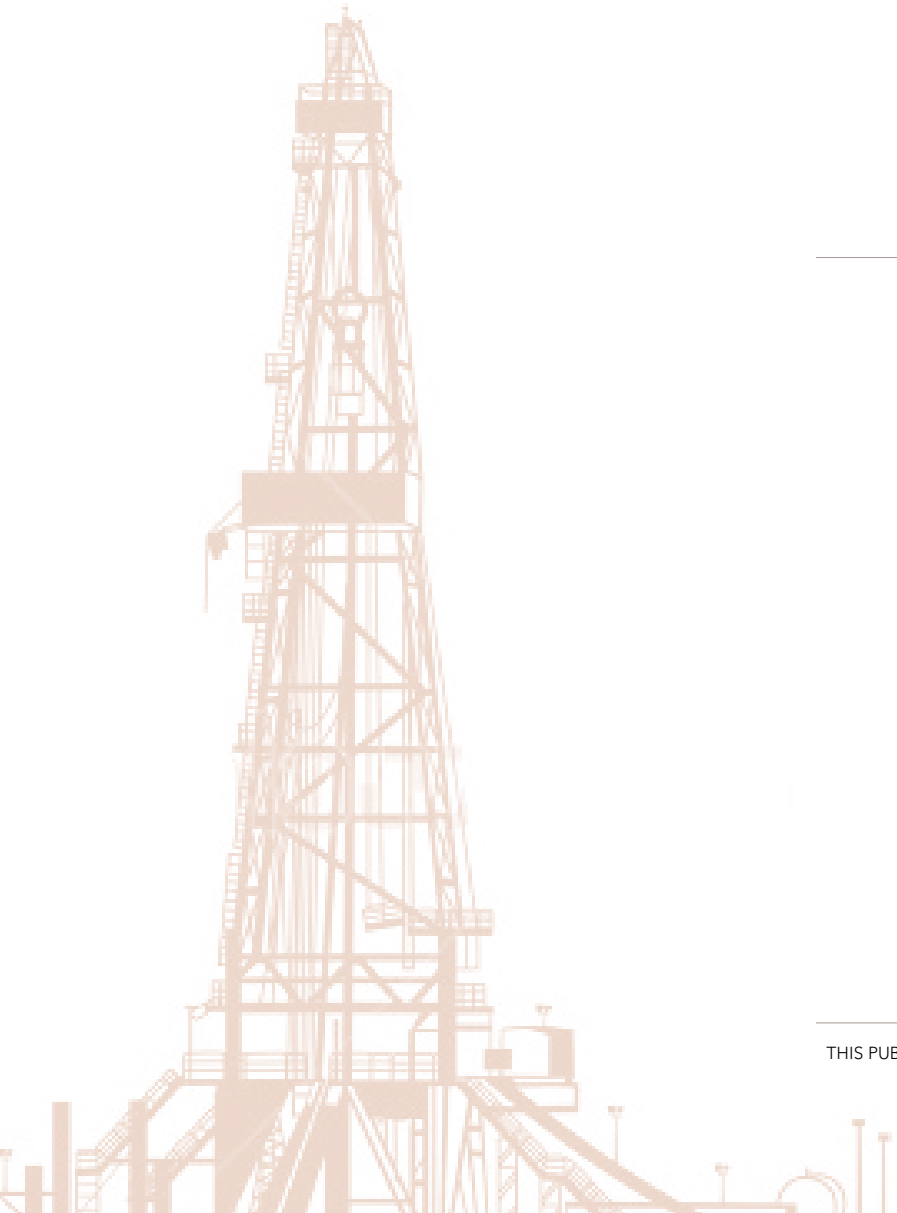

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EXECUTIVE SUMMARY

This report reviews the current state of knowledge on public perceptions of high-volume hydraulic fracturing (HVHF) and more broadly, deep shale natural gas development. The objective is to highlight issues that may be relevant to HVHF-related policy in Michigan. As there are few Michigan-specific data available, the report reviews opinion poll data and academic literature from across the U.S. to summarize how the public perceives HVHF and to identify the factors that make it a controversial issue. Our intent is neither to judge the public as being right or wrong in their perceptions, nor to suggest that we should necessarily try to change their opinions. Rather, the report draws on risk perception research to illuminate the challenges and opportunities for creating a constructive public dialogue on HVHF in Michigan.

Approach

The report is divided into three sections. The *Status and Trends* section summarizes public perceptions of HVHF and deep shale gas development using national and state-level opinion poll data, academic studies of communities directly impacted by HVHF (in NY, PA and TX), and an analysis of Michigan stakeholder perspectives. The next section examines the *Challenges and Opportunities* for encouraging stakeholder dialogue. Drawing on several decades of risk perception research, this section identifies factors that can heighten perceived risks and increase discord among stakeholders. It then examines current HVHF practices in Michigan in light of these factors and highlights opportunities for improvement. The final section of the report, *Prioritized Pathways*, builds off of this discussion and offers suggestions for the future.

Summary of findings

Status and Trends

Across national and state-level polls, common trends emerge concerning the public's awareness of "fracking," their beliefs about its risks and benefits, and their desire for regulation. In Michigan, a majority (82%) of residents have heard at least "a little" about fracking and nearly half report that they follow debates about fracking in the state "somewhat" to "very closely"[1]. Consistent with other national and state-level polls, a slight majority of Michiganians (52%) believes that the benefits of fracking outweigh the risks, but concerns remain about the impacts on water quality. In Michigan and elsewhere, most people support tighter regulation of the oil and gas industry, including requiring disclosure of the chemicals used in HF fluids.

Similar perceptions occur in communities directly impacted by HVHF. While many residents believe shale gas development will create jobs and stimulate the local economy, concerns remain about the amount of water used in HVHF as well as the potential for groundwater contamination. In addition, residents express concerns about changes to their communities as a result of industry equipment and the influx of natural gas workers moving into the area. Many residents note increases in truck traffic and degraded roads. Other concerns include noise and light pollution, negative aesthetic impacts, inflated housing prices, conflicts between residents and industry workers, and an unequal distribution of wealth as a result of mineral rights leases.

While no community-level studies have been conducted in Michigan on public perceptions of HVHF, disagreements about its impacts are apparent in the dialogue that is emerging among stakeholder groups. Nonprofit and grassroots organizations express concerns about the risks of HVHF to water resources and human health while industry groups downplay these risks and emphasize its potential economic benefits. Industry and government agencies alike note Michigan's long history with low-volume HF as evidence that HVHF is safe.

Challenges and Opportunities

There are several potential challenges to encouraging a constructive dialogue on HVHF in Michigan. The first is that experts and the lay public use fracking terminology differently. The public tends to view "fracking" as the entirety of the natural gas development process from leasing and permitting, to drilling and well completion, to transporting and storing wastewater and chemicals. Industry and regulatory agencies hold a much narrower definition that is limited to the process of injecting hydraulic fracturing fluids into a well. These differences in meaning can lead to miscommunications that ultimately increase mistrust among stakeholders.

Second, experts and the lay public have different conceptions of risk. While experts assess risk in terms of technical safety, the public takes into account additional psychological and social considerations. Past research shows that a number of factors can heighten perceived risk, such as when a potential hazard is involuntarily imposed, its consequences are unknown, and those in charge appear to be untrustworthy or unresponsive to public concerns. Several aspects of HVHF in Michigan may fit this description, including the limited opportunities for public input and the uncertain risks posed by the chemicals in HF fluids.

Finally, failing to understand how the public perceives risks can lead industry and government experts to assume that the public just needs to be better educated about technologies such as HVHF. Research shows, however, that providing technical information alone is unlikely to change the public's perceptions and may even fuel further conflict. The goal of risk communication should not be to persuade the public but rather to facilitate a process

that leads to socially agreed upon decisions. Research suggests this can best be done by meaningfully involving the public early on in the policy-making and regulatory process.

Prioritized Pathways

The final section of the report lays a foundation for Phase 2 of the integrated assessment, highlighting the areas of greatest concern in Michigan and outlining potential directions for future research. Specifically, the report suggests examining community preparedness in communities most likely to be impacted by HVHF, investigating public concerns in those same communities, exploring opportunities for improving transparency about HVHF in Michigan, and examining options to increase public consultation and participation.

Limitations and gaps in the literature

Although a wealth of data were reviewed for this report, research on how the public perceives HVHF and deep shale gas development is in its infancy. Compared to other controversial issues, relatively few studies have been conducted to date on this topic. However, the consistency of results across data sources and geographic regions suggests that the findings of this report are likely applicable to Michigan and other regions where HVHF is an emergent issue. The reader should keep in mind, though, that as the issue of HVHF evolves, public perceptions may change.

1.0 INTRODUCTION

Over the past decade, advancements in horizontal drilling technology and high-volume hydraulic fracturing (HVHF) have created opportunities for extracting natural gas from plays that were previously inaccessible. Two of these—the Collingwood and Utica formations—underlie the state of Michigan, and as a result of a successful test well drilled by the Encana Corporation in Missaukee County in 2010, interest in natural gas development in Michigan has experienced a tremendous upswing. The significance of this renewed interest in Michigan was exemplified by the May 2010 minerals lease sale, which netted over $178 million for the state, almost equaling the cumulative $190 million the state had previously earned since it began issuing mineral leases in 1929[2].

Although only a handful of wells in Michigan have been completed with HVHF, the potential for large-scale natural gas development in deeper shale formations has garnered considerable attention in the state and a concomitant rise in public concern. As shown in Figure 1, newspaper coverage of hydraulic fracturing (HF) or "fracking" in Michigan has dramatically increased since the initial May 2010 mineral lease auction. In most states where HVHF is proposed or underway, the politics surrounding the technology can be divisive and pose major challenges for local and state decision makers. Numerous citizen groups in Michigan and elsewhere have pushed for increased regulation of the industry, if not an outright ban, while in other states, townships have found themselves in conflict with state governments over whether they have the right to ban the practice locally[3]. The widespread controversy surrounding HVHF suggests that if it is managed poorly, it can have significant social costs, regardless of whether it poses environmental or health consequences. As decision makers consider how to manage the changing nature of gas development in their states, incorporating public concerns into the decision-making process can allow them to reach outcomes that have long-term benefits for public trust and the social well-being of their states.

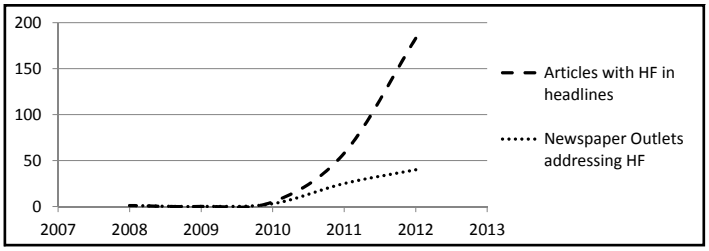

Figure 1. Michigan newspaper coverage of fracking[a]

This report aims to provide the reader with a better understanding of the current state of public perceptions of HVHF and to highlight issues that may be relevant to shale gas development policy in Michigan. As there are few Michigan-specific data available, the report reviews opinion poll data and academic literature from across the U.S. to summarize how the public perceives HVHF and to identify the factors that make it a controversial issue. Our objective is neither to judge the public as being right or wrong in their perceptions, nor to suggest that we should necessarily try to change their opinions. Rather, the report draws on risk perception research to examine how public opinion is formed and to illuminate the challenges and opportunities for creating a constructive public dialogue on HVHF in Michigan.

The remainder of this report is divided into three parts. The *Status and Trends* section strives to provide an objective summary of public perceptions based on national and state-level public opinion poll data and the limited number of peer-reviewed studies conducted to date. This section also includes a description of Michigan stakeholder groups (environmental, grassroots, industry, and government), and where their positions on HVHF align and conflict.

[a] We compiled all articles focusing on hydraulic fracturing from the year 2000 to October 2012 using the NewsBank newspaper database, which maintains records of 133 Michigan newspapers. To limit the search to articles in which HF was the primary focus, only articles that referenced "frack," "fracking," or "hydraulic fracturing" in the headlines were included.

The next section examines the *Challenges and Opportunities* for encouraging stakeholder dialogue. Drawing on several decades of risk perception literature, this section identifies factors that can heighten perceived risks and increase discord among stakeholders. It then examines current HVHF management practices in Michigan in light of these factors and highlights opportunities for improvement. The final section of the report, *Prioritized Pathways*, builds off of this discussion and offers suggestions for additional research in Phase 2 of the integrated assessment.

A note about terminology

The EPA defines hydraulic fracturing as "a well stimulation process used to maximize the extraction of underground resources; including oil, natural gas, geothermal energy, and even water"[4]. In Michigan, the Department of Environmental Quality specifies that "'high volume hydraulic fracturing well completion' means a well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid"[5]. In the public's mind, however, the definition of "fracking" is often broader, encompassing the entire lifecycle of deep shale gas development—from leasing and permitting of lands to well drilling, completion, and disposal of HF fluids. As we will discuss in the *Challenges and Opportunities* section, these semantic differences can have unintended consequences when communicating about this issue. For the purposes of this report, we have used "deep shale gas development" when we are referring to the suite of practices involved in developing a deep shale gas well with horizontal drilling and high-volume hydraulic fracturing (from leasing the land to continued operation of the well). We use the abbreviation HVHF when we are referring specifically to the process of high-volume hydraulic fracturing, and HF when differentiating between high-volume and low-volume fracking is either not necessary or not possible. When referring to an instance of public perception where the line is blurred between HF, HVHF, and gas development in general, we also use the more popular term "fracking." For example, many opinion polls ask questions related to "fracking" without identifying the specific process respondents should consider.

2.0 STATUS AND TRENDS

To evaluate public perceptions of HVHF—and more broadly, of deep shale gas development—we considered three sources of data: public opinion polls, empirical academic studies, and primary documents from stakeholder groups in Michigan. Each of these is explored in the following subsections. Section 2.1 examines national and state-level opinion polls to identify general trends in public perceptions of "fracking." These include awareness of fracking, perceived risks and benefits, degree of support for deep shale gas development, and opinions regarding HF regulations. This discussion includes results from the only poll to date that specifically samples Michigan residents[1]. Section 2.2 explores public perceptions in greater depth, using academic studies of communities where HVHF has occurred. This body of research, conducted in Texas, Pennsylvania, and New York, reveals additional public concerns about deep shale gas extraction and sheds light on how perceptions may change as development in an area matures or intensifies. Section 2.3 looks more closely at Michigan, identifying key stakeholder groups, their positions on HVHF, and issues that may be relevant to understanding public perceptions within the state. The final section, 2.4, summarizes the findings of the *Status and Trends* section and discusses possible implications for future development in Michigan.

2.1 National and state-level public opinion polls

This subsection reviews data from public opinion polls conducted in the United States between November 2010 and February 2013. Polls were identified by searching for the terms "fracking" or "hydraulic fracturing" in two poll databases: Polling the Nations and the iPoll Databank maintained by the Roper Center for Public Opinion Research at the University of Connecticut. In addition, we searched the University of Michigan's ArticlePlus database for news stories that reported poll results. The resulting data are drawn from numerous sources, including academic, commercial, and nonprofit organizations. Rather than summarizing all poll questions, our review focuses on those that are explicitly about HF and/or deep shale gas development.

Of the 38 polls considered in this report, 13 report on public opinion at the national level and 24 report on attitudes at the state level. This data set includes the first (and only) public opinion poll on HF conducted in Michigan[1]. The remaining poll in the set compares public opinions from a nationally representative sample to a sample drawn from states with mature gas plays (Arkansas, Louisiana, Texas) and another sample drawn from states with new gas plays (New York and Pennsylvania)[6]. Polls conducted at the state-level occurred in states where HVHF is already underway (California[b], Louisiana, Michigan, Ohio, Pennsylvania, and Texas)[1,7-12], in one state where fracking occurred but is currently under a moratorium pending further study of its environmental and health effects (New York)[13-24], and one state where HVHF for natural gas has not yet begun (North Carolina)[25,26]. Together, these poll data shed light not only on perceptions of fracking, but also on how perceptions differ regionally and over time. Appendix A provides more details about the results from individual polls.

[b] Hydraulic fracturing in California is currently used to extract oil, not natural gas.

2.1.1 Awareness

Across polls, roughly 50-60% of Americans are at least "somewhat aware" of hydraulic fracturing, and among nationally-representative samples awareness appears to be increasing[7,13,27-30]. A poll by the Civil Society Institute[27] found, for example, that 44% of Americans had some awareness of fracking in November 2010. By July 2012 that number increased to 58%[28]. When asked how much they have heard or read about fracking, around 30% of Americans nationwide report that they have heard "some" to "a lot" about the issue[31-33]. Not surprisingly, people tend to pay more attention to the issue in states where HF is actively debated. In Pennsylvania, where HF has garnered considerable media attention[34], 46% of respondents report that they have heard or read "a lot" about the issue and 59% report following debates on shale gas drilling "somewhat" to "very closely"[1]. In Michigan, where HVHF is in an early stage of development, the issue is still fairly salient to residents. Forty percent (40%) of Michiganians have heard "a lot" about "hydraulic fracturing" and 48% say they follow the issue "somewhat" to "very closely"[1] (see Appendix A, Tables 2 and 4).

Awareness of HF tends to vary with political orientation, gender, and socio-economic status. Democrats are consistently less aware of fracking than Republicans, with Independent voters usually falling in between[7,8,13,27,31]. Several polls also find significant discrepancies between male and female respondents[13-18,27,31]. For example, the Pew Research Center reported that 55% of women nationally have heard of fracking compared to 71% of men. Greater awareness is also associated with higher levels of education[7,9,14-18,27,31] and household income[7,13-18].

2.1.2 Perceived benefits and risks

When asked to weigh the benefits of HF against its risks, people tend to view it positively. Deloitte found that a majority (53-62%) of people in all three of its samples (national, mature gas plays, and newer gas plays) believed that the benefits of HF "somewhat" to "far" outweigh its risks[6] (see Appendix A, Table 7). Across these three samples, a significantly greater portion of respondents in newer gas plays (25%) indicated that they were "not sure" how the benefits and risks of HF compared[6]. The poll conducted in Michigan had similar results, with 52% of people believing that "drilling for natural gas" in the state had resulted in more benefits so far, 24% who thought it had led to more problems, and 8% who thought the benefits and problems were about equal[1]. Comparable results were observed in Pennsylvania[1].

Benefits

Economic growth and energy independence are the most commonly perceived benefits of fracking. Deloitte[6] found that approximately 45% of respondents familiar with HF believed that developing U.S. shale gas would be "very" or "extremely impactful" in boosting local economies, creating jobs, promoting energy independence, and boosting the national economy. A similar percentage also believed that natural gas development would lead to cleaner air. Polls conducted in Michigan and Pennsylvania asked respondents to rank potential benefits of fracking[1]. In both states, economic benefits and energy independence were seen as the most likely, followed by reduced carbon emissions and reduced energy costs for consumers and industries. Ten percent (10%) of Michiganians were not sure what the primary benefit of fracking would be while another 13% thought fracking would have no benefits. In a separate question, respondents were asked to rate how important natural gas drilling is to the overall condition of the state's economy. Among Michiganians, 46% thought natural gas drilling was "somewhat important," and 36% thought it was "very important" [1]. Similar results were observed among Pennsylvanians[1].

Risks

Multiple polls suggest that Americans are concerned about the potential for water contamination from shale gas development. In four national polls conducted by the Civil Society Institute, nearly 80% of respondents indicate that they are "somewhat" to "very concerned" about the impacts of fracking on water quality[27-30,35]. Similar percentages were reported for New York and Pennsylvania[7,13]. Polls conducted simultaneously in Michigan and Pennsylvania asked respondents to list what they perceived to be the most important risk from fracking[1]. In both states, water contamination was mentioned most often (18% of respondents in Michigan, 34% in Pennsylvania), with an additional 8-9% of respondents specifically mentioning groundwater or well water contamination. Respondents in Michigan were also concerned about health issues (14%), pollution and chemicals (8%), and general environmental damage (6%), among other concerns. A quarter (25%) of Michigan respondents were "not sure" what the most important risk related to fracking would be. In both Michigan and Pennsylvania, a majority of respondents "somewhat" or "strongly" agreed that natural gas drilling would pose a major risk to the state's water resources[1]. Another series of polls in New York and Ohio asked respondents whether they thought HF would cause environmental damage (see Appendix A, Table 13). A plurality (45-50%) in each state believed fracking would cause environmental damage, while another third of respondents were "not sure"[10,11,14-18].

2.1.3 General support/opposition

While a majority of Americans believe the benefits of fracking will outweigh its risks, this belief does not necessarily translate to support for this gas extraction practice. Eight polls asked respondents whether they favor or oppose fracking (see Appendix A, Table 5). Of these, five found that respondents are evenly divided on the issue. This was true primarily in states where HVHF for natural gas has not yet begun or is under moratorium (NC and NY)[25,36,37]. In Michigan,

where HVHF is in an early stage of development, a majority of respondents either somewhat supports (22%) or strongly supports (32%) "extraction of natural gas from shale deposits in Michigan" compared to 35% who somewhat to strongly oppose it[1]. A nationally-representative poll by the Pew Research Center similarly found a majority of respondents (52%) were in favor of HF development compared to 35% opposed[31]. In Pennsylvania, where there is extensive HVHF activity, support for shale gas development is not quite as strong[1]. Forty-nine percent (49%) of respondents somewhat or strongly support shale gas extraction compared to 40% who somewhat to strongly oppose it. Despite general support for natural gas extraction, a majority of respondents in both Michigan and Pennsylvania agree that their respective states should impose a moratorium on HF until more is known about its potential risks (MI: 16% somewhat agree, 36% strongly agree; PA: 17% somewhat agree, 41% strongly agree)[1].

As was the case for awareness, support for HF diverges depending on political party, gender, and education level. Support appears to be higher among Republicans and Independents than Democrats[8]. In Michigan 70% of Republicans support shale gas development compared to 53% of Independents and 46% of Democrats[1]. Among Americans who have heard of fracking, men are generally more supportive than women. Pew[31] reported, for example, that nearly two-thirds of men are in favor of fracking (61% vs. 29%), while women are more evenly divided (41% favor vs. 40% oppose). Respondents with a college education also tend to be less supportive of fracking. According to the Pew[31] poll, college graduates are evenly divided on the issue (45% in favor vs. 43% opposed), while individuals with a high school education or less support fracking nearly two-to-one (56% in favor vs. 29%).

2.1.4 Support for policy measures

Public opinion polls often explore support for three types of policies: (1) disclosure of chemicals in HF fluids, (2) increased regulation of the natural gas industry, and (3) severance taxes. Generally speaking, Americans are strongly in favor of all three. Across polls, a vast majority of respondents believe state and national officials are not doing enough to require disclosure of chemicals and that disclosure requirements should be tightened[7,13,27]. Likewise, a plurality of respondents (40-66%) believe that industry, in general, needs more regulation (compared to 15-25% of respondents who believe there should be less)[32,38-41]. Polls conducted in Michigan and Pennsylvania addressed whether the states should, respectively, retain or adopt a severance tax on natural gas[1]. Responses were overwhelmingly supportive of levying a severance tax on natural gas producers, with 77% in favor in Michigan and 65% in favor in Pennsylvania. The poll further questioned how tax revenue should be used. In both states, the top three preferences were the same: (1) reduce local property taxes, (2) support state research on alternative energy, and (3) reduce government debt. Finally, these polls asked respondents whether they agreed that tighter regulations and higher taxes on natural gas drillers should be avoided because these policies would lead drilling firms to leave the state. In both Michigan and Pennsylvania, a plurality of respondents disagreed.

2.2 Academic studies of localized HVHF development

While opinion polls conducted at a state or national level are useful for assessing broad-scale trends, they may not accurately reflect attitudes in communities directly affected by deep shale gas activities[42]. To date, a small number of empirical studies, primarily in Texas and Pennsylvania, have examined perceptions of deep shale gas development at the local level in greater depth.

Most of this research builds off of the "boomtown model," a framework that emerged in the 1970s in response to rapid energy development in the Western United States. During this period, many small, rural communities experienced exponential population growth as companies arrived from around the country to capitalize on favorable energy markets. Although towns benefitted from increased tax revenue, lower levels of unemployment, indirect stimulus to local businesses, and wealth creation from land leases, negative social impacts on communities were significant[43] and often resulted in changing attitudes toward energy development. In past boomtowns, community reactions have been observed to evolve through four stages:

> *enthusiasm* in initial stages when residents express positive expectations; *uncertainty* as residents notice that expectations are not being met and unexpected changes occur (…); *panic* as residents realize the magnitude of unexpected impacts on their community; and finally, *adaptation* as the changes become viewed as permanent[44].

There is some evidence in other states to suggest that deep shale gas development through HVHF could follow boomtown growth patterns[45]. In Sublette County, Wyoming, for example, the drilling rig count rose from two in the year 2000 to 56 in 2006, an increase that was paralleled by population rises between 16% and 44% in local communities over the same time[45]. In Pennsylvania, 195 deep shale wells were drilled statewide in 2008 and numbered 2,484 by the end of 2012[44,46].

Many of the HVHF studies conducted to date, while not longitudinal in nature, try to test for boomtown effects by comparing perceptions in communities that are at different stages of shale gas development. Of the studies available, four investigate perceptions in the Barnett Shale region of Texas[42,47-49] and six

examine perceptions in the Marcellus Shale region of New York and Pennsylvania[44,50-54]. Appendix B provides a brief summary of each study's purpose, methodology, and main findings.

All four studies in Texas were based on data collected in Wise and Johnson Counties during 2006. Researchers selected these counties to compare perceptions in a community with mature energy development (Wise County) to one at the beginning stages (Johnson County). The dataset included interviews with 24 municipal and county leaders[48] and a survey of 600 households[42,47,49].

Studies in the Marcellus Shale region have used similar methods. The first study conducted interviews with 61 key informants to compare perceptions across four counties in Pennsylvania and New York[44]. Counties were selected to represent communities with different degrees of HVHF activity (high/low) and experience with fossil fuel development (high/low). Two other studies have surveyed residents in communities with different levels of drilling activity. One compared perceptions in Pennsylvania (n=1,455) to New York (n=461)[51], while a later study compared perceptions in adjacent counties in Pennsylvania (n=1301)[54]. The fourth study we reviewed asked individuals in northern Pennsylvania (n=1,028) a series of questions about their perceptions of shale gas and wind energy development, both of which were occurring in the area[52]. The fifth study used survey data from 891 school administrators in 309 districts in Pennsylvania to compare perceptions of the economic benefits and socioeconomic challenges associated with HF in communities with different levels of drilling activity[50]. Finally, the last study reviewed explores some of the perceived health impacts that residents in Pennsylvania (n=33) attributed to shale gas extraction at an early stage of development and again nearly two years later[53]. While participants in this study were self-selected and not necessarily representative of the entire community, the results are informative for understanding how individuals believe HVHF can impact their personal health.

Together, these ten studies shed light not only on the perceptions of individuals directly impacted by HVHF, but also on how perceptions can vary across communities and over time. The following sections look across studies to identify common perceptions that emerge in communities impacted by HVHF and the contextual factors that may influence those perceptions.

2.2.1 Perceptions of HVHF and deep shale gas development

Across all studies, common trends emerge concerning the positive and negative aspects of deep shale gas development. In general, respondents tend to perceive development as economically beneficial but also perceive negative impacts related to public health and safety, the environment, local infrastructure, and quality of life.

Perceived benefits

Most study participants acknowledged that natural gas development had economic benefits for their region. Specific benefits included individual wealth creation from leases and royalties; job creation from employment in the natural gas industry; increased business revenue in the retail, service, and construction sectors; reduced unemployment; and increased tax revenues[44,47-50]. In Texas, survey respondents also indicated that they thought healthcare services, school quality, and fire protection services were improving as a result of natural gas development in their area[47].

When development occurs in economically depressed regions, studies show that the public may perceive natural gas development as a panacea to local economic issues[44,47-50]. One response from a school administrator in Pennsylvania captures this sentiment:

> We're seeing a lot of individual benefit beginning to develop locally, through leasing, but no benefits to the communities and schools as yet. […] However our communities have been depressed for so long since the mining industry left, that we are also desperate for the return of industry to the region[50].

Perceived risks and negative consequences

Public health and safety were seen to be at risk from a variety of factors. In Texas, the most prevalent concern was the risk of automobile accidents and fatalities from the dramatic increase in truck traffic associated with HVHF[48,49]. Compared to low-volume HF, HVHF has greater water transportation needs, both to deliver freshwater to the well site and, in some cases, to transport wastewater that emerges from the fractured well. Key informants and survey respondents in Texas viewed truckers as aggressive, dangerous, and lacking respect for locals[48,49]. Surveyed community members also feared the possibility of well explosions and negative health impacts from HVHF chemicals and disposal wells[48,49]. As one researcher noted[49], while the actual incidence rate of well explosions is actually quite low, past research suggests that fears and concerns about a perceived threat can have real, negative consequences on health[55]. In Pennsylvania, for example, concerns about potential health impacts of HVHF remained a constant source of psychological stress during the nearly two-year timespan of the study[53]. See Basu et al. (this series)[56] for more on the relationship of perceived risks and health impacts.

Across studies, participants also expressed concern about the effects of HVHF on the natural environment. While many worried that HVHF would threaten wildlife and livestock, increase air pollution, and lead to deforestation[44,48,49], by far the greatest concern was related to water use and quality. Among households surveyed in Texas, "amount of freshwater used by gas producers," "depletion of aquifers," and "water pollution" were among the top five

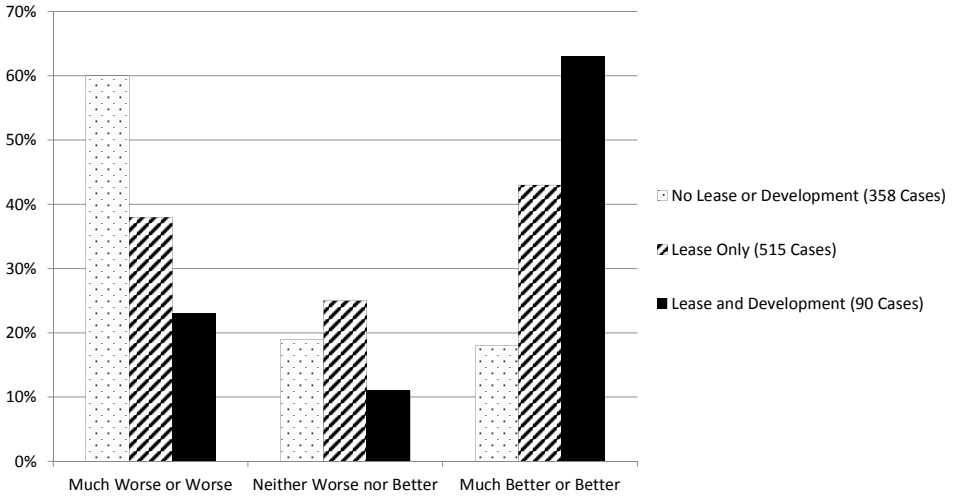

Figure 2. Relationship between mineral rights ownership and beliefs about whether "natural gas development has made the area better off or worse off than it was 5 years ago." Adapted from Jacquet[52].

attributes (out of 30 measured) that residents felt were "getting worse" as a result of natural gas development in the area[47]. These concerns were echoed by key informants in both Texas communities. County-level officials in Wise County, where HVHF had been established for some time, were particularly concerned about the availability of freshwater and cited multiple examples of private wells running dry[48]. In the Marcellus Shale region, interviewees in four counties expressed concerns about declining freshwater supplies and the potential for private water wells to be affected[44].

With regard to local infrastructure, the most important concern in areas with active HF was the extensive road damage caused by increased truck activity[44,49]. Respondents in Texas complained that although tax revenue helped support road repair, most municipalities had to wait for allocations from state governments, meaning delays and inconsistency in repairs. Infrastructure was also seen to be strained due to rapid population increases, particularly in the housing sector. One respondent in Pennsylvania reported that low-income housing was in such shortage that a homeless program had to begin putting people in hotels[44].

Many respondents also felt their community's character was negatively impacted by HF operations. These perceptions were due to changes to the local landscape as well as the influx of industry workers moving into the area. In addition to the nuisance of round-the-clock light and noise during drilling periods[49], study participants often lamented aesthetic changes to their communities. In particular, many worried that the natural beauty and rural quality of the area would be forever changed[44]. Other impacts included the loss of the "'small town' feel"[49], conflicts between seasonal and permanent residents, and the perception that new inhabitants had little understanding or respect for local ways of life[44]. Gas workers moving into the area were often blamed for increases in crime, drug use, and alcoholism[44,49]. In some communities, residents worried that the uneven distribution of mineral rights had accentuated the division between rich and poor and that local politics would eventually be coopted by wealthy mineral rights owners[48].

2.2.2 Contextual factors that influence perceptions

In accordance with boomtown theory, several studies examined how perceptions varied based on mineral rights ownership, the ability of communities to absorb increased population growth, and their current level of gas development. These findings are discussed below.

Mineral rights ownership

Numerous studies have demonstrated what common sense might suggest: landowners who stand to benefit from natural gas development are significantly more likely to perceive it in a positive light[42,49,52,54]. In Pennsylvania, mineral rights ownership was found to be the most significant contributing factor to positive opinions about natural gas development[52]. Represented visually, the correlation is striking (see Figure 2). Another study in the Marcellus Shale region similarly found that respondents were significantly more likely to "strongly support" shale gas development if they had a family member who had signed a natural gas lease[54]. In Texas, individuals without any personal or familial connections to the natural gas industry were significantly more likely than their counterparts to disagree with statements that suggested natural gas development in their area would benefit their community[42].

Population density (rural vs. urban character)

Evidence that smaller communities experience greater impacts was apparent in one of the studies conducted in the Marcellus Shale region of Pennsylvania[44]. Residents of Bradford and Washington counties were concerned about similar environmental and social impacts from deep shale gas development, but reported impacts were much greater in rural Bradford County than in the more populous Washington County, despite similar levels of drilling activity in both counties. The primary difference between the two counties is their population: Washington's population was more than three times that of Bradford's and had an established infrastructure that could more easily accommodate the influx of workers and industrial equipment.

Level of current natural gas development

Two studies in Pennsylvania found that perceptions of shale gas development varied depending on the level of drilling activity in the community[50,54]. In the first study, which surveyed high school administrators, higher levels of local development were correlated with higher expectations of both positive economic outcomes as well as greater concerns over environmental and social impacts. These results suggest that concerns about natural gas development do not necessarily dissipate with increased experience. Rather, residents become more acutely aware of the range of potential impacts—both positive and negative. The second study, which randomly sampled residents in two adjacent counties, found that respondents in the county with higher drilling activity were more likely to view shale gas development as an economic opportunity[54]. This belief, in turn, significantly predicted stronger support for shale gas development. No differences were found between counties in terms of residents' beliefs that drilling activities would threaten environmental and public health. In both counties, individuals who believed drilling posed risks to the environment and health were less likely to support shale gas development.

A comparison between Wise and Johnson counties in Texas revealed how perceptions can evolve as natural gas development in an area matures. While households in both counties shared concerns about increased truck traffic and depleted water supplies, residents in Johnson County, where the industry was less developed, were more likely to note the negative changes to their day-to-day lives such as degraded local roads and undesirable population growth[47]. Residents in both counties believed shale gas development brought more jobs, but this belief was more widely held in Wise County, where the industry was more mature. Residents there were also more likely to note improvements in fire protection services, local school quality, and medical services[47]. Despite these observations, Wise County residents had more negative views of the natural gas industry in general. Specifically, residents felt natural gas operators were too politically powerful, drilled too close to homes and businesses, and had little compassion for the natural environment[42]. They were also more likely to believe that gas development had resulted in water pollution. In contrast to their Johnson County counterparts, Wise County residents were more likely to disagree with the statement "In the long run, I'm sure that people in this area will be better off if our natural gas resources are developed"[42]. Respondents in Johnson County were generally more optimistic about the long-term benefits from shale gas development.

2.3 Michigan stakeholder perspectives

While no community-level studies have been conducted in Michigan on public perceptions of HVHF, concerns about environmental and health impacts are apparent in the dialogue that is emerging among stakeholder groups. Three types of stakeholder groups are prominent in Michigan: industry organizations, nonprofit and grassroots organizations, and state agencies. The following discussion examines the claims each of these groups makes with regard to the risks and benefits of HVHF in Michigan.

2.3.1 Industry organizations

Encana Corporation and Devon Energy are the two primary developers of deep shale gas plays in Michigan. Their influence on public perceptions occurs more through their leasing and drilling activities and their appearance in the press than through active public outreach. While it is not prominently displayed on the company's website, Devon Energy does provide information about HF and its stance on prominent issues. The company's statements on the history of HF, the economic benefits of natural gas, and its importance to America's energy future[57] largely mirror the more widely-publicized message of state industry organizations that HVHF is fundamentally safe. The company also expresses support for the national FracFocus.org chemical disclosure project:

> We at Devon have long believed there was a need for a central repository through which companies could voluntarily report data about hydraulic fracturing fluids. FracFocus.org fulfills that need. Created by regulators, this site helps remove the mystery about a process that is vital to America's energy independence[58].

Examination of a FracFocus data sheet for a Devon well treated with HVHF in Roscommon County reveals, however, that information for over 6,000 gallons of chemicals is withheld as "CBI" or "confidential business information"[59].

The Michigan Oil and Gas Association (MOGA), together with its public outreach branch, the Michigan Oil and Gas Producers Education Foundation (MOGPEF), represent the collective voice of oil and gas development in Michigan. They are much more active than energy companies in disseminating information to the general public, as evidenced by references to them in state newspapers and the prominence of educational materials on their websites. MOGPEF was founded in 2003 with the mission to "provide facts about the Michigan oil & gas industry to the public and to provide financial support for programs that will inform the people of Michigan about the importance of our local oil and natural gas industry and about the environmental safeguards that we employ"[60]. Materials published by MOGPEF provide insights into the natural gas industry's perception of HVHF and how it responds to public concerns over health and environmental issues.

MOGPEF emphasizes the economic benefits of deep shale gas

extraction, namely increases in jobs, tax revenue, and energy security[61,62]. The organization's materials also underscore the importance of natural gas as a plentiful source of clean energy and describe HF as an essential tool to produce it[61]. Published materials address risks associated with shale gas extraction by focusing on the strength of state regulations and the negligibility of risks. They advertise the most recent regulatory developments, such as the publication of Material Safety Data Sheets (MSDSs) and water withdrawal assessments on the Michigan Department of Environmental Quality's (MDEQ) website, while stressing the state's long history of using (low-volume) HF to extract natural gas[61,63]. In fact, a two-page document states four times that Michigan has safely used HF for "nearly 60 years and 12,000 wells"[61]. MOGPEF diminishes the role of chemicals in the HF process by emphasizing the ratio of 2% chemicals to 98% water and sand[61], without mentioning the overall volume of liquids used in each well. Concerns about drinking water are dispelled with a description of how far below aquifers HF takes place and the lack of studies linking HF to contamination of drinking water[61,62]. Overall, the words "safe," "proven," and "necessary," appear throughout MOGPEF materials, portraying the use of HF in natural gas extraction as a risk-free process that is essential and desirable for Michigan's future.

2.3.2 Nonprofit and grassroots organizations

Dozens of national and Michigan-based nonprofit organizations are currently involved in educating the public on HF and lobbying state legislature for regulatory changes. The goal of this section is not to enumerate all of these organizations, but to identify the most active groups and their respective positions on HF. At a most basic level, a division can be made between organizations that seek greater regulation of HF and those that seek a permanent ban on HF in Michigan.

The former category includes local chapters of major national environmental organizations, such as the Sierra Club, the National Wildlife Federation, Clean Water Action, and the Michigan League of Conservation Voters, all of which have formed partnerships with established Michigan-based nonprofits. Prominent state-level nonprofits that support more regulation include Great Michigan, Michigan Environmental Council, and Tip of the Mitt Watershed Council, among others. All of these organizations have a high level of engagement with HF in Michigan, as expressed in letters to government agencies and politicians, educational materials for the public, petitions, board resolutions and policy statements[64-68].

The Tip of the Mitt Watershed Council has played a leadership role in networking with other nonprofits, engaging with state regulators, and publishing educational materials. In fall 2011, Tip of the Mitt and other partners published a series of informational documents describing the HF process and associated risks and current regulations[65]. The documents present a clear picture of the Michigan nonprofit perspective on HF and underscore what they perceive to be the strengths and weaknesses of current regulations. In particular, they argue that relatively little is known about the overall environmental impacts of large-scale application of HVHF and draw attention to legal exemptions for HF, including the Safe Drinking Water Act, the Resource Conservation and Recovery Act, and the Emergency Planning and Community Right to Know Act. While they suggest improvements to current legislation, the documents are careful to recognize the importance of existing regulations and recent efforts to make them stronger, such as the publication of MSDSs on the MDEQ website and the enforced use of the state's water withdrawal assessment tool[65].

The information sheets raise concerns about the risks of HF to water resources[69], the use of chemicals[70], the regulation of flowback[71], and the lack of opportunities for public involvement[72]. Water concerns include impacts to drinking water from cumulative high-volume withdrawals and the contamination of ground and surface waters from spills during well construction, treatment, and operation[69]. With regard to chemicals, the documents recognize that chemicals represent less than two percent of the total volume of HF fluids[70]. They draw attention, however, to the fact that because millions of gallons of water are used in a multi-stage treatment, the volume of chemicals used in HVHF dwarfs amounts previously used in low-volume HF treatments. Concern is also expressed for the fact that MSDSs are required only 60 days after well treatment and that chemicals protected as "trade secrets" are not disclosed. The information sheets describe the toxic nature of some of the chemicals found in flowback fluids and note the possibility of naturally-occurring radioactive elements leaching into the fluid[71]. The materials also express concern that flowback fluids are not analyzed prior to their disposal in injection wells and that drilling operators do not have to identify hazardous waste components. Another information sheet focuses on the lack of opportunity for public participation in the permitting process: "In Michigan, permits for oil and gas drilling operations are granted by the [MDEQ], with limited public participation. There is no general public review and comment on permit applications"[72]. Attention is drawn to the fact that only cities of over 70,000 inhabitants are notified of drilling permit applications if drilling will occur within 450 feet of a residential building.

In contrast to Tip of the Mitt and its partner organizations, other nonprofits seek a permanent ban on HF in Michigan. Two prominent groups are Ban Michigan Fracking and the Committee to Ban Fracking in Michigan, a volunteer group dedicated to amending the state constitution to permanently ban HF. Other groups that support a ban on HF include Save Michigan Water, Don't Frack Michigan, and Citizens for Alternatives to Chemical

Contamination. In many respects, the concerns of these groups are similar to those of more moderate organizations. They differ primarily in their prognosis: groups seeking to ban HF believe that further regulations will be unable to eliminate the risks associated with it. According to a co-founder of Ban Michigan Fracking, "Once you put this amount of poison into the earth there is no way to make it safe… That's why we are working to ban it in the first place"[73]. Educational materials produced by these organizations focus heavily on risks to public health and the natural environment with virtually no mention of the potential economic benefits of development. Reports of accidents and other issues are taken from around the United States, and even other countries. For example, Ban Michigan Fracking's website highlights a high-profile lawsuit between a Canadian homeowner and Encana Corporation; the MDEQ's alleged approval of dispersing flowback on roads through a campground and state parks in Northern Michigan in May 2012; and ongoing fracking protest efforts around Michigan[74]. Mistrust of oil and gas companies and state regulatory agencies is also a recurrent theme. Don't Frack Michigan's website, for example, directs readers to newspaper articles about the antitrust probe of Chesapeake Energy and the numerous land deals that its shell company later reneged on[75]. Although their objective is different and the tone of their communications more emotive, groups in favor of banning fracking cite similar events and studies to those featured in moderate organizations' publications.

Communication efforts of Michigan nonprofits differ from those of industry groups in several important ways: (1) economic aspects of natural gas development are not emphasized, while risks and uncertainties are highlighted, (2) HVHF is emphatically presented as a fundamentally new process due to the unprecedented amount of water and chemicals used relative to low-volume HF, and (3) studies of environmental and health impacts from other states are presented as evidence of the potential risks of HVHF.

2.3.3 State organizations

Through their direct involvement in HF development, state agencies have a prominent role in the public HF debate. Three agencies are closely involved in the development of deep shale plays: the Michigan Department of Natural Resources (MDNR), which handles minerals leasing for the state; the Michigan Department of Environmental Quality, Office of Geological Survey (MDEQ), which issues permits for well drilling and regulates gas production; and the Michigan Public Service Commission (MPSC), which regulates gas transmission and prices. Of these, MDNR and MDEQ have the most public exposure, the former through auctions of minerals leases, and the latter through ongoing interaction with groups that seek increased regulation of HF activity or an outright ban. MDEQ, in particular, has found itself at the heart of the debate over HF in Michigan. With the rise of public awareness and concern, the agency has increasingly had to explain and defend its permitting procedures.

MDEQ provides information to the public about HF through published materials[76], participation in public meetings[77-79], and interviews with the press[80]. A review of these resources reveals common themes in MDEQ's presentation of information on the risks and benefits of HF and deep shale gas development.

The primary divergence between common public concerns and MDEQ's message lies in whether or not modern high-volume HF should be treated as a variation on a proven industrial practice or a new process. The agency maintains that the latest developments in high-volume HF are the continuation of a long history of successful regulation and that new developments should not require significant changes to the current system. A Q&A document on HF from MDEQ'S website underlines this message:

> **Is hydraulic fracturing new?** No. Gas and oil operators have been using hydraulic fracturing around the country since the late 1940s. […]
> **Is hydraulic fracturing used in Michigan now?** Yes. Companies in Michigan have been using it to facilitate oil and gas production for about 50 years. Approximately 12,000 wells have been fractured in that time […][81]

Hal Fitch, director of MDEQ's Office of Oil, Gas, and Minerals, communicated a similar message during a congressional hearing in May, 2011:

> Hydraulic fracturing has been utilized throughout the United States for more than 60 years, and the states have a long history of successful regulation of the practice. [...] In Michigan we have more than 12,000 wells that have been hydraulically fractured[82].

The assertion that HVHF represents a continuum with past low-volume HF is the foundation of MDEQ's communications regarding the risks of HVHF. Discussions of associated risks consistently point to successful past management of oil and gas development to justify the sufficiency of current regulation. The agency tries to allay public concerns about the risks of HF by arguing that that no conclusive evidence links HF to environmental or public health issues. For example, in his testimony to Congress, Hal Fitch stated, "We don't have one instance of groundwater contamination resulting from the practice"[82]. The Q&A document emphasizes the same concept: "[Q:] Has hydraulic fracturing been responsible for environmental damage in Michigan? [A:] No"[81]. In general, the MDEQ clearly states that the risks of HF are negligible and already under strict agency management: "If this process posed a threat to the

public or the environment, the DEQ would further regulate it or outlaw it. To the contrary, Michigan's regulatory structure has been held up as a national model for effective, protective regulation"[81]. This represents an important departure in the framing of risk from environmental organizations, which draw on examples of accidents related to deep shale gas extraction in Michigan, as well as other states.

While maintaining that current regulations are sufficient, MDEQ acknowledges five concerns with gas drilling that are commonly raised by the public: (1) migration of gas or fracking fluids into aquifers, (2) the amount of fresh water resources used during the HF process, (3) management of flowback fluids, (4) surface spills, and (5) the identification of chemical additives[79,82]. To the public, however, MDEQ portrays these concerns more as misconceptions about current regulations than actual risks:

> Michigan has strict rules about how much water can be used for fracturing, how wells are constructed, how they are tested before they are employed, and how the used 'flowback' water is contained and disposed of. These are the four top risks from gas and oil development. The DEQ has developed a regulatory structure that has effectively protected Michigan's environment and public health for decades[81].

Despite MDEQ's public discourse that emphasizes the adequacy of current regulations, the Supervisor of Wells Instruction 1-2011 issued in June 2011[5] represented an unprecedented initiative to differentiate between the management practices necessary for low-volume and high-volume HF. Indeed, it responded directly to many of the concerns expressed in a November 2010 letter to MDEQ signed by a coalition of 33 Michigan nonprofits[83], including the publication of MSDSs, and the application of the web-based water withdrawal assessment tool. It further provided a basis for distinguishing HVHF from low-volume HF. Since the Supervisor of Wells Instruction 1-2011 was issued, it has been widely touted as a means of ensuring safe development by both the MDEQ and industry groups[61,81]

Overall, although MDEQ's messages focus more heavily on risk prevention than natural gas development as an economic imperative, the agency's portrayal of the risks involved with natural gas extraction and manner of communicating them to the public is almost identical to communication efforts of industry organizations. That is, risks are downplayed, emphasis is placed upon Michigan's long experience with low-volume HF, and the sufficiency of current regulations is emphasized.

2.4 Summary of Status and Trends

This section reviewed the current state of knowledge on public perceptions of HVHF and deep shale gas development. National and state-level opinion polls were examined to determine broad trends, such as level of support for HVHF and commonly perceived risks and benefits; academic studies were reviewed to understand perceptions in local communities and to identify factors that influence them; and Michigan stakeholder perspectives were explored to understand the current dialogue on HVHF in the state. Across these different sources of data, common trends emerge.

Awareness of HF and its potential impacts is moderate, but appears to be growing. While most people acknowledge that natural gas development through HVHF could create new jobs and boost local economies, concerns remain about the potential of deep shale gas development to affect freshwater supplies, health, and community well-being. How individuals weigh these risks and benefits appears to vary according to a number of socio-demographic and contextual factors. Opinion poll data suggest that support for fracking varies with political affiliation, gender, education, and income—with Republicans, males, and individuals with lower levels of education and income generally being more supportive of HF than their respective counterparts.

In communities directly impacted by deep shale gas development, studies reveal additional factors that can influence perceptions. Evidence suggests a strong linkage between the population density of a developed area and perceptions of increased economic, social, and environmental impacts. The smaller a community is relative to the level of development, the greater the perceived impacts are likely to be. In Michigan, researchers may be wise to carefully evaluate where development is most likely to occur and how local infrastructure will be affected.

Studies also suggest that it is important to consider how development will affect a community with diverse levels of land ownership and intentions to lease mineral rights. Some of the negative perceptions articulated previously (see section 2.2) often arise from conflicts between those who have leased their land and those who have not. Disparate wealth creation, shifting local political power centers, and uneven risk sharing can all have lasting impacts on the social fabric of a community.

3.0 CHALLENGES AND OPPORTUNITIES

As discussed in the *Status and Trends* section, there are many diverging views about HVHF as well as competing claims from stakeholder groups about its risks and benefits. This section examines some

of the key challenges that may arise from such different viewpoints and highlights opportunities for fostering a constructive dialogue on HVHF in Michigan.

3.1 Semantic differences complicate communication efforts

Seemingly innocuous aspects of the way deep shale gas development is communicated can have significant impacts on how the public interprets its associated risks and benefits. Two issues are apparent in the current dialogue between technical experts (industry and state agencies) and public stakeholder groups. The first relates to how the terms "hydraulic fracturing" and "fracking" are defined[84]. The second concerns whether high-volume hydraulic fracturing is framed as a "new" technology or a continuation of previous industrial practices. This subsection discusses the nature and potential impacts of these issues.

3.1.1 The meaning of "fracking"

To industry and state agency experts, hydraulic fracturing refers to the process of injecting a high-pressure mixture of water, sand, and chemicals into a well to fracture the underlying shale formation and release trapped natural gas. The public's definition, by contrast, is often much broader and includes every aspect of well development, completion, and continued operation. This all-encompassing definition of HF or "fracking" is clearly illustrated in a recent online posting by Ban Michigan Fracking:

> To accept regulated fracking is to accept the entire frack industry–all of it. All the thousands of frack wells, all the pipelines, all the compressor stations, all the thousands of injection wells, all of the new natural gas plants. And with it, you accept all the contaminations, the people and businesses who will lose their precious water supplies, their health, their land, their land values, their crops and livestock[74].

These different meanings of "fracking" can be problematic, especially when communicating about potential risks. Many of the concerns the public raises about HVHF are, by industry standards, risks associated with other oil and gas processes—and not actual fracking[84]. For example, natural gas migration into water wells is a prominent concern that many have about HVHF. MDEQ addresses this issue in its "Questions and Answers" document:

> **I saw a video where someone lit their tapwater on fire. Is that from hydraulic fracturing?** No. There have been a few rare cases where gas from drilling operations has escaped into fresh water aquifers; however, that was caused by improper well construction, not hydraulic fracturing[81].

While the above answer may be technically accurate, it does not address the public's concern that deep shale gas development could contaminate freshwater aquifers if other aspects of well drilling and completion are not properly managed. As will be discussed shortly, failing to acknowledge and discuss these concerns can increase public distrust and heighten perceived risks.

3.1.2 New technology or old?

A second point of contention is whether HVHF should be considered an extension of an established technique or a fundamentally new technology. MDEQ has largely portrayed HVHF as an established practice (see section 2.3 in *Status and Trends*) though it acknowledges in its online materials that certain aspects of HVHF are different, including the amount of water consumed, the smaller physical footprint on the landscape, and the use of horizontal drilling[81]. Industry communications echo this strategy and cite Michigan's long safety record with low-volume HF as evidence that HVHF poses no new risks to public health or the environment[63].

While this communication strategy is ostensibly used to allay public fears about HVHF, it may in fact have the opposite effect. Many of the risks that individuals and stakeholder groups associate with HVHF relate specifically to aspects of the process that distinguish it from low-volume HF. These include the amount of water consumed, the volume of chemicals added, the amount of flowback that must be processed, and the increased rate at which natural gas is extracted from highly productive regions. The following comparison between low-volume natural gas extraction and HVHF-extraction highlights these differences:

- **Water volume**. Low-volume hydraulic fracturing uses between 40,000 and 100,000 gallons of water per HF treatment over a total of 3-4 stages. By contrast, typical horizontal wells use between 3 and 5 million gallons of water per HVHF treatment over 15 or more stages[85]. Certain HVHF treatments may require much higher volumes of fluid, such as the State Excelsior 3-25 HD-1 well in Kalkaska County, Michigan, where 21,112,194 gallons of water were employed in a single treatment[86].
- **Chemical volume**. Although modern HVHF and low-volume HF use a comparably small *percentage* of chemicals relative to the total volume of fracking fluid, the increased scale of HVHF results in an overall larger volume of chemicals used. For example, although the HVHF treatment of the State Excelsior 3-25 HD-1 well in Kalkaska only contained 0.5% of hydrochloric acid, the total volume used in the treatment was 116,377 gallons[86]—the volume of nearly ten standard 12' x 24' swimming pools.
- **Flowback volume**. Modern wells typically produce between 300,000 to 1.2 million gallons of flowback, which in Michigan must be captured, transported, and then injected into EPA Class II wells[2]. For heavily exploited areas, the high-volume of flowback has created management challenges[87].

- **Truck traffic**. A vertical well may employ between 817 to 905 truck journeys over the course of well drilling and HF treatment; a typical horizontal well may require between 1,420 and 1,979 truck journeys[2].
- **Drilling activity intensity**. Technical experts often emphasize that a single horizontal well can replace many vertical wells, thereby reducing the footprint of the well pad. This portrayal detracts from the reality that deep shale plays can contain unprecedented amounts of natural gas, which leads to higher levels of drilling activity despite the increased productivity of each well pad. For example, the number of active wells in Pennsylvania rose from 36,000 to 71,000 in between 2000 and 2011[88]. Likewise, since drilling in the Marcellus Shale began to gain momentum in Pennsylvania in 2008, natural gas production has risen from just over 500 million cubic feet per day to almost 3,500 million cubic feet per day in 2011[89].

When state agencies and industry groups minimize the differences between HVHF and low-volume HF—even though information to the contrary is widely available to the public—they may send a signal that public concerns do not matter, or that they are intentionally obscuring the associated risks. As a result, individuals concerned about the potential risks of HVHF may find salience in claims that industry groups and government agencies do not fully acknowledge the challenges that large-scale horizontal drilling may present.

In both the case of HVHF's definition and its framing as an established activity, discrepancies in public and government portrayals can lead to mistrust on the part of the public. MDEQ and other agencies involved in public discussions of HVHF must be mindful of how their communication efforts resonate with their target audience. It is also important for policy makers and regulatory agencies to recognize that the public's broad definition of "fracking" may be resistant to change, regardless of how much effort is expended to clarify the boundaries of the HF process. This by no means signifies that the public lacks intelligence. Rather, in the popular discourse, "fracking" has come to represent the new phase of natural gas development in the United States. Disassociating "fracking" with the broader issue of deep shale gas extraction is unlikely to be within the scope of any one organization's abilities. Understanding and accepting the public's notion of "fracking" may be the first step toward bridging communication gaps and building trust among stakeholders.

3.2 Technical experts and the lay public often have conflicting perceptions of risk

Beyond assigning a different meaning to the term "fracking," the lay public is likely to view the risks of deep shale gas development differently from industry and state agency groups. These conflicting perceptions can complicate efforts to arrive at socially-acceptable policies, as stakeholders are likely to reach different conclusions about which issues are most important or merit greater regulatory attention.

Such discrepancies in risk perception have long been observed in other contexts such as the siting of noxious facilities and the adoption of other emergent technologies (e.g., nuclear power, wind power, or genetically modified food). A key lesson learned from research in this area is that neither technical experts nor the lay public are necessarily "right" in their assessments of risk; rather they evaluate risks using different criteria[90,91]. Understanding these differences can illuminate some of the issues that make a topic like HVHF controversial as well as help identify opportunities for improving communication and resolving conflicts. While a thorough review of the risk perception literature is beyond the scope of this report, the following discussion looks at some of the issues most pertinent to shale gas development.

Technical experts and the lay public consider different factors when evaluating how risky a potential hazard is. In the minds of technical experts, risk involves calculating the probability and severity of negative events that might occur. By contrast, the public takes into account other psychological and social considerations. Often, the public's perception of risk is influenced as much by the potential for direct harm as it is by the circumstances under which a potential hazard is imposed. Early studies on risk perception revealed that people find potential hazards less acceptable when they are perceived as involuntary, uncontrollable, and potentially catastrophic[90,92,93]. Perceived risk also increases when the consequences are unobservable, difficult to detect, or delayed in time[90,92,93]. As Table 1 illustrates, several of these characteristics are likely to influence public perceptions of HVHF and deep shale gas development in Michigan.

The public's perceptions of risk are also sensitive to other social and cultural factors[94,95]. These could include a community's history with other hazards, past dealings with the regulatory agency in charge, how the media portrays an issue, or memorable events related to the hazard. For example, news reports of fracking-related earthquakes in Ohio or the *Gasland* footage of a man lighting his tap water on fire can amplify perceived risk by making the potential dangers of HVHF more concrete and real. Sandman[96,97] calls these non-technical aspects of risk "outrage factors" because they explain why low-probability risks can still be very upsetting to the public. As Sandman argues, and other research demonstrates, unless efforts are taken to reduce the factors that create outrage, controversy will remain—even if a potential hazard is shown to pose a negligible threat.

TABLE 1. Characteristics that may increase the perceived risks of HVHF and deep shale gas development

Risk characteristic	Applications to HVHF and deep shale gas development
Involuntary. People are less accepting of risks imposed by others (e.g., pollution from nearby industries) than those they voluntarily undertake (e.g., driving a car, smoking).	To many in Michigan, deep shale gas development is likely to feel involuntarily imposed. With the exception of mineral rights owners who can choose whether to lease their land, most Michiganians have little say in whether HVHF occurs near their homes or in their communities. As noted by the Tip of the Mitt[72] and described in detail by the law and policy report[101], there are few formal opportunities for Michigan residents to weigh in on deep shale gas development. Residents can provide comments to MDNR on proposed mineral rights auctions of public lands, but there is no mechanism for the public to comment on permit applications—even when proposed wells are on neighboring properties.
Uncontrollable. People are less accepting of risks in which they have no direct control or ability to mitigate negative outcomes.	The public clearly has no direct control over the equipment or processes involved in developing a HVHF well. But the public may also believe that state regulators and drillers have little control either. With drilling and fracking occurring far beneath the surface of the ground, people may believe there is little anyone can do to remedy a HVHF procedure gone awry.
Inequitable. When people must bear the burden of risk without receiving direct benefits from it, tolerance for the hazard decreases.	Michiganians without mineral rights to lease may perceive the costs of HVHF to be much greater than its benefits. Individuals living near HVHF wells may feel they are bearing the risk of groundwater contamination and likewise, suffering changes in their community without any real personal benefit to make the risks worthwhile. Evidence of this factor was seen in Texas, where individuals without any personal connections to the gas industry had more negative perceptions of the industry than those who stood to benefit from it[42].
Uncertain. Risks with unknown or potentially delayed consequences tend to be less acceptable than those that are well understood or have immediate effects.	There are several aspects of HVHF that may be perceived as uncertain: the risk of exposure from chemicals used in fracking fluids, the long-term impact of leaving fracking fluids underground, potential exposure to naturally occurring radioactive materials released from fractured rocks, and the potential of groundwater contamination either from well sites or disposal wells. Past research has shown that people tend to associate chemical risks, in particular, with high levels of uncertainty[90,92,93].

Technical experts and the lay public may also use different frames of reference for evaluating whether potential risks are worthwhile to undertake. Technical experts tend to appraise risks in terms of tradeoffs or degrees of safety[98]. They may compare, for example, the risks of a new technology with its costs and benefits or to the risks of alternative solutions. The lay public tends to think more in absolutes: people want to know whether a proposed technology is safe or not[98,99]. This mindset may reflect that people have a natural aversion to loss and try to avoid situations that negatively impact the status quo[100]. In the context of HVHF, for example, if the public perceives that their current water supplies are clean and safe to drink, any risk of contamination—however low the probability—may be perceived as an unacceptable loss[98]. Research suggests people are particularly averse to loss in situations where they have little involvement in the decision-making process and perceive few benefits[93,98].

Finally, the public wants assurances that risks are well-managed. Whereas experts turn to technological solutions to minimize risks, the public looks at the larger social system: who is in charge and can they be trusted?[98] People are generally more accepting of risks when they perceive that those in charge are trustworthy[98,102-106]. Trust can have several dimensions. It is based not only on whether those in charge have the appropriate knowledge and skills to manage the potential hazard, but also on whether they demonstrate care and concern for the public's interests[104,107,108]. Establishing trust can be difficult, especially when—as is the case for HVHF—those directly responsible for managing a potential hazard stand to profit from it[109]. There is already some evidence to suggest that the public is less trusting of information from the natural gas industry and state regulatory agencies than information that comes from neutral parties such as researchers, scientists, and cooperative extension offices[51]. To increase trust, past studies suggest that industry and government agencies should provide accessible channels of communication, consult impacted communities at an early stage, and demonstrate that they have mitigated all risks that are of concern to the public—even if they have a low probability of occurring[109].

3.3 Better information is important, but not sufficient

Failure to understand how the public perceives risks can lead industry and government experts to assume that the public just needs to be better educated about technologies such as HVHF[110]. This common fallacy is based on the assumption that the public's concerns will dissipate once people have more evidence of a technology's safety. However, as discussed above, technical safety is a small part of what informs the public's perceptions of risk. Consequently, providing more technical information about HVHF may do little to reduce the fears and frustrations that people may have about how it has been managed[110,111].

Studies have also shown that strongly held beliefs are resistant to change[93,112,113]. When faced with conflicting claims about a situation, people are more likely to trust and accept information that matches their prior beliefs; contradictory information will be dismissed as erroneous or unreliable. Carlisle et al.[114] demonstrated this effect in an experimental study that tested beliefs about offshore drilling. People who already supported oil drilling were significantly more likely to trust reports that stated offshore drilling was safer than previously believed; those who opposed drilling were more likely to trust reports that offshore drilling was riskier than previously thought.

One consequence of this phenomenon is that risk managers, attempting to assuage the public's concerns, can inadvertently fuel further conflict by trying to persuade the public of a potential hazard's safety. This outcome has been observed in numerous studies of noxious facility siting processes[109,115]. As groups become more adamant in their positions, discussions about a proposed technology become about who is "right" rather than about what issues need to be addressed. Additionally, if the public feels they have been left out of the decision-making process, they may perceive communications from government or industry as propaganda designed to obscure the facts. Public skepticism of expert communications may be particularly acute when information is presented in technical language that is difficult to understand or contradicts what people have personally experienced[116].

Leong and colleagues[117] have suggested that public information campaigns are most appropriate in noncontroversial situations where involved stakeholders "not only agree fundamentally on the topic of concern, but also realize that they are in agreement." Under these circumstances, where involved parties share common beliefs and attitudes about an issue, it may be sufficient to keep the public informed through educational websites, press releases, and other non-interactive forums. But, when parties disagree about an issue or misunderstand each other's perspective, more involved forms of public participation may be needed to ensure that parties feel that their respective concerns are heard.

There are a number of ways to involve the public in risk management decisions, from surveys and focus groups, to public meetings, workshops, and citizen advisory committees. Research suggests that the particular form of participation is less important to the outcome than how state agencies structure and manage the process[118]. Specifically, public participation tends to be less fruitful when agencies fail to sufficiently publicize public forums, seek public approval for finalized proposals, or dominate the discussion. A review of public participation studies[118] found that agencies can encourage more successful outcomes by following several rules of thumb: (1) clarify the goals of participation, (2) involve the public early in the process, (3) invite neutral parties to facilitate, (4) use multiple forms of public participation throughout the decision-making process, and (5) ask the public to provide feedback on each participation effort. Other researchers suggest that before engaging in public participation, it may be worthwhile to investigate the attitudes different stakeholders hold toward an issue and their perception of the attitudes held by others[117]. This exercise can identify misunderstandings that may be causing unnecessary tension and also clarify which issues are of greatest concern.

3.4 Different "publics" have different information needs

Finally, it is important to recognize that information needs are likely to vary with different segments of the population. A common mistake among experts is to treat the public as an undifferentiated group of individuals with shared beliefs and attitudes about an issue[99,104]. As discussed at length in the *Status and Trends* section, the public is far from unified in its assessment of the risks and benefits of deep shale gas development. Perceptions are likely to vary between communities, between individuals within the same community, and over time. Furthermore, as the issue of HVHF evolves in the state, stakeholder groups may change as different aspects of HVHF become more prominent, with some groups leaving the conversation and others taking new interest[99]. Efforts to engage the public on the issue of deep shale gas development must strive to understand these differences. A one-size-fits-all approach can lead to communication failures and increase controversy.

4.0 PRIORITIZED PATHWAYS

Based on the previous sections, we suggest four pathways for future research that can address some of the most pressing issues related to public perceptions of deep shale gas development. These include examining: (1) community preparedness if development activities are expected to increase, (2) opportunities for improving transparency,

(3) public perceptions of HVHF at regional and local levels in Michigan, and (4) options for increasing public consultation and participation.

4.1 Examine community preparedness

Current natural gas prices are too low to justify rapid development in the Utica and Collingwood plays of Northern Michigan, but if energy markets shift, that situation could change quickly. As documented in the boomtown literature, sudden influxes of drilling rigs, workers, trucks, and even money to small communities can change the social fabric of rural areas and create new public concerns. Our first suggestion for Phase 2 involves investigating how communities can prepare for increased natural gas development in a way that minimizes negative impacts.

The experiences of Bradford County, Pennsylvania, offer a glimpse of possible changes that could happen if development pressure increases in Michigan. In 2011, one-fifth of Pennsylvania's 1,700+ horizontal wells were drilled in Bradford, a county with only 63,000 inhabitants. A study examining public reactions to drilling activity in Pennsylvania found that perceptions of gas development—both positive and negative—were more acute in Bradford County than in counties with higher populations[44]. While residents were optimistic about the potential economic benefits to their community, many also noted negative impacts: local businesses lost workers to the natural gas industry and the influx of industry workers brought increases in rent, fuel, and food prices. Socially, informants observed a rise in divisive local politics: neighbors fighting, contentious town meetings, and "divisions between who would benefit and who would bear the burden of development"[44]. As a result of rapidly increasing industry activity, informants reported "extensive damage to local roads; limited and increasingly expensive housing; limited storage capacity for trucks, equipment, pipe, and machinery; and significant construction related to gas pipelines, compressor stations, roads, and related infrastructure"[44].

Although Michigan's current rate of development is low by comparison, small increases in volatile natural gas prices could potentially lead to a surge in drilling activity. The distribution of the Collingwood and Utica shale plays under northern Michigan make it likely that the vast majority of future development would occur in that area, primarily in Kalkaska, Missaukee, Gladwin, Roscommon, and Cheboygan counties[119]. By comparison with Bradford County, Pennsylvania, which has a population density of 54 inhabitants per square mile, the average density in these five counties is 39 inhabitants per square mile[120]. From a public perception standpoint, the low population density of the region offers the benefit of fewer individuals being exposed to potentially negative aspects of natural gas development. However, it also means that communities are more likely to be adversely impacted if development occurs rapidly.

Phase 2 of the integrated assessment should consider to what extent small communities are prepared to accommodate an influx of workers, rigs, trucks, and even wealth, without negative impacts on local economies, housing, roads, and the local social fabric. Christopherson and Rightor[121] suggest that local governments can prepare by:

- collecting baseline data on "roads, water treatments, rents, traffic" so that they can hold well operators and subcontractors accountable for negative impacts and/or seek appropriate assistance from the state;
- developing a dedicated stream of revenue from gas production to help with the costs of repairs; and
- budgeting for future demands on their communities and setting aside monies to defray anticipated costs.

Areas with low population densities are also likely to have a higher percentage of residents who depend on private wells for fresh water. Studies relating well problems to water withdrawals and the HVHF process are highly contentious, but the integrated assessment should ensure that the most current studies are used to evaluate risk in areas that are highly dependent on private wells. Finally, Phase 2 could consider whether appropriate tax structures are in place to support rapid population growth in small communities. As the example of Bradford County exemplifies, taxes can lead to urban-rural divisions if small communities are not provided the means to keep pace with rising demands on local infrastructure.

Another potential concern is related to inequities that can arise when landowners sell mineral rights at different phases of development. Early in the development process, natural gas companies have been perceived to take advantage of residents' inexperience with mineral rights leasing. As one respondent in Washington County, Pennsylvania, explained, "There are many inequalities. Leasing is one. Those who signed leases early in the leasing phase signed for much lower amounts than those holding out, those with larger land holdings, and those participating in landowner groups"[44]. Future research could assess mineral rights owners' awareness of standard leasing procedures and help connect them to resources like the Michigan State University Cooperative Extension, which provides information about best practices.

4.2 Explore opportunities for improved transparency

The *Challenges and Opportunities* section examined how factors such as uncertainty and lack of trust can heighten perceived risk. Increasing transparency is one means to address these concerns. Transparency has two distinct components. The first pertains to the rules that govern when and how the public is notified of events during the course of well development and operation (permit

applications, disclosure of chemical additives, spills and accidents, etc.). The second relates to how information about HVHF and deep shale gas development in Michigan is generally communicated to the public. Phase 2 of research should carefully investigate the current state of transparency in HVHF and opportunities for enhancing it. Certain issues are highlighted below as areas of concern.

As noted previously, the Supervisor of Wells Instruction 1-2011[5] significantly enhanced the transparency of HVHF activities in the state by requiring natural gas companies to report water withdrawal amounts through a web-based water withdrawal assessment tool, and by stipulating that MSDSs must be submitted to the MDEQ within 60 days of a HVHF treatment. MDEQ also committed to making this information available to the public on its website, enhancing both the data collection and communication aspects of transparency. This initiative was applauded by a joint press release from three prominent Michigan nonprofits—the Tip of the Mitt Watershed Council, Michigan League of Conservation Voters, and Michigan Environmental Council—shortly after the directive's publication[122].

Despite these positive steps toward transparency, chemical additives in HVHF fluids remain a primary point of contention for many stakeholders in Michigan. As discussed in the *Status and Trends* section, many nonprofits and concerned citizens stress the point that chemical compositions of HF fluids are only reported to MDEQ within 60 days following a treatment, rather than prior to its occurrence. The often stated concern is that if a spill were to occur during or immediately following a treatment, the public and government agencies would not be as well prepared as they would be if MSDSs were available prior to use[2,65]. An equally contentious issue related to chemicals is the protection of certain mixtures as trade secrets, even after the publication of MSDSs. Phase 2 might evaluate approaches considered in other states. For example, the New York Department of Environmental Conservation proposed that operators seeking a drilling permit must disclose chemicals they plan to use *before* HF occurs[123,124]. Furthermore, under New York's proposed guidelines, operators must evaluate the use of alternative additives that pose less of a risk to water resources and apply for an exception if they wish to designate certain additives as confidential business information.

Two additional issues pertain to public notification of incidents during well development and operation. Currently, information about accidents is not provided to the public unless there is a risk of emergency, such as a release of hydrogen sulfide, at which point local emergency personnel are notified, and, in extreme cases, nearby residents are evacuated[125]. Phase 2 should investigate whether it may be beneficial to provide a forum for providing more information about accidents to the public. Such an initiative could potentially enhance public trust in government, and even decrease concern over risks if accidents are shown to be infrequent. Another issue concerns how residents dependent on water wells are notified if groundwater withdrawals result in water quality issues. Current MDEQ requirements stipulate that well operators must install a test well to monitor water quality during withdrawals for HVHF treatments[5]. If issues with water quality are observed in the test well, operators must "curtail the withdrawal or negotiate an agreement with the owner of the freshwater well to resolve the issue," but there is no requirement for notification of other nearby residents whose wells may potentially be impacted[72]. Phase 2 should assess whether or not it may be beneficial for developers to provide this information to the public.

More generally, transparency involves the avenues by which information is communicated and the clarity of its presentation. To this final point, Phase 2 should assess how MDEQ and other agencies may improve the user-friendliness of their websites and the understandability of published materials provided to the public. There is a wealth of information available on the MDEQ website, but finding a specific document or fact can take significant time even for an experienced researcher who knows what he or she is looking for. Future research could explore options for creating better educational resources about what HVHF is, how wells are developed, and how deep shale gas development is managed in Michigan. Importantly, such a resource should help address public concerns—even if those concerns are about other aspects of natural gas development that are not specific to the HVHF process.

4.3 Investigate perceptions at regional and local levels

Opinion polls and peer-reviewed papers examining perceptions of HVHF in other states provide valuable insights into the types of issues that may arise in Michigan. However, there may be unique factors in Michigan that are not accounted for in others studies or by the Michigan poll conducted in October 2012. For example, Michigan has a number of iconic natural areas and tourist destinations in the general vicinity of where future HVHF could occur. How local residents value these areas may influence their perceptions of nearby development. Likewise, regulatory differences between states may lead to different types of concerns with respect to public participation and the way HVHF wells are managed. To better account for public interests in HVHF policy in Michigan, more targeted research is needed to understand the perceptions, beliefs, and values of residents in different communities across the state. We suggest that Phase 2 consider an in-depth study of local perceptions in communities where natural gas extraction through HVHF is likely to continue and expand. Based on the location of the Collingwood and Utica shales, these likely include Kalkaska, Missaukee, Gladwin, Roscommon, and Cheboygan counties in

Northern Michigan. In consultation with MDEQ, Phase 2 could determine the geographic boundaries of other areas to be researched.

Such research could take many forms and could also be conducted in coordination with public health researchers and economists as part of a more comprehensive social impact assessment. The research method commonly applied in previous HF studies used interviews with community leaders to inform the development of a survey, which was distributed to households. In Michigan, informants might include municipal and county leaders, local and regional nonprofit representatives, and representatives from homeowners associations. Variables of interest might include perceived risks and benefits of deep shale gas development, concerns about current regulations and natural gas management practices, and levels of trust in different stakeholders and sources of information.

4.4 Explore opportunities for increased public consultation and participation

Finally, we suggest that Phase 2 investigate opportunities for increasing public participation in HVHF decision-making in Michigan. Currently, communication is primarily a unidirectional, expert-to-layperson provision of information rather than a two-way dialogue. Under existing legislation, the public is notified before state lease sales and can submit comments to the MDNR, but no public involvement occurs during the permitting phase of HVHF well development. Although state governments generally retain the sole right to determine when and where drilling may be permitted, public perceptions of risk can be significantly ameliorated if people have a meaningful opportunity for involvement before development is allowed to take place in their communities.

In this regard, lessons can be gleaned from other states. Former Colorado Governor Bill Ritter led a comprehensive reform of the rules governing the oil and gas industry in light of HVHF. After his election, the state legislature passed a law to change the composition of the Oil and Gas Conservation Commission to be more representative of stakeholder interests. The commission then spent nine months traveling to communities with large oil and gas reserves to solicit public input on regulations[92].

Lessons for improving public participation may also be drawn from parallel industries. For example, in Michigan's mining industry, the Natural Resources and Environmental Protection Act requires that public meetings be held to review permit applications[126]. Following the public meeting, public comments are solicited for 28 days, after which a public hearing is scheduled to disclose the outcome of the permit evaluation. It is not the suggestion of this report that HVHF be treated identically to mining, but that Phase 2 consider in greater detail how other existing public participation processes in Michigan could be applied to HVHF.

Securing public trust depends on more than innovative legislation. The results of Phase 2 research should illustrate specific ways in which officials can acknowledge public questions and concerns and incorporate them into communication efforts and decision-making processes. As HVHF is in an early stage here in Michigan, there still exists an opportunity to engage the public in a constructive way. Actively listening to the public's concerns can help shift the focus of the conversation from who is "right" to identifying specific areas of joint concern[98].

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APPENDIX A: PUBLIC OPINION POLL DATA

Awareness of Hydraulic Fracturing or "Fracking"

APPENDIX A: TABLE 1. How aware are respondents of HF or fracking

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Very aware (%)	Somewhat aware (%)	Not very aware (%)	Not at all aware (%)	Don't know/ Unsure (%)	
USA	—	Nov. 2010	Civil Society Institute[27]	1012	19	25	13	43	0	
USA	—	Oct. 2011	Civil Society Institute[30]	1049	27	32	15	26	1	
USA	—	March 2012	Civil Society Institute[29]	1019	25	31	16	28	1	
USA	—	July 2012	Civil Society Institute[28]	1017	26	32	14	27	1	
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	838	22	28	12	37	0	
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	403	24	36	10	30	0	
					Very familiar (%)	Somewhat familiar (%)	Not very familiar (%)	Heard the term, but not familiar (%)	Never heard of it (%)	Don't know (%)
USA	—	Dec. 2012	Civil Society Institute & Environmental Working Group[35]	809	19	32	13	13	23	0

APPENDIX A: TABLE 2. How much have respondents heard or read about HF or fracking

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	A lot (%)	Some (%)	Not much/ A little (%)	Nothing/ Not at all (%)	Don't know (%)
USA	—	Mar. 2011	CBS News/New York Times[32]	1382	10	17	16	56	1
USA	—	Mar. 2012	Pew Research Center[31]	1503	26	(n/a)	37	37	0
USA	—	Sept. 2012	Yale University Project on Climate Change Communication, George Mason University Center for Climate Change Communication[33]	1061	9	22	16	39	14
CA	Unconventional oil only	July 2012	Public Policy Institute of CA[8]	2500	23	(n/a)	31	46	0
LA	Extensive production	Feb. 2012	Louisiana State University[12]	731	18	18	18	45	0
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	40	(n/a)	42	17	1
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	46	(n/a)	40	13	1

APPENDIX A: TABLE 3. Have respondents heard or read anything about fracking

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Yes (%)	No (%)	Don't know (%)
NY	Moratorium pending further study	Aug. 2011	Quinnipiac University[17]	1640	57	42	1
NY	Moratorium pending further study	Dec. 2011	Quinnipiac University[18]	1143	59	39	1
NY	Moratorium pending further study	July 2012	Quinnipiac University[15]	1779	62	37	1
NY	Moratorium pending further study	Sept. 2012	Quinnipiac University[14]	1589	65	34	1
NY	Moratorium pending further study	Dec. 2012	Quinnipiac University[16]	1302	66	33	1
OH	Extensive production	Jan. 2012	Quinnipiac University[11]	1610	59	40	1
OH	Extensive production	May 2012	Quinnipiac University[10]	1069	64	35	1

APPENDIX A: TABLE 4. How much attention/how closely respondents have paid attention to fracking debate/news in state

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Some to a great deal (or) Somewhat to very closely (%)	Not very much – none (or) Not too closely – not at all (%)	Don't know (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	48	52	<1
NC	Nonproducing but allowed pending new regulations	Oct. 2011	Elon University[26]	529	20	53	27
NC	Nonproducing but allowed pending new regulations	Mar. 2012	Elon University[25]	534	39	45	16
NY	Moratorium pending further study	Sept. 2011	Siena Research Institute[19]	808	51	47	1
NY	Moratorium pending further study	May. 2012	Siena Research Institute[20]	766	66	34	
NY	Moratorium pending further study	Aug. 2012	Siena Research Institute[21]	671	63	37	1
NY	Moratorium pending further study	Oct. 2012	Siena Research Institute[22]	750	66	33	
NY	Moratorium pending further study	Nov. 2012	Siena Research Institute[24]	822	63	37	
NY	Moratorium pending further study	Jan. 2013	Siena Research Institute[23]	1154	60	40	
PA	Extensive production	Nov. 2011	University of Michigan & Muhlenberg College[9]	525	48	51	1
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	59	42	<1

APPENDIX A: TABLE 5. Support for/opposition to hydraulic fracturing

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Support/ Favor (%)	Oppose (%)	Not sure/ Undecided (%)
USA	—	Mar. 2012	Pew Research Center[31]	1038	52	35	13
USA	—	Sept. 2012	Yale University Project on Climate Change Communication, George Mason University Center for Climate Change Communication[33]	1061	22	20	58
CA	Unconventional oil only	July 2012	Public Policy Institute of CA[8]	1350	42	46	12
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	54	35	12
NC	Nonproducing but allowed pending new regulations	Mar. 2012	Elon University[25]	534	21	22	57
NY	Moratorium pending further study	Oct. 2011	Marist College[36]	1030	39	42	19
NY	Moratorium pending further study	Feb. 2013	Marist College[37]	673	40	41	20
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	49	40	12

APPENDIX A: TABLE 6. Acceptability of fracking (even if it threatens water quality) if it lowers heating bills

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Very acceptable (%)	Not very to Not at all acceptable (%)	Don't know/ Not sure (%)
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	838	34	65	1
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	403	50	47	3

APPENDIX A: TABLE 7. Perceptions of benefits vs. risks

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Benefits outweigh risks (%)	Risks outweigh benefits (%)	Not sure (%)	
USA	—	Nov. 2011	Deloitte[6]	663	58	19	23	
USA	—	Sept. 2012	Harris Interactive[127]	2562	31	32	38	
TX, AR, LA	Mature shale plays with extensive production	Nov. 2011	Deloitte[6]	537	62	21	18	
NY, PA	Newer shale plays (with different levels of development)	Nov. 2011	Deloitte[6]	494	53	23	25	
					Benefits outweigh risks (%)	Risks outweigh benefits (%)	Not sure (%)	About equal (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	52	24	16	8
PA	Extensive production	Nov. 2011	University of Michigan & Muhlenberg College[9]	525	41	33	(n/a)	26
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	54	30	8	9

APPENDIX A: TABLE 8. Importance of natural gas drilling for state economy

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Very important (%)	Not very important/ Not important at all (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	82	15	3
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	84	13	3

APPENDIX A: TABLE 9. Perceived safety of HF

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Safe (%)	Unsafe (%)	Don't know (%)
USA	—	Mar. 2011	CBS News/New York Times[32]	1382	55	34	11
LA	Extensive production	Feb. 2012	Louisiana State University[12]	375	35	24	42

APPENDIX A: TABLE 10. Level of concern if HF were to happen near home

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Very concerned (%)	Not at all/ Not very concerned (%)	Not sure (%)
USA	—	Nov. 2010	Civil Society Institute[27]	496	73	26	1
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	444	91	8	1
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	268	82	18	

APPENDIX A: TABLE 11. Concern about the impacts of HF on water quality

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Very concerned (%)	Not at all/ Not very concerned (%)	Not sure (%)
USA	—	Nov. 2010	Civil Society Institute[27]	493	69	31	
USA	—	Oct. 2011	Civil Society Institute[30]	1049	78	19	2
USA	—	Mar. 2012	Civil Society Institute[29]	649	81	19	
USA	—	July 2012	Civil Society Institute[28]	1017	77	22	1
USA	—	Dec. 2012	Civil Society Institute & Environmental Working Group[35]	809	79	21	1
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	444	86	14	
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	268	79	20	

APPENDIX A: TABLE 12. Belief that natural gas drilling poses a major risk to the state's water resources

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	51	36	13
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	59	34	8

APPENDIX A: TABLE 13. Belief that HF will cause environmental damage

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Yes, will damage (%)	No, won't damage (%)	Not sure (%)
NY	Moratorium pending further study	Aug. 2011	Quinnipiac University[17]	1640	52	15	33
NY	Moratorium pending further study	Dec. 2011	Quinnipiac University[18]	1143	55	13	32
NY	Moratorium pending further study	July 2012	Quinnipiac University[15]	1779	53	12	35
NY	Moratorium pending further study	Sept. 2012	Quinnipiac University[14]	1589	48	14	38
NY	Moratorium pending further study	Dec. 2012	Quinnipiac University[16]	1302	50	17	33
OH	Extensive production	Jan. 2012	Quinnipiac University[11]	1610	43	16	41
OH	Extensive production	May 2012	Quinnipiac University[10]	1069	45	19	36

FRACKING REGULATIONS

APPENDIX A: TABLE 14. Desire for regulation

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	About right (%)	Not enough regulation (%)	Too much (%)	Don't know (%)
USA	—	Mar 2011	CBS News/New York Times[32]	1382	30	40	15	16
						More regulation (%)	Less regulation (%)	Unsure (%)
USA	—	Mar. 2012	Bloomberg National Poll[40]	1002		65	18	17
USA	—	Sept. 2012	Bloomberg National Poll[38]	1007		56	29	15
USA	—	Dec. 2012	Bloomberg National Poll[39]	1000		66	18	16
					Ban fracking (%)	More regulation (%)	Less regulation (%)	Unsure (%)
USA	—	May 2012	United Technologies, National Journal[41]	1004	15	53	25	7

APPENDIX A: TABLE 15. Belief that tighter government regulations will lead drilling firms to leave the state and so should be avoided

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	42	51	8
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	41	48	10

APPENDIX A: TABLE 16. Belief that increasing taxes on natural gas drillers will lead firms to the leave the state and so should be avoided

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	37	54	10
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	32	64	4

APPENDIX A: TABLE 17. Support to stop fracking or impose a moratorium

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Good idea to halt fracking (%)	Bad idea to halt fracking (%)	Don't know/ Not sure (%)
OH	Extensive production	Jan. 2012	Quinnipiac University[11]	1610	72	23	5
Belief that state should impose a moratorium until there is a fuller understanding of possible risks					Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	52	41	7
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	58	31	10

APPENDIX A: TABLE 18. Should NY allow drilling

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Allow drilling (%)	No drilling (%)	Not sure (%)
NY	Moratorium pending further study	Aug. 2011	Quinnipiac University[17]	1640	47	42	12
NY	Moratorium pending further study	Dec. 2011	Quinnipiac University[18]	1143	44	45	11
NY	Moratorium pending further study	July 2012	Quinnipiac University[15]	1779	43	44	23
NY	Moratorium pending further study	Sept. 2012	Quinnipiac University[14]	1589	45	41	13
NY	Moratorium pending further study	Dec. 2012	Quinnipiac University[16]	1302	44	42	15

APPENDIX A: TABLE 19. Belief that state and national officials are doing enough to require disclosure of chemicals

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Doing some to Everything they should (%)	Not doing as much as they should/ Not doing anything at all (%)	Don't know/ Not sure (%)
USA	—	Nov. 2010	Civil Society Institute[27]	493	33	56	10
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	444	25	63	8
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	268	33	62	5

APPENDIX A: TABLE 20. Support to tighten public disclosure requirements and require studies of health and environmental consequences of chemicals

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly support (%)	Somewhat to Strongly oppose (%)	Don't know/ Not sure (%)
USA	—	Nov. 2010	Civil Society Institute[27]	1012	68	16	6
USA	—	July 2012	Civil Society Institute[28]	1017	79	18	3
NY	Moratorium pending further study	Nov. 2010	Civil Society Institute[13]	838	83	14	3
PA	Extensive production	Nov. 2010	Civil Society Institute[7]	403	82	16	3

APPENDIX A: TABLE 21. Support to tighten public disclosure requirements

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly support (%)	Somewhat to Strongly oppose (%)	Don't know/ Not sure (%)
USA	—	Dec. 2012	Civil Society Institute & Environmental Working Group[35]	809	78	20	1
Believe drilling companies should have to disclose chemicals					Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	90	8	3
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	91	7	2
Believe drilling companies should NOT have to disclose chemicals because they are trade secrets					Somewhat to Strongly agree (%)	Somewhat to Strongly disagree (%)	Not sure (%)
MI	Early stage production	Oct. 2012	University of Michigan & Muhlenberg College[1]	415	15	83	3
PA	Extensive production	Oct. 2012	University of Michigan & Muhlenberg College[1]	424	10	87	4

APPENDIX A: TABLE 22. Support more studies of health and environmental consequences of chemicals used in natural gas drilling

Study Area	Status of High-Volume Fracking	Field Date	Sponsor	Sample size	Somewhat to Strongly support (%)	Somewhat to strongly oppose (%)	Don't know/ Not sure (%)
USA	—	Dec. 2012	Civil Society Institute & Environmental Working Group[35]	809	86	13	1

APPENDIX B: SUMMARY OF STUDIES THAT EXAMINE PERCEPTIONS OF SHALE GAS DEVELOPMENT AT A COMMUNITY LEVEL

Barnett Shale Region

Author, year	Study location	Methods	Purpose	Main findings
Anderson & Theodori, 2009	Johnson and Wise Counties, Texas	Interviews with 24 municipal and county leaders	Compare perceptions of HVHF impacts in two communities with different levels of development	Both communities believed gas development had increased economic prosperity but also threatened environmental and public health as well as the quality of life. Informants in Wise County (mature development) felt that, overall, the costs of gas development had outweighed its benefits. Informants in Johnson County (early stage development) felt the opposite.
Theodori, 2009	Johnson and Wise Counties, Texas	Survey of 600 randomly selected households	Compare perceptions of HVHF impacts in two communities with different levels of development	Overall, residents in both counties acknowledged the economic benefits to shale gas drilling but disliked its environmental and infrastructural impacts. Both counties identified increased truck traffic and the amount of freshwater used as the most problematic concerns. Community services such as local police and fire protection and the quality of schools were seen as improving in both communities, but especially in Wise County (mature development). Wise County residents also noted greater job availability.
Wynveen, 2011	Johnson and Wise Counties, Texas	Qualitative analysis of written comments on above survey	Compare perceptions of HVHF impacts in two communities with different levels of development	Both counties noted economic benefits, but residents in Wise County (mature development) were more likely to note that benefits were not shared by all. Both counties perceived threats to health, safety, and quality of life. Only Wise County residents noted concerns about environmental and water issues.
Theodori, 2012	Johnson and Wise Counties, Texas	Survey of 600 randomly selected households Regression analysis	Compare perceptions of the natural gas industry in two communities with different levels of development	Residents in Wise County (mature development) were more likely to believe that drilling was occurring too close to homes and businesses and that the gas industry was too politically powerful and uncaring toward local residents. In Johnson County (early stage development), residents were more optimistic that development would benefit the community. In both counties, mineral rights owners viewed the natural gas industry more positively than their counterparts.

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Marcellus Shale Region

Author, year	Study location	Methods	Purpose	Main Findings
Brasier, et al., 2011	Bradford, Lycoming, & Washington Counties, Pennsylvania Steuben County, New York	Interviews with 61 key informants in 4 counties	Compare counties with different levels of HVHF activity (high/low) and past experience with fossil fuel development (high/low)	The impacts of gas development – both positive and negative – were more acute in communities that had high levels of drilling activity but low population densities. Participants in all four counties expressed concerns about the environmental impacts of gas development based on the region's past history with coal extraction.
Jacquet, 2012	Ward County, Pennsylvania	Survey of 1028 randomly selected households	Compare perceptions in a region undergoing simultaneous wind and natural gas development	Land owners had more negative attitudes toward natural gas development than wind farm development. Positive attitudes toward natural gas development were associated with mineral rights ownership, lower levels of environmental concern, and past employment experience in the industry.
Stedman, et al., 2012	Pennsylvania & New York	Survey of randomly sampled households in PA (n=1,455) and NY (n=461)	Compare communities with different levels of drilling activity on knowledge, perceived impacts, engagement in the issue, and trust in information sources	Perceived level of knowledge of HVHF did not differ by state, even though gas development was more advanced in Pennsylvania. New York residents were more opposed to development, more likely to have engaged in various forms of public participation related to gas development, less trusting of various information sources, and more likely to expect that natural gas development would negatively impact the environment and their quality of life.
Schafft, Borlu & Glenna, 2013	Pennsylvania	Survey of 891 school administrators representing 309 of the state's 500 school districts.	Compare perceived risks and opportunities associated with gas development as a function of the drilling intensity in the area	Participants in areas with higher levels of local drilling were more likely to recognize the potential economic benefits of shale gas development as well as the socioeconomic challenges it poses. Job creation was rated as the greatest economic impact, while road congestion and wear and tear were seen as the most negative socioeconomic impact.
Kriesky, Goldstein, Zell, & Beach, 2013	Washington and Allegheny Counties, Pennsylvania	Random digit dialing telephone survey of households in Allegheny (n=799) and Washington Counties (n=502)	Compare support for HF, perceived opportunities and threats, and information sources in two counties with different levels of drilling activity	Residents in Washington County (higher drilling activity) were more likely to support shale gas development than residents in Allegheny County (lower drilling activity). Analyses suggest this was because residents in Washington County were more likely (1) to have a family member who signed a mineral rights lease, and (2) to view shale gas extraction as an economic opportunity.
Ferrar, et al., 2013	Pennsylvania	In-depth interviews with 33 individuals (convenience sample) 20 participants were re-interviewed 19-22 months later	Investigates self-reported health impacts and perceived stressors from shale gas development among community members active in shale gas issues (who were presumed to oppose it)	Participants attributed 59 physical health impacts and 13 psychological stressors to shale gas development. The most frequently reported symptom was stress (primarily as a result of health concerns and distrust in regulatory agencies, natural gas land men, and politicians). Skin irritations and digestive system upset were the most commonly reported physical health impacts. Perceived health impacts increased over time while psychological stress remained constant.

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