Assessing Opportunities and Barriers to Reducing the Environmental Footprint of Natural Gas Development in Utah's Uintah Basin

Brian Gentry[1], Douglas Jackson-Smith[1], Lorien Belton[1], and Gene Theodori[2]

Utah State University
Institute for Social Science Research on Natural Resource (ISSRNR)
Research Report

April 2011

Institute for Social Science Research on Natural Resources
Utah State University
0730 Old Main Hill, Logan, UT 84322-0730

[1] Respectively, doctoral student; Professor of Sociology; and Natural Resources Program Coordinator at Utah State University, Logan, UT.
[2] Professor of Sociology at Sam Houston State University, Huntsville, TX.

EXECUTIVE SUMMARY

Introduction

Development of natural gas resources in the United States has increased dramatically over the past two decades, a boom driven by favorable prices, new technological developments, and growing interest in domestic sources of energy with a smaller carbon footprint than coal or oil. Most of the expansion in U.S. natural gas production has been from so-called 'unconventional' reserves in which extensive natural gas resources trapped in continuous sandstone and shale formations can now be extracted using modern directional drilling and hydraulic fracturing technologies. The Uintah Basin in northeastern Utah has been one of several areas in the U.S. where major tight sands and shale gas plays have been the focus of recent natural gas exploration and development.

While unconventional natural gas is likely to be a major contributor to America's energy future (NRC 2009), development of this new resource has not been without controversy. Local and national critics have expressed concerns about possible environmental impacts associated with the relatively dense surface disturbance footprint associated with unconventional natural gas development. Reports of ground and surface water contamination, air pollution, and wildlife impacts have attracted the attention of state and federal regulatory agencies. Access to many unconventional natural gas reserves that are located in/around environmentally sensitive areas likely will depend on the industry's ability to successfully lessen environmental impacts.

In response to local and national pressure, a growing number of industry and academic leaders have made efforts to develop technical options and managerial strategies designed to reduce the environmental footprint of unconventional gas exploration and production. The Environmentally Friendly Drilling (EFD) program, managed by the Houston Advanced Research Center (HARC), is one such example. The EFD program was initiated in 2005; its stated objective is to identify, develop and transfer critical, cost effective new technologies that can provide policy makers and industry with the ability to develop U.S. domestic reserves in a safe and environmentally friendly manner. Presently, the EFD partnership includes 11 universities, 5 national research laboratories, and numerous industry sponsors.

While new options exist, many U.S. producers face a number of challenges and barriers that may impede the adoption and diffusion of these new technologies. In 2009, the EFD program approached researchers at Utah State University and Sam Houston State University to conduct an exploratory study of the opportunities and barriers to the expanded use of EFD practices among natural gas industry actors in the Uintah Basin in Utah.

Our team worked in the Uintah Basin to accomplish four main research goals:

- Better understand local viewpoints on the main environmental issues, concerns, and challenges associated with natural gas development in the Uintah Basin,
- Discover what steps have been, or are being, taken by industry actors in the Basin to reduce their environmental footprint,
- Determine the drivers of and barriers to the expanded use of more environmentally-friendly practices by private industry, and
- Investigate the role, both positive and negative, played by various regulatory agencies at the local, state, and federal levels in shaping the use of these types of practices by private industry.

Methods

Our research relied on semi-structured interviews with key individuals from local, state, and federal government agencies, as well as key private sector actors in different sectors of the local energy industry. In addition, we gathered data from public records, previous studies, and other secondary sources to provide historical background on the evolution of the energy industry in this region and to provide context for the information we obtained from interviewees.

Our interviewees were purposefully selected from a master list of various stakeholders involved with energy development in the Uintah Basin. This list included county administrators, state and federal regulatory agency employees, and representatives from a diverse range of private and public groups and agencies. Key informants were selected to provide a diverse array of topical and organizational experience in the Basin. A total of 26 key informant interviews, each lasting about 75 minutes, were conducted during the spring and fall 2010.

Results of key informant interviews were summarized in written narrative reports and then analyzed using standard qualitative analysis techniques. The analysis focused on identifying related themes of response for each of the major research topics. These themes were used to organize the results presented in this report.

Our findings are not meant to reflect the views of a statistically representative sample of natural gas energy development stakeholders in Utah. However, they provide insight into of the common issues, priorities, and concerns of the diverse public and private parties working on natural gas energy development in this region. Moreover, the results paint a robust picture of the major drivers and barriers that have shaped the past and present use of technologies and management practices designed to minimize the environmental footprint of natural gas development.

Primary Findings

Our key informants identified a number of environmentally-oriented innovations currently being used by the energy industry in the Uintah Basin, helped explain the drivers behind decisions to use these innovations, and elaborated some of the barriers that impede the more widespread use of technologies and practices designed to reduce the environmental footprint of energy industry activities.

Examples of Current Environmental Innovation

- A number of companies working in the Basin have taken steps to **reduce their surface impact** by implementing interim and post-drilling reclamation and – when feasible – drilling multiple wells from a single pad. Other examples include adjusting pad locations or the timing of drilling activities to **protect endangered plants and other wildlife**.

- Similarly, our informants identified a number of **water quality** innovations used in the Basin, including the use of centralized piping facilities, reusing and recycling water, and protecting aquifers during drilling through the use of steel and cement casings.

- While less common, we heard reports of companies using innovations specifically designed to improve **air quality**. These include using higher tier engines, reducing release of hydrocarbon and volatile organic compounds (VOCs) from well pad machinery or pipelines, and taking steps to reduce dust particles in the air associated with surface disturbances or trucking.

Drivers of Change

Respondents identified several drivers associated with decisions by industry actors to utilize some innovative new technologies to reduce their environmental footprint. Examples of drivers of environmental innovation generally fell into 7 categories:

- The requirements of state and federal **regulatory agencies** are a major factor inducing the use of Best Management Practices (BMPs) and other innovations to reduce the environmental footprint of natural gas development in the Basin.

- Advancements in **engineering and technology** were mentioned as critical to enabling industry to address environmental concerns in a technically and economically viable manner.

- Although new environmentally-oriented practices were often perceived to add to the cost of exploration and production, respondents indicated that periods of **higher energy commodity prices** were important to facilitate the ability of industry to try new innovations. In addition, although adopting new practices may at first appear to be cost-prohibitive, upon implementation, many ended up saving money over traditional methods.

- Energy companies appear to be sensitive to the importance of **marketing and public relations,** and were willing to use environmentally-oriented practices as a means to improve their public image.

- A **desire to avoid legal battles** (particularly related to the NEPA process for federal agency decisions) may prompt the industry to anticipate and adopt new and innovative techniques or technologies.

- Some industry actors appear to be motivated by a sincere **sense of responsibility to local communities**, and adopt environmental practices in part to limit negative impacts on local residents.

- Many respondents attributed the energy industry efforts to reduce their environmental footprint to **changes in corporate culture** toward a more environmentally-oriented ethic as younger managers enter the leadership ranks, a trend that reflects similar changes in American society at large.

Barriers to Change

In addition to highlighting the ‘drivers’ behind the adoption of new practices, our key informants were asked to identify barriers that prevented the expanded use of innovative technologies to reduce the environmental footprint of natural gas industry activities in the region. Responses were collapsed into three categories.

- **Economic barriers** were common reasons given for not implementing some new technologies or drilling practices.

- A number of respondents indicated that the current **state of technology** was inadequate due to the **geological formations** in the Basin.

- One challenge facing companies interested in using some new environmentally friendly technologies and practices in the Basin is the **complex mix of regulatory agencies** that oversee energy development in the region. Both industry and regulatory agency respondents indicated concern about the ability of current agency jurisdiction and regulatory rules to facilitate the use of new types of environmental innovations.

Implications and Conclusions

There appears to be a high level of interest by nearly all parties to accelerate and facilitate efforts to reduce the environmental footprint of fossil fuel production in the Uintah Basin. Our research suggests that investments in new technical and engineering innovations are important to help reduce logistical and economic barriers to adoption. However, new technology alone is unlikely to generate changes that are not already of interest to (and demanded by) industry and agency actors. Market factors appear to affect the pace of change: robust economic conditions in energy commodity markets make it easier for industry actors to experiment with and invest in new technology and practices, but are not likely to be a primary driver for change.

The role of regulation in driving future changes is likely to be mixed. On the one hand, if there were no possibility of stricter environmental rules and regulations in the future, the willingness of industry actors to incur costs to meet environmental objectives might be much lower. However, movement to reduce the environmental footprint of the industry will likely occur in ways that are not simply dictated by clear environmental laws and requirements. Conversations between regulators and industry are critical to clarify which kinds of environmental impacts are of most concern and to create the space for environmental innovation to occur. In addition, the perception that stricter regulatory standards will be coming down the pipe in the near future will likely serve as a major motivator for companies to proactively develop new strategies. It is likely that a handful of larger industry actors will provide a leadership role in generating and adopting environmental innovations, with smaller firms and local service contractors following their lead (perhaps only when such changes become mandatory).

The link between regulation and behavior is made more complex because of uncertainties about regulatory jurisdiction and authority in the Basin, and perceptions of variability in federal agency practices across political administrations in Washington. If they continue, these uncertainties will make it more difficult for industry actors to make informed judgments about which kinds of environmentally-oriented change are most likely to be required. A number of industry informants suggested that they would be happy to live with stricter environmental rules if (a) all relevant agencies would agree to follow the same rules, (b) they know they could get decisions on applications for leases and permits more quickly and in a predictable manner, and (c) they could be assured that these rules would be stable for the foreseeable future.

PART I

INTRODUCTION

Development of natural gas resources in the United States has increased dramatically over the past two decades, a boom driven by favorable prices, new technological developments, and growing interest in domestic sources of energy with a smaller carbon footprint than coal or oil. Most of the expansion in U.S. natural gas production has been from so-called ‘unconventional’ reserves in which extensive natural gas resources trapped in continuous sandstone and shale formations can now be extracted using modern directional drilling and hydraulic fracturing technologies. The Uintah Basin in northeastern Utah has been one of several areas in the U.S. where major tight sands and shale gas plays have been the focus of recent natural gas exploration and development.

While unconventional natural gas is likely to be a major contributor to America’s energy future (NRC 2009), development of this new resource has not been without controversy. Local and national critics have expressed concerns about possible environmental impacts associated with the relatively dense surface disturbance footprint associated with unconventional natural gas development. Reports of ground and surface water contamination, air pollution, and wildlife impacts have attracted the attention of state and federal regulatory agencies. Access to many unconventional natural gas reserves that are located in/around environmentally sensitive areas likely will depend on the industry’s ability to successfully lessen environmental impacts.

In response to local and national pressure, a growing number of industry and academic leaders have made efforts to develop technical options and managerial strategies designed to reduce the environmental footprint of unconventional gas exploration and production. The Environmentally Friendly Drilling (EFD) program, managed by the Houston Advanced Research Center (HARC), is one such example. The EFD program was initiated in 2005; its stated objective is to identify, develop and transfer critical, cost effective, new technologies that can provide policy makers and industry with the ability to develop U.S. domestic reserves in a safe and environmentally friendly manner. Presently, the EFD partnership includes 11 universities, 5 national research laboratories, and numerous industry sponsors.

While new options exist, many U.S. producers face a number of challenges and barriers that may impede the adoption and diffusion of these new technologies. In 2009, the EFD program approached researchers at Utah State University and Sam Houston State University to conduct an exploratory study of the opportunities and barriers to the expanded use of EFD practices among natural gas industry actors in Utah’s Uintah Basin.

Our research team worked to conduct research in the Uintah Basin to accomplish four main goals:

- Better understand local viewpoints on the main environmental issues, concerns, and challenges associated with natural gas development in the Uintah Basin,
- Discover what steps have been, or are being, taken by industry actors in the Basin to reduce their environmental footprint,
- Determine the drivers of and barriers to the expanded use of more environmentally-friendly practices by private industry, and
- Investigate the role, both positive and negative, played by various regulatory agencies at the local, state, and federal levels in shaping the use of these types of practices by private industry.

PART II

METHODOLOGY

A mixed methods approach was used to address the four study objectives. Project scientists from Utah State University and Sam Houston State University reviewed previous literature on the social, institutional, and technical aspects of natural gas development, with particular focus on social and institutional dynamics of environmental behavior in the energy industry sector. We also collected secondary data from various government sources to better understand the spatial and temporal nature of natural gas development in this region. These secondary sources of information provided historical background on the evolution of the energy industry and provided a benchmark against which to compare information obtained from our key informants.

Our primary data collection methods involved key informant interviews with 26 purposively sampled individuals. The key informants were selected to provide different perspectives on the drivers, obstacles, and opportunities for using specific technologies and practices to reduce the environmental footprint of energy exploration and development activities in the Uintah Basin. Individuals were sampled from a master list that included over 100 possible respondents representing the following categories:

- Local farming and ranching interests
- Local and state environmental groups
- Energy industry actors, including both natural gas exploration and production companies, as well as representatives of the service and support industries that carry out much of the field operations in this sector
- Private consultants working with the energy industry to address environmental issues as part of their state and federal permitting requirements
- Federal agency representatives, including the Bureau of Land Management, Forest Service, Fish and Wildlife Service, Environmental Protection Agency, and Bureau of Indian Affairs
- State agency representatives, including the Division of Oil, Gas and Mining, Division of Air Quality, Division of Water Quality, Utah Geologic Survey, Division of Water Rights, and School and Institutional Trust Lands Administration
- Tribal government representatives
- Local government representatives
- Higher education representatives from Utah State University-Uintah Basin, Uintah Basin Applied Technical College, and the Utah Science Technology and Research (USTAR) system.

A total of 26 key informant interviews, each lasting around 75 minutes, were conducted between spring and fall 2010. Interviews were arranged by phone call and were mainly conducted in a face-to-face setting. Respondents were provided with full information about the study and given the option to voluntarily participate. When possible, interviews were digitally recorded. Written field notes and summarized recordings were used as the basis for our analysis below.

Results of key informant interviews were first summarized in written narrative reports and then analyzed through the use of standard qualitative analysis techniques. The analysis focused on identifying related themes or clusters of responses for each of the major research topics. These themes were then used to organize the results presented in this report. After drafting initial conclusions, we revisited the interview recordings to reacquaint ourselves with the rich detail in each interview and to validate the conclusions that we had developed. We are confident that the summary of results below is an accurate representation of the perspectives and information provided by the key informants. Where possible, we also note ways in which interview information is consistent with or diverges from patterns seen in the secondary data.

The results presented below represent our best effort to understand the drivers and constraints faced by key actors as they seek to reduce the environmental footprint of natural gas exploration and development activities in the Uintah Basin. The key informants were not selected to be a statistically representative sample of natural gas energy development stakeholders in Utah. However, the diverse perspectives of different respondents and the consistency of their answers suggest that our findings reflect a reasonably comprehensive inventory and assessment of the types of issues, priorities, and concerns that are most common among the interested public and private parties working on natural gas energy development in this region.

PART III

BACKGROUND AND CONTEXT

Natural Gas in the Utah and US Energy Economy

Natural gas currently provides roughly 25% of energy used in the United States and is considered the cleanest fossil fuel, with about half the CO_2 emissions of coal when burned for electricity generation. Most natural gas used in the U.S. is produced from domestic supplies, with most of the remainder imported from Canada. While domestic production from 'conventional' natural gas reserves – defined as concentrated pockets of gas trapped in reservoirs in geologic formations -- has declined in recent decades, the development of new techniques to economically extract natural gas from 'unconventional' reserves has generated dramatic increases in production from these sources over the last decade (NRC 2009).

Gas shales, coalbed methane, and tight sands represent the largest untapped sources of unconventional natural gas (UNG) formations in the United States (NRC 2009). Over the past thirty years, research and development on these geologic formations has produced technologies to evaluate and develop gas reserves with the potential to significantly boost national natural gas production. New development of domestic natural gas reserves has been associated with advancements in geologic and engineering sciences and the creation of drilling techniques capable of extracting natural gas from previously unobtainable reservoirs. These technological advancements have combined with a national energy policy focused on improving domestic U.S. energy production to decrease dependence on foreign energy supplies. This, plus favorable market conditions, has increased development of natural gas reserves on both public and private lands across the U.S. in the past few decades.

The recent boom in unconventional natural gas exploration and development was also driven by historically high energy prices during the early part of this decade. Figure 1 illustrates trends in the annual natural gas wellhead prices in the U.S. and Utah from 1976 through 2010. It is clear that two large booms in production occurred in the years following sustained price spikes in the wellhead price of natural gas. The delay of a few years from the price spike to the production jump reflects the time lag associated with gaining permits, drilling wells, and initiating production. Utah's natural gas wellhead prices have tended to be slightly below national averages, indicative of the fact that pipeline capacity constraints and lack of proximity to major metropolitan markets limit the ability of the market to utilize Utah's reserves on a competitive basis.

In 1970, federal lands, such as those administered by the Bureau of Land Management (BLM), produced roughly 10 percent of U.S. fossil fuels. By 2009 federal lands produced 35 percent of U.S. fossil fuels, making up 32 percent of natural gas production and 29 percent of crude oil and lease condensate production (EIA 2009). While these statistics include both on- and off-shore resources, the importance of energy extraction on western public lands has continued to grow.

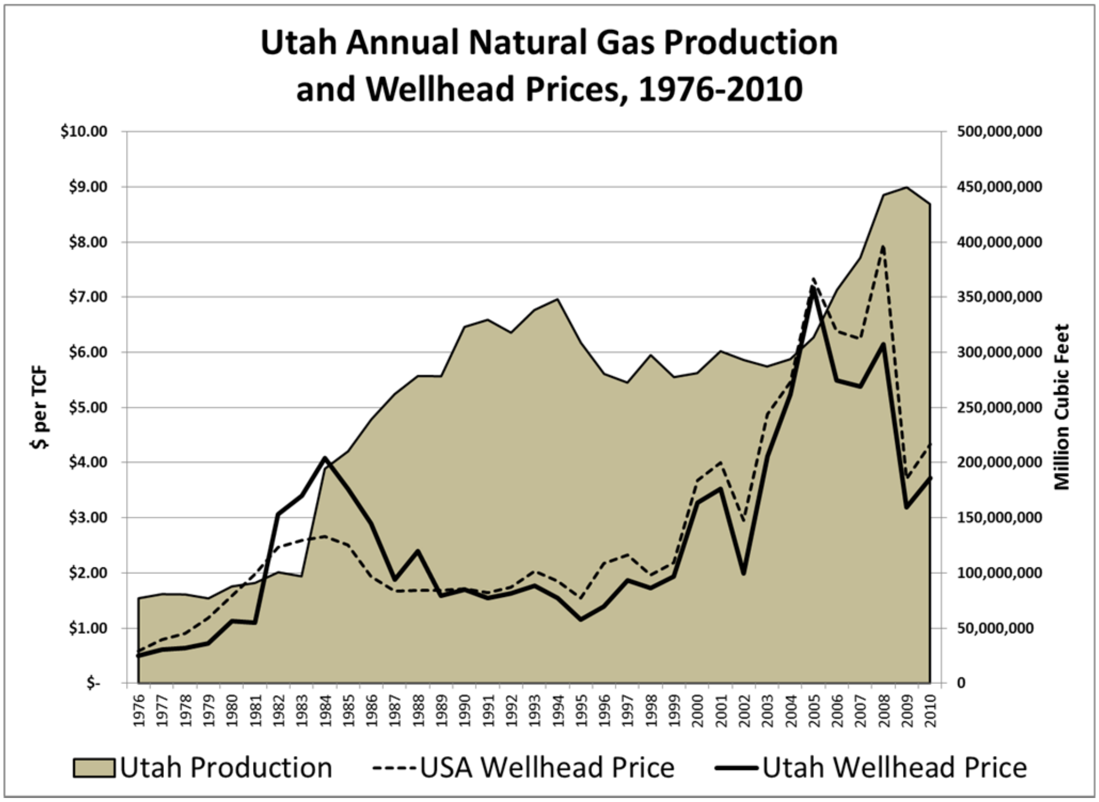
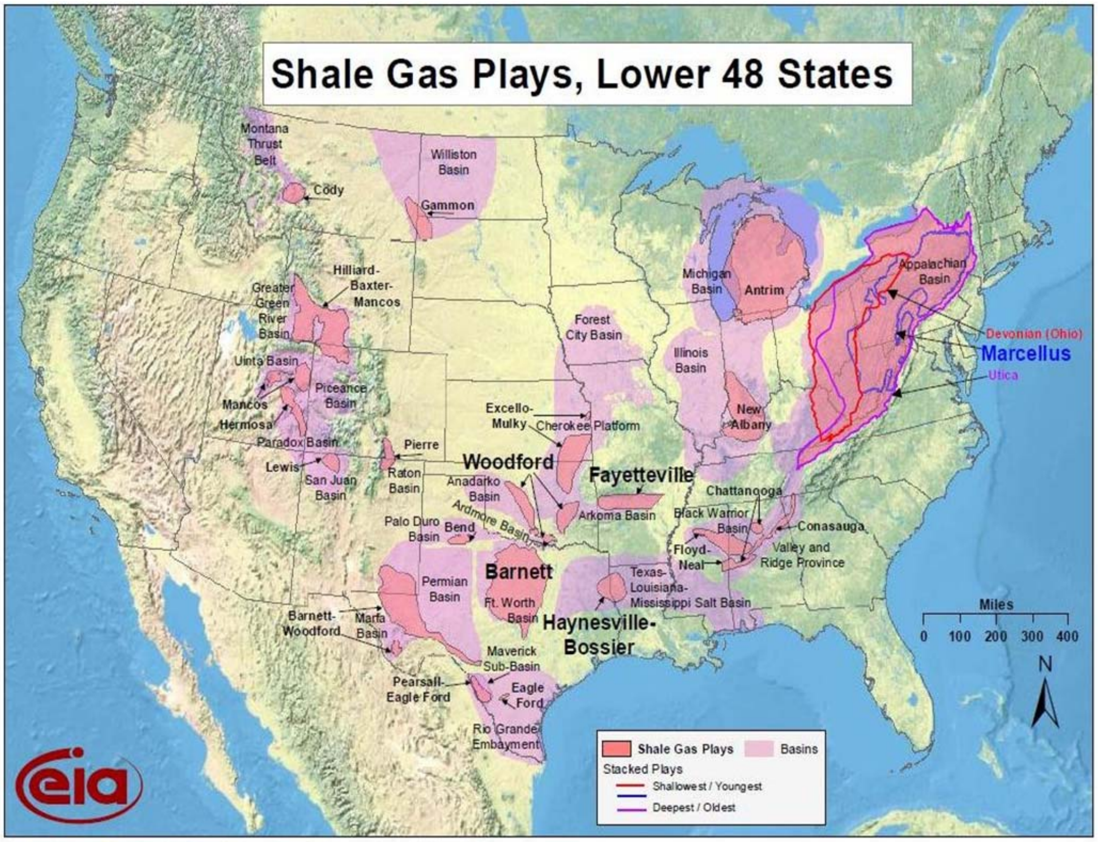


Figure 1: Trends in Utah Annual Natural Gas Prices and Production, 1976-2010.
Sources: Utah Division of Oil, Gas and Mining; USA Energy Information Agency.

The Role of the Intermountain West

The Energy Information Administration (EIA), the statistical agency of the U.S. Department of Energy, breaks down the continental United States into six major natural gas production regions. While natural reserves exist across the country, the Intermountain West represents a significant contributor to current and future natural gas production. The EIA estimates that onshore production of coalbed methane and shale gas will make up 34 percent of total U.S. natural gas production by 2035 (EIA 2010). Figure 2 shows the location of the major shale gas plays in the continental U.S. It also illustrates the importance of shale gas resources in the Intermountain West, Texas, and the Appalachian region along the east coast.



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

Figure 2: Shale Gas Plays in the Continental United States.
Source: Energy Information Administration, 2010

These numbers come on the heels of The National Oil and Gas Assessment, a periodic examination of potential oil and natural gas resources in the United States conducted by the U.S. Geological Survey (USGS). In just the Eastern Great Basin Province, which includes Nevada, Utah, Idaho, and Arizona, there is an estimated mean of 1.8 trillion cubic feet of gas (TCFG), 1.6 million barrels of oil, and 85 million barrels of total natural gas liquids (USGS Eastern Great Basin Assessment Team 2007). Estimates of natural gas reserves are frequently revised upward based on changes in technology and economic conditions. For example, trends in the annual estimated volume of Utah's proven natural gas reserves are shown in Figure 3 below.

Between 2000 and 2008, the George W. Bush administration actively worked to speed up the approval process for oil and gas drilling permits on federally managed public lands. This is reflected in a dramatic increase in the number of Applications for Permits to Drill (APDs) reported on public lands during this time. From 1997 to 2007 the Intermountain West alone experienced an increase of 177 percent in the number of APDs approved (see Figure 4). These permits were approved for over 47.5 million acres of on-shore federal lands, about 13 million of which have been actively engaged in energy development (U.S. House Committee on Natural Resources 2008).

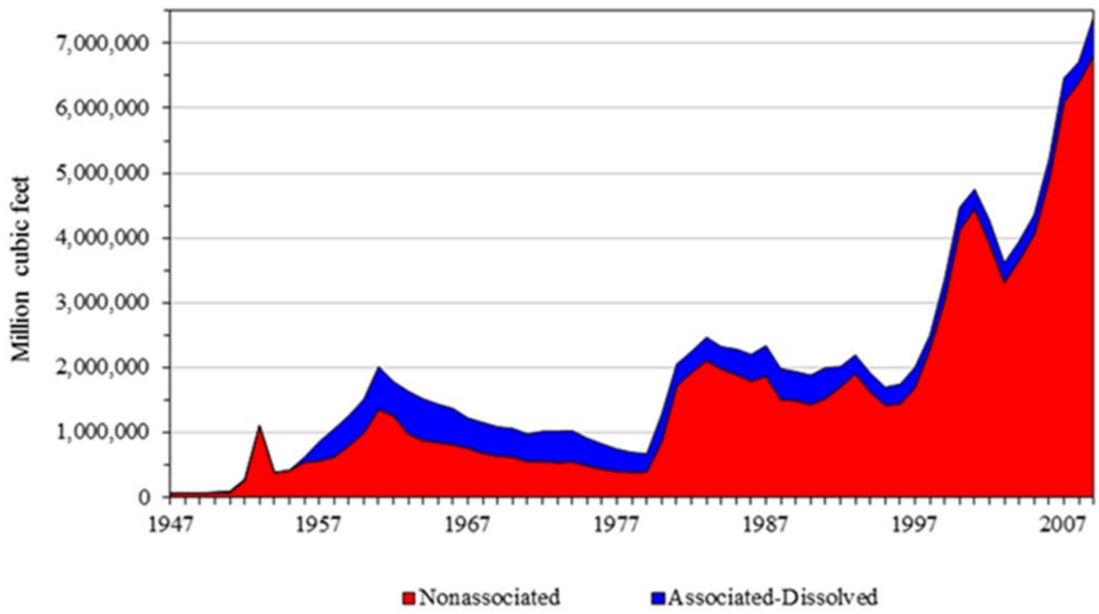


Figure 3: Proved Reserves of Natural Gas in Utah, 1947-2009
Source: Utah Geological Survey website (http://geology.utah.gov/emp/energydata/natgasdata.htm)

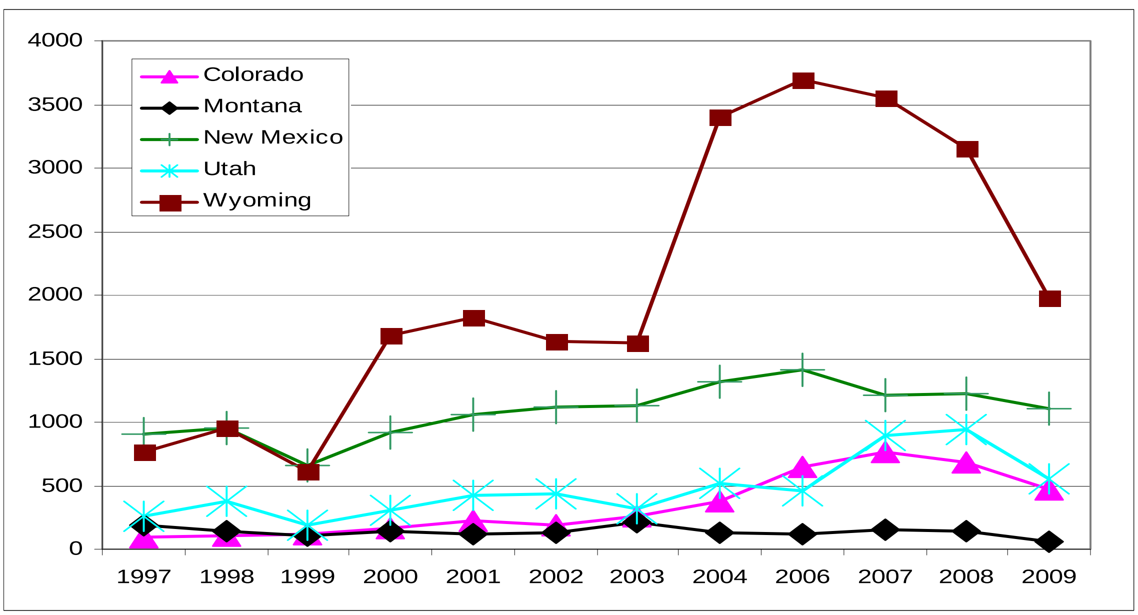


Figure 4: APDs Approved for Federal Lands, 1997-2009.
Source: "Public Lands Statistics," BLM

The Uintah Basin

Located in northeastern Utah, the Uintah Basin is the largest oil and natural gas producing area in the state. Almost all of the production activity associated with oil and natural gas is located in Duchesne and Uintah counties. At just shy of five million acres, 53 percent of which is controlled by the federal government, these counties provide a large area for natural gas and oil development. The Bureau of Land Management is responsible for managing around 32 percent of this land, with an additional 14 percent controlled by the U.S. Forest Service and lesser amounts in the hands of the U.S. Fish and Wildlife Service and National Park Service. The state of Utah controls additional lands predominately through the use of the Utah School and Institutional Trust Lands Administration (SITLA). SITLA administers 6 percent of the land in these counties with lesser amounts controlled by the Utah Division of Wildlife Resources and the Utah Division of State Parks and Recreation. Tribal holdings make up 16 percent of the Basin while the remaining 21 percent is private ownership. The resulting land tenure patterns produce a complex mosaic of different landowners and managers (see Figure 5).

Federal lands are also where most oil and gas extraction is taking place. In 2010, Uintah County had 7,349 oil and gas wells located on BLM lands, with an additional 2,438 located on Tribal property (Utah Division of Oil, Gas, and Mining 2010).

Oil and Gas Production in the Uintah Basin

Industry interest in oil and gas development in the Basin is reflected in trends in applications for permits from the State Department of Oil, Gas and Mining to drill exploratory wells and to develop completed producing wells. Figure 6 illustrates some of these trends between the years 2001 and 2010. It is apparent that interest in new drilling permits for natural gas rose quickly and peaked in 2006 (with almost 1,400 wells permitted), though the peak in well spudding activity and well completions came in 2007 and 2008, respectively. The lag between permitting and well completions reflects the time it takes for companies to mobilize drilling rigs and invest time and resources in developing permitted wells.

Natural gas production in the Basin more than tripled from 97.0 billion cubic feet (BCF) in 2000 to 308.3 BCF by 2010 (Figure 7). Uintah County experienced the majority of this growth and was responsible for approximately 65 percent of the natural gas produced in Utah in 2010, a production increase of 237 percent from 2000 to 2010. Over this same period the Basin's share of the state's total production more than doubled from 35 percent to 72 percent. Most new spudded wells are in the Basin (see details in Appendix 1 and 2).

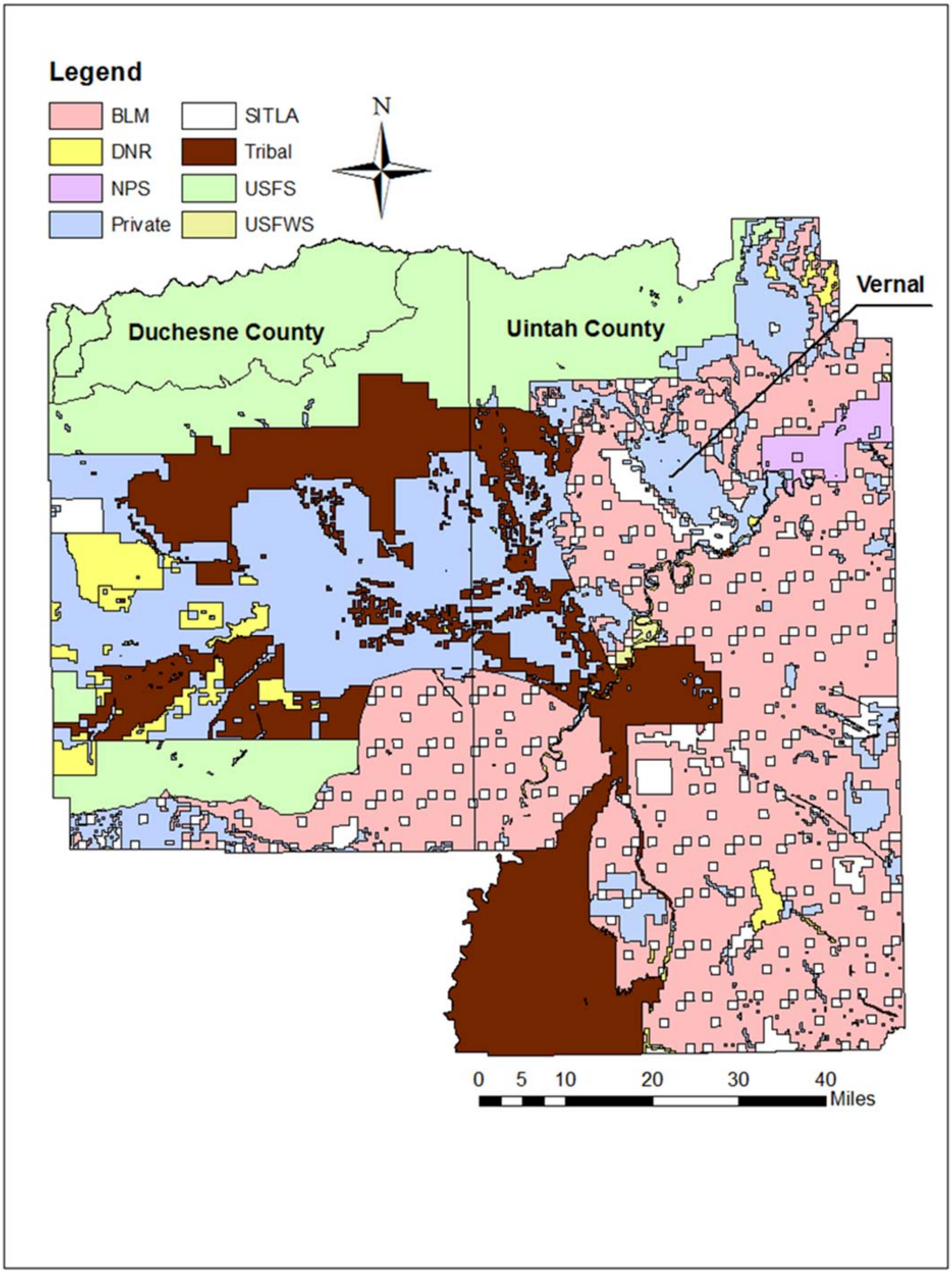


Figure 5: Land Ownership in the Uintah Basin.
Source: Utah State Geographic Information Database (SGID)

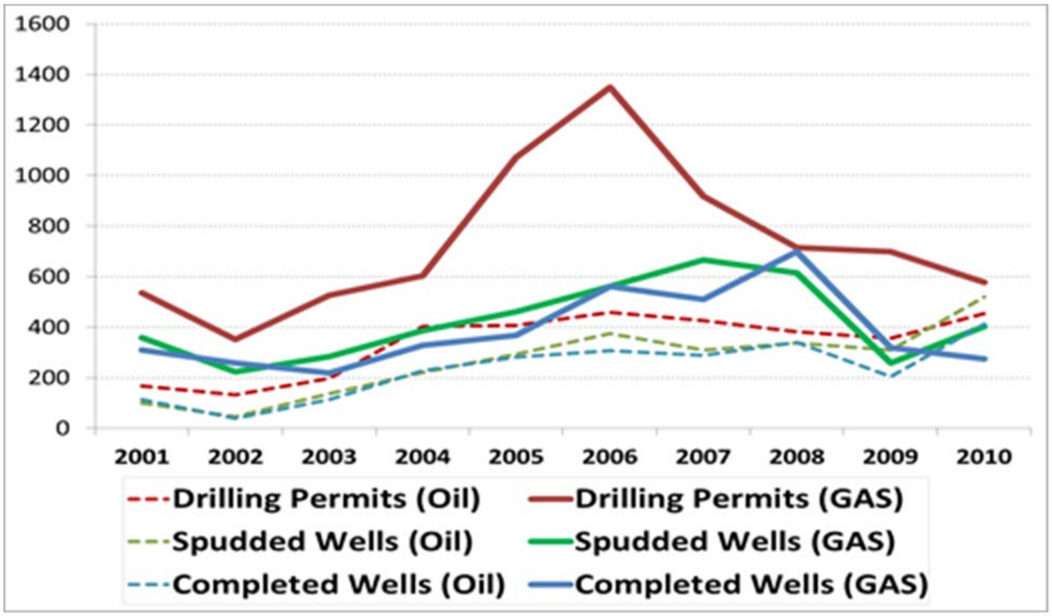


Figure 6: Trends in Oil and Gas Permits in Duchesne and Uintah Counties.
Source: Utah DOGM Permit Database.

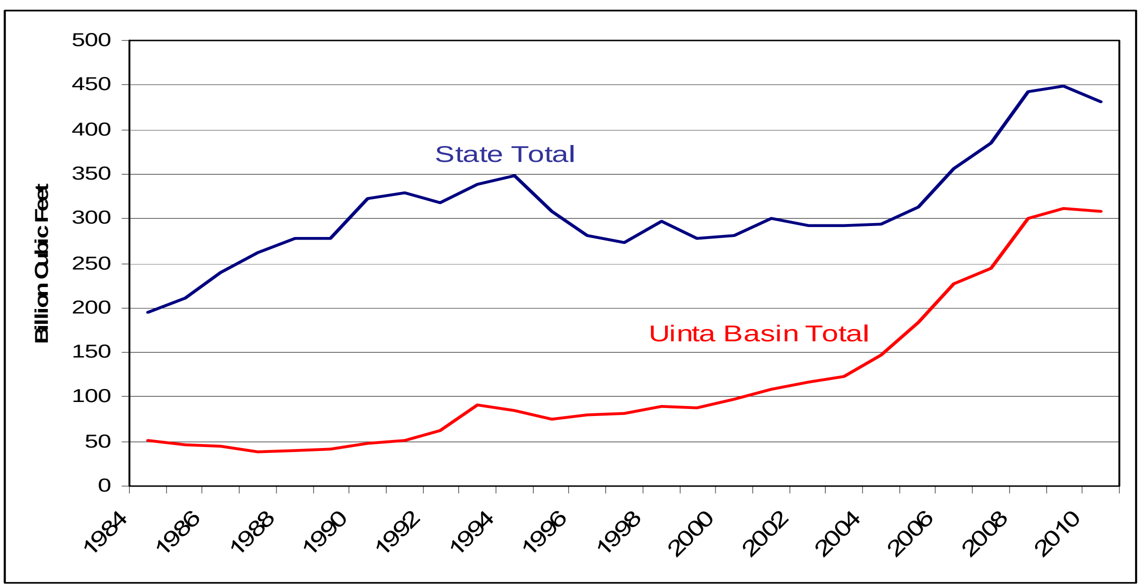


Figure 7: Natural Gas Production in the Uintah Basin and the State of Utah.
Source: Utah Department of Natural Resources, Division of Oil, Gas and Mining.

Socioeconomic Trends in the Uintah Basin

While activity has intensified in recent years, Uintah and Duchesne Counties have a long history of reliance on energy extraction to support local economic growth. As a result, trends in population have fluctuated in conjunction with boom and bust cycles in the energy sector. Between 1980 and 2009, Uintah County population grew from just over 21,000 to over 31,500 in 2009, with the majority of this growth attributable to the rapid rise in employment in the Basin during heavy exploration and production periods for both oil and natural gas.

Recent trends in direct employment in the energy sector in Uintah Basin are summarized in Figure 8. Employment rose rapidly between 2003 and 2008, with most of the jobs coming in support activities. The recent downturn in energy prices and drilling activity is reflected in a decline in total energy employment in 2009. Energy jobs provide significantly higher wages than most other job opportunities in the Uintah Basin and during the recent boom, average annual wages for drilling jobs exceeded $70,000. Those working in the support services for oil and natural gas production also saw compensation grow rapidly, reaching an average of $62,000 in 2009.

Total contributions of the energy industry to the local economy are not limited to direct employment in energy sector jobs. A recent economic study by the University of Utah (Downen et al. 2009) suggests that each direct job in the oil and gas industry creates another 1.1 jobs in indirect and induced economic activity. Taken as a whole, the direct and indirect contribution of the oil and gas industry accounted for almost 45% of all jobs and 50% of all wage income in the Uintah Basin in 2007.

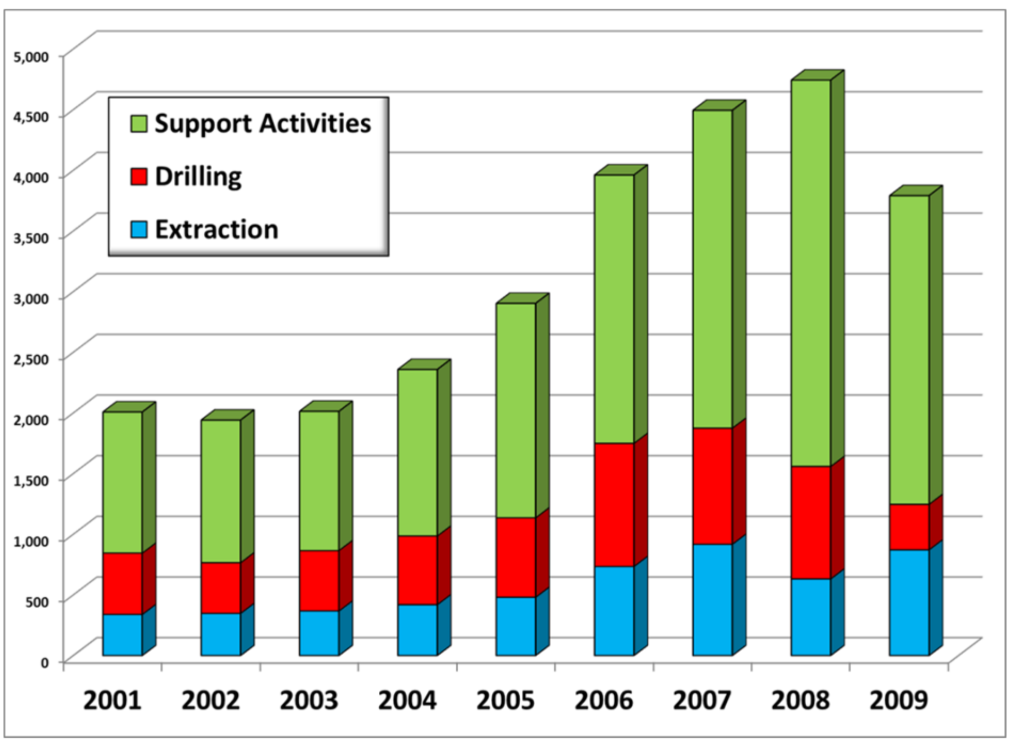


Figure 8: Employment in Oil and Natural Gas Drilling 2001 – 2009.
Source: U.S. Bureau of Labor Statistics.

National Environmental Concerns and Best Management Practices

As background to our study, we compiled information from other regions that highlighted particular areas of environmental concern and best management practices associated with natural gas exploration and production in the United States. As new techniques and technologies have allowed for greater access to previously untapped energy resources, a growing number of environmental concerns have been raised by local and national environmental groups and community leaders. This national debate has centered around issues of water quality, air quality, and the effects of energy development on wildlife. In many cases, regulatory agencies, industry leaders, and research scientists have identified technical and management strategies that can help mitigate potential environmental impacts.

National Water Quality Concerns

A key aspect of the extraction of natural gas from unconventional reserves is the use of hydraulic fracturing. The process of hydraulic fracturing involves the pumping of a fluid and sand mixture into a formation under sufficient pressure to create fractures in the rock. The result is that oil and gas flows more freely from the factures to the wellbore (EPA 2004). Since the only current alternative would be to drill multiple vertical wells in areas with low permeability, many within the energy production industry consider hydraulic fracturing to be a critical part of the process. Environmental organizations, such as the Natural Resources Defense Council (2007), have suggested that "slickwater" fractures, those which use certain types of additives, may be dangerous to human health if chemicals such as benzene migrate from the fractured zones, well bores, or fluid storage ponds into drinking water sources. The increasing public concerns over the use of hydraulic fracturing additives have prompted some development and investigation of environmentally benign fracture fluids (see Halliburton's Ultra Clean Fracturing Fluid Technology 2007).

To protect against possible contamination of groundwater aquifers, most states require operators to use cement or metal casings which extend from the ground's surface past the depth of all possible underground sources of drinking water (U.S. Department of Energy 2009). Casings provide an important barrier between freshwater zones and the fluids involved in drilling and producing from a natural gas well. The U.S. Department of Energy (2009) explains that the most important part of this process is the quality of the initial cement job. During this process it is common in a number of states for agency personnel to witness the running and cementing of casing strings, or at least require a report detailing the amounts and types of casings and cement used in the completion of the well.

A recent study conducted by the Global Water Partnership (GWP) and DOE found that the unrecovered hydraulic fracturing fluids are typically trapped via pore storage or behind healed fractures, effectively isolating the fluids from ground water (EPA 2004). The DOE (2007) goes on to suggest that implementing and following state well construction requirements, using appropriate vertical distance between the fractured zone and ground water, and ensuring the presence of vertically impermeable formations between the fracture and groundwater zones may help reduce the risk of potential drinking water contamination.

After a gas well is hydraulically fractured, the well begins to generate frac flowback and produced waters. Frac flowback is the term used to describe the injected water that returns to the surface after the fracturing procedure is completed. Produced water refers to the water present in underground hydrocarbon-bearing formations brought to the surface during crude oil or natural gas production. Operators manage and dispose of both flowback and produced waters using methods that comply with state regulatory requirements. In the Barnett, Fayetteville, Haynesville, Woodford, Antrim, and New Albany Shale regions, underground injection into saline aquifers is the preferred mode of disposal. The Safe Drinking Water Act (SDWA) regulates injection wells, and the U.S. EPA has a backlog of applied for permits for the creation and use of new injection wells. In Texas tens of thousands of licensed injection wells are in operation, but various constraints have prevented their proliferation in the Marcellus Shale and in the Intermountain West.

In some states, particularly in the arid or semi-arid West, operators have utilized open evaporation pits to dispose of flowback and produced waters. Surface pits represent potential point sources for surface and water contamination, but are typically built with multiple layers of lining to prevent contamination.

Air Quality

Natural gas exploration and development has also been linked to potentially harmful impacts on local or regional air quality. Air quality concerns include dust and particulates generated from surface disturbances and truck traffic, fugitive and engine emissions of hydrocarbons and noxious gases, and odors associated with evaporation ponds.

Drilling operations typically require the creation of significant above ground infrastructure because established roads frequently do not exist near drilling or well sites, and the impermeability of unconventional gas reserves requires tightly spaced drilling operations. These newly created roads are also needed to transport natural gas and produced waters from the wellhead to a pipeline or disposal facility. Numerous trucks are required to carry fresh water and fracture fluids that are used during drilling and hydraulic fracturing operations. Creation of drilling pads, roads, and truck traffic have been linked to dust emissions which can create visual impairments and potential health risks, particularly in arid or semi-arid areas (EPA 2009). Recommended techniques for managing road dust include the use of water or chemical suppressants, paving of roads, and building pipelines and other infrastructure to minimize the need for truck traffic.

Aside from dust and particulates, the US-EPA has been studying the potential impact from emissions of carbon dioxide, carbon monoxide, nitrogen and sulfur oxides (NO_x and SO_x) associated with diesel engines used in trucks, drilling rigs, compressors and pumping stations. Similarly, wellheads and pipelines associated with natural gas operations may release hydrocarbons and related volatile organic compounds (VOCs) to the atmosphere. A number of state and federal agencies have begun to require the use of newer, less polluting types of diesel engines, or innovative valve and pipeline systems that leak fewer hydrocarbons to the atmosphere. Efforts to electrify production fields also reduce the need for diesel engines.

Wildlife, Plants, and Habitat Concerns

As natural gas exploration has increased, the opportunity for energy activities to interact with or interrupt wildlife has been a growing public concern. The dense networks of roads and well-pads associated with unconventional natural gas exploration and development can fragment wildlife habitat, disrupt migration routes, affect breeding success, and increase predation from human-adapted predators. Similarly, threatened or endangered plant species that coexist in areas of intensive activity can be negatively impacted by natural gas production activities.

Efforts to address these concerns have involved the use of multi-well pads (which reduce surface disturbance at a landscape scale), limitations on the timing of drilling activities, mandatory setbacks from sensitive areas, and efforts to reclaim surface vegetation conditions after initial drilling activities are concluded. Multi-well pads use specialized rigs that drill multiple wells that fan out in different directions from a single pad, gradually turning to reach numerous target areas beneath the surface. Specific strategies to reduce wildlife impacts have included limiting drilling operations to specific time windows when wildlife are not present, using enclosed surface pits surrounded by chicken-proof wiring and netting, and employing the use of buried underground power and telephone lines to reduce and prevent predator perches. Other actions include limiting lights, sounds, roads, and traffic. Surveys of threatened and endangered plants have been used to identify sensitive areas around which buffers may be created to protect populations from potential impacts.

PART IV

RESULTS

The following sections present the results of our fieldwork and are based primarily on interviews with key informants from industry, state and federal government, and the local community. Our interviews were complemented by an examination of publicly available reports and documents from the state and federal agencies that are responsible for overseeing energy exploration and development in the Uintah Basin. Our research in the Uintah Basin focused on four core questions:

1) What environmental concerns are most relevant and important to local stakeholders and actors?
2) What types of innovative technical or management strategies are already being used by the natural gas industry in the Basin?
3) What factors have driven the adoption of current practices designed to reduce the environmental footprint of natural gas development?
4) What barriers or obstacles hinder more widespread use of innovative environmental practices by the energy industry in the region?

Environmental Challenges Identified by Stakeholders in the Uintah Basin

Water Quality and Supply

Potential impacts to water resources in the Basin mentioned by key informants included disposal of produced waters, the loss of contaminants from pits, possibility of contamination of both surface and ground water from spills, sediment loading in watersheds, and competition for scarce water supplies in an arid region.

The most common concerns about water quality in the Basin related to the disposal of produced waters. Industry is faced with multiple challenges related to management, treatment, and disposal of the vast quantities of water produced as a byproduct of drilling. Produced water, although it comes from natural sources deep beneath the earth, is generally very poor quality and contains many dissolved salts as well as hydrocarbons, like oil. It flows up the wells with the extracted natural gas. Oil and gas production companies in this region have primarily relied on evaporation ponds and, to a much lesser extent, injection wells to dispose of the large volumes of saline water produced as a byproduct of oil and gas extraction. Evaporation ponds were most commonly identified as a source of potential concern, particularly over the potential for ponds to leak if not properly lined or monitored. Injection of produced waters into deep formations was widely – but not uniformly -- viewed to be a more environmentally sound method, but use of this disposal method is limited by the availability of permits from the U.S. Environmental Protection Agency. Relatedly, a number of respondents believe that evaporation ponds were unsightly and generated noxious odors. As one person put it, evaporation ponds are “an eyesore, grow algae and smell, and it takes a lot of work to get the condensate or liquid hydrocarbons off the top of the water.”

A separate environmental concern relates to the use of temporary on-site storage pits for the large volumes of water used for hydrofracturing operations when wells are ‘stimulated’ to initiate flows of natural gas. Some respondents expressed concern about methods used to reclaim or remediate these temporary pits once the water has evaporated, particularly with regard to possible concentrations of contaminants in the bottom of pits. One regulator commented that it was common practice to “roll up the sheets” and either put it in a landfill or refill and re-landscape.

Just a few respondents expressed concerns about the large volumes of water required for drilling and well stimulation procedures. One industry actor acknowledged that the “allocation of water resources is an issue” but explained that economically it is safer and easier to “get rid of all produced water, and then use only fresh water for everything when it’s possible.”

Subsurface groundwater quality concerns associated with hydrofracturing techniques, although prominent in the national dialogue, did not arise as major concerns in our interviews. They were also not a focus of Environmental Impact Statements for major energy field developments in the Basin. It appears that current conservation protocols are viewed as adequate to mitigate most groundwater-related concerns – including agency requirements for casing wells and locating facilities away from areas where contamination of drinking water aquifers would be more likely to occur. Moreover, the lack of human settlement or private uses of subsurface drinking water aquifers on public lands (where most of the gas exploration and development activity occurs) results in fewer opportunities for drilling to directly affect residential wells, or garner public attention about the potential issue.

More minor concerns brought up during the interviews included surface water contamination concerns, primarily focused on potential impacts of sediment erosion and spills from pipelines on the Green and White Rivers and their tributaries. In the former case, the general view of respondents was that soil erosion is largely contained by standard best management practices for natural gas drilling pad designs required by state and federal agencies and outlined in the Bureau of Land Management’s “Gold Book” (BLM 2007). Informants mentioned several instances of surface spills of oil or produced waters from pipelines or trucks, but indicated that these tended to be spatially isolated and mostly occurred along roads or in dry or intermittent minor streams. Recent efforts to exclude drilling pads and storage facilities from the floodplains of major rivers reflect recognition that past drilling practices may have posed a threat to surface water quality during periods of high water flows.

A handful of respondents noted that growing demands for water for drilling and hydrofracturing operations by the oil and gas industry may eventually compete with traditional uses of water in this region for irrigated agriculture and urban consumption. To date, sufficient water has been made available for these purposes through the use of temporary permits and/or leasing of water rights.

Air Quality

One of the predominant concerns about energy-industry impacts on air quality in the Basin have focused on the windblown dust particles generated from drilling pad and road network surface disturbances, as well as the large volumes of heavy truck traffic on dirt roads in the region. One individual we interviewed explained that the regulatory requirements around dust were very limited despite evidence of large occurrences of dust plumes around the oil and natural gas fields. Residents expressed frustration with the effects of dust on grazing quality.

Attention has also focused on the potential air quality impacts of emissions associated with truck and large diesel engines, leaky storage tanks, compressors, pipelines, and other potential production-related sources of air pollution. State and federal agency reports discuss efforts to measure particulate matter (PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and hazardous air pollutants like benzene and formaldehyde. A few recently published Environmental Impact Statements suggest that criteria pollutants in the Basin have been below the designated threshold levels of the National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency and the Utah Department of Environmental Quality.

Meanwhile, multiple respondents indicated concerns about levels of ozone pollution in the Basin. Ozone pollution results from a chemical reaction likely driven by increased hydrocarbon releases. One respondent cited the "twenty-one incidents of ozone spikes this year. That is a dramatic increase to having had only one three years ago." Recent detections of high levels of atmospheric ozone in the winter of 2009/10 were cited by several respondents as indicators of a potentially more widespread problem associated with the aggregated impact of the large number of new wells drilled between 2003 and 2009.

With growing measurement of air quality problems, local discussions have increasingly focused on fears of possible future regulatory restrictions on industry activity. Several industry representatives indicated that air quality was becoming their largest environmental concern. As one noted, "the 100-pound giant the BLM is wrestling with now...is air quality." Regulators echoed this sentiment, saying that "air quality...will continue to be a driver" of future regulatory actions. Several respondents cited a recent collaborative effort by the BLM and EPA to expand air quality monitoring stations in the Basin (and to develop better statistical models of air quality for the region) as evidence of growing concerns about air quality issues. Ongoing air quality concerns were also reflected in efforts cited by agency and industry informants to encourage the use of more efficient and less polluting diesel engines, the electrification of well pads, and reductions in the number of trucks or volume of truck traffic.

Wildlife, Plants, and Habitat Concerns

A number of respondents discussed concerns about the impacts of energy activities on threatened and endangered plant and animal species and other important wildlife populations. Removal of vegetation during initial construction and drilling operations means that local vegetative communities are disrupted. Within the Uintah Basin, two plant species – the hookless cactus and horseshoe milkvetch -- are both protected under the federal Endangered Species Act and grow in areas within and nearby oil and natural gas developments. Concerns over their removal or the encroachment on their habitat were cited by one industry respondent who noted that "for the last five or six years, one of our bigger issues has been surface disturbance." These concerns have led to specific protective buffer provisions being included in all recently issued exploration and development permits.

In addition to sensitive plant species, big game (like deer and elk), raptors, upland game birds, migratory birds, and species like the black-footed ferret, bald eagle, and greater sage-grouse may be located around current or proposed drilling projects. According to our respondents, energy activities have the potential to impact these animal species through disruption of local vegetative communities or via nuisance impacts associated with drilling activities and truck traffic during critical breeding or overwintering periods. A critical impact of concern for wildlife is the impact of surface disturbance on wildlife habitat. Despite growing efforts to reclaim disturbed drilling sites and roads, vegetative communities in this arid region take significant time to recover: around 30-40 years for local sagebrush vegetation and potentially 75-150 years for pinyon-juniper woodlands (BLM 2003). Mitigation efforts such as time-restricted drilling and the greater use of multi-well pads were discussed by several informants as a means to avoid displacement of wildlife breeding grounds and fragmentation of habitat.

Along with the potential for disruption of habitat and mating activity, some forms of energy activities can post direct threats to wildlife species. Several respondents discussed the potential for collisions with vehicles and heavy equipment. Others mentioned that migratory birds can be killed if they land in reserve pits. Industry representatives indicated that waterfowl and bird issues have been a major focus for their preventative practices. As one put it, "it is very much in our interest to not have waterfowl issues." These comments were echoed by state and federal representatives. One industry informant explained that "we work with Fish and Wildlife [Service] to try and make sure ponds are netted... (migratory) birds dying in the ponds is a big, big deal." The possibility of a future listing of greater sage-grouse as a federal threatened or endangered species drew comments from several respondents who felt that a listing would require significant changes in location options and operational practices in the industry. Meanwhile, accidental spills were mentioned by one respondent as a potential threat to aquatic species, including a number of federally-listed Colorado River fish species.

Examples of Environmental Innovation in the Uintah Basin Energy Industry

The previous section detailed the primary environmental concerns related to natural gas industry activities in the Uintah Basin that were expressed in our interviews with local key informants. In this section, we summarize information from our interviews and secondary documents that illustrate the kinds of innovations that are already being used in the Basin to address environmental concerns associated with natural gas exploration and production activities.

Water Protection and Disposal of Water

As noted above, the issue of produced water management arose in most of the interviews we conducted. Produced water first becomes a potential environmental challenge as it comes up the well. Preventing this flow from contaminating near-surface drinking water aquifers is typically done through the use of sealed well casings, a practice that is heavily regulated by state and federal agencies. Multiple industry representatives discussed the importance of using steel casings and sealing them with a bentonite and concrete mix. As one industry representative noted, "casings need to be good. The technology continues to get better, and that is what protects our water." This was confirmed by regulatory officials who agreed that the industry does "an awful lot of work to not have contamination. They know it's a bad thing and they work really hard to not do it." Government oversight of methods used in 'downhole' operations appears to be quite extensive, and all companies are required to case wells appropriately to avoid groundwater contamination. A few respondents noted that older abandoned wells in the Basin may not have been constructed using modern best practices. Efforts to 'restimulate' these wells using modern hydrofracturing techniques may require new environmental management strategies.

Once at the surface, a number of environmental management practices are used to prevent produced waters from contaminating surface water resources. As indicated above, two primary methods of produced water disposal are used in the Basin. The most common is to truck water from the well sites to evaporation ponds. Some industry respondents discussed the use of specific techniques for managing their evaporation ponds to minimize the potential for environmental impacts. Some utilize pretreatment facilities that extract valuable hydrocarbons and potentially harmful pollutants before releasing produced waters into evaporation ponds. Some use monitoring systems to detect and fix leaks that could contaminate groundwater. One interviewee explained that "[our] ponds have multiple layers, leak detection, and other preventative measures. If there's a leak we have to drain the pond to fix it and... that is a pain in the neck." This same informant discussed how making sure they take every step possible to prevent leaks makes it easier on them and the environment.

The preferred method for handling produced waters is re-injection into deep geologic formations. While respondents identified this technique as their preferred option, only four injection wells were currently permitted and operating in the Basin at the time of our study. Transportation of produced waters to reinjection wells is almost always done by truck, though one industry informant discussed a project whereby pipelines were used to connect well pad sites to injection wells. This project reduced truck traffic and the footprint of their injection facilities, and also helped curtail the likelihood of ground and surface water contamination. If the EPA and State agencies that permit injection wells determine that this practice is environmentally benign, then we would expect more widespread use of this water management technique.

A number of respondents mentioned that there are several private companies seeking to develop on-site water treatment units that would allow the extraction of salts, hydrocarbons, and other contaminants from produced waters at the well-pad, leaving water that meets water quality standards that would allow its use for other purposes. While experimental units have been developed and are being deployed in the Basin, most respondents felt that these were at present impractical or uneconomical for widespread use.

A final environmental strategy designed to protect water quality addresses the potential for contamination associated with temporary fluid storage pits used during well drilling and hydrofracturing operations. To minimize the number of such facilities, a few operators in the Basin are exploring the use of centralized water storage facilities from which water can be piped to and from individual drilling pads (as opposed to having multiple containers present at each well pad). At least one company has begun reusing the water from its hydraulic fracturing processes, with one informant noting how "we take the water, clean it up, and then use it on other pads. This reduces the need for fresh water, our truck traffic, and keeps dust down."

Air Quality

A number of innovations are used to minimize impacts on air quality. Dust reduction is addressed through a variety of mechanisms that reduce truck traffic. Specifically, the use of more pipelines and closed-loop systems had the effect of reducing the need to haul water and created a situation where "dust is not as bad as it was three years ago." Dust is also reduced by applying water or magnesium chloride to dirt roads, or actually paving the main roads that are traveled most frequently. One company innovation came about from a recognized need to improve well monitoring. Originally trucks inspected each well site on a rotating basis, but the installation of computer aided monitors at the wells eliminated the need for frequent truck visits and resulted in reduced traffic and dust disturbances. Efforts to reclaim drilling pads by reestablishing vegetation also provide dust minimization benefits.

Concerns about air quality have also stimulated efforts to reduce engine emissions. Aside from strategies to reduce vehicle traffic (mentioned above), air quality management strategies in the Basin include the growing use of natural gas to run compressor engines in lieu of diesel engines, and incorporation of more efficient engines into exploration and production equipment. The uses of tier 2 engines and motors that can run off of their produced natural gas were all mentioned as a means of trying to reduce CO_2 emissions. Installing electric power lines can also reduce the need for diesel motors on drilling rigs.

A variety of approaches to detect and reduce fugitive emissions from pipelines, compressors, and storage tank vents have been used to address air quality concerns. Some companies have used combustors on storage tanks to burn off fugitive emissions. In some cases, blasts of natural gas have been used to help start compressor engines, but result in a loss of all the gas used. As one person explained, "Every time they needed to open a valve or something, someone would throw a switch... and gas would make the valve turn... but be exhausted into the air." In response, some companies have started using pneumatic control technologies that are "low-bleed" or "no-bleed" systems so that gas is no longer continuously vented into the air. A handful indicated they also started reclaiming some of this vented gas, and can run compressors using gas when electricity is not available. Regulatory staff pointed out that most companies are doing "a better job of taking vents and rechanneling them back into the engine as fuel." Other comments centered on the advances made by engine manufacturers to include air-fuel controllers as a standard, and noted that overall the industry has done a better job capturing emissions.

Surface Disturbance

Many informants discussed how industry is actively addressing habitat fragmentation and surface disturbance concerns. Reclamation, erosion control, strategic well-pad siting, and multi-well pads all help address concerns about surface disturbance.

Industry informants explained that "reclamation is important... [the] critical thing is to do it fast." In some cases, reclamation begins as soon as drilling is finished. Restoration often involves recontouring, loosening packed soil, seeding, and managing weeds, among other tasks. The push to rehabilitate as soon as possible allows for companies to "take advantage of the soil in the area... since it still has moisture and seed banks." In addition, some companies are using snow fences to trap water, applying mulch to help with the soil moisture, and using shot rock to create landscape diversity and microhabitats. One respondent explained, "we call these 'advanced reclamation' since they are not required by agency regulations." Others explained that while some reclamations may never be as good as what was originally there, it is still important to reclaim everything. As one informant noted, "About 90 percent of what we use is federal ground, meaning other people use it too. We reclaim because someone else's livelihood depends on that grass."

In addition to reclamation, most industry actors have been required by state and federal agencies to incorporate techniques to help prevent or slow soil erosion. Many of these techniques are outlined in the BLM's 'Gold Book' (BLM 2007) which offers guidelines on standard road and pad construction.

The combination of multiple wells on a single pad is perhaps the most direct way to reduce the footprint of energy activities. Regulators like them because multi-well pads reduce surface disturbances and the need to provide an expansive utility infrastructure. Industry informants expressed similar sentiments, with one explaining how "everyone is mostly switching over... to six to eight wells per pad... at this point [it's] almost an industry standard."

At the same time, a handful of observers suggested that multi-well pads were still relatively rare in the Basin, and highlighted potential problems associated with directional drilling and multi-well pads, including concerns about losing production efficiency in non-vertical sections of wells, difficulties in loading and unloading, and safety concerns due to crowded pads. Nevertheless, most interviewees recognized that multi-well technologies “for the most part are pretty good and have a lot of upside. It’s much easier to move a rig ten feet instead of three miles.”

Some companies are increasingly interested in the reuse of old well pads, particularly since it enables additional drilling with the potential to avoid new surface disturbance. One regulatory official pointed out that new directional techniques have been used such that “in some places all wells are drilled from existing pads so the footprint doesn’t increase.” In some cases, using old pads provides new opportunities to reach reserves that previously were inaccessible, particularly when multiple wells can be drilled from an old site.

Drivers and Barriers to Change

The central focus of our study was to better understand the factors that are both driving and constraining the use of practices that could reduce the environmental footprint of the energy industry in the region. The responses we heard in the Basin underscore the complexities faced by both industry and regulators with regard to environmental concerns. The following sections summarize the major examples of drivers and barriers reported by key informants in our study.

Drivers of Change

The methods used to explore and develop natural gas resources in the Uintah Basin have changed constantly over the last few decades, including many innovations designed to reduce environmental impacts. In order to understand how changes occur in the energy industry, we asked respondents to identify the specific factors that have encouraged the more widespread use of various kinds of environmentally-oriented practices in this region. Their responses were diverse, but clustered around seven major categories: regulations, technological change, economics, corporate culture, feelings of responsibility to the community, public relations, and a desire to avoid legal battles. In the following section we provide examples and explanations of the kinds of 'drivers' mentioned in each category.

Regulatory Atmosphere

Not surprisingly, many of the specific environmental practices adopted by the energy industry have come about in part because of state or federal regulatory requirements. Agency employees provided numerous examples where specific types of technologies were required to be used before issuing new drilling permits. Most industry respondents were frank in noting that the industry will always do what they have to meet standards set by the state and federal government. In this sense, regulations set the 'floor' for environmental behavior. One agency staffer noted that while "it's clear that some good companies come up with ideas on their own, without regulations... they wouldn't do it if they didn't have to." Another agency informant explained that "it's because of self-preservation. They want their permits... they aren't out here to reclaim the land, they're out here to make money for their shareholders." One industry informant explained how they felt change happens: "bad things happen, regulations occur, and companies figure out how to deal with those regulations."

Some of the clearest examples of regulation-led environmental behavior lie in the area of endangered and threatened plants and animal species. Because of the rigidity of the rules under the Endangered Species Act (ESA), regulatory agencies have placed clear timing restrictions on drilling activity and strict and inflexible setback or surface occupancy requirements, such as for a particular cactus species. As one regulator noted in our interview, the "plant issue is contentious. Operators don't like it but they know they have to do it." Industry informants pointed out how companies, in response to strict regulations, now spend more time exploring the potential impacts on wildlife, and may even support research or provide data to agencies to ensure that their ESA-mandated practices will have their desired impacts.

Similarly, industry respondents felt that many of their innovative approaches to managing produced waters came directly from regulators pushing for their use. Natural gas developers are required to identify any aquifers they may go through, and are then required to case their wells to protect them. These respondents believed that specific innovations to deal with produced water came from the need to comply with the US Clean Water Act.

While environmental regulations are obviously a significant driver, the links between regulations and the use of concrete environmental innovations can be complex. This is partly because many regulations are written to require attention to various potential environmental impacts, but allow significant flexibility in how these end points are met. A good example is the environmental review required under the federal National Environmental Policy Act (NEPA). Industry respondents often pointed to NEPA as a major driver of environmental behavior. Said one, "NEPA is a big driver. When we fail to [address NEPA requirements], we are subject to fines." Yet while NEPA requires government agencies to assess and address the potential environmental impacts of major projects on federal lands, the law does not prescribe specific steps that must be taken to avoid or mitigate serious impacts.

Most respondents felt that this flexibility was important because of the differences in scale and underlying biophysical conditions associated with various proposed projects. A lot of discussion appears to take place around what practices are good, feasible, or cost effective for particular locations, but agencies appear to try to work with industry, keeping in mind that not all technologies fit all situations. For example, geologic differences between gas fields can influence which technologies are cost effective or even feasible given current technology.

Even when regulations do not prescribe exact practices or procedures, the fact that federal and state governments own most of the land on which drilling takes place creates a situation where industry actors seek to maintain a good relationship with regulatory agencies. In addition, industry informants expressed that in many ways the oil and gas industry has begun policing itself in order to speed-up the regulatory process and maintain positive relationships with regulators. A representative of a regulatory agency suggested that "about the only time I've seen them willingly adopt conservation measures... [is] if it improves or keeps good relations with an enforcement agency."

According to many of the people we spoke with, companies working hard to avoid negative environmental impacts in order to minimize future regulatory restrictions. Specifically, some industry respondents indicated that their companies had been more proactive in developing environmental innovations *in anticipation* of future regulatory requirements, figuring that it would save money and avoid bottlenecks in production if they stayed ahead of the regulatory standards. One indicated that they wanted to "meet or beat the regulatory standards" to better position themselves for future changes in regulation. In response to air quality, regulators who we interviewed indicated that the industry "sees the writing on the wall. If they want to develop these fields as densely and concentrated as they want, they're going to have to think about emissions or we're going to have air quality issues."

Stories about the role of governmental environmental regulatory oversight also highlighted the ways in which the use of specific environmental practices may depend on negotiations between agencies and industry actors and long-term patterns of environmentally responsible behavior by particular companies. It is clear that novel environmental practices that at one time were 'recommended' or optional can become 'mandatory' or standard practices years down the road. One regulatory official discussed how a company was given a set of stipulations to meet once it was discovered that dust would be an issue for nearby petroglyphs, but then allowed them to figure out the best way to meet these requirements. "The company had to figure out how to better do it or risk getting restrictions placed on them." Another regulator explained how a company may be invited to provide input into how best to address a certain problem:

> *"[They] come in with a first cut proposal, and if looks reasonable then the permitting authority will say OK. But, if they bring in something we determine is inadequate then we'll tell them why, and explain that we're aware of certain technologies that they should maybe consider. We don't dictate the technology, but we do dictate that someone has to do an evaluation and come up with what they consider the best controls, so there is some flexibility."*

Other agency respondents talked about working in partnership with industry in order to encourage innovation and meet environmental objectives in advance of formal regulations. Said one, "we try to get innovative technologies from the R&D status to a fully mature and ready to be used everywhere status." Similarly, innovations surrounding management of surface water ponds emerged as industry actors came to believe the EPA was not going to give them injection well permits.

Good working relationships between regulatory agencies and industry were also cited as important to identifying win-win situations, such as helping both agencies and industry improve air quality and operational efficiencies. For example, natural gas losses, intentional or otherwise, both cause a loss in otherwise marketable product and create an environmental concern. Emissions reduction technology and opportunities for emission reclamation can remedy both problems.

Engineering and Technology

Progress in reducing the environmental footprint from energy development also hinges on the development and availability of appropriate technologies and engineering techniques. This is particularly true if new technology can be shown to both improve environmental quality and efficiency of industry processes.

Recent growth in the use of multi-well pads and increasingly distant pad spacing were linked by several respondents to advancements in directional drilling technology that provided environmental benefits while also making it easier to reach resources that might otherwise be inaccessible with traditional vertical drills due to difficult terrain. Noted one respondent, "Everything is either in the bottom of a wash or the top of a ridge; we've pretty much used all the flat spots." Improvements in the technology for casing wells were also mentioned as important because they enhanced the ability of the industry to protect aquifers and fresh water sources in the Basin. Regarding innovations in air quality, one agency informant asserted that "the technology has to evolve, at some point the tech was maybe not there, so operators were resistant to using it." At the same time, they felt that as new diesel engines, compressor valves, and other forms of technology improved, businesses have been more willing to implement and use them.

Economics

Of course, technical feasibility alone is unlikely to ensure adoption of new environmental practices. All respondents noted that economic considerations help explain the timing, pace, and direction of environmental innovation in the Basin.

Broadly speaking, energy commodity prices were linked to the level of interest in and active development and implementation of new environmentally-oriented practices. During periods when energy commodity prices are high, companies have been more willing and able to pay the extra costs associated with some environmental innovations. As one industry representative put it, "if the price of oil and gas is high enough, we'll jump through any hoop." Regulatory agency informants expressed similar sentiments: "as long as there's money there, new technologies will come along." Indeed, the relatively high natural gas prices throughout the mid-2000s provided liquidity and economic justification for the use of more extensive efforts to minimize environmental impacts in the Basin. Conversely, recent market downturns have generated stronger pushback by industry against rigid environmental regulations due to perceptions that these requirements are prohibitively expensive and might slow the pace of new exploration and resource development.

The costs associated with many environmental practices may also hinge on a company's cumulative experience with the new innovations. Greater familiarity and adoption at a larger scale were often associated with reduced expenses. Respondents noted that some of the technologies that industry players originally viewed as cost prohibitive turned out to save money in practice. One industry informant discussed how the smaller footprint associated with multi-well pads proved to be better, not just because of the reduced surface disturbance, but because it can save money. As they explained,

> *"We thought [multi-well pads] were going to break us... but we got going on it and saved money in areas we weren't even considering. Don't have to move the rig every time you go to another pad and with the new style rigs there is no need to relay pipe. Just pick it up and drop it in where it needs to be, either 10 or 20 feet apart."*

New technology (such as multi-well pads and improved directional drilling equipment) can also change the economics of accessing reserves previously thought to be unrecoverable or impractical while reducing the environmental footprint of drilling activity."

Corporate Culture

Changes in leadership and the corporate culture within some energy companies may help explain adoption of many of the environmental innovations in the Basin. Agency informants indicated that a handful of companies are more motivated to be environmentally friendly because "they have more of a vision of where [things] are going without being told or led." They felt that the "best innovators at the end of the day are because you've got a *leader* somewhere that's innovative, and a thinker, willing to take a risk." This kind of leader is viewed as key because having the "right person in the position... who's thinking ahead" creates an atmosphere where new technologies and techniques are significantly more likely to be implemented. As evidence of changes in leadership, some companies now invite regulators to company planning meetings, explaining that "[Environmentally friendly] is our ethic now, we want to hear what we should do." These sentiments then trickle down to employees in the field.

Interviewees speculated on reasons why some corporate cultures value environmental stewardship more highly than others, noting that in industry, environmental changes "seem to be a personal choice with some companies going the full extent to protect the environment." Several people we spoke with indicated that the retirement of an older generation of oil and gas company leaders has allowed a more "environmentally adept and concerned" new generation to move into positions of management. "Their corporate ethic... I think it comes from the newer generation who is just more environmentally aware."

Community Responsibility

Several industry informants expressed feelings of personal or corporate responsibility to local communities in driving their adoption of as a major reason for taking extra steps to protect the environment. One interviewee relayed a story about how a handful of residents living near an evaporation pond began to smell strong odors. These residents "were very diligent in tracking down the source of the odors and became credible even in the eyes of the industry." As a result, the involved industry actors voluntarily began mixing in dissolved oxygen and bacteria that eat hydrocarbons into the evaporating water as a method of minimizing negative impacts on these local residents.

Industry practices may also reflect an appreciation that there are other uses of the public and private lands on which natural gas development takes place. In reference to reclamation processes, one agency employee claimed, "we reclaim because someone else's livelihood depends on that grass. We don't want to be the bad guy." Others felt that simply living in the community and engaging in local hobbies and outdoor activities created a sense of community responsibility. In particular, many of those working in the energy industry participate in outdoor recreation and hunting. As one informant noted, "People that love the outdoors would be pissed if you're out there frickin trashing it... you don't get people who love the outdoors going out and trashing it."

Public Image

A number of informants discussed the role of public relations in driving the use of environmental innovations in the Basin. One industry respondent mentioned concern about their company's public image as a major factor in their use of techniques to reduce visual impacts and to voluntarily go beyond regulatory requirements in reclaiming land. Another noted that this is related to the emergence of a "green ethic that's grown within the U.S. over the last 40 years. We have no desire to rape and pillage."

Some felt that the attention drawn by outside environmental groups to industry actions helped make the public more aware of their activities, which places pressure on agencies and industry actors to find a better way to do things. Regulators explained that innovations tend to come from the largest companies because they are more likely to be in the public eye and to care about their image. As one informant put it "big companies are more likely to try new things and publicize it for the PR value of looking greener." Others felt that the nature of the areas the industry was operating in probably had a lot to do with the increased focus on public relations. Citing one recent company decision to voluntarily agree to stringent environmental constraints on developing a proposed new gas field, the respondent explained that the area is very well known and "because they are drilling in such a sensitive area, an awareness has been forced on them, probably more than they would want."

One local informant described how the industry tries to be conscious of things on the whole because "they'd rather it not become an issue. They are facing so much opposition that I think they try and avoid creating more issues." An agency employee pointed out that "spills are costly, bad PR is costly. It's better to be a green company now, politically and every other way." An industry respondent agreed that "energy companies must understand that what other people say about you is what your brand is." Another noted that "most people who run these companies aren't there to destroy things. If they did, there would be a media frenzy... no one wants that….you do not want to be tried in the media."

Lawsuits

While not mentioned as frequently, legal rulings (or a preemptive desire to avoid legal battles) can also drive the use of environmental innovations in this region. Respondents described how environmental groups, like the Southern Utah Wilderness Alliance (SUWA), regularly use lawsuits as a means of forcing agencies to adopt higher environmental standards. One regulator suggested that "if a practice is going to be changed, it's going to happen because SUWA took the BLM to court and the courts ruled that yeah, you need to do this. Then it becomes a regulation."

Industry informants described the varying ways lawsuits and their avoidance played a role in their permitting process. In one case, a particular company included SUWA in discussions early in their planning stages and negotiated concessions before they applied for new drilling permits. This prevented a costly and time-consuming appeal of the agency's decision to approve the development proposal. As a result, this company regularly tries to bring environmental group leaders "up to our field to show them around. This company has nothing to hide. We try and work with them."

Barriers to Implementation of Environmentally Friendly Practices

While the use of some practices to reduce the footprint of the energy industry is becoming more common, it was clear from our interviews that there are many possible practices that are not yet used in the Basin and others have only been adopted by one or two companies. A key objective of this project was to identify the obstacles that prevent the more widespread use of environmentally friendly practices. In our analysis of the respondents' comments, we identified three major categories of barriers to adoption: the complex local regulatory context; adverse economic conditions; and engineering or technological limitations.

Regulatory Context

While state and federal regulations are seen by many as important drivers of new environmental practices, the complexity of regulatory authority and overlapping jurisdictions in the Uintah Basin also create disincentives to adoption of other innovative approaches. In our interviews, problems related to ambiguous or conflicting regulatory jurisdiction and a perceived lack of consistent regulatory implementation frustrated industry actors, regulatory agency staff, and local government officials alike.

As noted earlier, the Uintah Basin has a diverse mix of landownership, with significant portions owned by federal agencies (53%), tribal governments (16%), the Utah state government (10%), and private landowners (21%). The complexity is increased because ownership of subsurface mineral rights is often different from the ownership of the land's surface. A large proportion of non-federal land has federal mineral rights that require companies to engage the federal environmental review process while at the same time negotiating with non-federal landowners for surface access. As the individuals we interviewed explained, the complexity of jurisdiction and ownership makes it unusually difficult to understand and negotiate environmental regulations in the area.

A particularly thorny issue in the Uintah Basin is the complex relationship between state and federal agencies and tribal authorities. On official tribal reservations, local tribal governments have some direct authority to establish environmental rules for activities that take place on tribal trust property. In the case of the Uintah-Ouray reservation, some aspects of environmental oversight responsibilities lie with the tribal Energy and Minerals Department, while a separate tribal Business Committee approves the formal contracts with companies to lease mineral rights and approve energy development projects. Meanwhile, the Bureau of Indian Affairs (BIA) (a separate federal agency) retains some statutory authority as the federal trustee designated to protect tribal natural resources and assets. The BIA must approve lease agreements negotiated by the tribe[3] and is involved in the process of reviewing permit applications to explore and develop energy resources (though final approval of permits on Indian trust leases is granted by BLM, after receiving concurrence from the BIA). In addition, where tribal trust lands are underlain by federally-owned mineral rights, the BLM is directly involved in the permitting process as the owner of the mineral rights. Recent agreements have

[3] Except on special property called the "Naval Oil Shale area" that was returned to the Tribe as trust fee lands.

shifted some of the BIA's authority and role to tribal government officials, in which case the BLM can be required to obtain the concurrence of the tribal authority to approve permit applications. Environmental review by the BLM and BIA is not only governed by specific agency rules and policies relating to development of federal and Indian trust minerals, but also by the broader National Environmental Policy Act (NEPA) requirements that mandate the assessment of many types of possible environmental impacts, require a formal evaluation of management alternatives, and often involves the use of systematic public input processes.

Another layer of complexity is the fact that the federal Environmental Protection Agency (EPA) – which has no local office in the Basin – is the lead agency on issues of air and water quality protection on tribal lands. However, in some cases, local agencies are given some authority to handle the duties on behalf of the lead agency, handling monitoring or emergency response efforts, but may not have authority in situations such as deciding whether to fine a company for violations. Finally, because of complex local legal rulings, the lead EPA authority on water and air issues in the Basin extends into a larger geographic area (called 'Indian Country') that reflects the original boundaries of tribal lands in the early 20th century that existed before large swaths of land were privatized through sale to non-tribal settlers.

Given this complexity, industry informants expressed frustration over what they perceived as particularly unclear lines of regulatory authority on tribal lands and in Indian Country. One interviewee explained that when they moved from operating on federal to tribal lands, there was considerable debate and disagreement about which state, federal, or tribal agencies would be involved in reviewing and approving their applications for exploration and drilling. The frustration was not limited to industry players, however. State regulators recognized that addressing accidents or spills that occurred within or along the boundaries of tribal lands (e.g., in Indian Country) were particularly muddled. In one example, an informant felt that the scale of a particular spill merited a notice of violation and a fine, but the unique aspects of tribal authority meant that "this would be like suing Spain. We can't even fine them." As a result, regions where regulatory authority is uncertain or complex may become a lower priority for allocating scarce time and staff resources in some state and federal agencies. This has led to problems for some tribal representatives interested in enforcing stronger environmental standards, who indicated that the "biggest problem with feds is inconsistency. Getting the BLM to come down hard on a company is like pulling teeth."

To further complicate matters, as one regulator described, "there are something like twelve agencies intermixed here." This situation has made it difficult for another respondent "to figure out what agency is in charge... someone must have the rules and regs on who enforces [what], but we haven't seen it." These concerns appeared to be a major concern for both industry and regulators. One regulatory informant noted that, although "operators would like a one-stop shop... that's not the reality of the situation and they have to answer to multiple masters." Federal regulators commented on how the fractured jurisdictional situation meant that they could only regulate what they were given authority over, and there was little opportunity for coordinating the efforts of multiple agencies.

Aside from ambiguous agency authority, industry informants frequently complained about a perceived lack of consistent implementation of regulations. One felt that "so much of what the BLM does is discretionary, and there really aren't that many regulations about what needs to be done environmentally." The specific practices required by both state and federal agencies of different energy companies are often negotiated through the planning and permitting process. While this may make sense (since different projects pose different threats and require different solutions), it produces situations where competing companies feel that they are being treated differently. One industry informant's comments represent the frustration expressed in several of our interviews:

> *"One of the huge problems we have in Utah is we can't get [Agency X] to write down the stinking regulations. It's all verbal... from our perspective, we don't have a problem dealing with meeting a certain regulation, so long as my competition... has to jump through the same hoops."*

Other informants discussed how this moving regulatory target made it difficult to plan for the future. As one put it, "regulatory uncertainty is scary. It's no fun to go to an agency... and have them say they don't know if they can approve that or not."

In at least one instance, changes in regulatory approaches are related to growing concerns about the aggregate impact of energy industry activities (as opposed to the incremental impacts of individual wells or smaller projects). Regulators explained that rapid increases in exploration and production activity have forced them to rethink their assessment techniques. Said one, "the more gas we produce, the more water comes with it. We've had all these rules and regulations that served us well until... volumes overwhelmed our rules." In general, the rapid growth in applications for permits and attempts to get approval for innovative (yet unconventional) approaches to managing environmental challenges has also overwhelmed regulatory agency staff in recent years. With respect to constraints on the expanded the use of injection wells to dispose of produced waters (considered more environmentally friendly than using evaporation ponds), another respondent explained that "more than anything the EPA delay was just a backlog due to being understaffed in Denver."

While the ambiguity of regulatory expectations produced universal frustration, most respondents were not clear about what approach might work better. One agency informant believed that setting performance standards or goals that allowed industry to be innovative in designing approaches will be the most technically and economically efficient solution. However, the use of flexible performance standards means that industries proposing to use particular behaviors or technologies will not know in advance if their efforts have met regulatory expectations.

Economics

Much as strong energy prices facilitated adoption of environmentally-oriented practices, weak macro-economic conditions were cited as a barrier to the increased use of technologies to reduce the environmental impact of drilling. This is due to the combination of recent price declines in the natural gas sector, as well as the fact that producers in the Basin receive lower prices than other regions in the U.S. (due to limited pipeline infrastructure to deliver natural gas to major urban markets, which are also more distant from Utah than other natural gas sources). Low prices for natural gas (overall and relative to oil) discourage investment in new technology for natural gas exploration. As one industry informant put it, now that "the money is not in natural gas, most of our [company's] resources are now going to the Dakotas for oil." Another informant noted that "directional drilling is only affordable at certain gas prices. The technology is there, but utilization is cost dependent." The general message was that as the price of natural gas goes up, the ability to implement better technologies becomes more affordable. Industry informants discussed how the economic downturn in natural gas forced a number of the companies in the Basin to cease drilling and exploration activities. One agency respondent claimed the use of optional environmentally-friendly technologies "depends, of course, on the price of oil and gas." In other words, a poor economy is a bad time to adopt what many view as practices that involve high costs.

Most specific instances of 'non-adoption' were explained by perceptions that particular environmental practices were not yet economically viable. Some pointed to the importance of scale economies and the fact that some new technologies are too expensive or inappropriate for smaller operators in the region. They felt that larger companies "know what they've got, and it's easier to do an eight well pad in an established field." Others discussed how many local service companies have already invested in older technology and cannot afford to jettison those sunk investments. They also have trouble raising capital for purchasing the expensive cutting edge drilling rigs that are required for directional drilling or multi-well pads. For these companies, until better and cheaper exploration equipment comes out, "going straight down is easier."

In one case, an agency respondent noted that disposal of produced waters could be technically solved through the use of available onsite water treatment technology, but that the cost for such systems is prohibitive. The industry would "all switch tomorrow if there were an economic way." In a discussion about the recycling of water another respondent suggested that "until there is an economic benefit, it will be more on the fringe." Industry informants agreed, with one detailing how the biggest barrier to improved water management was always money. Despite preferences of regulatory agencies for the use of closed-loop systems (instead of evaporation pits or injection wells), the cheaper cost of using evaporation ponds, even when employing leak prevention and detection, was significant enough to prevent companies from recycling their drilling and hydrofracturing water. As one industry respondent related, while "there are areas where [water recycling] gets used... it adds a lot to the cost of drilling a well."

In discussions about directional drilling, most of our informants recognized that from a surface management standpoint, multi-well pads offered many advantages. The problem, as one informant explained, is that "for operators it has to be economics. Drilling superintendents would rather do vertical because it's easier" and better able to recover more gas than angled wells. They felt that smaller companies have a much harder time adopting and disseminating many of the new drilling techniques and technologies. As one regulatory informant illustrated, the costs of these practices manifest themselves in many ways, such as training employees in the use of new equipment. Regulators may ask the industry to engage in new practices, but they often find the industry response to be, "who will train our guys?"

In terms of air quality issues, agency informants believed that progress on adopting new environmentally-friendly approaches will depend on financial considerations. One explained that "even though you can make money by reducing emissions, [industry] has to demonstrate a rate of return for these projects, and they compete against one another for money." In air quality discussions as well as conversations regarding retrofitting or restimulating older wells using modern hydrofracturing techniques (which could reduce the footprint of new exploration activities), respondents explained that drilling new wells had a much higher rate of return than retrofitting equipment. The problem, as they saw it, was that the capital investment required for retrofitted wells in the Basin had a lower rate of return relative to improvements in efficiency than either the industry and regulators had hoped to see.

Engineering and Technology

Engineering and technology barriers came up least frequently in the interviews, but a handful of informants did identify a few key problems. One regulatory informant asserted that the biggest potential for environmental improvements in the Basin lies in the expanded reuse and recycling of water by the energy industry. They discussed types of new technologies they were hearing and reading about from other regions, but explained that these technologies were not well adapted to production conditions in the area and were either impractical or not cost-effective in this Basin. As another informant put it, "the holy grail would be small portable units that you could use to treat the water onsite, and then discharge it into a nearby stream. Whoever invents that would be a billionaire."

Other limitations had more to do with the current state of drilling technology. Several informants thought local geologic formations were not appropriate for directional or horizontal drilling technologies. One argued that to be practical, "with today's technology, [you] have to be going vertical to hit where you want to drill." They explained that directional wells lose out on production potential through the zones of sandstone where they not drilling vertically. Another informant made the link between geology and economics more explicit by claiming that the "topography and underground geology will be what drives costs." Several industry informants claimed that vertical drilling was required in much of this region due to the presence of corrosive salts and large geologic holes, and to ensure there was "any hope of hitting the target resource."

The specific geologic formations that characterize the Uintah Basin were cited by respondents as one of the reasons injection wells are not more widely used. The absence of proven suitable geologic formations in the area left them with "no guarantee that the well will take water for long." Others explained that while "the public perception is that you ought to make more injection wells... the geology just isn't right." Regulatory informants expressed similar feelings stating "there aren't that many zones geologically that can take a lot of water."

A final geologic or technical concern reflects the uneven, steep topography of this region. A handful of regulators and industry informants explained that options for consolidated multi-well pads and centralized hydraulic fracturing operations may be limited in areas that lack sufficient areas of flat land.

PART IV

IMPLICATIONS AND CONCLUSIONS

As noted at the outset of this report, our research project was designed to identify opportunities and barriers to reducing the environmental footprint of natural gas extraction in the Uintah Basin. The results presented above suggest that the techniques used for natural gas exploration and development have changed in important ways over the last two decades, and that many of those changes have been motivated by efforts to reduce environmental impacts and externalities. Prominent examples of environmental innovation include the use of multi-well drilling pads and directional drilling techniques to reduce surface disturbance, and the pre-treatment and careful management of produced waters prior to disposal in injection wells or evaporation ponds. Compared to standard practices in place a decade ago, there is much greater attention to protection of wildlife and threatened and endangered plants and animals. Similarly, upgrading access roads, electrification of some drilling pads, and new technologies (like improved diesel engines) have been used to improve air quality.

At the same time, the rate of adoption of different environmentally-oriented technologies or management practices has been uneven (both across companies working in the Basin and also compared to other natural gas production areas in the United States). Examples of approaches that are less widely used in the Basin are closed loop or recycled hydrofracturing water systems, aggressive treatment systems for cleaning and reusing produced waters, the use of drilling pad mats or disappearing roads, and the capture, testing and treatment of drilling muds and cuttings.

The natural gas industry in the Uintah Basin represents an important case study of how environmental practice ‘adoption’ occurs in a major industrial sector. Clearly, changes in production practices have occurred and there are important lessons to be learned about how these examples of environmental innovation have come about. In the interviews, our informants identified a wide range of drivers and barriers which they believe have affected the specific rate and direction of environmental innovation in the natural gas industry working in this region.

A simple theoretical model listing the important influences likely to shape changes in production practices is illustrated in Figure 9 below. The model shows that scientific research and technical innovation may be a key step in facilitating changes in behavior, but that economic factors will influence whether industry actors find it worthwhile (or possible) to utilize new technologies. Beyond the role of technology and economics, it is likely that regulations and public policies will shape the kinds of practices that are used in the natural gas industry (mainly by establishing a regulatory floor or creating incentives to encourage greater attention to environmental impacts). Regulations themselves often evolve because of changing societal and political demands for environmental quality and protection of natural resources. Finally, there is a potential role for corporate leadership to drive innovation by adopting new practices that go beyond regulatory requirements. This may occur because they believe it is the right thing to do (as a reflection of their corporate ethos), to improve public relations, to allow for faster regulatory approvals, or to prevent lawsuits in the future.

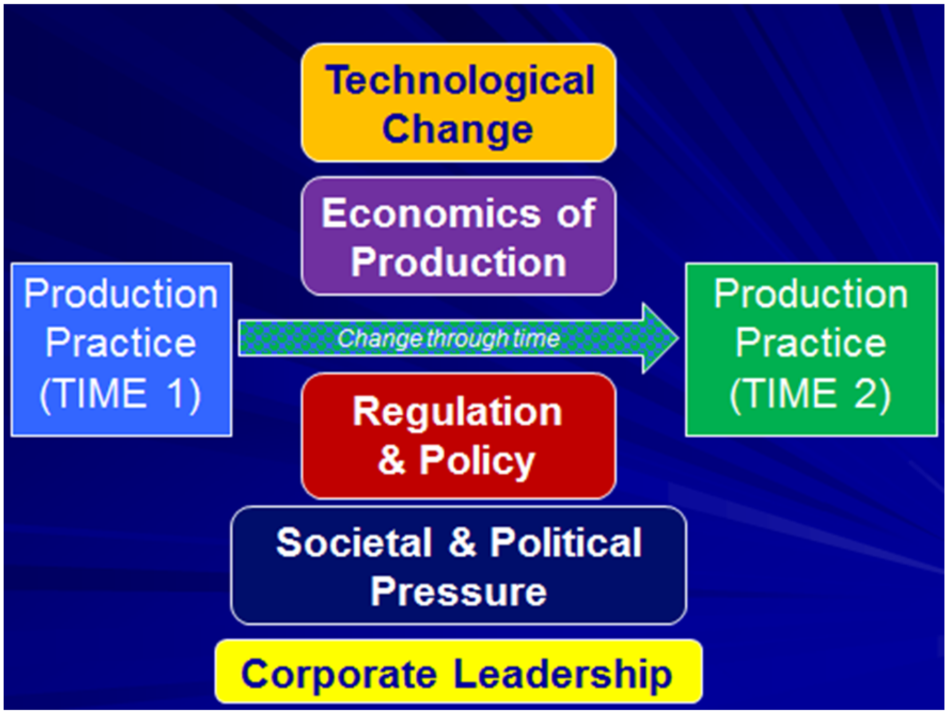


FIGURE 9: Factors Influencing Changes in Production Practices in the Energy Industry

Our research findings suggest that while technological innovation is an important link in the chain of events that lead to adoption, technical or engineering discoveries alone were rarely the primary driver of changes in behavior in this region. Put differently, sudden technical breakthroughs or cutting edge engineering advances were rarely cited as the event that allowed industries to change their practices. Also, there appears to be a long lag time between initial development of new approaches (by scientists or industry engineers) and the willingness of industry actors to deploy these on a large scale. Our industry respondents indicated a familiarity with many examples of environmentally-oriented technologies or practices being used in other areas, but perceived most of these to be impractical or too expensive for widespread use in the Uintah Basin.

We found that technology serves less as a driver of changes than as a mechanism to help remove obstacles or barriers to reducing the environmental footprint of the energy industry activities. It is clear that the absence of practical, reliable, and economically viable technical options can be a barrier to addressing some environmental concerns. The most common instances of voluntary adoption of environmental innovations – such as the recent adoption of multi-well pads and centralized hydrofracturing water systems by one company – were examples of "win-win" solutions where greater environmental protection could be accomplished using mature technology that simultaneously saved the company money.

The results indicate that public agency regulation and oversight are important drivers of changes in industry practice. However, the role of regulation is much more complex than appears on the surface. While a few instances of the adoption of environmentally-friendly practices could be directly linked to the passage of new rules or regulations, there were even more cases where industry leaders were 'ahead of the regulatory wave' and were exploring and testing new practices in advance of being required to do so. Some of the more innovative companies explained that they were voluntarily adopting new practices now in anticipation of future regulatory mandates because it was easier to experiment and refine their approaches without the constraints of strict agency rules. Similarly, most state and federal regulators were reluctant to require the use of specific practices until they were convinced that they were technically and economically viable. Examples of innovative companies successfully using these practices were important to increase the confidence and willingness of agency actors to adopt stricter environmental standards.

The complexity of state, tribal, and federal regulatory jurisdiction over energy development in the Basin further complicates the story. While one agency may feel they are sending clear regulatory signals to encourage (or require) changes in industry practices, other agencies may be sending contradictory signals. Moreover, most regulatory agencies have flexible standards that required project-specific site assessments and negotiations with individual companies to determine the specific mix of environmentally-protective practices that would be required in order to receive permits to drill or produce energy. The combination of complex jurisdictions and negotiated practice standards caused many of our industry respondents to express frustration and confusion about just what was being required of them. As a result, the direct impact of regulation on changes in environmental behaviors in the Basin is complex and difficult to document.

Social and political pressures provide an important backdrop to the ways in which technical, economic, and regulatory factors work to change industry practices. The dominant pattern of federal ownership of land and mineral rights in the Basin shapes the ways in which public concerns and pressures for change are expressed. Unlike natural gas development that has generated intense public debate and local environmental opposition in the northeastern United States (Barnes 2010, Robinson 2011), local social and political pressure in the Basin has not been a primary driver of increased environmental standards.

The prominent role of the federal government in the Uintah Basin translates to frequent requirement to use standard NEPA procedures that engage a wide range of stakeholders in a structured public input and review process. The respondents in our study frequently talked about how most environmental stakeholders who participate in that process are not from the local area, and instead represent statewide, regional or national environmental interest groups. At the same time, the tremendous importance of the energy industry to the local economy has led most local stakeholders to express formal concerns in the NEPA process that environmental issues be balanced against the economic benefits associated with resource development. Similarly, local and state elected representatives in the area express serious concerns that excessive environmental oversight might make energy companies shift their attention to other regions. Our informants suggested that political pressure to increase environmental regulation in the area has come from national elected officials and agency leaders, not from grassroots local organizations.

Finally, aside from the factors mentioned above, our study results suggest that some of the changes in environmental behavior originated from key actors within particular energy companies working in the Basin. Specifically, we found that concerns about public relations and the desire to cultivate a public image as a 'green' company with a national or international audience were often part of the motivation for particular companies to adopt new practices. In other cases, genuine corporate values in support of environmental responsibility and a desire to avoid negative impacts on the local community were part of the decision-making calculus when changes in industry practices were made.

Working Model for How Change Often Happens

Taken as a whole, our research suggests a somewhat complicated model for how important changes in production practices designed to minimize environmental impacts take place in the Utah energy industry. The first step in this model begins with growing awareness of and concern about a potential environmental issue (by industry, by agencies, and by societal actors). An example might be growing awareness of the aggregate or cumulative impact of drilling activities on dust and air quality conditions in the Basin. As awareness and concern about this issue become more widespread, a few companies proactively identify the need to come up with strategies to mitigate these problems. While new research or technical innovation can be required, it seems most typical for companies to mainly draw from existing proven technologies and practices that had been developed and tested by other industry players, universities or in other production regions. Simultaneously, regulatory agencies engage in both internal agency staff discussions and informal conversations with key industry actors to evaluate the seriousness of the issue and the possible changes in production practices that might improve the situation. The experiences of early innovators in industry often contribute to growing confidence at the agencies that (a) it is possible to address the concerns in a way that is technically and economically feasible; and (b) that some approaches are more likely to be viable and/or effective than others. Formal changes in state and federal regulations appear to influence behavior relatively late in the process, and seem to normalize emergent changes in behavior and extend them to actors who had (to that point) not voluntarily adopted these new approaches. Overall, the pace of these kinds of changes in the Uintah Basin are only indirectly affected by pressure from environmental groups, and most of that pressure filters through national organizations, federal agency administrative directions, and local formal processes for environmental review under NEPA.

Implications

There appears to be a high level of interest by nearly all parties to accelerate and facilitate efforts to reduce the environmental footprint of fossil fuel production in the Uintah Basin. Our research suggests that investments in new technical and engineering innovations are important to help reduce logistical and economic barriers to adoption. However, new technology alone is unlikely to generate changes that are not already of interest to (and demanded by) industry and agency actors. Market factors appear to affect the pace of change: robust economic conditions in energy commodity markets make it easier for industry actors to experiment with and invest in new technology and practices, but are not likely to be a primary driver for change. The role of regulation in driving future changes is likely to be mixed. On the one hand, if there were no possibility of stricter environmental rules and regulations in the future, the willingness of industry actors to incur costs to meet environmental objectives might be much lower. However, movement to reduce the environmental footprint of the industry will likely occur in ways that are not simply dictated by clear environmental laws and requirements. Conversations between regulators and industry are critical to clarify which kinds of environmental impacts are of most concern and to create the space for environmental innovation to occur. In addition, the perception that stricter regulatory standards will be coming down the pipe in the near future will likely serve as a major motivator for companies to proactively develop new strategies. It is likely that a handful of larger industry actors will provide a leadership role in generating and adopting environmental innovations, with smaller firms and local service contractors following their lead (perhaps only when such changes become mandatory).

The link between regulation and behavior is made more complex because of uncertainties about regulatory jurisdiction and authority in the Basin, and perceptions of variability in federal agency practices across political administrations in Washington. If they continue, these uncertainties will make it more difficult for industry actors to make informed judgments about which kinds of environmentally-oriented change are most likely to be required. A number of industry informants suggested that they would be happy to live with stricter environmental rules if (a) all relevant agencies would agree to follow the same rules, (b) they know they could get decisions on applications for leases and permits more quickly and in a predictable manner, and (c) they could be assured that these rules would be stable for the foreseeable future.

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Table A-1: Uintah Basin Natural Gas Production, 1984-2010 *(Gross Withdrawals, MCF).*

Year	Duchesne County	Uintah County	Uintah Basin	State Total	Basin Share %
1984	16,635,636	33,843,635	50,479,271	194,446,539	26.0%
1985	18,035,067	28,721,729	46,756,796	210,266,787	22.2%
1986	16,594,450	27,445,347	44,039,797	239,259,285	18.4%
1987	14,870,376	24,056,594	38,926,970	262,084,427	14.9%
1988	15,356,855	23,971,638	39,328,493	278,578,413	14.1%
1989	15,452,052	26,316,449	41,768,501	278,321,040	15.0%
1990	19,554,495	29,007,555	48,562,050	323,028,470	15.0%
1991	20,168,073	31,248,012	51,416,085	329,464,328	15.6%
1992	19,877,439	42,911,913	62,789,352	317,763,088	19.8%
1993	17,640,155	73,518,068	91,158,223	338,276,008	26.9%
1994	16,750,850	67,275,895	84,026,745	348,139,804	24.1%
1995	17,582,965	57,143,899	74,726,864	308,694,651	24.2%
1996	19,332,426	60,051,360	79,383,786	280,438,951	28.3%
1997	20,631,221	60,599,426	81,230,647	272,553,774	29.8%
1998	19,204,848	70,603,801	89,808,649	297,503,246	30.2%
1999	15,352,521	72,190,796	87,543,317	277,494,312	31.5%
2000	13,934,444	83,100,193	97,034,637	281,170,016	34.5%
2001	13,933,698	93,909,207	107,842,905	300,975,578	35.8%
2002	12,476,159	104,385,705	116,861,864	293,030,079	39.9%
2003	11,954,655	111,242,334	123,196,989	293,030,079	42.0%
2004	14,642,364	132,682,346	147,324,710	293,832,276	50.1%
2005	20,077,706	164,133,003	184,210,709	313,563,064	58.7%
2006	22,530,227	203,629,241	226,159,468	356,442,840	63.4%
2007	25,336,254	218,563,830	243,900,084	385,540,208	63.3%
2008	26,575,078	273,658,822	300,233,900	442,524,364	67.8%
2009	28,805,123	283,383,299	312,188,422	449,573,832	69.4%
2010	28,075,846	280,259,594	308,335,440	430,551,694	71.6%

Source: Utah Department of Natural Resources, Division of Oil, Gas and Mining

Table A-2: New, Spudded, Wells in the Basin from 2001-2010.

Year	Duchesne County	Uintah County	Uintah Basin	State Total	Basin % of Total
2001	74	390	464	631	73.5%
2002	44	226	270	391	69.1%
2003	89	333	422	480	87.9%
2004	166	441	607	660	92.0%
2005	184	570	754	890	84.7%
2006	281	656	937	1068	87.7%
2007	271	705	976	1137	85.8%
2008	234	719	953	1144	83.3%
2009	161	315	476	513	92.8%
2010	306	355	661	704	93.9%

Source: Utah Department of Natural Resources, Division of Oil, Gas and Mining