Chapter Two

Operations and Environment

Abstract

Expanded natural gas and oil resources have dramatically improved the North American energy supply outlook. However, prudent production and delivery of these resources presents operational and environmental challenges. Technological advances have made shale gas, tight oil, deepwater offshore, oil sands, and other resources economically recoverable. If these resources are to be available and economic for development, continuous attention to reducing risks is essential to ensure pollution prevention, public safety and health, and environmental protection. These outcomes are important in their own right, but also in order to enjoy access to the resources for extraction and ultimate satisfaction of consumers' energy demand. Given the importance of these issues, they have strongly influenced the study process.

This chapter examines the major environmental and safety issues that must be addressed in order to safely produce and deliver North American natural gas and oil resources; examines the historical context of environmentally responsible development and improvements in technology, regulation, and environmental management; and describes the variation in natural gas and oil resources and the resulting variation in environmental impacts and issues. The main focus of this chapter is to consider ways in which industry and government can improve environmental performance, reduce risk, engage with stakeholders, and develop and communicate important information on environmental impacts.

The outline of the Operations and Environment chapter is as follows:

- Introduction and Summary
- Resource Play Variations and Associated Environmental Challenges
- History of Innovation in Environmental Stewardship
- History of Natural Gas and Oil Environmental Laws
- Sustainable Strategies and Systems for the Continued Prudent Development of North American Natural Gas and Oil
- Offshore Safety and Environmental Management
- Key Findings and Policy Recommendations.

INTRODUCTION AND SUMMARY

Environmental Challenges

Expanded potential of natural gas and oil resources has dramatically improved the North American energy supply outlook. The increased use of natural gas is likely to reduce the overall carbon intensity of energy use, benefit the economy, and improve energy security. Prudent production and delivery of these resources presents operational and environmental challenges. Through technological advances, tremendous new natural gas and oil supply sources have been identified in the North American resource base. These advances make shale gas, deepwater offshore, tight oil, oil sands, and other resources economically recoverable. Continuous attention to reducing risks is essential to ensure pollution prevention, public and worker safety and health, and environmental protection. These are essential outcomes in order to enjoy access to the resources for extraction and ultimate satisfaction of consumers' energy demand. Due to the importance of these issues, their influence on the study process has been significant. Risk to the environment exists with natural gas and oil development, as with any energy source. Local, state, and federal governments have developed a mix of prohibitions, regulations, and scientific study to reduce potential environmental impacts of natural gas and oil development. Parties discussing energy policy can be missing a common vocabulary and set of references to have a constructive conversation and make educated decisions. No form of energy comes without impacts to the environment. An appropriate framework for discussing energy sources is necessary.

Environmental challenges associated with natural gas and oil development vary by location, such as onshore versus offshore, and by the methods employed to extract the resource. Although each well involves drilling into the crust of the earth and constructing well casing using steel pipe and cement, differences arise from the affected environment, resource type, regional and operating conditions, and proximity to environmental receptors. The public, policymakers, and regulators have expressed the following environmental concerns about onshore operations:

- **Hydraulic Fracturing** – Consumption of freshwater (volumes and sources), treatment and disposal of produced water returned to the surface, seismic impacts, chemical disclosure of fracture fluid additives, potential ground and surface water contamination, chemical and waste storage, and the volume of truck traffic.
- **Water Management** – Produced water handling and disposal has created apprehension about existing water treatment facilities and the ability to treat naturally occurring radioactive material, adjust salinity, and safely discharge effluent.
- **Land Use Encroachment** – The encroachment into rural and urban areas results in perceived changes to quality of life, especially in newly developed or redeveloped natural gas and oil areas.
- **Methane Migration** – Methane in domestic drinking water wells, either naturally occurring or from natural gas development.
- **Air Emissions** – Emissions generated from combustion, leaks, or other fugitive emissions during the production and delivery of natural gas and oil present challenges regarding climate change and human health impacts.

Offshore operations environmental challenges are somewhat different than onshore due to the sensitivities of the marine environment, harsh operating conditions, remote locations in the case of the Arctic, and advanced technologies employed. These challenges include:

- **Prevention of and Response to a Major Release** – The pressures and temperatures associated with remote wellhead locations that are difficult to access on the bottom of the ocean floor, and high flow rate of deepwater wells, make the containment of a subsea release challenging.
- **Safety** – Offshore natural gas and oil drilling practices, called into question by the recent Deepwater Horizon incident, have resulted in a weakened public perception of offshore process and worker safety. The limited operating space coupled with significant production volumes can create a higher-risk work environment.
- **Marine Impacts** – Seismic noise generated by offshore natural gas and oil exploration activities is recognized as a concern for whale populations and other marine life, including fish.
- **Arctic Ice Environments** – Responding to an oil spill in seasonal subzero temperatures with the presence of broken sea ice and 24-hour darkness is difficult and presents challenges not faced in other marine environments.

The development of oil sands poses unique environmental challenges that differ from those associated with other onshore oil resources, including:

- **Water Consumption** – Large volumes of water have generated public and regulatory issues associated with water sourcing, groundwater withdrawals, and protecting water quality.
- **Land Disturbances** – Removal of overburden for surface mining can fragment wildlife habitat and increase the risk of soil erosion or surface runoff events to nearby water systems, resulting in impacts to water quality and aquatic species.
- **Greenhouse Gas (GHG) Emissions** – Transportation fuels produced solely from oil sands result in

well-to-wheels life-cycle GHG emissions 5% to 15% higher than the average crude oil refined. The carbon intensity of oil sands can vary based on extraction, refining and transport method. And, in 2009, well-to-wheel emissions from oil sands processed in the United States were only 6% higher than the average crude oil consumed in the United States. Over time, incremental efficiency improvements,

Hydraulic Fracturing

Hydraulic fracturing is the treatment applied to reservoir rock to improve the flow of trapped oil or natural gas from its initial location to the wellbore. This process involves creating fractures in the formation and placing sand or proppant in those fractures to hold them open. Fracturing is accomplished by injecting water and fluids designed for the specific site under high pressure in a process that is engineered, controlled, and monitored.

Fracturing Facts

- Hydraulic fracturing was first used in 1947 in an oil well in Grant County, Kansas, and by 2002, the practice had already been used approximately a million times in the United States.*
- Up to 95% of wells drilled today are hydraulically fractured, accounting for more than 43% of total U.S. oil production and 67% of natural gas production.†
- The first known instance where hydraulic fracturing was raised as a technology of concern was when it was used in shallow coalbed methane formations that contained freshwater (Black Warrior Basin, Alabama, 1997).
- In areas with deep unconventional formations (such as the Marcellus areas of Appalachia), the shale gas under development is separated from freshwater aquifers by thousands of feet and multiple confining layers. To reach these deep formations where the fracturing of rock occurs, drilling goes through shallower areas, with the drilling equipment and production pipe sealed off using casing and cementing techniques.
- The technology and its application are continuously evolving. For example, testing and development are underway of safer fracturing fluid additives.
- The Interstate Oil and Gas Compact Commission (IOGCC), comprised of 30 member states in the United States, reported in 2009 that there have been no cases where hydraulic fracturing has been verified to have contaminated water.‡
- A new voluntary chemical registry (FracFocus) for disclosing fracture fluid additives was launched in the spring of 2011 by the Ground Water Protection Council and the IOGCC. Texas operators are required by law to use FracFocus.
- The Environmental Protection Agency concluded in 2004 that the injection of hydraulic fracturing fluids into coalbed methane wells poses little or no threat to underground sources of drinking water.§ The U.S. Environmental Protection Agency is currently studying hydraulic fracturing in unconventional formations to better understand the full life-cycle relationship between hydraulic fracturing and drinking water and groundwater resources.
- The Secretary of Energy's Advisory Board is also studying ways to improve the safety and environmental performance relating to shale gas development, including hydraulic fracturing.

* Interstate Oil and Gas Compact Commission, Testimony Submitted to the House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources, June 18, 2009, Attachment B.

† IHS Global Insights, "Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing, 2009; and Energy Information Administration, "Natural Gas and Crude Oil Production," December 2010 and July 2011.

‡ Interstate Oil and Gas Compact Commission, Testimony Submitted to the House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources, June 18, 2009, Attachment B.

§ U.S. Environmental Protection Agency, Office of Water, Office of Ground Water and Drinking Water, "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs" (4606M) EPA 816-R-04-003, June 2004.

as well as new technologies, such as the application of solvents to mobilize oil in situ (as an alternative to heat) are expected to continue to reduce the GHG intensity of unconventional operations.

The natural gas and oil industry today is notably active. The rig count, for example, has doubled in the United States in the last 10 years, largely as a result of deep shale and other unconventional natural gas and oil resources. This has increased the need for regulators to respond in an appropriate and timely fashion and companies to engage with local communities and ensure that responsible and effective environmental management practices are used. This heightened level of activity, especially in shale gas development, exists within a context shaped by:

- **Public Awareness of Industry Operations** – The public has been disappointed by low performance of some operators, creating a sense of alarm about technologies and practices with which they may not be familiar, such as hydraulic fracturing.
- **Location** – Development is occurring in areas where there has not been significant activity in decades.
- **Transparency** – Questions have arisen regarding the transparency of the industry from policymakers, nongovernmental organizations, and stakeholders.
- **Regulatory Responsibilities** – There is increased pressure on the regulatory agencies to oversee the growing activity, be knowledgeable about the technological developments, and administer regulatory programs during times of extraordinary budget pressures.
- **Complex Regulatory Framework** – There is increased environmental regulatory complexity at the federal, state, and local levels.

To address public concerns, some in the industry have made efforts to be more transparent by voluntarily disclosing information about chemical additives and practices, initiating expansions of training and information exchange programs, investing in research and development efforts, and embarking on extensive community and government outreach programs. Furthermore, emphasis on safe and environmentally responsible performance, coupled with environmental sustainability, has been or has recently become part of the business principles in many companies. In 2009, the U.S. natural gas and oil industry spent about $14.6 billion on the environment, including over $4.3 billion for implementing new technologies and other environment-related expenditures in the exploration, production and transportation sectors.[1]

Prudent Development

Prudent development of natural gas and oil resources in North America reflects concepts related to achieving a broadly acceptable balance of several factors: economic growth, environmental stewardship and sustainability, energy security, and human health and safety. Prudent development necessarily involves tradeoffs among these factors. Consideration of the distribution of costs and benefits is a key part of prudent development.

Environmentally responsible development is another key element of prudent development, underpinning environmental stewardship and sustainability. In the context of recovering natural gas and oil resources while protecting public health and the environment, environmentally responsible development requires:

- Thorough predevelopment planning
- Development of effective regulatory approaches
- A commitment to continuous improvement
- A commitment to implementing planned actions
- Evolution of development concepts and practices.

Predevelopment Planning – Appropriate planning includes identifying and mitigating risks to public health, worker safety, and the environment, conserving natural resources, using technologies appropriate to the task, and incorporating engagement with parties impacted by the development of a resource. Due to the diversity of areas with natural gas and oil resources, the specific requirements associated with prudent development vary between locations.

1 American Petroleum Institute, *Environmental Expenditures by the U.S. Oil and Natural Gas Industry: 1990-2009*, February 2011. The estimates in this annual report are derived from survey data. The number of survey responses can vary each year, and many companies do not track environmental spending directly. As such, the aggregate estimates for specific industry sectors may either over or underestimate environmental expenditures, and do not represent the expenditure patterns of any individual company. With increased emphasis on corporate environmental performance and the implementation of recently proposed or promulgated regulations, aggregate industry environmental expenditures may be substantially higher in future years.

Effective Regulatory Approaches – Environmentally responsible development requires regulatory approaches that are protective of environmental systems, land uses, human safety and health, and the development interests of surface and mineral right owners. In the context of federal and state or provincial jurisdictional relationships, prudent regulation involves assigning the various responsibilities for different aspects of development and protection to the level of government that can most effectively administer them.

Continuous Improvement – Continuous improvement of operations and regulations involves adherence to standards and adoption of improved practices based on advances in science, technology, methods for improved risk management, and lessons learned.

Planned Actions – Environmentally responsible development includes a commitment by all parties to follow through on planned actions to accomplish agreed-upon goals. The commitment of the chief executive officer or appropriate leader is critical to success. This will be evident, in part, by the leader acting as a visible and active champion and recognizing the time and effort involved in development and integration. In the end, all levels of the organization must be committed to and involved with the implementation.

Development Concepts and Practices – Societal expectations and understanding of the environment have changed over time. This must be reflected in the evolution of development concepts and specific practices that constitute environmentally responsible development. Past practices considered acceptable at one time may be inadequate now and in the future particularly due to competition for finite or constrained land, water, air, and other resources.

Major Findings: Assuring Prudent Development

The history of natural gas and oil development includes continual technological advances, improved systems management, and improved regulatory processes. This has allowed for the production of new and more challenging resource plays while improving environmental performance. The industry has demonstrated great innovation and success in addressing technological needs and environmental issues involved in accessing and developing conventional resources. Future development of the most promising unconventional natural gas and oil resources, such as shale gas, tight oil, deepwater offshore natural gas and oil, and oil sands, will require even more proactive efforts to successfully implement safe and environmentally responsible development. However, many in and outside of the natural gas and oil industry understand that inferior practices could undermine public trust. The result could be that parts of the natural gas and oil resource base become – or remain – off limits for development. Maintaining access to the resource does not depend on changing public perception so much as earning public confidence with excellent performance. This is crucial to realizing the full potential of North America's abundant natural gas and oil resources.

With that in mind, the following key topics should be considered to ensure that excellent environmental performance is the norm in all places where natural gas and oil development occurs. For each of these topics, findings and recommendations have been derived from the analysis, summarized in this chapter and discussed more fully in the Key Findings and Policy Recommendations section.

Environmental Sustainability and Community Engagement

The concept of environmental sustainability is often used to refer to the objective of a government, company, industry, or organization to set and work towards achieving goals related to improving society, protecting the environment, and driving economic success. The long-term goal of achieving environmental sustainability is often aspirational in nature. In addition, there is not one correct approach to encouraging or implementing environmental sustainability within a company or industry. It can be accomplished by individual companies adopting business strategies and activities that meet the needs of the company and stakeholders while protecting environmental sustainability and enhancing human and natural resources for the future. A number of natural gas and oil companies already have environmental sustainability goals incorporated into their business.

Providing information to the public is not enough. Community engagement involves both speaking and listening. Natural gas and oil companies should work with the community and seek ways to reduce the negative impacts of development. This includes predevelopment planning to identify issues such as noise and traffic and seek ways to mitigate them.

Community engagement needs to be a core value of companies. Even though a company may believe its environmental performance is at the highest level, it must nevertheless maintain transparency regarding issues important to public stakeholders. Industry needs to explain its production practices and environmental, safety, and health impacts in non-proprietary terms. Collaboration among companies, government, and other stakeholders is often essential to the success of industry-wide efforts. It can also increase the trust and support of government and citizens. Such discussions can more effectively incorporate local environmental sustainability priorities and challenges. Listening to these challenges can support a company in staying ahead of issues that can impact reputation, production delays, lawsuits, and regulatory actions. In order to make public engagement meaningful and successful, companies must listen to stakeholders, ask for alternative views, and reflect stakeholders' positions in strategic objectives and communications. Sufficient resources should be devoted to this effort.

Corporate Responsibility

Natural gas and oil companies should continue to improve the development and use of Environmental Management Systems (EMSs) and implementation of environmental sustainability practices. There is a wide variance in how these systems are defined and applied across the natural gas and oil companies and service companies in the industry. There is also variance in the effectiveness in managing environmental risks. The establishment of councils of excellence will go a long way to improve implementation of EMSs throughout the industry. A properly implemented EMS can provide greater efficiencies as consistent practices are developed and implemented by each company, which also helps establish responsibility to properly mitigate and manage risks. Each energy-producing company is accountable for its health and environmental impacts and each producer is obligated to minimize these impacts. In order to ensure environmentally responsible development, all levels of the natural gas and oil industry should be encouraged to use appropriate and comprehensive predevelopment planning, stakeholder engagement, risk assessment, and the innovative applications of technology. These elements must be adapted to the variability of resource plays and regional differences.

Councils of Excellence

While most natural gas and oil companies operate at a high environmental performance level, some companies are not as far along. Companies gain

Planning and Risk Assessment

Operators and regulators have long recognized that operations in extreme or sensitive environments, such as arctic climates, deepwater offshore settings, and wetlands, require careful planning to ensure operational success, worker safety, and environmental performance. As operations have moved into deeper, more challenging plays in more conventional settings, the need for more careful planning of these operations is necessary. The new paradigm for planning involves not only careful operational and logistic plans, but also requires that those plans be developed specifically to accomplish clear environmental protection goals as well as worker safety and public safety goals. In addition, risks must be identified and assessed.

Early planning for prevention of hazardous events preserves the largest numbers of response options; in contrast, during a crisis event, options are reduced as urgency overtakes systematic analysis, planning, and thought. Options become more abundant again only long after the event and as the latter stages of the recovery mode lead to detailed retrospectives and root-cause analysis.

Recent events have shown that careful planning across the entire operational life cycle is essential. The tragic events associated with the Macondo well blowout put a spotlight on the need to have plans that will prevent accidents, quickly and accurately identify incidents that do occur, and provide effective response to mitigate the impacts that may occur. In addition, public opposition to coalbed natural gas and shale gas development in several areas has highlighted the need for public involvement and public education to engage stakeholders and to inform the way firms manage environmental and operational risks.

Shell oil offshore safety study: http://www.scribd.com/doc/8438367/Bow-Ties-and-Offshore-Safety-Studies.

exposure to and adopt new technologies and operating practices in different ways and at different rates. Although accidents, spills, and other problems have occurred, overall environmental protection has improved. This has occurred as companies have applied more sophisticated technologies to drilling and production practices.

Broad systems (i.e., operational, management, technological, and communications) within the industry and government must be managed to work together to achieve consistently high environmental performance. More systematic mechanisms to identify, evaluate, and disseminate information about environmental best practices would promote consistently higher environmental performance. North American natural gas and oil companies should explore opportunities to share best practices for protecting the environment, safety, and public health while developing different types of resource opportunities.

An existing example of best practice sharing and recommended practice development is the Petroleum Technology Transfer Council, a national network of state universities, independent producers, service companies, federal agencies, and national labs established in 1994 to provide a forum for the transfer of technology and best practices within the producer community, adapted to the regional level. The latest example is the recently formed Center of Offshore Safety, which will promote the highest level of safety for offshore operations, through an effective program that addresses management practices, communication and teamwork, and which relies on independent, third-party auditing and verification. Natural gas and oil companies should draw upon existing activities, as appropriate, and form regionally focused "councils of excellence" to function as centralized repositories and systematic mechanisms to collect, catalog, and disseminate non-proprietary standards, practices, procedures, and management systems that would be made available to all appropriate government and private sources. Because development of natural gas and oil resources differs depending on factors such as the geology, water resources, and geography of the region, what constitutes effective practices is regionally defined. As such, there may be a need for multiple councils, each with a regional focus. The councils would be industry led and should be open to companies, regulators, policymakers, nongovernmental organization stakeholders, and the public. These recommendations are supported by findings and recommendations on sustainable systems and building public confidence in the Key Findings and Policy Recommendations section of this chapter.

Effective Regulation

High-quality regulation is often risk-based, considers flexible approaches where feasible, encourages innovation, is informed by public input, and is based on sound science. A balance between prescriptive and performance-based approaches is sought in developing high-quality regulation, with consideration given to efficiency and effectiveness. Such regulation is based on the best available data, takes into account benefits and costs, evolves as technology changes, and has other attributes necessary for implementing effective regulatory programs and enabling regulatory compliance without unnecessary burdens. High-quality regulation can increase the potential for protecting public health, safety, and the environment, while promoting economic growth, innovation, competitiveness, and job creation.

Regulation of oil and gas operations is best accomplished at the state level. A one-size-fits-all approach to regulation is not a viable option to ensure the highest level of safety and environmental protection. State agencies have extensive knowledge of geological conditions, which vary from state to state. State regulators are well suited to consider many variables, such as the regional hydrogeology, topography and seasonal climate variation to ensure wells are constructed properly, environmental footprints are minimized, and operations are conducted safely. State regulators are in close proximity to conduct inspections, oversee local operations, enforce existing regulations, and target new regulations to improve safety and environmental performance. State regulators have management responsibility for other natural resources (e.g., wildlife, fisheries, etc.) and are in the best place to integrate the regulation and management of all natural resources, including oil and gas.

Regulators should continue to evolve regulatory requirements to address new information and best practices for operations and safety programs. Each state with natural gas and oil development has laws and regulations governing the conduct of companies and potential impacts. But each state is not equal in maintaining knowledge of the implications of scientific and technological advancements in improving regulations to protect the environment, public health, and safety. Similarly, states may vary in the resources dedicated to conduct timely and thorough reviews of permit applications and plans, inspections, and enforcement. Each state should be able to ensure that: (1) actions are carried out efficiently and effectively; (2) regulatory staff have the appropriate technical competencies to provide oversight of industry actions and keep pace with industry practices and technology; (3) standards evolve over time to take into account technological innovation, intensity of development, and scientific advancements; and (4) regulations are enforced.

To deal with the limitations of prescriptive regulations, some agencies have developed performance-based requirements allowing for the use of new practices and technologies while meeting environmental protection goals. This approach potentially allows greater flexibility and innovation while ensuring environmental protection, but both operators and regulators have recognized that this is not the best approach in all cases. State and federal agencies must seek a balance between prescriptive and performance-based regulations to encourage innovation and environmental improvements while maintaining worker and public safety.

For these government initiatives to be successful, state and federal regulatory agencies will need a sufficient level of staff to carry out new and in some cases heightened regulatory requirements. To this end, state and federal governments must provide the necessary financial resources to support regulation and enforcement. A fee-based funding mechanism is one approach to provide these in states where there are neither the resources nor adequate industry contributions to support this function, provided that such fees support the institutional mission of efficient and effective regulation and are not used solely to increase taxes for general budgetary support.

Environmental Footprint Analysis

As discussed in the section entitled "Sustainable Strategies and Systems for the Continued Prudent Development of North American Natural Gas and Oil," an environmental footprint (EF) analysis can be a valuable tool for considering the environmental benefits, impacts, and risks associated with each energy source in comparison to the other energy sources that are available. In theory, an EF analysis is an objective, science-based assessment of the potential positive and negative impacts of each energy source. In

Issues on the Horizon: Decisions for the Regulatory Path Forward

State, federal, and in some cases, regional regulations are in place to govern oil and natural gas production for the purpose of achieving environmental protection. The interaction of these many layers of regulation is complex and generally effective. However, regulation among jurisdictions is uneven and in some cases requires strengthening resources available for staffing, continuous training to keep current with changes in the industry, and enforcement. In certain circumstances, there are federal legislative exemptions or special considerations afforded the natural gas and oil industry that some environmental advocates believe result in material deficiencies in environmental protection, particularly in relation to water and air quality. Others, including many in the natural gas and oil industry and in state governments, maintain that the special classifications under federal law are appropriate and supported by scientific or economic findings, and addressed by state laws. These special considerations exist for many industries.

There is a range of views on whether particular outstanding regulatory issues are best addressed through state or federal regulatory action. Many state agencies have unique knowledge and expertise relative to the local geological, hydrological, environmental, and land use setting, and are responsible for regulation and development of private and state natural gas and oil resources, as well as for implementing certain federal laws. Federal agencies have similar responsibilities for federal mineral development where the federal government owns or controls such mineral rights or lands. Some entities believe states are generally more nimble than federal agencies in their ability to adapt to changes in technology and new industry practices. Others believe that only through federal regulation can there be assurance of a reasonably consistent level of environmental and public health protection across the country.

practice, EF analyses tend to remain in early stages of development, with analyses exhibiting widely varying assumptions and different techniques for measuring impacts that often produce apples-to-oranges comparisons across fuels and energy resources. An EF analysis is often conducted in a manner to consider the environmental impacts across the life cycle of an operation or product. When this is done, a life-cycle assessment (LCA) is typically employed to define the beginning, middle, and end phases or steps to be considered in the EF analysis.[2]

There are technical issues such as incomplete data and the lack of consensus around quantification of impacts and risks. This latter fact complicates the ability of this potentially important analysis to provide policymakers with useful information to evaluate the relative importance of the different impacts. Moreover, the different resource types for the same fuel may have different impacts, such as with shale gas versus conventional gas. The results of an EF analysis are not intended to be a rationale to avoid mitigating the impacts of any fuel. An EF analysis can be an effective tool for evaluating the relative impacts of each energy source by each type of impacted environmental resource.

To illustrate why a standard EF methodology is needed, it is useful to examine existing studies on the subject and their similarities and differences. The fundamental assumptions and organization of any EF analysis strongly influence its quantitative results and the validity of comparisons to other studies. Different studies have different boundaries around the analysis – i.e., how far back and forward in the life cycle they go. Results will be very different when comparing the footprint of raw fuels vs. end uses, where the latter takes into account efficiencies of end-use technologies and their impacts. There are many other large and small assumptions that go into arriving at the final estimate of footprint.

The body of literature on EF represents an evolving set of related estimates rather than a set of independent analyses. Most EF analyses use previous studies as the sources for their data so that estimates from different studies cannot necessarily be seen as independent – nor can their agreement be taken as evidence for the reliability of the results if they are interdependent. Furthermore, due to the large scope of EF analyses, they face a wide assortment of analytical issues that arise from research in other fields such as geology, biology, health sciences, chemistry, engineering, climate studies, and social science. Adding to the difficulty of comparing the results is the fact that different EF studies have different definitions of what represents an environmental impact and may be estimating quantities whose definitions only partially overlap.

A comparison of two such studies serves to illustrate a few of these issues. The *Bonneville Power Administration Fish & Wildlife Implementation Plan Final Environmental Impact Statement* (BPA study) and *The Environmental Cost of Energy* prepared by the Applied Energy Studies Foundation (AESF) took different approaches to determining the EF for a range of energy sources. While the former focused on health effects and monetized those effects, the latter analyzed a broader range of environmental impacts and did not assign dollar values. The BPA study assessed a variety of energy sources but did not evaluate a full life cycle, neglecting to include transportation and production impacts. The AESF study addressed a wider range of energy sources considered under a full primary life-cycle assessment, including extraction, processing, transportation, and generation. There were also many methodological differences.

Figures 2-1 and 2-2 display some of the results from the two studies on water and land resources. The figures show that the results of the two studies vary widely, for the reasons stated above. Such differences argue for the development of a sound, consistent approach to footprint analysis that is vetted through the various stakeholder groups and would result in a comparable set of estimates for the impacts of the various energy sources.

The federal government should support the development of a methodology(ies) for conducting an EF analysis. As sound methodologies are established and vetted, regulators and other policymakers should refine their understanding of the environmental footprint of energy sources, including natural gas and oil, as part of providing a high-quality information base for making decisions about energy choices that reflect the different nature and intensity of impacts. As environmental considerations of energy choices become

2 Science Applications International Corporation (SAIC), *Life Cycle Assessment: Principles and Practice*, EPA/600-R-06-060, prepared for the National Risk Management Research laboratory, Office of Research and Development, U.S. Environmental Protection Agency, May 2006, accessed June 29, 2011, http://www.epa.gov/nrmrl/lcaccess/pdfs/600r06060.pdf.

Figure 2-1. Water Consumed to Provide Electricity to 1,000 Average U.S. Households Annually

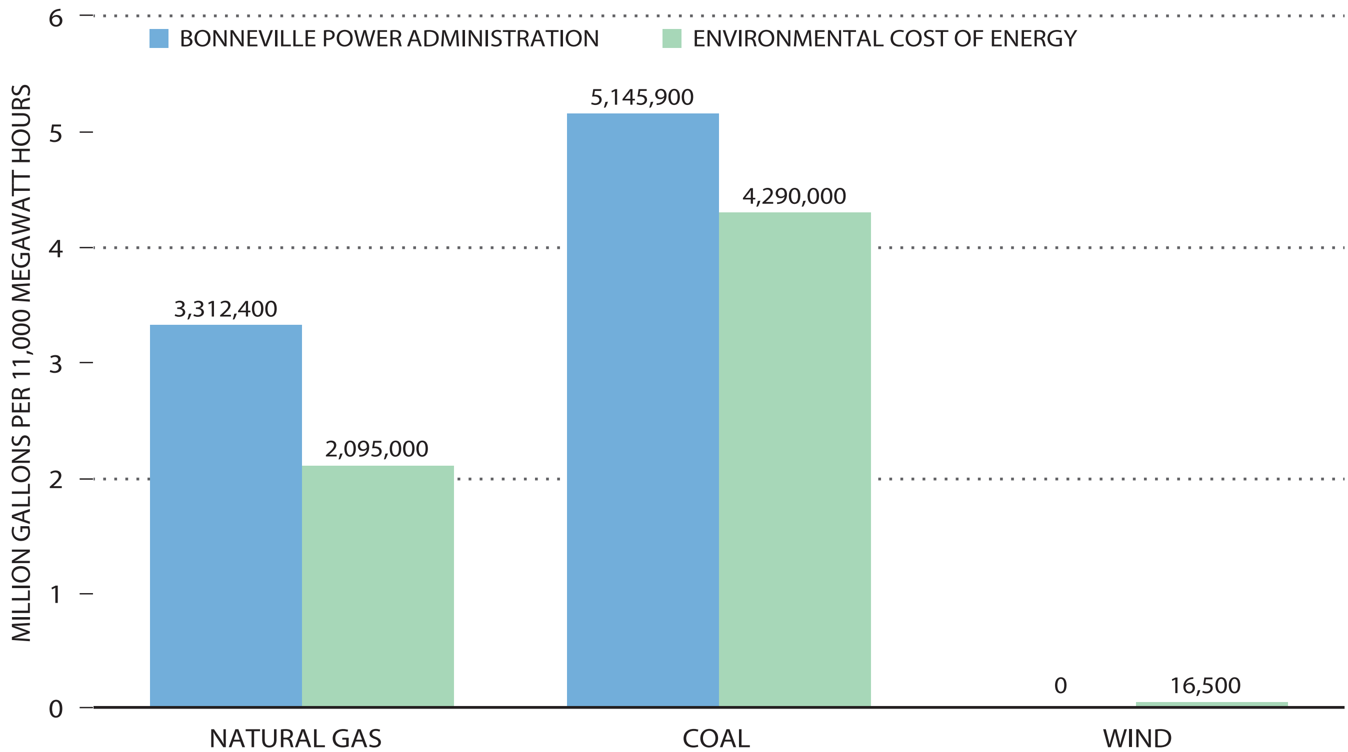
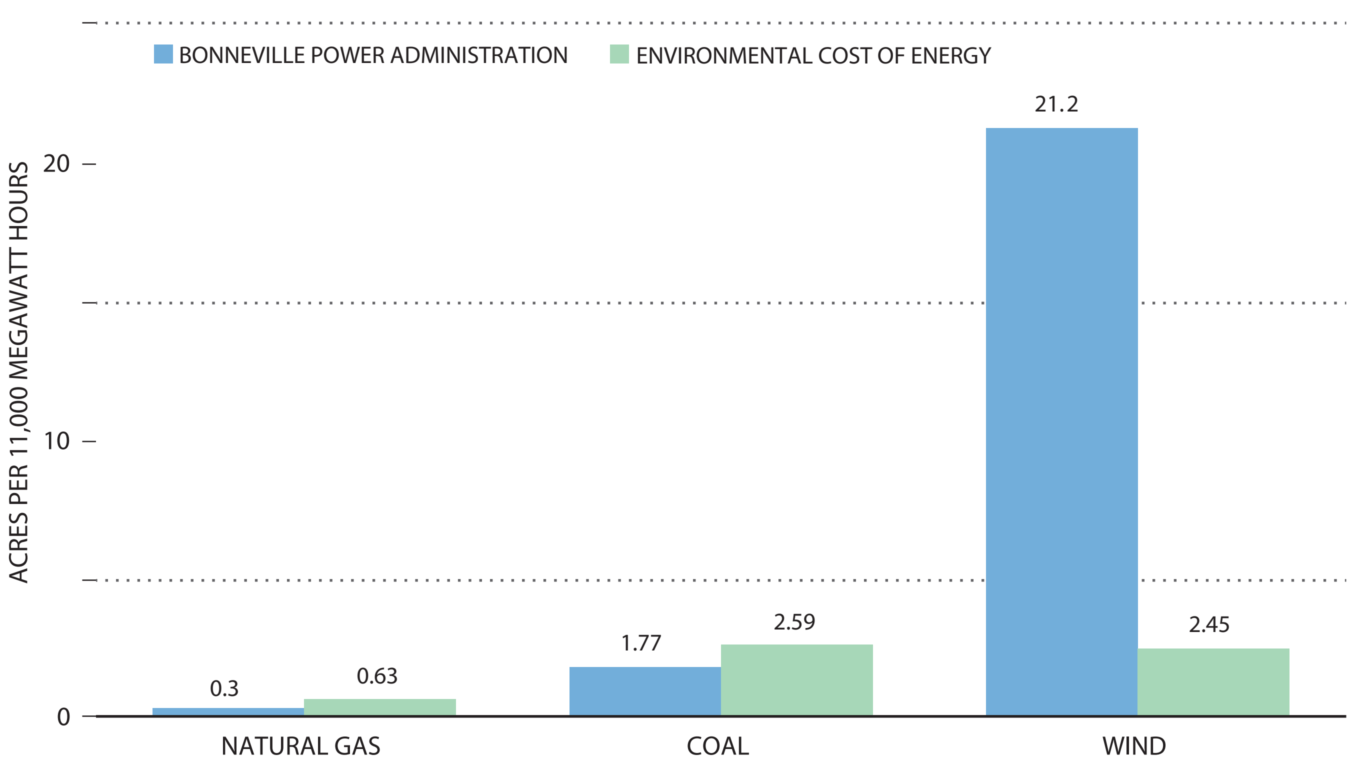


Figure 2-2. Area Disturbed to Provide Electricity to 1,000 Average U.S. Households Annually



more relevant in a carbon-constrained economy, developing better, more complete information about impacts from producing, transporting, and consuming different forms of energy will provide a more robust foundation for public policy decisions that affect the future energy mix of North America. Similarly, such information could be incorporated into analyses used in making investment and purchasing decisions by consumers, producers, and state and federal governments.

Technology

Improvements in environmental performance have occurred in every phase of natural gas and oil development for both offshore and onshore operations, from construction, drilling, completion and stimulation, through production, plugging of the well, and final reclamation. Industry has implemented new technologies and innovative practices to better control water use, reduce air emissions, and ensure groundwater protection. Additional performance improvements have been developed for hydraulic fracturing, materials management, and overall operations and management.

Continued development of advanced technologies and operating practices is critical to future recovery of high potential natural gas and oil resources along with improved environmental performance. Research and development conducted by both industry and government, in such areas as siting and planning, drilling, stimulation, and environmental management to minimize water, air, and land impacts, will make it possible to develop future natural gas and oil supplies

Examples of Industry Technological and Environmental Advances

Well Control Methods (such as rotary rigs, mud systems, casing and cementing, and blowout preventers): Designed to stop the uncontrolled releases of oil and gas from wells.

Drilling Advances (such as directional/horizontal drilling and multi-well drilling pads, and elimination of open pits through closed loop mud systems): Greatly reduces the number of wells drilled and surface area footprint (and attendant environmental impacts), allows for centralization of facilities, and avoids/minimizes risk to sensitive environments.

Deepwater Subsea Production Systems (such as subsea completions with tie back to production platforms): Offer an automated and leak-resistant system that significantly reduces the environmental footprint and enables recovery of previously uneconomic reservoirs.

Subsea Well Containment: Subsea containment systems are available that can operate in up to 10,000 feet of water and contain up to 60,000 barrels of oil per day. Equipment designed to contain 100,000 barrels of fluid per day will be available by the end of 2012.

Remote Monitoring Systems and Downhole Instrumentation: Allow for real-time view of downhole conditions – i.e., another set of eyes to review ongoing operations and provide feedback on critical operations.

Underground Injection Control Program (e.g., construction of enhanced oil recovery and disposal wells): Protects groundwater and allows subsurface disposal instead of surface disposal.

Water Treatment and Reuse Technology: Conserves freshwater, reduces transportation impacts, and decreases discharge volumes.

Modern Plugging Methods (such as cement formulation and plugging techniques): Greatly reduces environmental risks from abandoned wells.

Remote Operated Vehicles: Enables robotic capabilities in ultra-deepwater operations.

Long Distance Transport of Natural Gas (including pipeline technology and compression): Greatly reduces the venting of natural gas as a "waste."

Pipeline Leak-Detection Systems: Enables increased monitoring capability to determine pipeline integrity and provide for rapid response at the earliest signs of a pipeline leak or failure.

while protecting the environment. The accompanying text box includes examples of industry technology advancements that have led to better environmental protection.

While it is important not to jeopardize this private enterprise system of innovation, sometimes the payoff period for such research is too long to attract private support. Therefore, private investment cannot always be counted on to perform this research, and federal government agencies should also perform important roles in supporting the development of new technology. In other cases, the intellectual property developed by research is better held as a public good rather than being held privately. This can occur when the benefits of the research would accrue to the United States as a whole, yet do not meet the criteria of any individual company to justify the investment such as with methane hydrate extraction technologies. Public research and development investment may also be justified when it improves recovery of federally owned natural gas and oil, producing benefits that accrue directly to the government through the collection of royalties.

Data Management

Modern computer systems have provided a means for more data to be readily available to operators, regulators, and the public. Use and analysis of these data have provided a means to conduct more complex technical and environmental assessments, which may, in turn, increase regulatory requirements. The increased complexities of new technologies require that operators and regulators have access to and can quickly assess larger and more complex data sets so that they can minimize risk and maximize environmental protection. Widespread access to the Internet has also increased the opportunities for more efficient data sharing in the areas of regulatory reporting, data sharing between partners, and increased public access to operational and compliance information maintained by public agencies.

A common issue is that both private and public organizations have not created standard data management processes or common programs across their own enterprises. Non-centralized data limits the ability of users to share information and make more effective use of the information gathered. Historically, many agencies and companies developed their data management systems in relative isolation so that much of the data is not easily shared. Different software packages and data standards have been used over the years, which made it difficult for agencies to receive data from companies and also difficult, if not impossible, to share operational and environmental data.

Additional efforts are needed in the area of standardization of data and its communication between entities. This standardization is expected to provide benefits to the public in environmental and health protection, and could also provide industry with cost savings. These cost savings will result from making the data easier to communicate with others and report to regulators, as well as from streamlining regulations, reducing duplicative reporting, and providing means to review and learn lessons from past incidents.

Industry Transparency and Public Education

Earning public trust through excellent environmental performance includes maintaining transparency and informing the public about operations and risks. This information and understanding is critical to achieving and maintaining the public's permission to operate in many parts of North America. Industry needs to clearly explain nonproprietary production practices and environmental, safety, and health impacts. The public should have the information necessary to have a clear understanding of the challenges, risks, and benefits associated with natural gas and oil production. Transparent reporting of comparable and reliable information can provide companies the tangible and intangible benefits of stronger relationships with communities, employees, and public interest groups. This is an essential part of earning public trust and critical to establishing appropriate public policies and regulations. In addition to ensuring public access to important data about environmental and operational performance, public education can take many forms, including information libraries, K-12 curricula, media campaigns, speakers' bureaus, websites, and studies of risks in areas of special consideration.

One recent example of the natural gas and oil industry's efforts at transparency is found in FracFocus, the hydraulic fracturing chemical registry website. A joint project of the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas

Framing Questions

The Operations & Environment Task Group was tasked with answering the following framing questions:

1. What is the evolution of environmental improvements in operating practices and technologies used across the range of resource plays and regional differences?
2. What is the environmental footprint of upstream and midstream natural gas and oil operations, including greenhouse gas emissions, compared to other energy sources?
3. What is the environmental and regulatory framework for growth and development of North American natural gas and oil resources?
4. What technological and operational advances are on the horizon to improve efficiency and environmental performance in offshore and onshore operations?
5. What sustainable development principles and practices will enhance and demonstrate North American environmental leadership into the future?

Compact Commission (IOGCC), FracFocus provides information about the chemicals used in the hydraulic fracturing of natural gas and oil wells along with educational materials on hydraulic fracturing, groundwater protection, and regulation. Many natural gas and oil companies participate in FracFocus but not all do so. Increasing the participation in FracFocus to all natural gas and oil companies that engage in hydraulic fracturing, and adding into the system all wells currently in drilling and production, would be important steps in raising the level of industry transparency.

Chapter Organization

This chapter presents discussion and analysis leading to the major findings and recommendations presented above. The Resource Play Variations and Associated Environmental Challenges section describes how variations in natural gas and oil resource types lead to associated variations in environmental impacts and challenges. The History of Innovation in Environmental Stewardship section presents information showing how innovation in technology and practices has improved environmental performance throughout the history of the industry. The History of Natural Gas and Oil Environmental Laws section describes this history as it applies to natural gas and oil development. The Sustainable Strategies and Systems for the Continued Prudent Development of North American Natural Gas and Oil section addresses these topics and how they could be applied into the future. The Offshore Environmental Management section includes the unique aspects of offshore safety and environmental management that must be considered to ensure that offshore production is both safe and environmentally responsible. The Key Findings and Policy Recommendations section presents a more complete discussion of the Operations & Environment Task Group's findings and recommendations.

RESOURCE PLAY VARIATIONS AND ASSOCIATED ENVIRONMENTAL CHALLENGES

The accumulation of natural gas and oil requires three elements: a hydrocarbon source, a reservoir to store the hydrocarbons, and a trapping mechanism to hold them in place. These three elements exist in a wide range of resource plays throughout North America. Consequently, North American producers operate in diverse geographic regions, characterized by differences in topography/geomorphology, rainfall, and ecosystems, as summarized in Table 2-1.

Most natural gas and oil wells incorporate a common set of processes[3] that result in a common set of operational and environmental challenges. Despite these similarities, a one-size-fits-all approach to exploration and production would be impossible. Operators face unique or more intense challenges in developing resources of certain types or with certain physical, geographic, or physiographic characteristics. Unique

3 Paul Bommer, *A Primer of Oilwell Drilling: A Basic Text of Oil and Gas Drilling*, 7th ed. Austin: The University of Texas Continuing Education Petroleum Extension Service, October 2008.

Table 2-1. Play Variation by Geographic Distribution

Region	Topography	Rainfall	Ecosystem
Onshore			
Northeast/Midwest USA/ Canada	Hills and valleys, open flood plains	Rain and snow prevalent	Deciduous forests
Southwest/ Midcontinent	Relatively flat plain/ uplifted plateau	Mainly dry with rainy periods	Open rangeland
Western mountain region USA Canada	Upthrusted mountain ranges and foreland basins	Mainly dry with winter snows	Alpine
West Coast USA/Canada	Mixed terrain of high mountains and flats	Rainy on coast, very dry inland	Rainy forests near Pacific, desert
Offshore			
Coastal/Shallow	<1,000′ water depth to coastal marsh	Severe hurricane potential	Wetlands, marine estuaries to marine habitat
Deep, Outer Continental Shelf	>1,000′ water depth	Severe hurricane potential	Marine habitat
Arctic	Open water to ice-covered water	Severe weather, ice	Open water to ice-covered water

strategies, technologies, and environmental considerations are required when developing and managing each individual resource play. Table 2-2 summarizes some important operational and environmental concerns inherent in each type of play.

Significant geographic and physiographic diversity can be found within a single resource play type, again necessitating varying development strategies, as illustrated in Table 2-3 for current shale plays. Multiple play types may even be located in a single physiographic basin, as in the Uinta-Piceance basin in Utah and Colorado.[4] Figure 2-3 presents the play types found in the Uinta-Piceance basin, which include, but are not limited to, coalbed natural gas, shale gas, oil sands and tight oil, oil shale (kerogen), and conventional natural gas and oil.

Operational and environmental differences are particularly pronounced between onshore and offshore development, and between conventional and unconventional resource development.[5] Accordingly, this section addresses the challenges and potential impacts associated with development of conventional natural gas and oil resources both onshore and offshore, and then those associated with unconventional resources.

Overview of the Life Cycle of Natural Gas and Oil Exploration and Production

The following brief overview of natural gas and oil exploration and production is a general description that applies to all play types, both onshore and offshore, and provides context for this chapter.

- **Exploration** – Performed to establish the presence of hydrocarbon-bearing rocks in an area of interest, exploration typically begins with geologic evaluation to identify underground geologic structures and properties characteristic of hydrocarbon accumulations. Various surveys are employed to assess specific traits of rocks such as: magnetic surveys evaluate magnetic field intensity variations; geochemical surveys look for the presence of naturally migrated hydrocarbons near the surface; gravimetric surveys find variations in the gravity field; and seismic surveys, the most common survey type, evaluate the acoustic properties of the rock.

  Once a potential oil or natural gas accumulation is identified, an exploration well is drilled to confirm the presence of hydrocarbons and further

4 Charles W. Spencer, "Uinta-Piceance Basin Province (020)" (n.d.), accessed June 27, 2011, http://certmapper.cr.usgs.gov/data/noga95/prov20/text/prov20.pdf.

5 U.S. Department of Energy, *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*, DOE-FE-0385, October 1999.

Table 2-2. Resource Plays' Operational and Environmental Challenges

Resource Play	Operational and Environmental Challenges
Onshore	**Conventional: Oil** Typical direct impacts can include changes in land-use patterns, habitat fragmentation, aesthetic and noise alterations, extraneous light, atmospheric emissions (GHGs, VOCs, NO_x, etc.), soil erosion and sedimentation considerations, introduction of noxious vegetation, surface water quality and quantity changes, waste disposal challenges (drilling fluids, cuttings, muds, produced water), and spills and leakages. Typical indirect impacts can be associated with creation of new access routes that lead to unplanned consequences, social changes resulting from employment opportunities, stress on existing infrastructures, increased traffic, secondary ecological issues such as food and nutrient supply changes, breeding area and migratory route pattern changes, increased vulnerability to predators, and hydrology changes from siltation. All of these potential impacts can be compounded because long-term occupation of sites requires access to facilities resulting in long-term loss of habitat and land use, coupled with long-term effects of vegetation clearance, including erosion, and possible changes to surface hydrology. **Unconventional: Oil Sands, Heavy Oil** Requires special production operations that can be water and energy intensive. Surface disturbances per production unit are generally larger than conventional oil and require more infrastructure, resulting in greater air emissions. **Unconventional: Oil Shale** Requires special production operations that can be resource intensive. Potentially extensive surface disturbance required. Both in situ and surface retorting are energy intensive and produce large quantities of GHG emissions. **Unconventional: Tight Oil, Shale Oil** Requires horizontal wells and hydraulic fracturing to produce the resource. **Conventional: Gas** The same operational and environmental challenges as associated with conventional oil would be experienced with conventional gas development. **Unconventional: Tight Gas** Requires special completion techniques to produce gas in economic quantities. Hydraulic fracturing is typically required. Heterogeneity of resource requires unique development, which could affect level of environmental impact. **Unconventional: Coalbed Natural Gas** Withdrawal of large quantities of freshwater to liberate gas production may be required; to reduce the hydrostatic head, dense well patterns may be needed. Disposal and treatment of produced water create challenges and conflicts when associated with arid western conditions where freshwater can be scarce. **Unconventional: Shale Gas** High Volume Hydraulic Fracturing (HVHF) of horizontal wells is often required to develop this resource. Water sourcing and produced water disposal, treatment, and reuse from HVHF are a challenge. Development in a range of geographic and urban/rural areas creates socioeconomic challenges and increases demand on local infrastructure, traffic, labor force, education, medical, and other services.
Offshore	**Offshore** Long-term site selection based upon biological and socioeconomic sensitivities and minimum disturbance. Risk of impact to sensitive species and commercially important species, resource conflicts, and access difficulties. Long-term support and supply base requirement and impacts on local port infrastructure. Drill cuttings, drilling mud, produced water, sewage, sanitary and kitchen wastes, spillages, and leakage must be disposed of appropriately. Emissions from power and processing plants affect air quality. Impact of noise and light from facilities. **Offshore Arctic Specific** Ice-related environment must be addressed; special consideration for Arctic marine species and disturbance of habitat. Atmospheric emissions from vessel engines and platform equipment are heavily scrutinized by the U.S. EPA. Discharges to ocean limited due to environmental concerns. Bilges, sewage, spillages, waste, and garbage need to be disposed on shore.

Table 2-3. Shale Plays

Formation	Basin	Depth, ft*	Thickness, ft	Location	Comments
New Albany	Illinois Basin	500–2,000	50–100, 20†	KY, IL, IN	Shallow, produces formation water, small gas production since 1858, minor until horizontal drilling became an option. Produces from 60 main fields; possible control – natural fractures related to faulting, folds, and draping, high water levels indicate permeability. Well spacing, 80 acres; drinking water depth, 400 ft.
Antrim	Michigan Basin	600–2,200	20–200, 70–120‡	MI	Classic play – shallow, produces formation water, actively developed since 1980s, unique based on depth, water, thin pay zone to develop. Two sets of dominant fractures, no key fields developed, limited production outside of area of natural fractures, the fractures require stimulation for production. Well spacing, 40–160 acres; drinking water depth, 300 ft.
Marcellus	Appalachian Basin	4,000–8,500	<900,§ 50–200¶	NY, PA, OH, WV	Most expansive shale play in U.S., several attempts at development, but 2003 first economic well with horizontal drilling and hydraulic fracturing, key to success of play. Lower in relative gas content to other plays, but sheer size makes good play. Well spacing, 40–160 acres; drinking water depth, 850 ft.
Bakken	Williston Basin	8,000–10,000#		ND, MT	Shale oil
Mancos	San Juan Basin	>18,000**	1,000–5,000††	NM, CO	Exploration play – natural fractures and thin sands are key to production, there is shear failure at high drawdowns, fluid treatment selection important, overpressured.
Lewis	San Juan Basin	>5,000	200–300	CO, NM, WY	Classic play – late 1990s start of play, typically secondary completion in wells targeting other intervals, allows economics to not rely solely on Lewis. Well spacing, 80–320 acres‡‡; drinking water depth, <4,000 ft.
Baxter	Vermillion Basin		Up to 2,500	CO, WY, UT	Emerging play

* Ground Water Protection Council (GWPC) and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer*, prepared for the U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory, April 2009.

† EnergyIndustryPhotos.com, "The New Albany Shale, Maps and Info" (n.d.), accessed April 21, 2011, http://www.energyindustryphotos.com/new_albany_shale.htm.

‡ GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer*.

§ OilShaleGas.com, "Woodford Shale – Oil & Natural Gas Field – Arkoma Basin Oklahoma" (n.d.), accessed April 21, 2011, http://oilshalegas.com/woodfordshale.html.

¶ GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer*.

\# Montana Board of Oil and Gas Conservation, Online Oil and Natural Gas Database, (n.d.), accessed May 2011, http://www.bogc.dnrc.mt.gov/MBOGCdotNET/frmFilterNavigation.aspx.

** IHS, Inc., "Energy Information, Software & Solutions" (n.d.), accessed June 27, 2011, http://energy.ihs.com/NR/rdonlyres/345C2AAA-AAE3-435F-B1B0-6E8A883A105A/0/curtisnape08.pdf.

†† Halliburton, "The Mancos Shale," presentation (n.d.), accessed April 21, 2011, http://www.halliburton.com/public/solutions/contents/Shale/related_docs/Mancos.pdf.

‡‡ John B. Curtis, "Fractured Shale-Gas Systems," *AAPG Bulletin* 86, no. 11, November 2002, pages 1921–1938.

Table 2-3. Shale Plays (continued)

Formation	Basin	Depth, ft*	Thickness, ft	Location	Comments
Haynesville	AKA Bossier	10,500–13,500	200–270, 200–300§§	LA	AKA Haynesville/Bossier, still being delineated, potential realized in 2007. Well spacing, 40–560 acres; drinking water depth, 400 ft.
Conasauga				AL, GA	Very hydrosensitive formation, drilling involves minimal water use, and production began in 2005.
Barnett	Fort Worth and Permian Basins	6,500–8,500	100–600,¶¶ 50–200##	TX	Classic play – most prominent shale gas play in the United States, deep Barnett (>18,000) exploration play. Innovation has played a part in increasing recovery to 20%; however, infill drilling has been key to increases in reserves. Initial completions used 100,000–1,000,000 pounds of proppant, very costly and did not work, light sand fracturing introduced in 1998 and has been successful. Using horizontal drilling increased production rates by 2-3 times over vertical wellbores. Well spacing, 80–160 acres; drinking water depth, 1,200 ft.
Woodford		6,000–11,000	120–220*** †††	OK, TX	Emerging play – development began in 2003-2004 via vertical wells, horizontal now being explored, early phases of development, higher than average gas content. Well spacing, 640 acres, drinking water depth, 400 ft.
Floyd	Black Warrior Basin	9,000‡‡‡	80–1,000§§§	AL, MS	Exploration play
Fayetteville	Arkoma Basin	1,000–7,000	20–200¶¶¶	AR, OK	Emerging play – exploration began in 2000s, key to success horizontal drilling and hydraulic fracturing, early results from vertical wells mediocre. Well spacing, 80–160 acres, drinking water depth, 500 ft.
Utica		9,000###	200****	NY, OH, Quebec	Exploration play

§§ GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer.*

¶¶ GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer.*

John B. Curtis, "Fractured Shale-Gas Systems," *AAPG Bulletin* 86, no. 11, November 2002, pages 1921–1938.

*** OilShaleGas.com, "Woodford Shale – Oil & Natural Gas Field – Arkoma Basin Oklahoma."

††† GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer.*

‡‡‡ IHS, Inc., "Energy Information, Software & Solutions."

§§§ OilShaleGas.com, "Woodford Shale – Oil & Natural Gas Field – Arkoma Basin Oklahoma."

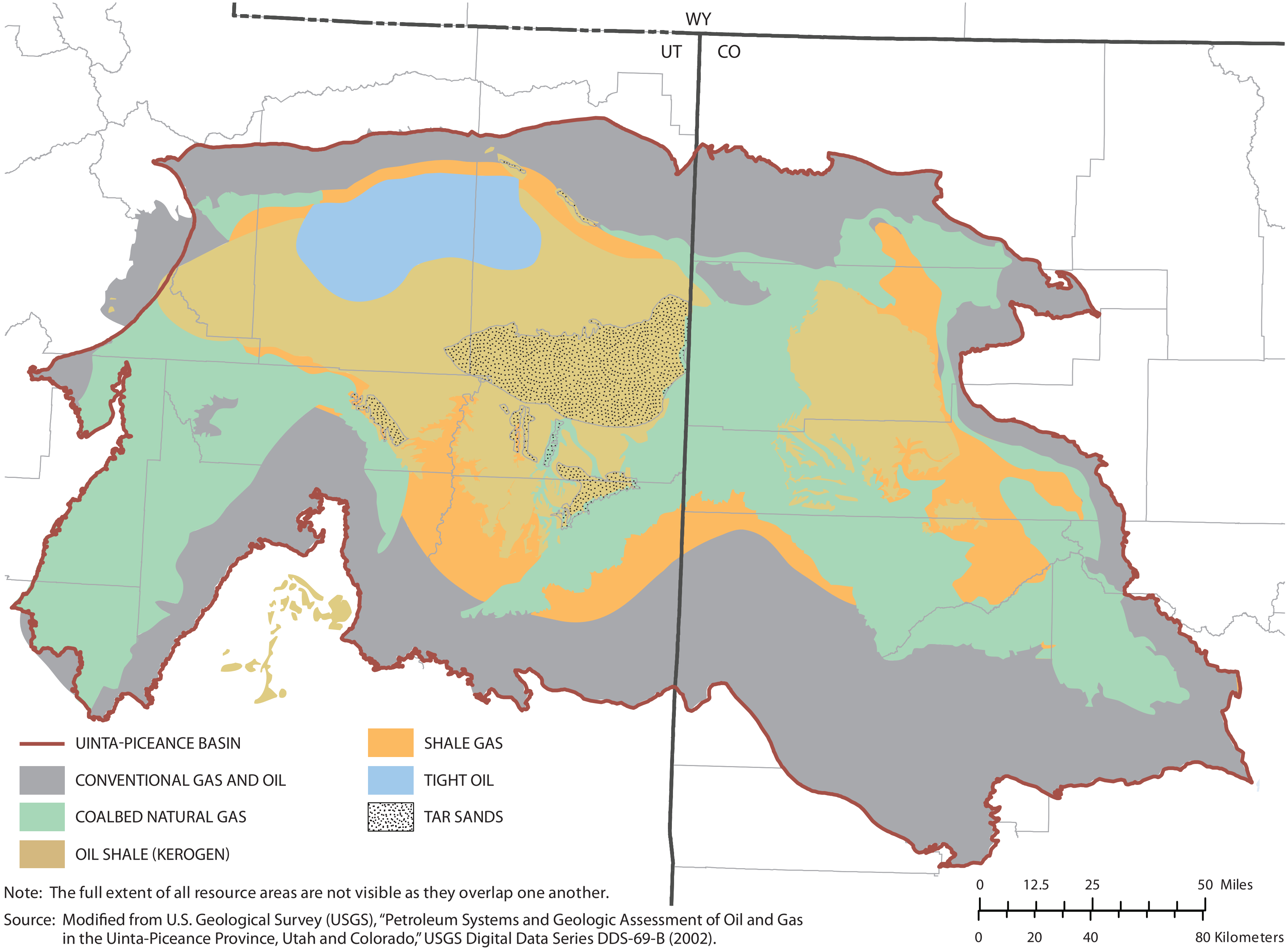
¶¶¶ GWPC and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer.*

IHS, Inc., "Energy Information, Software & Solutions."

**** OilShaleGas.com, "Woodford Shale – Oil & Natural Gas Field – Arkoma Basin Oklahoma."

Note: Additional Shale Plays Include: **Huron** (Ohio Shale, OH, WV, KY), **Pearsall-Eagle Ford** (Maverick Basin, TX), **Pierre** (Raton Basin, CO), **Gammon** (Williston Basin, MT), **Collingswood** (Michigan), **Niobrara** (CO, WY), **Monterey** (CA), **McClure** (West Coast), **Horton Bluff & Lorraine** (Eastern Canada), **Horn River Muskwa** (British Columbia) and **Montney** (Alberta, Northeast British Columbia).

Figure 2-3. Generalized Resource Areas within the Uinta-Piceance Basin Showing the Distribution of Fossil Fuel Source Rocks and Reservoirs



Note: The full extent of all resource areas are not visible as they overlap one another.

Source: Modified from U.S. Geological Survey (USGS), "Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado," USGS Digital Data Series DDS-69-B (2002).

evaluate the reservoir rock. Numerous tests are run to characterize the formation, allowing geologists and engineers to determine whether or not the site is likely to produce oil or natural gas in economic quantities. If the site is determined to be of poor quality, the exploration well is plugged and abandoned and no further action is taken. If the well is successful, the operator will run further appraisals of the area to delineate the extent of the reservoir and type and quantity of oil or natural gas.

- **Siting** – During site selection, operators identify optimal drilling locations, formulate a land control strategy, and design the infrastructure to rapidly bring wells into production. Available drilling technologies may also be a factor in site selection and planning. Site selection involves geological characterization; habitat evaluations; storm water management; road and feeder pipeline development; construction; and reclamation planning, including topsoil conservation and revegetation. Companies take actions to adhere to federal, state, tribal, and local regulatory and permitting requirements addressing environmental, archaeological, development, and surface use issues. Regulations and enforcement can vary widely among different agencies. These rules require companies to plan for the entire life of the well, unexpected events, safety, environmental protection, and final reclamation once the production cycle is complete. Public outreach efforts may also be initiated during the siting phase.

- **Planning and Design** – The site is then prepared and a well pad constructed to support the variety of heavy equipment needed during drilling, completion, and production operations. A location that is not part of an existing gas field or large development design may require construction of additional facilities. The current design paradigm includes a flexible drilling site that can accommodate multiple wellheads. Multi-well drilling pad locations have a slightly larger footprint than single-well pad sites, typically ranging from one to five acres or larger. Multi-well pads on a local and regional scale can comparatively reduce environmental impacts, particularly habitat fragmentation and land use coupled impacts such as erosion and sedimentation.

  Site preparation includes clearing, grubbing, and leveling an area and preparing the surface to support movement of heavy equipment. The site preparation usually includes spreading a uniform layer of crushed stone over geotextile fabric constructing an access road, establishing erosion and sediment control structures, and installing surface impoundments for retention of drilling fluid and possibly freshwater. The potential environmental impacts of site development include erosion and sedimentation, habitat fragmentation, noise, introduction of invasive vegetation, increased traffic, direct disturbance of sensitive resources, and dust. Most impacts can be mitigated by locating a site in less-sensitive areas and with proper site design.

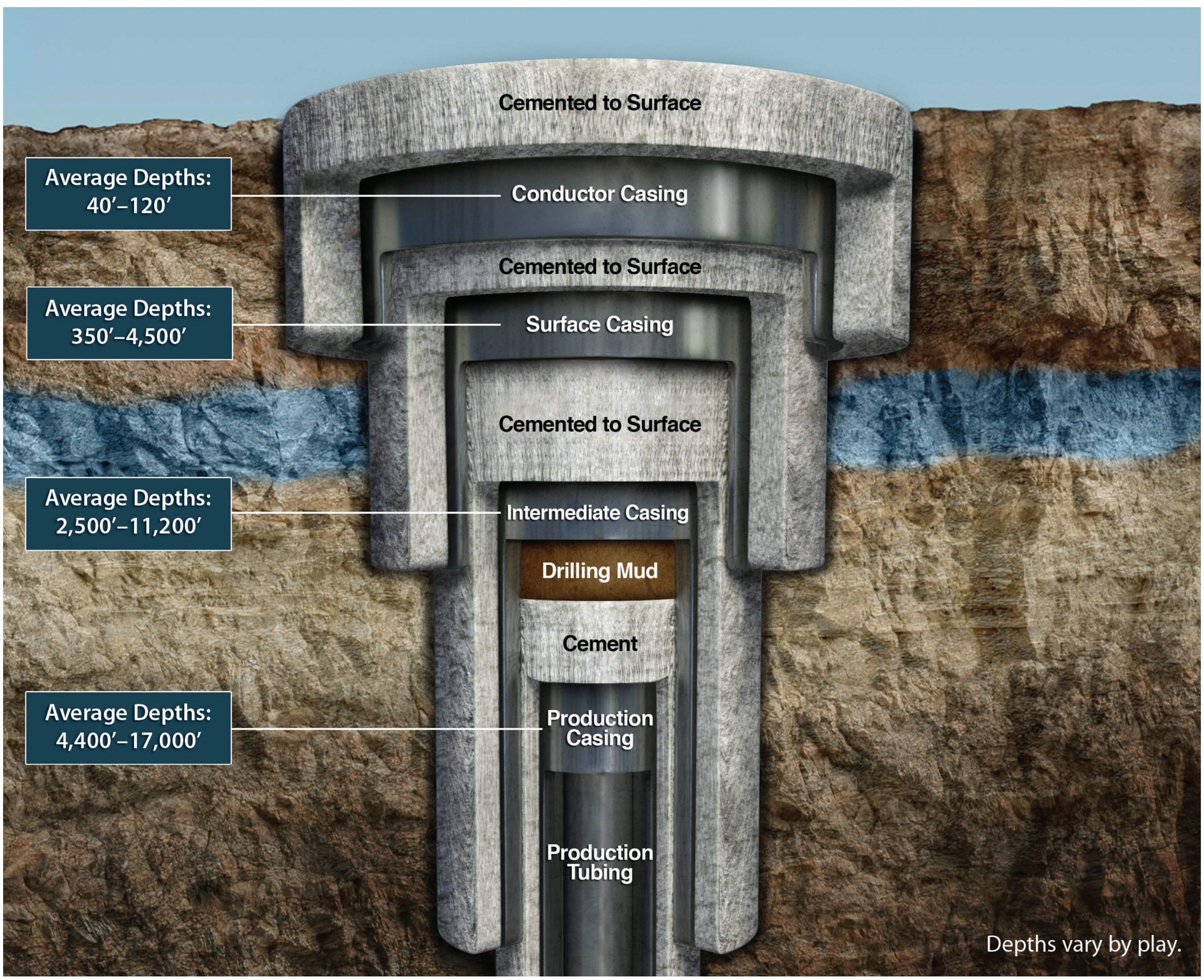
- **Drilling** – Drilling is conducted to reach natural gas and oil reservoirs, creating a pathway for the extraction of hydrocarbons. Optimization of time is essential in this highly coordinated and expensive process, with most rigs running 24 hours a day. The time needed to drill a well is highly variable, ranging from days for shallow coalbed natural gas (CBNG) wells to months for more complicated and deeper exploratory wells in a new field.

  A well is drilled by a rotating bit that cuts through rock. Fluid specifically designed for each well is circulated through the drill pipe and bit and back up the space between the drill pipe and the wellbore to condition the hole, manage pressure, keep the bit cool, and move the drill cuttings to the surface. This fluid can be compressed air or water, but most often is drilling mud, which is comprised of water, clays, and chemicals. As drilling proceeds, lengths of pipe are added onto the drill string. Surface casing is run into the wellbore to isolate the drilling process from any shallow aquifer zones once a predetermined depth is reached. Depending on the geologic conditions, one or multiple strings of intermediate casing may be run to isolate shallow hydrocarbons and to protect shallower formations from deeper pressures.

  Drilling continues through the surface and possibly intermediate casing until the total depth of the well is reached. Each string of casing is cemented in place and the integrity evaluated to protect the groundwater and formation. Liquid and solid materials and waste brought to the surface during drilling are disposed of by a variety of permitted processes that are chosen to meet the needs of individual well-construction projects. Depending on data needs and regulatory requirements, open-hole well logs or other measurements may be run. At this point, production casing or liner and cement are run in the wellbore or, depending on the completion plan, the portion of the wellbore containing the producing formation may be left open. The integrity of the casing and cement is essential to avoid possible groundwater contamination. Figure 2-4 is a schematic of a completed well showing the casing and tubing strings and cement. After installation, wellbores are evaluated and if everything is intact and effectively working, a collection of valves, gauges, fittings, spools, and chokes (a "Christmas tree") is placed on top of the well to control the flow of formation fluids, isolating the well while still allowing access for completion and maintenance.

- **Completion** – Once a well has been drilled and tested (logged, cored, and pressure data), the target reservoir rock's porosity and permeability are examined to determine whether the well will be completed or plugged. If the potential flow of hydrocarbons is low, the well may not justify the cost of completion. In these cases, the well is plugged with cement in several places and abandoned. If test information indicates a well will be commercially productive, it is completed by preparing the bottom of the hole as necessary and running the tubing or other equipment into the wellbore. In most formations, stimulation is necessary to make a connection between the formation and the wellbore to enable the flow of oil or gas. During stimulation, the casing at the depth of the reservoir rock is perforated, if necessary, and the rock is either hydraulically fractured, acidized, enhanced, or otherwise stimulated to increase the permeability. Hydraulic fracturing is the practice of injecting water, chemicals, and sand into a

Figure 2-4. Example of Wellbore Schematic



wellbore for the purpose of fracturing the formation to create the permeability necessary for movement of natural gas and oil in the formation to the wellbore.

In initial (primary) production, the natural pressure of the reservoir is usually enough to drive liquid and gas hydrocarbons to the surface. However, in some types of reservoirs, this pressure drops over time and additional lift is required. A pump jack or gas lift system may be installed on a well to provide artificial lift. In some cases, reservoir pressure is enhanced with the injection of gas, water, or steam directly into the reservoir to increase hydrocarbon flow into the wellbore. The reservoir injection process may require additional wells. Enhanced oil recovery and secondary recovery are important components in increasing potential production from oil-bearing formations.

- **Production and Delivery** – Well products are often a complex mixture of liquid hydrocarbons, gas, water, and solids. Once well products reach the surface, field facilities gather and separate the mixture, removing and disposing of or recycling constituents that are not saleable. The hydrocarbons are then transported by pipeline to end users. Purchasers have contract standards for the natural gas and oil accepted, often called pipeline quality. For example, oil purchasers typically limit the amount of basic sediment and water to less than 1%. Gas purchasers set similar limits on water, water vapor, hydrogen sulfide, carbon dioxide, and British thermal unit (Btu) content.

  Throughout its producing life, a well is continually monitored and maintained to ensure that its integrity is maintained and its production is optimized. Interim reclamation also takes place throughout the life of an operation. For example, when a portion of the pad can be reclaimed following drilling and completion, reseeding can be initiated to start the process towards complete mitigation.

- **Reclamation** – Once a well is no longer economic, after years or decades of production, it is plugged and abandoned, which involves filling the well casing with cement and removing the wellhead, pump jacks, tanks, pipes, and other location facilities and equipment. Federal land and state natural gas and oil agencies specify the time frame and methods for plugging the well, reclaiming the soil, and completing other environmental and safety protections. Reclamation does not necessarily require full ecological restoration, but focuses on creating short-term stability and restoring the visual and hydrological potential to allow the site to naturally return to its original state or serve a future intended use.

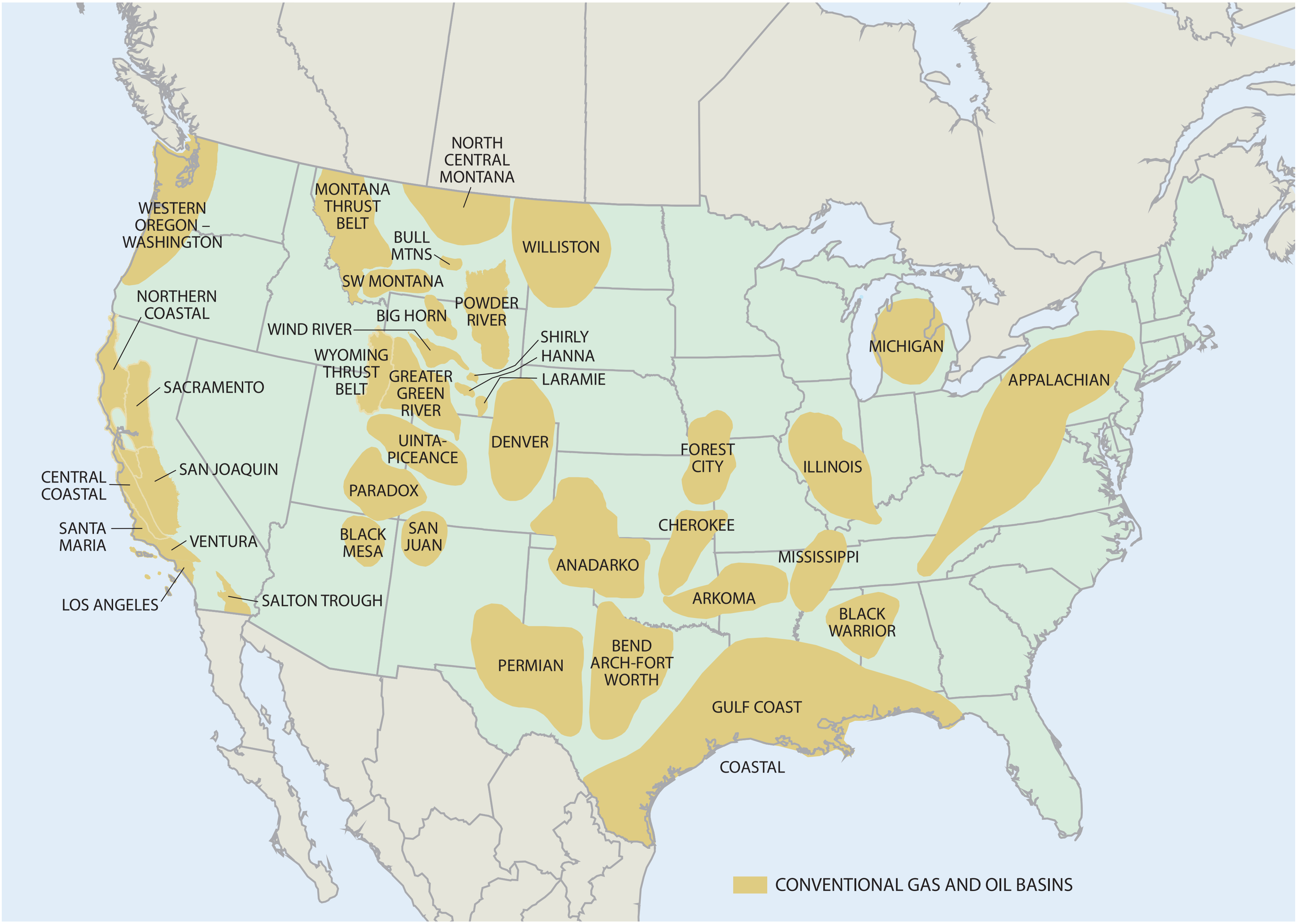
Developing Onshore Conventional Natural Gas and Oil Resources

Conventional oil is accessed by what could be termed standard well extraction methods. Typically, conventional oil wells produce from a pressure-driven system, meaning oil flows from the reservoir to the wellbore and to the surface based on a pressure difference between the reservoir rock and the wellbore. Over time, the well may require assistance in lifting the oil from the reservoir to the surface, via pumps, secondary recovery methods (e.g., waterflood), and/or enhanced oil recovery methods (e.g., thermal, miscible, or chemical means). Primary production from a conventional oil well may only average 10% of the original oil in place; with the use of enhanced oil recovery, recovery may only reach 30–60% original oil in place.

Conventional natural gas deposits, similar to conventional oil, originate from proximal organic-rich source beds, such as shale. The gases migrate into either structural or stratigraphic traps, which are sealed by low-permeability shale formations, mudstones, or salt. The gas remains trapped in these discrete accumulations of sandstone or carbonate reservoirs, both of which have interconnected pore networks that allow gas flow to the wellbore. Due to their ease of access and high porosity and permeability, conventional gas resources require a low number of wells to economically access the resource, which is often held in small pockets within the stratigraphy.

Conventional oil has been produced from a wide geographic area across the country. Characterized as a more mature resource development, conventional oil currently accounts for only 30% of the existing North American reserves. Although some conventional oil wells have gone into abandonment and cleanup, many of the fields are becoming prolific again via unconventional drilling techniques. Figure 2-5 outlines conventional natural gas and oil basins that have been developed in the lower-48 states of the United States.

Figure 2-5. Major Conventional Natural Gas and Oil Basins in the Lower-48 States



Environmental challenges for onshore conventional natural gas and oil development include potential impacts to surface water, groundwater, air quality, land, public health, wildlife and habitat, and community character and quality of life that will vary depending on local conditions.

- **Wildlife** – Potential impacts to wildlife are attributable primarily to construction of roads and pads through habitat loss and habitat fragmentation. Migratory or reproductive behavior may be disturbed due to noise and vehicle traffic. Improperly managed surface impoundments can result in injury or death for terrestrial wildlife and birds, especially migratory waterfowl. In addition, the movement of equipment and materials creates the risk of introducing invasive species from one area to another.
- **Surface Water** – The potential for impacts to surface water primarily results from storm water runoff or spills. During construction, storm water runoff must be managed to prevent erosion of roads and slopes of well pads. Such soil erosion, if allowed to reach streams or lakes, can adversely affect surface water quality and may impact aquatic wildlife. In addition, if pads are not properly constructed, storm water runoff can wash lubricants and other chemicals from machinery or surface stains and transport these chemicals to surrounding soils or streams. Potential impacts from spills can result from produced water, fuels, or other chemicals that may be temporarily stored on site. If such spills are not contained on the well pad, they may reach surface water bodies and affect both water quality and aquatic life.
- **Groundwater** – The potential for groundwater impacts exists during drilling and produced water management as well as after plugging and abandonment. During drilling, proper casing and cementing is required to ensure that groundwater aquifers are protected. If produced water is injected into an underground injection control (UIC) well for secondary recovery or disposal, wells must be properly constructed and cemented to ensure that injected fluids do not contaminate underground sources of drinking water. Groundwater impacts also can result from improper disposal of wastes. In addition, wells must be properly plugged to ensure that the plug is not degraded by subsurface chemical and pressure conditions. Improperly plugged wells can allow oil, gas, or saltwater to migrate into groundwater aquifers over time.
- **Air Quality** – The potential for air quality impacts comes primarily from engine emissions, dust, and methane emissions. Engine emissions include construction equipment, transport trucks, personal vehicles, drilling rigs, and compressor engines. Such emissions can contribute both regulated pollutants and greenhouse gases. Dust can be generated by truck and personal vehicle traffic. In addition, methane can be released by flaring or venting and may also escape through leaks in piping or equipment.

Each of these challenges can be magnified depending on site-specific geologic, geographic, climatic, or other environmental factors. For example, the potential for erosion is greater in areas with steep slopes or erosive soils. In addition, sensitive or extreme environments, such as wetlands, deserts, and arctic regions, can be susceptible to impacts from relatively small disruptions and may be very slow to recover from adverse impacts. Furthermore, threatened and endangered species are more likely to be encountered in such areas.

Developing Offshore Conventional Natural Gas and Oil Resources

Offshore development is a major source of natural gas and oil to North America. Typically, offshore resources must be well proven and capable of producing greater volumes per well to justify the added cost of their development relative to onshore resources. The reservoirs themselves usually are of a conventional nature.

The offshore environment presents extreme variations in physical conditions. From potential hurricane conditions on the East and West Coasts and in the Gulf of Mexico to the rigors of the Arctic North, these conditions demand special considerations when planning for development, timing, and safety. Managing subsea operations and maintaining equipment in this environment also adds to the development and operational complexity.

Operating in a water environment eliminates or minimizes many of the challenges associated with soil and habitat disturbance that affect onshore development; yet offshore production poses a number of unique environmental challenges. Seismic noise generated by offshore natural gas and oil exploration activities is recognized as a concern for whale populations and other marine life, including fish.

Other considerations germane to offshore operations include special health and safety precautions; physical and other logistical constraints affecting the offshore management of drilling fluids, cuttings, and wastewater; noise and air emissions generated from the drilling equipment and support vessels and aircraft; industrial or solid waste including paint, spent solvents, and packing materials; subsea pipeline integrity; harmful aquatic organisms introduced from vessels traveling from other geographic regions; decommissioning offshore platforms; and ice-related environmental adaptations in arctic environments.

Properly trained personnel whose knowledge is continually assessed through regular drills and exercises are the first line of defense in detecting spills or other problems. Quickly detecting and responding to spills is one of the biggest challenges for offshore production, given the remote location of these facilities and the fact that drilling is occurring under water and out of human sight. Detecting spills or other problems also depends on indirect indications provided by instruments, gauges, or sensors. Once a problem is detected, identifying its cause and the most effective response also depends on this equipment, coupled with visual inspection by divers or by remotely operated vehicles. After corrective action, any material or personnel not already on the rig must be transported from shore via helicopter or ship.

The high volume of production from offshore wells means that large quantities of hydrocarbons can be released in a relatively short time, affecting aquatic, terrestrial, and avian wildlife. Stationary and bottom-dwelling aquatic organisms can be especially vulnerable. Terrestrial wildlife can be affected when oil is washed ashore, and birds can be affected both by oil that is washed ashore and by oil floating in the sea. Mitigating harmful impacts requires that spill response capabilities are in place and can be rapidly deployed. In arctic environments, periods of prolonged darkness, subzero temperature, and the presence of ice requires that response equipment and strategies are adequately developed to be effective under these challenging conditions.

Developing Unconventional Natural Gas and Oil Resources

Unconventional resources are so termed because they require additional techniques to produce beyond those necessary for conventional resources. Unconventional play types, which are nearly all onshore, offer high resource potential and can pose specific environmental challenges due to the technologies required to produce them.

- Classes of unconventional oil include heavy oil, such as bitumen found in oil sands; oil shale or kerogen, which must be heated to transform it into a hydrocarbon; and tight oil, which may be conventional in form, but is produced from low permeability formations using unconventional methods.
- Unconventional gas resources, sometimes called continuous gas reservoirs, include shale gas, tight gas, and CBNG. These resources typically lack the matrix permeability that is characteristic of conventional accumulations, connecting the pores of the rock together. Since this lack of permeability greatly reduces the ability for gas to flow, production requires induced fracturing or permeability. Recent advances in stimulation techniques, such as hydraulic fracturing, have improved the economics of these reservoirs, enabling them to become key resource plays in North America.

Oil Sands and Heavy Oil

Oil sands (e.g., extra heavy oil, bituminous sands) are a type of bitumen deposit. The sands are naturally occurring mixtures of sand, clay, water, and an extremely dense and viscous form of petroleum called bitumen. Oil sand reserves have only recently been considered part of the world's oil reserves, as higher oil prices and new technology enable them to be profitably extracted and upgraded to usable products. Found in many countries throughout the world, oil sands exist in greatest quantities in Canada and Venezuela. Currently, the Western Canada Sedimentary Basin in northern Alberta is the only producer of synthetic crude oil from bitumen deposits. The main deposits are located in three areas in Alberta: Athabasca, Peace River, and Cold Lake.

Heavy crude oil feedstock needs pre-processing before it is fit for conventional refineries. This upgrading adds to the production cost and environmental considerations. In addition, the production of oil sands entails substantially greater water consumption than conventional methods. Conventional oil production, on average, uses from 0.1 to 0.3 barrels of water per barrel of oil produced. Unconventional oil supply water use ranges from 0.6 to 4 barrels of water per barrel of oil produced.[6] In some cases, fresh water is required for unconventional extraction; however non-potable water sources are also used where possible. For example, in steam-assisted gravity drainage (SAGD) operations in the Alberta oil sands, the industry uses saline, or non-drinkable, water from deep underground formations, which has allowed the industry to reduce the amount of net water for operations to 0.6 to 0.9 barrels per barrel of bitumen produced.[7] Furthermore, due to extensive recycling of process water by oil sands producers, the average amount of fresh water used per barrel of bitumen produced is lower: 0.39 barrels for SAGD. Also, the amount of fresh water consumed to produce a barrel of bitumen has steadily declined over the last 25 years and is much lower than producing a barrel of bitumen from surface mining operations (2.5 barrels of water). However, because the void left by the extracted bitumen in the underground formations is filled by water, the final ratio of water used to oil produced for in situ operations is closer to 1:1.[8]

Instead of being produced by wells, oil sands are sometimes harvested by surface mining and separating the bitumen from the inorganic material at centralized surface facilities. Surface mining can create many of the same challenges faced by surface coal mines, including large-scale surface disturbance, changes to surface contours and surface water drainage, and reclamation. Mining also can disrupt surface water flows, remove portions of formations that contain usable groundwater, and potentially affect aquifers that occur below the producing zone. In addition, because the bitumen is separated from the sand by hot water, the process uses large volumes of water and results in large volumes of processed water that is frequently stored in surface ponds while awaiting treatment and disposal. There are concerns that these ponds could result in surface or groundwater contamination and in adverse impacts to wildlife, especially birds, if not properly managed.[9]

Another production method for oil sands is SAGD, a process that, again, requires substantially more water than conventional production. Combusting fuels to heat water for steam injection can also result in higher air emissions. In addition, mobilizing the bitumen in the subsurface can create concerns about the potential impacts to any aquifers that may occur below the production zone.[10]

Oil Shale

Oil shale is a fine-grained sedimentary rock containing organic matter that yields substantial amounts of oil and combustible gas upon destructive distillation. Destructive distillation (i.e., retorting) uses heat to decompose the organic matter in the shale, producing hydrocarbon liquids and gases. This need for additional thermochemical decomposition, or pyrolysis, is the main difference between oil sands and oil shale; oil sands already have the product hydrocarbons, whereas oil shale yields kerogen that must be cooked to make the product hydrocarbons.

The economic potential of an oil shale resource is largely determined by the price of petroleum and the depth of the deposit; if it is near enough to surface, it can be developed via open pit or conventional mining or by in situ methods. Additional factors include transportation access, workforce availability, and the chemical characteristics of the geology. Upon retorting, the number of gallons per ton of rock that can be generated also largely influences the economic viability of the play.

Oil shale resources in North America are highly variable in composition and much of the supply remains to be further evaluated. In Canada, 19 deposits have been discovered, with the greatest potential coming from the Albert Formation in New Brunswick. Additional deposits of interest in Canada include the Devonian Kettle Point Formation and Ordovician Collingwood Shale located in southern Ontario, and the Carboniferous oil shales in the Grinnell

6 Energy-Water Nexus Committee, "Energy Demands on Water Resources – Report to Congress on the Interdependency of Energy and Water," Department of Energy, Sandia National Laboratory, December 2006.

7 Donahue, William, "In Situ Oil Sands – get ready for massive water demands in northern and central Alberta," *Water Matters*, Table 1 "Annual Water Use in Situ Oil Sands Operations in Alberta," August 2010.

8 Griffiths, M., A. Taylor, and D. Woynillowicz. "Troubled Waters, Troubling Trends: Technology and Policy Options to Reduce Water Use in Oil and Oil Sands Development in Alberta," Pembina Institute for Appropriate Development, Table 3-1, 2006.

9 National Energy Technology Laboratory (NETL), "Unconventional Oil Resources Annual Report Fiscal Year 2004," November 3, 2004.

10 NETL, "Unconventional Oil Resources Annual Report Fiscal Year 2004."

Peninsula in the Canadian Arctic Archipelago. Oil shales in the United States are found throughout the East between formations known as Devonian through Mississippian black shales and in Pennsylvanian aged shales in association with coal. In the West, the Green River Formation is found in the U.S. Rocky Mountain region. Other deposits exist throughout the West and Alaska; however, limited research has been conducted on these areas. The main potentially productive area for oil shale is the Green River Formation near the common borders of Wyoming, Utah, and Colorado, which contains about half of the world reserves.

The environmental challenges associated with oil shale development using surface mining, coupled with surface retorting, are similar to those discussed above for oil sands and heavy oil. However, in situ retorting, which is expected to be more widely used in the future, has different environmental challenges. The in situ conversion process developed by Shell involves placing electrical heaters in deep vertical holes drilled through a section of the underground oil shale. The portion of oil shale penetrated is heated over a two- to three-year period, until a temperature of 650–700 degrees Fahrenheit is reached, at which point the oil shale releases the liquid hydrocarbon. The released hydrocarbon product is collected in production wells located within the heated zone.[11]

In situ retorting of deep shale oils requires the development of a dense network of roads, pipelines, well pads, and processing facilities. The surface disturbance associated with this development is envisioned to be greater than the disturbance associated with conventional oil or gas fields, to which in situ processing can be compared. However, the technical feasibility of the concept centers on solving two major environmental issues: controlling groundwater during production and preventing subsurface environmental contamination, including groundwater impacts.[12]

11 Bureau of Land Management, *Oil Shale and Tar Sands Programmatic Environmental Impact Statement,* (2008), accessed June 2011, http://ostseis.anl.gov/guide/oilshale/.

12 James T. Bartis, T. LaTourrette, L. Dixon, D. J. Peterson, and G. Cecchine (RAND Corporation), *Oil Shale Development in the United States: Prospects and Policy Issues*, MG-414-NETL, prepared for the National Energy Technology Laboratory, U.S. Department of Energy, 2005, accessed June 27, 2011, http://www.rand.org/pubs/monographs/2005/RAND_MG414.pdf.

Both mining and in situ conversion process recovery, coupled with processing activities for oil shale, involve a variety of environmental challenges, such as GHG emissions, disturbance of mined land, and potential impacts to wildlife, air, and water quality. The development of a commercial oil shale industry in the United States would also have social and economic challenges for local and regional communities as activity increases and workers move into the area. Of singular concern would be development in the arid western United States because a large amount of water is required for oil shale processing.

Tight Oil, Shale Oil

Tight oil or shale oil (not to be confused with oil shale) fields typically have some conventional oil resource play characteristics and produce light crude. However, they are unconventional in the sense that porosity and permeability are too low to produce the oil without stimulation. Two examples of successful tight oil fields are the Bakken in North Dakota and Montana, and the Eagle Ford in South Texas. Oil companies discovered these fields decades ago, but only with recent advances in horizontal drilling and hydraulic fracturing technologies have they become economic to drill and produce.

Extracting oil from shale uses the same process as extracting gas from shale: injecting large quantities of water, sand, and chemicals deep underground at high pressure to create fractures that allow the oil flow. The potential environmental impacts associated with hydraulic fracturing practices associated with shale are discussed in the following shale gas section.

Shale Gas

Shale gas is produced from low permeability shale formations that are both the reservoir and the source of the gas. As discussed below, tight gas is also sourced from low permeability formations, but unlike shale gas, the methane is not generated by the source rock. Coalbed natural gas is generated by its source rock through either biogenic or thermogenic reactions, whereas shale gas is generated only by thermogenic processes.

Subtle trapping mechanisms typically hold the gas in the shale, allowing large areas of shale to be gas saturated. The potential for shale gas production in a reservoir is determined in part by the amount of gas generated by the shale, retention of this gas, presence of fractures, and the mechanical properties of the rock. The storage of the gas in the shale can greatly affect the speed and efficiency of production. The percentage of gas recovered by current production methods in shale gas reservoirs is low.

Shale gas is one of the most rapidly expanding play types in onshore North America. This rock was formerly seen as only a source of natural gas and a seal for conventional reservoirs, but, with advances in drilling and completion technology, shale gas plays are becoming economically viable. As shown in Figure 2-6, North American shale basins are widespread across the continent. Currently, the most active shale plays include the Barnett, Haynesville/Bossier, Antrim, Fayetteville, Marcellus, and New Albany in the lower-48 states. Significant variations across these areas present operational challenges that must be addressed through play-specific strategies, with exploration and development approaches suited to the unique characteristics of each reservoir. Shale basins are source rocks and the development of horizontal drilling coupled with hydraulic fracturing has made the development of these resources viable.

Advances in horizontal well drilling and hydraulic fracturing have been instrumental in spurring the production of shale gas. Horizontal drilling within the formation allows more exposure of the formation to the wellbore than a vertical well. This enables production with fewer wells overall, which lessens associated environmental impacts. Use of multi-well drilling pads further reduces the environmental footprint and economic costs. The use of horizontal wells for shale gas production can reduce the wildlife and other surface use related challenges associated with conventional oil and gas production. Because multiple wells are frequently drilled from a single pad, and because each well is so productive, the amount of infrastructure and associated disturbance per well and per unit of energy produced can be reduced by as much as 90%.

Whether shale gas wells are drilled vertically only or with horizontal lengths in the formation, most are hydraulically fractured to stimulate production.[13] (For more information on hydraulic fracturing, see the "Hydraulic Fracturing" section later in this chapter.) Given the variability seen in the shale formations, no single technique for injection has worked universally. Numerous techniques have been applied in the Appalachian Basin alone, including carbon dioxide, basic fluid and chemical mix, foam nitrogen and carbon dioxide, and just water.

Horizontal wells require large volumes of fluids to fracture, introducing a number of environmental challenges. Use of freshwater has raised questions about the potential impacts of surface water and groundwater withdrawals on other users and on aquatic life. Produced water from shale gas wells has posed additional challenges because some production areas lack UIC wells with sufficient capacity to receive the volume of water generated. Where produced water has been treated and discharged into surface water bodies, questions have been raised about the potential impacts to the receiving stream.

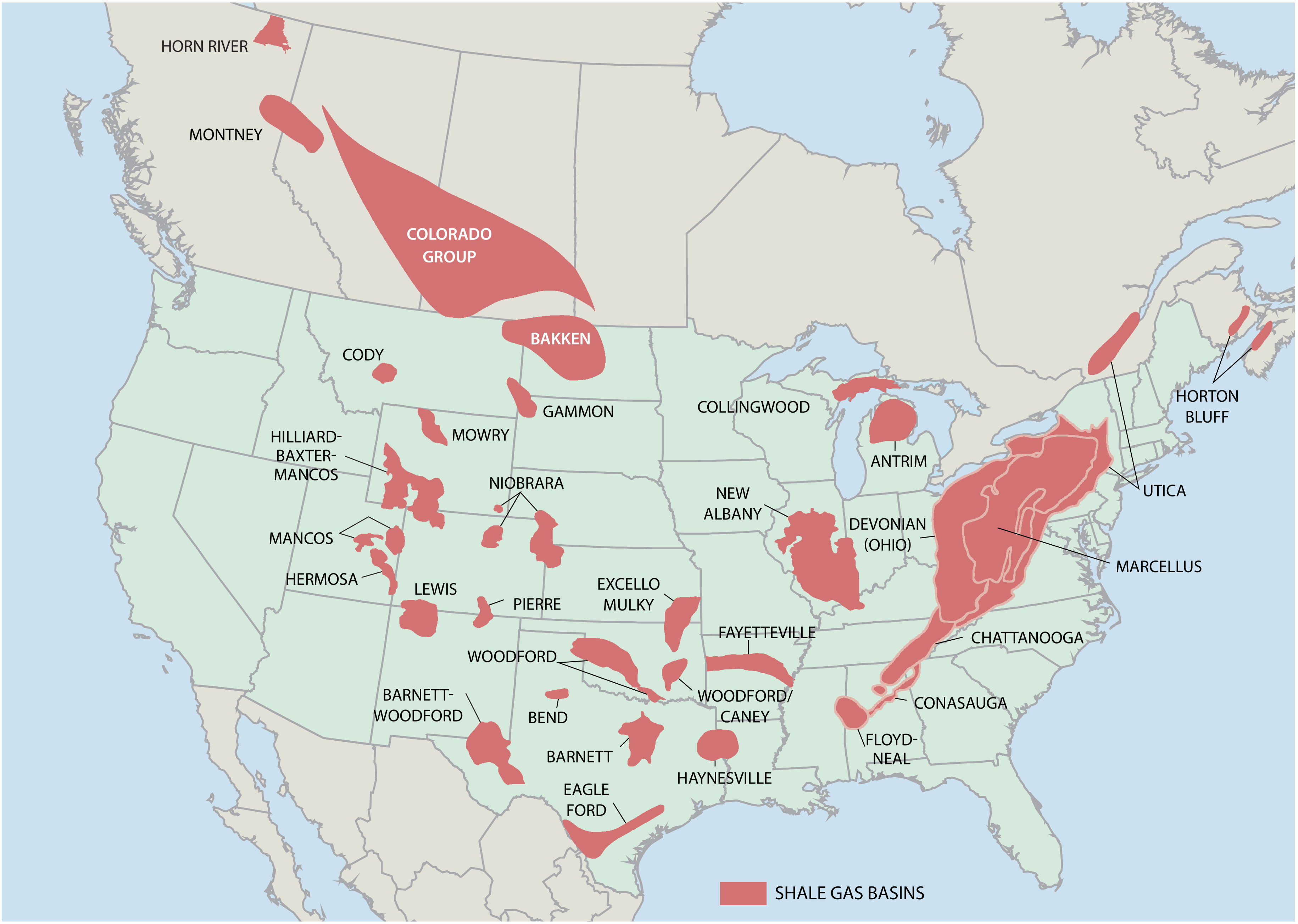
Chemicals needed for fracturing fluids also pose challenges regarding safe transportation and storage to prevent impacts to drinking water that might result from spills. The potential for residual chemicals in the produced water exacerbates the challenges associated with its management. Concerns about the chemicals used in hydraulic fracturing have led to repeated calls for public disclosure of this information. While some states have added rules requiring chemical disclosure for hydraulic fracturing, the requirements to date are not widespread and are not consistent. In addition, in order for such disclosures to be useful, the information must be readily available. To address the concern about chemical use and to make the information easily accessible over the Internet, industry has teamed with the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission to create a voluntary disclosure and information website called FracFocus.

The rapid expansion of shale gas development has brought natural gas activity to regions that have not recently experienced widespread development. The introduction of these activities has brought changes in land use to both urban and rural areas. Along with the development have come changes in traffic, noise, and the landscape. In addition to provoking concerns about health and safety, these changes in local areas have drawn attention to shale gas development and the environmental challenges associated with it.

While not unique to shale gas production, there have been some widely publicized instances of water wells being contaminated by methane. This

13 Ground Water Protection Council and ALL Consulting, *Modern Shale Gas Development in the United States: A Primer*, prepared for the U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory, April 2009.

Figure 2-6. North American Shale Gas Basins



contamination has not been associated with fractures created by hydraulic fracturing, but can occur during drilling when shallow geologic zones that contain some natural gas are encountered. Drilling through these zones can cause the gas to migrate to drinking water aquifers and into domestic wells. Industry continues to develop and apply drilling and cementing strategies to further minimize the occurrence of gas migration.

As with conventional gas production, emissions of criteria pollutants, hazardous air pollutants, and GHG emissions from combustion, leaks, or other fugitive emissions are associated with various points in the shale gas development life cycle. In particular, concerns about methane emissions from shale gas wells and chemical emissions from produced water have been raised as concerns for climate change and human health.

Tight Gas

While tight gas is produced from conventional reservoir rock types such as sandstone and (less often) carbonates, it is considered an unconventional resource because the very low porosity of the reservoirs necessitates special completions techniques to stimulate production. Reservoirs commonly lack a water contact, and can range from a single reservoir that is laterally extensive (tens of thousands of acres) to stacked reservoirs thousands of feet thick.

Stimulation techniques often involve hydraulic fracturing. Tight-gas drilling programs are under way in the Appalachian Basin, Rocky Mountain basins into Canada, and eastern and southern Texas. Figure 2-7 presents the tight gas basins in the lower-48 states.

Different drilling and completion techniques must be used in different areas to respond to the heterogeneity of tight gas accumulations in both geology and surface environmental setting. The appropriate wellbore design allows optimum contact with the producing formation, while avoiding infill drilling and minimizing footprint.

Environmental challenges for tight gas are similar to those associated with shale gas with regards to hydraulic fracturing. Other more common challenges associated with surface disturbances and waste disposal are similar to conventional natural gas and oil practices.

Coalbed Natural Gas

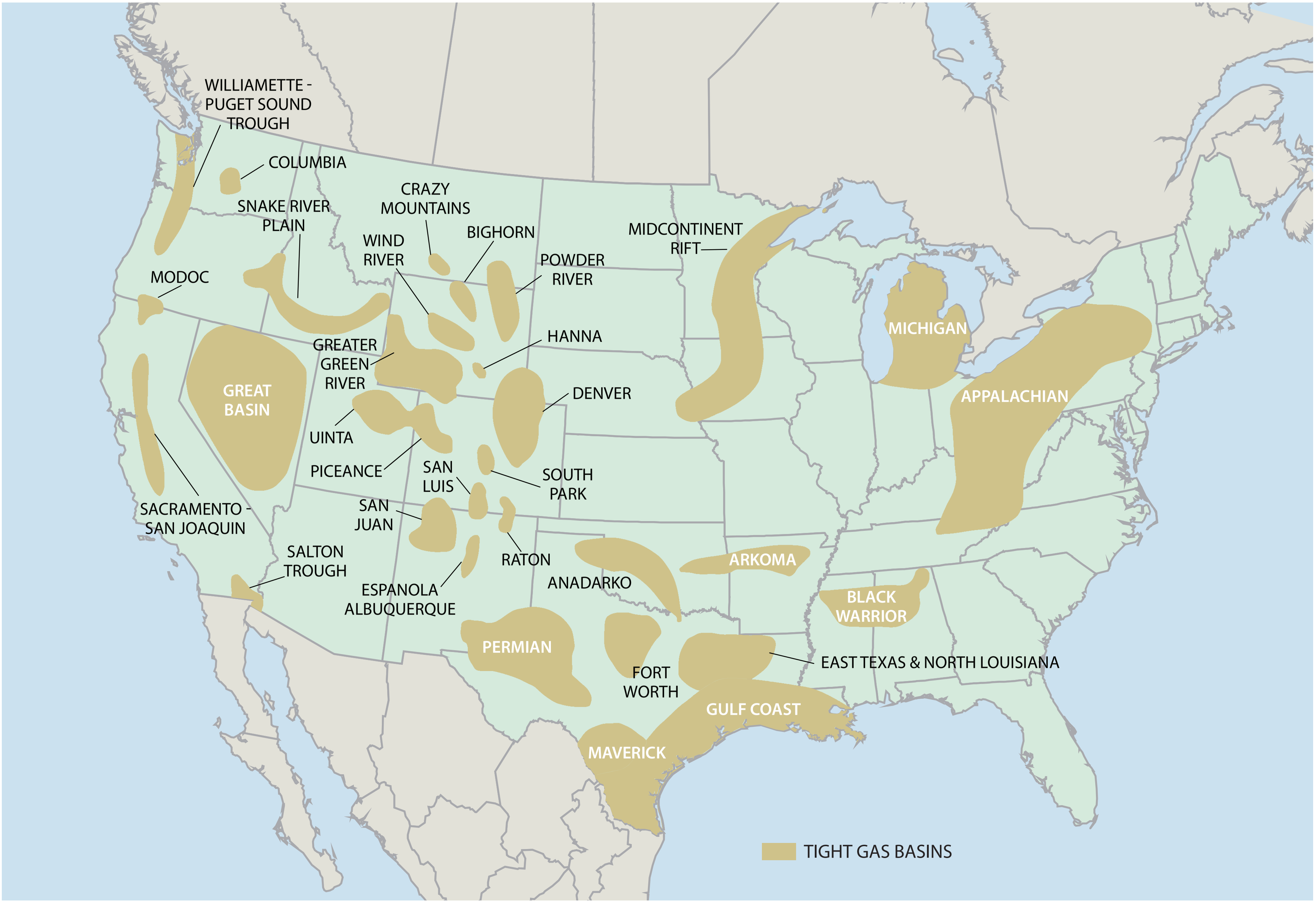
Natural gas is created naturally in coal formations through one of two distinct pathways: a bacterial (or biogenic) pathway, with anaerobic bacteria reducing carbon dioxide to form methane at low temperatures, or a thermogenic pathway, where the natural heat and pressure within the earth convert organic matter from coal into gas. Under the biogenic process, very shallow accumulations can occur, with maximum depths of 4,000 feet, and the gas is composed mostly of methane with some carbon dioxide and nitrogen. Thermogenic CBNG is formed deeper in the earth, thousands of feet below the surface, and contains methane and heavier hydrocarbons. It may also contain hydrogen sulfide. Thermogenic gas can migrate into shallower coalbeds, adding to the self-sourced gas stored there.

The shallow coalbeds where CBNG occurs are completely permeated by water, the pressure of which holds the gas in the reservoir, adsorbed onto the grain surfaces of the coal or as a free phase in the water. In order to produce the gas, the water must be removed, reducing the pressure and allowing the gas to move within the coal matrix to the wellbore. Production of water dominates shallow CBNG wells until the pressure in the coal is reduced below saturation, allowing gas to readily move. At this point, gas production begins and water declines, a process that typically takes several months. Understanding this driver for production has been essential in the successful development of CBNG plays. The need for safe and efficient wastewater disposal is a significant environmental challenge for producing CBNG.

Although the most prolific CBNG basins are located in the western United States (see Figure 2-8), the Appalachian Basin, Illinois Basin, and some areas of Alaska and Canada also have notable accumulations.

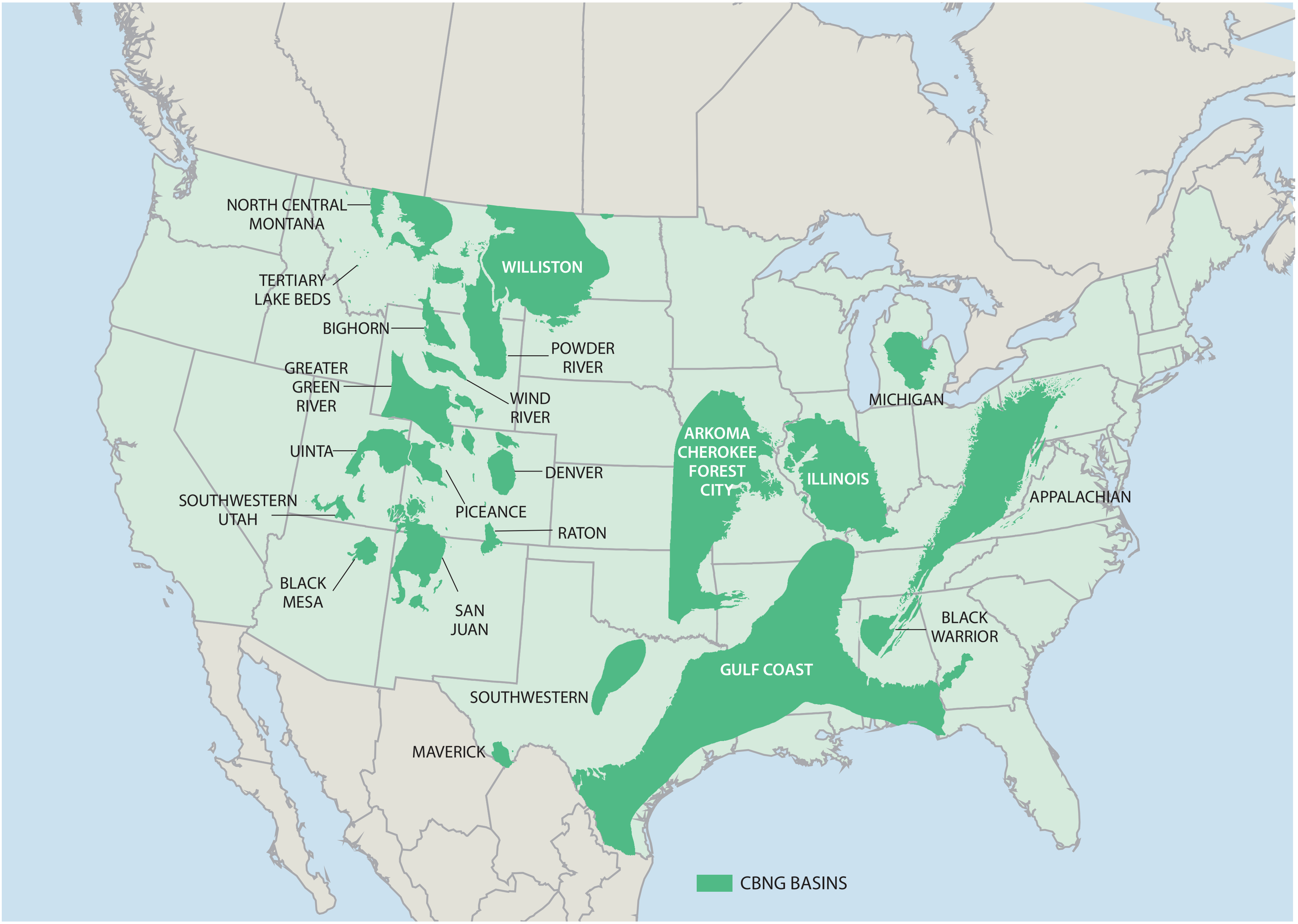
CBNG production generally is accomplished by tightly spaced vertical wells. Several completion technologies have been evaluated including open hole cavity completion, open hole completion, and (most common) cased hole single- or multi-seam completion. Cased hole single- or multi-seam completions may involve a form of hydraulic fracturing. Unlike hydraulic fracturing in tight gas reservoirs, no proppants are used in CBNG production. Instead, water is injected into the coal, a process that may result in fracturing of the coal, but predominantly acts to flush out the coal grains, flossing existing fissures to allow the gas to flow to the wellbore.

Figure 2-7. Tight Gas Basins in the Lower-48 States



Source: Energy Information Administration, last updated April 2009.

Figure 2-8. Major Coalbed Natural Gas (CBNG) Basins in the Lower-48 States



CBNG produced water varies in the amount of salts and metals in some cases, depending on the geology and hydrology of the coal formation and surrounding rocks. Both the quality and quantity of the produced water have a large influence on the way in which the water is managed. For example, the large amounts of water produced from the relatively shallow coalbeds in the Powder River basin of Montana and Wyoming contain fairly low levels of salt that is easily treated to meet state standards prior to being reused or released. If this water is released into local rivers and streams for disposal, the concerns focus on the assimilative capacity of the receiving body so that downstream irrigation is not adversely affected. The produced water is sought after by ranchers and farmers for beneficial uses such as livestock watering and irrigation, but again, the quality has to meet appropriate standards. Some produced water meets quality standards for beneficial reuse or release without having to be treated.

The opposite is true of the deep coal formation of Colorado, New Mexico, and Utah where very saline water is produced but only in small quantities as compared to the Powder River basin coals. However, generally in these locations, suitable geologic formations for underground injection are readily available and, therefore, much of the produced water is injected into deep formations for permanent disposal. As this example illustrates, many factors influence the treatment or disposal options chosen by operators. Some of the factors include quality and quantity of produced water, availability of suitable geology for injection, exiting infrastructure, cost of treatment and transport, the water's age in the coalbed and possible connections to other groundwater sources, and state regulatory requirements.[14]

HISTORY OF INNOVATION IN ENVIRONMENTAL STEWARDSHIP

Key Points:

- Advances in technology and operating practices, in all phases of the development life cycle and in all production settings, have allowed production of new and more challenging resources while at the same time improving environmental protection.
- Moving forward, we can expect to see technology and operational advancements that will allow production of even more challenging resources while continuing to improve environmental performance.

The modern history of natural gas and oil began in 1858 when Colonel Drake applied saltwater boring techniques to drill for rock oil in Titusville, Pennsylvania. He unknowingly ushered in a new era that would see the escalation of capitalism and modern business, the linking of national strategies and global politics, and the emergence of a society dominated by hydrocarbons and the conveniences that define 21st-century man. The history of natural gas and oil development encompasses geographical advances across North America and the world; an enhanced knowledge of geology and ecology; breakthroughs in chemical, mechanical, and environmental engineering; and countless conveniences that utilized the energy density of hydrocarbons to deliver energy and products to enhance the quality of life for Americans. Today, the history of natural gas and oil across the United States has come full circle, from the initial development of oil in western Pennsylvania in the 1860s to the current boom in Marcellus Shale natural gas drilling initiated in 2006. Drilling has returned to its birthplace, Pennsylvania, with new challenges (albeit natural gas instead of oil) for a new century.

Resource extraction in North America has been transformed over the last century to reflect the social values of providing cleaner energy with fewer environmental impacts. As the natural gas and oil industry has matured, measures for protecting threatened or endangered species and other environmental resources have grown more sophisticated and effective. Regulatory agencies at the federal, state, and local level have endeavored to be vigilant in overseeing natural gas and oil operations for compliance of rules, regulations, and statutes. Public concerns and involvement have become increasingly important in driving the evolution of environmental regulations, as well as the technologies and operational practices employed by industry to protect the environment or community beyond regulatory requirements.

14 National Academy of Sciences, "Management and Effects of Coal Bed Methane Produced Water in the Western United States," 2010, accessed June 2011, http://www.scribd.com/doc/44556385/Coalbed-Methane-Produced-Water-Report-in-Brief.

New technologies – coupled with management systems and conscientious employees – are responsible for reducing the environmental footprint of natural gas and oil development activities over time. Flexibility within environmental regulations has allowed technology to be adapted to different settings and circumstances encountered during development. In some cases, new production technologies have required changes to the strategies employed to protect the environment; in other cases, the efficiencies associated with advanced technologies have resulted in improved environmental performance. In still other cases, new environmental regulations have resulted in innovative practices and technologies that have been employed to ensure compliance.

Together, voluntary actions and regulatory oversight have led to a more harmonious concert between the natural gas and oil industry and the environment. Today's industry views environmental stewardship as a strategy to assuring access to future reservoirs. Continued innovation in exploration and production technologies can further minimize the risks in developing North American natural gas and oil resources, particularly those in highly sensitive areas and frontier resources plays.

This section discusses the evolution of technologies and practices for onshore and offshore exploration and production, followed by a discussion of future expectations in environmental stewardship. Advances have taken place in all phases of the development, as well as across environmental media, giving rise to the prospect of future natural gas exploration and production trends that are progressively smarter and more effective in environmental protection.

- **Air Quality** – Improvements have been realized through advances in pipeline technologies, which have reduced the venting of natural gas as a "waste"; use of natural gas-fired or electric engines during production to reduce site emissions; measures to reduce emissions and dust from truck traffic; and industry efforts to reduce methane emissions through the Natural Gas STAR Program.
- **Water Quality** – Innovations in protecting water resources include improvements in well construction, well control, and plugging practices; development of produced water injection wells for enhanced oil recovery; and advances in water use management practices, including reuse of produced water in hydraulic fracture operations.
- **Land Management and Wildlife Protection** – Seismic and drilling technologies, including horizontal drilling, have significantly reduced the amount of land surface disturbance in onshore development, lessening impacts such as erosion and habitat fragmentation.
- **Materials Management** – Ongoing improvements in managing drilling fluids and cuttings, as well as produced water during production, have reduced environmental impacts of operations. Closed loop drilling systems reduce the volume of waste and eliminate a potential source of contamination.
- **Offshore Environmental Management** – Extended-reach and horizontal drilling, unmanned satellite production systems, and floating production systems have been instrumental in reducing the amount and surface extent of the infrastructures needed to produce subsea hydrocarbon resources. Other environmental improvements have included mitigation measures to reduce the potential impacts of seismic surveys on marine life, and the adoption of environmental management systems as a means of systematically and continuously improving environmental performance.
- **Data Management** – Digital data acquisition and telecommunications technologies have facilitated prudent development of natural gas and oil – for example, through measurement-while-drilling systems. Internet technologies have increased the opportunities for more efficient data sharing in the areas of regulatory reporting, data sharing between partners, and public access to operational and compliance information maintained by public agencies.

Figure 2-9 depicts the advancement of the U.S. natural gas and oil industry in six roughly quarter-century time blocks. Drilling activity is shown from 1844 to 2010, indicating the percentage of wells that were oil or natural gas (with the remainder assumed to be freshwater or saltwater). Also shown are natural gas and oil discoveries and technological achievements, environmental laws and regulations, and historical highlights.

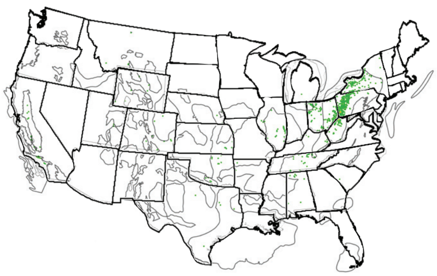
Onshore Development of Natural Gas and Oil

Just like the gold rushes of the 1800s, early oil exploration and production conjures images of wooden derrick forests with operators working in close proximity

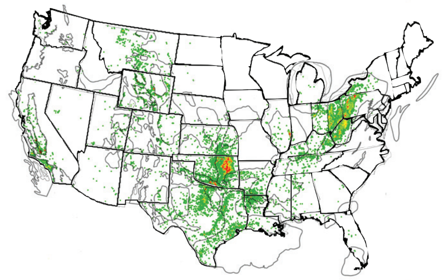
Figure 2-9. The Evolution of Technology in the Natural Gas and Oil Industry: Continuous Innovation of Technology and Environmental Stewardship in the Natural Gas and Oil Industry

DRILLING ACTIVITY IN THE UNITED STATES

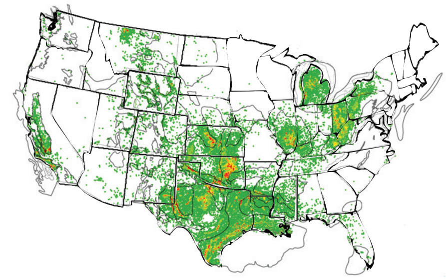
January 17, 1844 to December 31, 1899



January 1, 1900 to December 31, 1924



January 1, 1925 to December 31, 1949



- 1–50 wells per 64,000 acres (100 square miles)
- 50–250 wells per 64,000 acres (100 square miles)
- 251–500 wells per 64,000 acres (100 square miles)
- 501–1,000 wells per 64,000 acres (100 square miles)
- >1,000 wells per 64,000 acres (100 square miles)

ENVIRONMENTAL LAWS & REGULATIONS

1863 PA enacts first anti-pollution law preventing running of tar and distillery refuse into creeks

1879 NY mandates plugging of abandoned oil and natural gas wells to prevent freshwater contamination

1883 OH enacts law regulating methods of casing and plugging oil and natural gas wells

1890 PA enacts first law requiring non-producing wells to be plugged

1899 TX enacts law on groundwater protection, well abandonment, and conservation of natural gas

OIL & GAS TECHNOLOGY

1821 First well dug specifically intended to obtain natural gas in Fredonia, NY, by William Hart

1839 Marcellus Shale identified and named by NY state geologist James Halls

1854 First oil company, Pennsylvania Rock Oil Company, formed by James M. Townsend

1858 First shale gas well fracture using gun powder in Fredonia, NY, by Preston Barmore (first petroleum engineer)

1859 First successful oil well, Drake Well, drilled in Titusville, PA (about 70 ft.)

1870 First and largest multinational corporation, Standard Oil Company, founded by John D. Rockefeller and Henry Flagler

ENVIRONMENTAL LAWS & REGULATIONS

1915 CA enacts well drilling, production, and abandonment law

1917 OK expands oil and natural gas regulatory mandate to groundwater protection and well plugging and abandonment

1918 Migratory Bird Treaty Act

1924 Oil Pollution Control Act

OIL & GAS TECHNOLOGY

1891 First lengthy natural gas pipeline constructed from wells in central IN to Chicago, IL (120 mi.)

1897 First offshore well drilled south of Santa Barbara, CA (455 ft. below seabed)

1901 Oil explorer Captain Anthony Lucas drills Spindletop Gusher in Beaumont, TX

1905 Oil strike in Glen Pool, OK, heralded as largest discovery of its time

1909 H. Hughes Sr. and Walter Sharp introduce Two-Cone Drill Bit, enabling deep boring

1911 Standard Oil Company dissolved by Sherman Antitrust Act

1917 American Association of Petroleum Geologists founded

1921 First horizontal oil well drilled in Texon, TX

1921 First experimental use of seismic imaging at Vines Branch, OK

ENVIRONMENTAL LAWS & REGULATIONS

1935 Interstate Oil & Gas Compact Commission (IOGCC) established (OK, TX, CO, IL, NM, and KS)

1941 Multiple states enact moratoria on aspects of oil and gas conservation and environmental regulation to support war effort

1946 KS Board of Health authorized to regulate oil field brine disposal

1946 Bureau of Land Management created by President Harry Truman

1948 Federal Water Pollution Control Act (FWPCA)

OIL & GAS TECHNOLOGY

1922 Wildcatter James S. Abercrombie and machinist Harry S. Cameron develop successful ram-type blowout preventer

1927 First patent on caustic flooding for improved oil recovery

1929 Barite introduced to drilling fluids

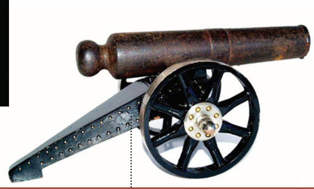
1929 First controlled directional drilling in Huntington Beach, CA, by H. John Eastman

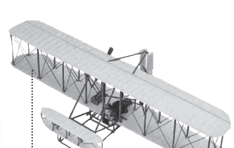
1930 East Texas Oilfield discovered by Dad Joiner

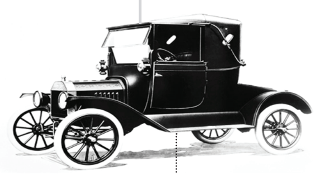
1933 Hughes Tool Company develops Tricone Drill Bit

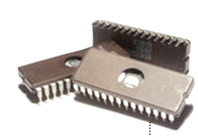
1934 First relief well to control a blowout used in Conroe, TX, by H. John Eastman

1938 Cooper-Bessmer Integral-Angle Gas Engine Compressor installed in natural gas pipeline









1840 First recorded use of natural gas for manufacturing, Centerville, PA

1861–1865 Civil War

1858–1890 Internal combustion engine

1897 Thomas Edison invented incandescent lamp

1903 Wright Brothers' first flight

1905 First gas station

1908 Ford Model-T

1911 U.S. military converts to oil as fuel source

1914–1919 WWI

1929 Start of Great Depression

1939–1945 WWII

1945 World's first nuclear explosion at Trinity test site, Alamogordo, NM

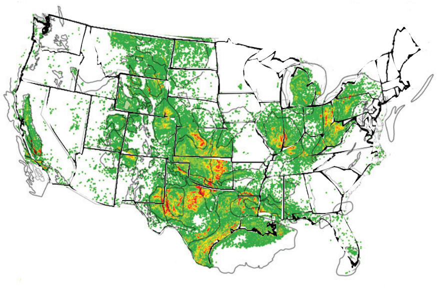
1958 First commercial nuclear power plant, Shippingport, PA

1958 First integrated circuit silicon chip

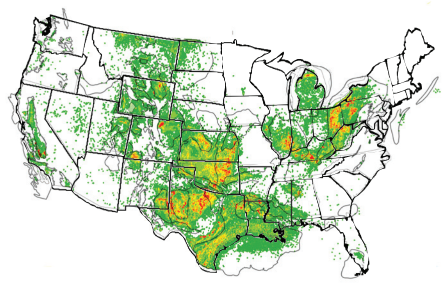
1960 OPEC formed

Figure 2-9. The Evolution of Technology in the Natural Gas and Oil Industry (Continued)

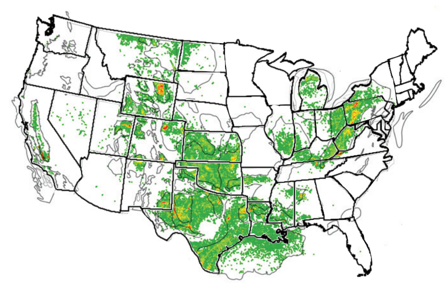
January 1, 1950 to December 31, 1974



January 1, 1975 to December 31, 1999



January 1, 2000 to January 6, 2011



ENVIRONMENTAL LAWS & REGULATIONS

1953 Outer Continental Shelf Lands Act

1968 Cuyahoga River engulfed in flames in northeastern OH

1969 Santa Barbara oil spill leads to environmental legislation and is the impetus for the environmental law movement in the U.S.

1970 National Environmental Policy Act, Occupational Safety and Health Act, Clean Air Act, and the U.S. EPA established

1972 Noise Control Act

1973 Endangered Species Act

1974 Safe Drinking Water Act

OIL & GAS TECHNOLOGY

1947 Hydraulic fracturing first used in the U.S. as experiment to stimulate an oil well, Grant County, KS (Stanolind Oil)

1947–2011 Kerr-McGee drills first offshore well out of sight of land, Vermilion Parish, LA, with continuous firsts in offshore technology afterward

1967 First 3D seismic survey (Exxon) in Friendswood field, Houston, TX

1968 First well drilled in >1,000 ft of water by Humble Oil in Santa Barbara channel

1968 Oil discovered on Alaska's North Slope

1972 Landset satellite used for remote sensing

1972 First use of carbon dioxide-enhanced oil recovery, Scurry County, TX

ENVIRONMENTAL LAWS & REGULATIONS

1976 Resource Conservation and Recovery Act and Federal Land Policy and Management Act

1977 Surface Mining Control and Reclamation Act, Toxic Substances Control Act, and FWPCA renamed Clean Water Act

1977 FERC established

1980 Comprehensive Environmental Response, Compensation and Liability Act

1986 Title III Superfund Amendments and Reauthorization Act

1987 Pipeline Safety Act

1989 Hazard Communication Standard

1989 Exxon Valdez runs aground in Prince William Sound, AK

1989 GWPC and IOGCC initiate reviews of state oil and natural gas regulatory programs

1990 Oil Pollution Act

OIL & GAS TECHNOLOGY

1977 Trans-Alaska Oil Pipeline System completed after three years of work

1977 U.S. DOE established

1978 First fixed offshore platform >1,000 ft. deep, Shell Cognac

1982 First steerable drilling system

ENVIRONMENTAL LAWS & REGULATIONS

1999 State Review of Oil and Natural Gas Environmental Regulations (STRONGER) established

2001 U.S. House passes legislation opening a portion of the Arctic National Wildlife Refuge to oil and gas drilling; Senate rejects proposal

2005 Energy Policy Act clarifies hydraulic fracturing with regards to SDWA

2005 DOI opens thousands of acres on the Alaska North Slope for drilling

2008 Ten-year moratoria on U.S. offshore oil and natural gas leasing end

2010 WY enacts new oil and gas regulations requiring full chemical disclosure for hydraulic fracturing fluid additives

2010 Deepwater Horizon oil rig explodes in the Gulf of Mexico, causing largest offshore oil spill in U.S. history

2010 San Bruno, CA, natural gas pipeline explosion

OIL & GAS TECHNOLOGY

1995 Mitchell Energy refines hydraulic fracturing coupled with horizontal wells in the Barnett Shale, TX, to recover natural gas

1997 Baker Hughes Corporation introduces rotary closed loop drilling system

1999 Largest oil discovery in Gulf of Mexico, BP Thunder Horse field (6,000 ft.,1 billion BOE)

2006 New seismic recording technique measures hydraulic fracture propagation in unconventional reservoirs

1960 First large-scale geothermal electric plant, The Geysers, CA

1969 First man walks on the moon (Neil Armstrong)

1970 Founding of Earth Day

1973 First personal computer

1973 Arab Oil Embargo

1978 Natural Gas Policy Act enables competitive wellhead pricing, which spurs production

1978 NASA dedicates first solar photovoltaic system, AZ

1980 Iraq-Iran War

1980s Large-scale wind farm technology used for the first time in CA

1986 Crude oil price collapses

1990 World Wide Web

1990–1991 Persian Gulf War

1991 Drawdown of Strategic Petroleum Reserve

1997 Kyoto Agreement to limit greenhouse gases

2003 U.S.-Iraq War

2009 Oil price tops $140/bbl; Dow Jones Industrial Average plunges 360 points

2010 World oil demand reaches 87 million bbls/day with little or no regard for the environmental impacts of their actions. The petroleum industry has matured over the last century, evolving into a highly technical industry that develops and employs innovative solutions in all aspects of exploration, drilling, completion, production, and site restoration.

Exploration

Hundreds of years ago, before any wells were drilled, natural gas was found to be naturally percolating up through the soil and through creeks, where mischievous children would light it for entertainment. The original production system for oil involved damming up an oil seep, and then floating the oil down a river to be picked up by a weir.

During the 19th century and into the early years of the 20th century, prospecting was pretty much a hit-or-miss proposition. A geologist looked for exposed beds of asphalt, oil springs, naturally occurring methane in streams, or traces of hydrocarbons in water wells to help identify potential sources of oil. Methods ranged from divining rods to "creekology" (drilling inside the curve of a creek), but none was a sure thing and most wildcatters thought "close" was the best geologic method (meaning being close enough to the last well to smell it).[15]

Analyzing streams and domestic water wells for the presence of naturally occurring methane proved to be one of the more successful prospecting methods. A map of domestic well locations with corresponding concentrations of hydrocarbons would be drawn and potential drilling locations plotted based on isotropic concentrations, zeroing in on the sweet spot.[16] The presence of naturally occurring methane in domestic water wells prompted several states, including New York, Pennsylvania, Colorado, and Wyoming, to pass laws regarding the placement of wells in relationship to construction of a house.

Slowly, oilmen, geologists, and drillers began to notice seismology and subsurface structure. Due to anomalies of Appalachian regional geology and topography, oil there was located in valleys, leading many people to surmise that oil flowed downward and that drilling on ridge tops would result in dry holes. Exploration in other regions revealed the error in this assumption. In actuality, oil floats on top of water and, outside the Appalachians, often exists on ridge tops. The paradigm continues to shift as today natural gas and oil can be extracted from impermeable rock.

Once the relationships between oil location and anticline geology were understood, exploration quickly expanded beyond Pennsylvania and the exploration industry was born. Prior to 1920, exploration activities were noninvasive and typically conducted on foot or on horseback, producing no noticeable impacts to the environment. Exploration usually involved field mapping and gravity surveys, neither of which left an obvious impression.

The development of more sophisticated seismic methods for subsurface imaging changed all that. Seismic imaging required the drilling of holes for dynamite and the laying of miles of cable across the countryside, and large trucks and other support vehicles were often used to carry equipment and machines. In the 1930s and 1940s, it was commonplace to see systematic patterns of drill holes across the landscape, reaching down through soil layers to bedrock for the placement of charges, coupled with heavy truck tracks traversing the fields.

With the availability of computers in the late 1960s, processing of large seismic data sets became manageable, and common depth point seismic operations became the standard operating procedure. More recently, three-dimensional (3D) seismic tools for subsurface imaging have provided economically viable methods of discovering and producing natural gas and oil from ever more challenging and remote locations.

Today, geologists and geophysicists use an array of advanced techniques to find commercial accumulations of natural gas and oil. High-speed computing, remote sensing and imaging, geologic interpretation, and visualization technology are coupled with global positioning systems, the latest geographical information systems, and 3D seismic and four-dimensional (4D) imaging capabilities to pinpoint promising new reservoirs. In place of dynamite, seismic technology now employs less intrusive methods designed to mitigate surface and near-surface impacts, such as designed-for-purpose air explosives, contained surface explosions, and vibrators. These technological advances, combined with state regulations for registering seismic surveys, have eliminated or reduced

15 O. Scott Perry, "Oil Exploration," *The Handbook of Texas Online,* Texas State Historical Association, accessed April 11, 2011, http://www.tshaonline.org/handbook/online/articles/doo15.

16 Craig Miner, *Discovery! Cycles of Change in the Kansas Oil & Gas Industry 1860-1987*, Wichita, KS: KIOGA, 1987.

many of the onshore environmental impacts associated with seismic exploration (e.g., unplugged shot holes and vehicle tracks).[17]

Modern sensing technology has significantly reduced dry holes in both exploration and production operations, conserving valuable natural resources and minimizing drilling activities and associated impacts. Thanks to this technology, success rates for discovery of economical quantities of natural gas and oil are up more than 50% over the last 30 years.[18] In the most recent decade alone, the drilling success rate improved from 75% successful wells in 1999 to 90% success as of 2009.[19]

Drilling

Drilling was rudimentary in the 19th century, employing wooden derricks that raised and lowered cable tool drills repeatedly, taking advantage of gravity to grind up the bottom of the hole. To clean cuttings from the borehole, workers would bail out the waste and pour it on the ground next to the rig.

As drilling technology matured, engine-powered rotary drilling rigs combined drilling and setting of the string, enabling deeper wells (more than 30,000 feet today) and the discovery of more resources. The first rotary drilling rig was developed in France in the 1860s, but it was not until 1901 when Captain Antony Lucas used one to drill a gusher (Spindletop) near Beaumont, Texas, that they were adapted for natural gas and oil development. Drillers for the first time could steer the bit to maintain a straight hole and perform real-time examination of rock samples for densities, allowing them to maintain pressure on the drilling process to control fluid entering and exiting the borehole. Early circulating systems in rotary drilling were focused on controlling subsurface pressures and cleaning the cuttings from the wellbore.

At first, there was no mechanism to control the flow of oil or gas once the drill bit penetrated the target formation. Wildcatter James S. Abercrombie and machinist Harry S. Cameron are credited with developing the first successful ram-type blowout preventer (BOP) in 1922. Mud system advances occurred in the late 1920s with the addition of barite and bentonite into drilling fluids to add weight to the fluid, which prevented formation fluids from entering into the wellbore, kept the drill bit cool and clean, and transported the cuttings to the surface. Use of rotary drilling and mud systems has helped to stop blowouts and resulting spills and fires. Another important advance in well control technology has been casing and cementing for wellbores, which forms a seal between potable water aquifers and the borehole, keeping freshwater from being mixed with other fluids.

When introduced in 1984, steerable drilling was very expensive; but cost improvements enabled its use by 1990 to establish horizontal wellbores in large resource plays, accessing many more feet of formation than a conventional vertical well. Using horizontal drilling, bores of more than a half-mile have been drilled successfully. Horizontal drilling can access the same resources with fewer wells spaced further apart, reducing the environmental impacts including waste disposal, material use, and energy consumption. Operational footprints are further reduced since the drill rigs no longer stay at the site but are moved to the next project. Today, horizontal drilling permits access to previously inaccessible reservoirs, production from unconventional source rock, and the ability to produce resources in deeper offshore waters. The benefits of this technology include reduction of the number of wells required to produce a resource; development of multi-well pads that confer a variety of environmental advantages; the ability to avoid sensitive surface environments; and use of centralized facilities to service multiple wells.

Prudent resource development has been greatly facilitated by data management systems. Today's measurement-while-drilling and logging-while-drilling technologies, for example, allow real-time analysis of rock properties and more effective steering of the drill into reservoirs. Basic rig instrumentation has been an integral part of drilling operations since the early 20th century. With the introduction of the Geolograph in 1937, time-based analog charts soon became the de facto record of events and a basic tool for trend analysis and identification of anomalies. A gradual shift to digital information capture began in the mid-1970s, as computerized mud-logging units were deployed to drill sites.

17 Diane Freeman, "No Seismic 'Footprints' Left Behind," *AAPG Explorer*, October 1999, accessed April 11, 2011, http://www.aapg.org/explorer/1999/10oct/conoco3d.cfm.

18 Lee C. Gerhard and William F. Larson, "The Environmental Evolution of the Petroleum Industry," Interstate Oil and Gas Compact Commission, April 2001.

19 M. C. Godec, "Environmental Performance of the Exploration and Production Industry: Past, Present, and Future," SPE Paper 120918, 2009.

Digital data acquisition offered greater flexibility in how data were stored, displayed, and utilized, while advances in telecommunications technology enabled transmission of the data to other locations, aggregating data from various sources, coordinating data analyses, and engaging remotely located personnel.

As drilling technology continues to advance, rigs are becoming smaller. Coiled tubing rigs allow drilling of shallow to intermediate-depth wells without a derrick, using a motorized drill bit and flexible coiled tubing applied from a revolving drum and fed by mud pumps. With a smaller hole ("slim hole"), drilling waste is reduced along with environmental impacts.

Drilling fluids and cuttings are the largest potential waste stream during drilling. Fluids consist primarily of water with entrained solids. Barite, a heavy mineral, is commonly introduced to add density to the drilling fluid; bentonite, a swelling clay, is used to add viscosity and provide a slick wall cake on the wellbore. Both of these key additives have low environmental impacts. Improvements in waste management include milling of cuttings for reinjection in former or abandoned wellbores, where supported by the geology, eliminating mud pits and reducing the potential environmental impact of leaks and handling. Current technologies such as closed-loop drilling systems allow for cuttings to be separated and disposed via landfill while the muds are reused in subsequent drilling operations. The approach can reduce cost for operators, reduces the volume of waste, and promotes zero discharge of wastes.

Operators have instituted a variety of practices to address regional and site-specific air quality concerns associated with drilling. In some cases, operators have employed natural gas-fired engines or electric engines for compressors or drilling rigs in order to reduce site emissions. Intensive planning and the use of remote monitoring and reporting equipment have reduced truck traffic during both drilling and production phases, limiting engine emissions and fugitive dust. These practices have the added benefit of mitigating community impacts by reducing road damage and traffic congestion.

In scenic areas, measures are taken during development to minimize surface disturbances and habitat fragmentation, although some visual impacts remain until all the reclamation activities are completed. Typical methods include stockpiling topsoil and replanting vegetation to reclaim roads. Some roads are reclaimed when production ceases while others remain in place for recreational or other beneficial activities; in Alaska, ice roads and ice pads may be used to facilitate development without leaving a permanent impact.[20]

Advanced drilling technologies have reduced the amount of surface disturbance required to develop natural gas and resources by as much as 90% in some cases. Less surface disturbance reduces the potential for erosion and reduces vegetation loss including deforestation. In addition, the need for fewer well pads and roads minimizes habitat fragmentation for wildlife, and also results in fewer vehicle miles traveled with the attendant lower air emissions. Evidence of the reduced environmental impact resulting from new drilling technology is widespread. On Alaska's North Slope, for example, the surface footprint of drill pads has been reduced from 60 acres to 6 acres. Tens of wells are drilled from these small pad footprints, resulting in the elimination of other pad sites and associated infrastructure; and the Department of Energy (DOE) reports that the volumes of waste generated from 100 barrels of oil equivalent of reserve additions has shrunk from 7.5 to 3.4 barrels.[21] Another example is found in Ecuador, where ARCO developed a 200-million-barrel field from one 5-acre rainforest site using directional drilling. The facility was normally unmanned as an impact-reduction measure and there was no road to the site. The pipeline was carefully placed between the trees under the rainforest canopy, making it near invisible from the air. Electricity was used on the production site to reduce engine noise and eliminate exhaust emissions; the power was supplied along the same path as the pipeline, further consolidating any disturbances. This approach was implemented with no increase in cost over conventional methods.[22]

Hydraulic Fracturing

Hydraulic fracturing is an integral part of natural gas and oil development across the United States. Its objectives are to increase the rate at which a well is

20 U.S. Department of Energy, *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*, DOE-FE-0385, October 1999, accessed April 15, 2011, http://fossil.energy.gov/programs/oilgas/publications/environ_benefits/env_benefits.pdf.

21 U.S. Department of Energy, *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*.

22 K. Lathrop, C. Slack, and R. Draper, "The Villano Project: Preserving the Effort with Words and Pictures," Atlantic Richfield Corporation, 1999.

able to produce natural gas or oil and to increase the economically recoverable reserves for a well. Production increases from this technology, especially when it is combined with horizontal drilling, dramatically reduce the environmental footprint of development while economically commercializing historically undevelopable resources.

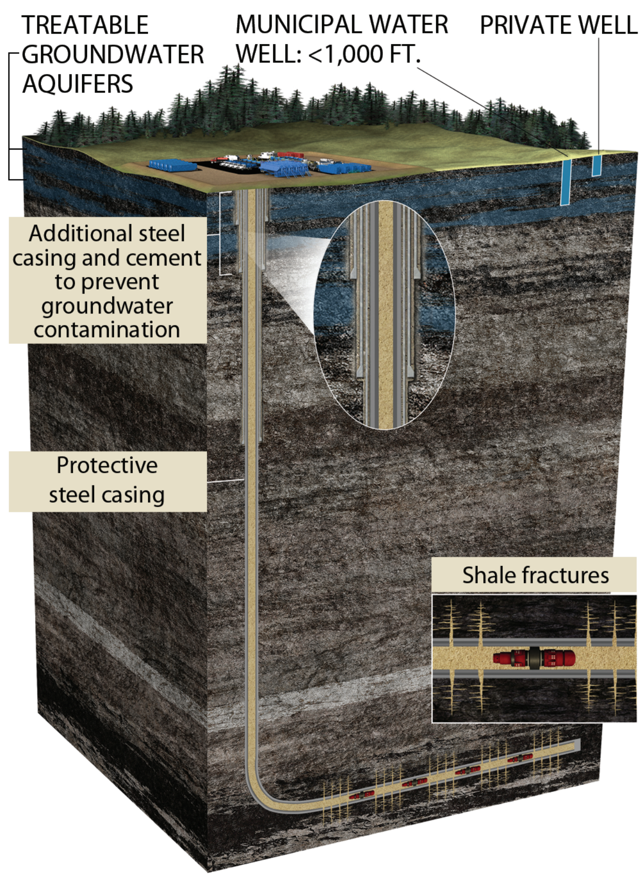
Fracturing in its various forms is over 150 years old.[23] The first shale gas fracturing job was performed in 1858 in Fredonia, New York, prior to Colonel Drake drilling his first oil well.[24] Black powder was used in multiple stages and the resultant flow rate changes were recorded after each stage. The first experimental hydraulic fracturing treatment for oil production was performed in Grant County, Kansas, in 1947 by Stanolind Oil. A limestone formation approximately 2,400 feet below ground level was fractured using 1,000 gallons of naphthenic-acid and palm-oil thickened gasoline, followed by a gel breaker. Following the experiment, an industry paper was written by J. B. Clark of Stanolind Oil introducing the technology. In 1949, a patent was issued granting Halliburton Oil Well Cementing Company the exclusive right to pump the new "Hydrafrac" process.

The first commercial application of hydraulic fracturing was performed in March 1949, at a well 12 miles east of Duncan, Oklahoma. The same day, a second well was hydraulically fractured near Holliday, Texas. In the first year, 332 wells were hydraulically fractured with the new technology, yielding an average production increase of 75%. Since then, more than 2 million hydraulic fracture stimulations have been completed in the United States.[25]

Over time, hydraulic fracturing has evolved in response to challenges posed by different resource types and diverse locations, environmental challenges, costs and economics, and regulatory considerations. Today, the technology is used on up to 95% of new wells and is continuously refined and modified to optimize fracture networking and maximize resource production. The future influence of hydraulic fracturing technology on the industry and energy market could be staggering, as new sources of unconventional hydrocarbon resources are discovered and exploited.

Modern hydraulic fracturing technology involves sophisticated, engineering processes designed to create distinct fracture networks in specific rock strata. Figure 2-10 shows a cross-section diagram of a horizontal well with multiple completion stages where pathways have been created and filled with proppant. Advanced fracturing processes are continually refined to account for in situ reservoir characteristics and optimize natural gas and oil production, using tools such as modeling, micro-seismic fracture mapping, and tilt-meter analysis to define the success and orientation of the fractures created. While

Figure 2-10. Horizontal Well Completion Stages



Source: Chesapeake Energy, "Well Stimulation Technology" (January 2011), unpublished.

23 John A. Harper, "The Marcellus Shale – An Old 'New' Gas Reservoir in Pennsylvania," *Pennsylvania Geology*, 38, no. 1, Spring 2008: pages 2–13, accessed June 29, 2011, http://www.dcnr.state.pa.us/topogeo/pub/pageolmag/pdfs/v38n1.pdf.

24 Eileen and Gary Lash, SUNY Fredonia Shale Research Institute, "Kicking Down the Well," *The Early History of Natural Gas* (© 2010), accessed June 29, 2011, http://www.fredonia.edu/shaleinstitute/history.asp.

25 Carl T. Montgomery and Michael B. Smith, "Hydraulic Fracturing – History of an Enduring Technology," *JPT: The Journal of Petroleum Technology* 62, no. 12, December 2010: pages 26–32, accessed June 29, 2011, http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf.

hydraulic fracturing typically is used during the initial completion of the well, it also can occur after the initial completion of a well, when it is believed that stimulation of the well could provide additional economic benefit.

The makeup of fracturing fluids is varied to meet specific reservoir and operational conditions, precluding one-size-fits-all formulas. Water and sand are the most common constituents of most fracturing fluids. More recently, advances in water use

Hydraulic Fracturing

Hydraulic fracturing is the treatment applied to reservoir rock to improve the flow of trapped oil or natural gas from its initial location to the wellbore. This process involves creating fractures in the formation and placing sand or proppant in those fractures to hold them open. Fracturing is accomplished by injecting water and fluids designed for the specific site under high pressure in a process that is engineered, controlled, and monitored.

Fracturing Facts

- Hydraulic fracturing was first used in 1947 in an oil well in Grant County, Kansas, and by 2002, the practice had already been used approximately a million times in the United States.*
- Up to 95% of wells drilled today are hydraulically fractured, accounting for more than 43% of total U.S. oil production and 67% of natural gas production.†
- The first known instance where hydraulic fracturing was raised as a technology of concern was when it was used in shallow coalbed methane formations that contained freshwater (Black Warrior Basin, Alabama, 1997).
- In areas with deep unconventional formations (such as the Marcellus areas of Appalachia), the shale gas under development is separated from freshwater aquifers by thousands of feet and multiple confining layers. To reach these deep formations where the fracturing of rock occurs, drilling goes through shallower areas, with the drilling equipment and production pipe sealed off using casing and cementing techniques.
- The technology and its application are continuously evolving. For example, testing and development are underway of safer fracturing fluid additives.
- The Interstate Oil and Gas Compact Commission (IOGCC), comprised of 30 member states in the United States, reported in 2009 that there have been no cases where hydraulic fracturing has been verified to have contaminated water.‡
- A new voluntary chemical registry (FracFocus) for disclosing fracture fluid additives was launched in the spring of 2011 by the Ground Water Protection Council and the IOGCC. Texas operators are required by law to use FracFocus.
- The Environmental Protection Agency concluded in 2004 that the injection of hydraulic fracturing fluids into coalbed methane wells poses little or no threat to underground sources of drinking water.§ The U.S. Environmental Protection Agency is currently studying hydraulic fracturing in unconventional formations to better understand the full life-cycle relationship between hydraulic fracturing and drinking water and groundwater resources.
- The Secretary of Energy's Advisory Board is also studying ways to improve the safety and environmental performance relating to shale gas development, including hydraulic fracturing.

* Interstate Oil and Gas Compact Commission, Testimony Submitted to the House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources, June 18, 2009, Attachment B.

† IHS Global Insights, "Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing, 2009; and Energy Information Administration, "Natural Gas and Crude Oil Production," December 2010 and July 2011.

‡ Interstate Oil and Gas Compact Commission, Testimony Submitted to the House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources, June 18, 2009, Attachment B.

§ U.S. Environmental Protection Agency, Office of Water, Office of Ground Water and Drinking Water, "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs" (4606M) EPA 816-R-04-003, June 2004.

management practices have resulted in reduced demands on freshwater sources. The volumes of freshwater used for hydraulic fracturing of shale gas wells have led to concerns about the potential impacts to local and regional water supplies as well as potential impacts to aquatic wildlife. Going beyond regulatory requirements designed to ensure that water withdrawals do not adversely affect the environment, many operators are pursuing reuse of produced water in subsequent fracture operations. This reuse of produced water reduces demands on freshwater, and impacts associated with trucking of water, such as traffic congestion, road damage, dust, and engine emissions. In addition, reuse reduces the amount of water to be disposed.

Production

Oil and saltwater are almost always produced together. Produced saltwater – which can be up to 10 times the salinity of seawater at 400,000 parts per million – represents the largest potential waste stream during oil production. Improper disposal of saltwater can affect freshwater and can harm vegetation, in turn increasing erosion.

In the 19th century, there was little interest in properly disposing of saltwater since population densities were low and potable water supplies plentiful. Typically, saltwater was simply poured out on the ground. By the early 20th century, it became commonplace to store produced water in ponds. A thin film of oil on the water's surface reduced the rate of evaporation, increasing the chance for infiltration and damage to underlying aquifers. Some states instituted regulated disposal, requiring lined ponds or impoundments.

Today, injecting produced water into approved disposal zones (injection wells) has become the preferred alternative for disposal, greatly reducing surface and groundwater contamination. Injection of produced water to improve production began as early as 1910 in Pennsylvania. The Safe Drinking Water Act, passed in 1974, established the UIC program, which sets well casing and cementing standards to ensure protection of underground sources of drinking water.

If disposal systems cross salt beds, it is necessary to protect well casings against corrosion by inserting tubing in the casing. Historically, when disposal wells were reaching the end of their useful life or sold, operators would pull the corroded tubing and then inject saltwater. This caused rapid casing corrosion and leaks into salt beds. Many states have regulations in place to inspect and conduct mechanical integrity tests of disposal systems, to prevent the escape of saltwater.

Another environmental issue in producing and transporting oil is prevention and remediation of spills. Although oil is naturally biodegradable, spilled oil stains the soil; and with large spills, animals and birds could be adversely affected. In the early days of oil production, spills occurred regularly as product was flowed into tanks or barrels, especially when the volume of the container was miscalculated. Gushers were common as well, spilling oil onto the ground where it found its way to ponds or other drainage systems. Today, the product is rigorously defended. Mechanical integrity inspections detect any small leaks in the piping at the producing wellhead to prevent potential minor spills. Additionally, with the diking of tank batteries, crude oil releases are contained and remediated. Contaminated soils are removed and deposited in an approved landfill or cleaned using bioremediation technologies such as oil-metabolizing microbes. Several studies have found that turning the soil and using additives such as fertilizers can speed biodegradation without the use of microbes. Soil amendments can be added to salt-impacted soil to increase permeability and lessen clay hydration; additionally, a cap of new soil can be used.

In the early days of oil production, coproduced natural gas (termed "casinghead gas") was either flared or vented into the air. Venting has been outlawed over the past 50 years in most states and most cases. In some situations, reinjection of casinghead gas into the reservoir allows the operator to increase production by maintaining field pressures. This method was used on Alaska's North Slope; the U.S. Department of Energy (1999) reported that, as a result, the reserves at Prudhoe Bay were 30% higher than originally thought.[26]

A byproduct of natural gas and oil production is hydrogen sulfide (H_2S), a flammable gas that can be toxic above certain exposures. Hydrogen sulfide presents a danger to workers who might have to be in an enclosed space, such as those inspecting inside tanks. In large-scale production fields where oil is produced with H_2S, constant odors are an issue.

26 U.S. Department of Energy, Office of Fossil Energy, *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*, DOE-FE-0385, October 1999, accessed June 29, 2011, http://fossil.energy.gov/programs/oilgas/publications/environ_benefits/env_benefits.pdf.

Production sites are constantly monitored to protect both workers and nearby communities from hydrogen sulfide. Hydrogen sulfide in natural gas can be processed to produce sulfur as a marketable byproduct.

Visibility of natural gas and oil facilities is considered by some to be intrusive, and to have negative impacts on recreation and aesthetics. Many times the visible impact can be mitigated through camouflage paints or barriers. In the Barnett Shale in the Dallas-Fort Worth area, for example, companies have landscaped, built decorative walls, and painted to blend facilities to the surroundings.

Today, most production operation activities involve continual monitoring, maintenance, and assessment of the well and well site to ensure integrity, safety, and security. Maintenance and assessment are accomplished using wireline units or workover rigs, both of which are much smaller than the drilling rig used to bore the well. Monitoring activities include Bradenhead[27] pressure monitoring; air emissions monitoring; storm water, spill prevention, and wildlife controls maintenance; interim reclamation assessment; and water management.

Pipelines

As new uses for natural gas were developed, pipelines were needed to transport it to major population centers. Over time, improvements have been made in the construction material and welding techniques used in pipelines. In addition, compressor stations have been added to enable transportation of natural gas over longer distances from remote fields. Developments of pipelines and compressors have reduced the widespread venting of natural gas as a "waste," substantially reducing the amount of greenhouse gases being released.

As an example of practices that go beyond regulatory requirements, industry has teamed with the EPA to reduce methane emissions through the Natural Gas STAR Program. The program is a voluntary partnership that encourages the dissemination and use of cost-effective practices and technologies that reduce emissions of methane, including pipeline-related practices. Because methane is a potent greenhouse gas, these emission reductions help protect the environment while at the same time conserving a clean energy source.

Today, pipelines are essential for the transport of produced hydrocarbons within North America. Maintaining a safe and environmentally sound pipeline network that meets growing energy demands represents a major challenge for the pipeline industry. Pipeline location is crucial to minimize the potential risk to the public and the environment. Pipeline route planning is coordinated with public officials and supported by best engineering practices. Once operational, integrity of the pipeline network incorporates best management practices, including sound integrity management practices and ongoing damage prevention programs involving public officials, emergency officials, and the affected public.

Reclamation

Once production drops below an economically feasible level, an oil or gas field is plugged and abandoned to remediate the site for recreation, wildlife management, industrial, or agricultural uses. In the 1800s and early 1900s, plugging was not done at all or consisted of simply throwing a tree down the wellbore. These early practices resulted in oil and brine contamination of groundwater. In the 1890s, Pennsylvania passed the first plugging requirements, which were aimed at protecting the oil resource from flooding by freshwater.

Modern plugging techniques ensure groundwater and surface water protection. Operators remove any recyclable materials during plugging and move in a workover rig that sets cement plugs to separate any production zone from water zones. A steel plate may be welded over the hole below farm-plow depth.

Additional activities associated with reclaiming a wellsite include restoring the soil and the contour of the landscape. Over time, nature reclaims producing sites even without human intervention, as evidenced by the former Drake discovery well. Despite extensive industrial activities in the mid and late 19th century, the site now shows no trace of development.

Offshore reclamation is similar to onshore except that plugging is done with the platform in place and freshwater protection is not an issue. Offshore platforms have been used to support recreational

27 The monitoring of the pressure between the well casing and the drill pipe using a device (Bradenhead) that is situated at the top of the well casing, where it allows a drill pipe to be extended into the well while the wellhead is sealed and the annulus is pressurized.

fisheries and abandoned platforms have been sunk to provide artificial reefs for aquatic habitats. Other disposal methods for the platform include towing it to the shore and dismantling it.

Offshore Development of Natural Gas and Oil

Drilling offshore began near the turn of the 20th century when shallow-water fixed platforms were used to access offshore reservoirs. Offshore production accelerated after 1947, when the first offshore well was drilled at a location completely out of sight of land. Since then, offshore production, particularly in the U.S. Gulf of Mexico, has contributed significantly to total U.S. energy production. Today, about 35% of crude oil production in the United States comes from offshore developments.

Because costs of offshore development typically are considerably higher than for land-based development, economic justification hinges on the potential for larger volumes of hydrocarbon reserves. The need for detailed research and exploration on the potential play prior to drilling has driven advances in technologies used offshore; some of these technologies have also been adapted for onshore exploration and production.

Three technologies are instrumental in reducing the amount and surface extent of infrastructures necessary for offshore production. First, extended-reach and horizontal drilling allows for greater hydrocarbon production with fewer facilities and a smaller environmental footprint. Second, unmanned satellite production systems, which contain wellhead and manifold systems with no or minimal processing facilities, are being used to develop smaller fields or sections of larger fields. Production from these systems flows to a central facility for processing. Satellite facilities can either be installed on small platform structures or on the seafloor. Third, floating production systems typically are used in deepwater and in conjunction with subsea production or satellite systems. Since fixed structures are not utilized, these systems have the added advantage of being easily removed at the end of the field development.

Advances in such areas as seismic, drilling and completion, and well control technologies have overcome many barriers to prudent development of offshore resources. The development of offshore natural gas and oil technologies is complicated by overlapping statutes and regulatory agencies. Environmental rigors of subsea operations include maintaining pipeline integrity and addressing offshore safety and environmental management as a broad safety sustainability planning challenge. Because of the complexities faced in subsea operations, the use of EMSs has been particularly beneficial in offshore development.

Seismic Technology

Geophysical technologies have been a critical tool in hydrocarbon exploration since the early part of the 20th century. Prior to the mid-1980s, the majority of seismic data collected in offshore settings were two-dimensional (2D), meaning they defined a plane where the seismic-derived structure (depth of the plane) pertained to a single surface traverse (edge of the plane). Since that time, techniques to assemble 3D seismic data were developed by integrating multiple 2D planes (as multiple surface traverses) into projection of a 3D volume. Currently, 3D seismic has become the standard tool for exploration and development, especially in the Gulf of Mexico. In an exploration context, seismic data are used to identify regions or geologic trends that have higher potential for commercial resources, with the ultimate goal being to reduce the amount of wildcat drilling necessary to successfully locate economic reserves. Once a prospect has been identified, seismic is a critical tool to identify potential drilling hazards. During the production phase, time-lapsed 3D seismic acquired over months or years (commonly called 4D seismic in recognition of the time dimension) can be a critical tool for understanding the effectiveness of the development strategy and allow for adjustments to maximize production from existing wellbores, potentially eliminating the need for additional drilling. 4D seismic can also help increase overall resource recovery.

Seismic noise generated by offshore natural gas and oil exploration activities is recognized as a concern for whale populations and other marine life, including fish. Scientific understanding of these potential impacts has expanded significantly in the last two decades, but important gaps in knowledge still exist. Potential impacts include behavioral changes, masking, auditory injury, physical injury, and other indirect effects, and for fisheries, reduction in catch rates of some commercial species. Seven nations – the United States, Australia, Brazil, Canada, Ireland, New Zealand, and the United Kingdom – have national guidelines requiring mitigation measures during marine seismic surveys. In the United States and in most of the other countries that have guidelines, the two most commonly used mitigation measures involve visually observing a "monitoring zone" around the array and temporarily suspending seismic activities when a protected species is detected within the zone; and gradually increasing the emitted sound level from the seismic array (called soft-start or ramp-up) before a survey begins or resumes after a period of silence. The intent of a soft-start procedure is to warn marine animals of pending seismic operations and to allow sufficient time for those animals to leave the immediate vicinity. The questioning of the efficacy of the "soft-start" method by some has prompted a four-year Australian study to gain better understanding as to whether animals do move out of the immediate vicinity of the seismic source as it slowly ramps up. Seasonal and geographical restrictions have been implemented in some jurisdictions, including Australia, Brazil, Canada, the United Kingdom, and the United States. In the United States and other jurisdictions, research is underway to develop additional mitigation and monitoring tools and to investigate the effectiveness of current mitigation measures. Additional technological refinement can be developed to supplement current seismic acquisition and mitigation methods, leading to a more environmentally sustainable approach to geophysical data acquisition. Additional considerations for design changes include reducing unwanted noise from air gun seismic sources and refining limited alternatives to air guns (e.g., marine vibroseis devices).

Drilling and Completion Technology

One of the remarkable accomplishments of the petroleum industry has been the development of technology for drilling wells offshore. While the rotary drilling process used for offshore drilling is similar to that for land-based drilling, modified drilling rigs and methods are required to suit the more complex subsea environment. For example, offshore operations often require closed-loop drilling so that there is limited discharge of drilling wastes. Important drilling developments related to offshore resources have included:

- Embedded operation-while-drilling functions (measurement, logging pressure management, reaming, casing installation)
- Improved mud motors
- Polycrystalline Diamond Compact bits and bi-centered bits
- Top drives
- Expandable casings
- Low-viscosity non-aqueous drilling fluids (clay-free, flat-rheology, and micronized barite systems)
- Improved software modeling (wellbore stability, hydraulics, torque and drag, etc.)
- Improved hole-cleaning practices
- Sharing of nonproprietary operational best practices.

Industry anticipates that additional improvement to drilling technologies and performance will further reduce environmental impacts, providing for more environmentally responsible development of offshore resources.

Significant differences also exist in well completion methods for offshore development. The advent of the first horizontal Christmas tree in 1993 allowed operators access to the wellbore for workovers and interventions without having to disturb the tree and associated flowlines, service lines, or control umbilicals.[28] Developments of subsea and other equipment for higher pressures and temperatures continued as operators progressed to drill deeper wells with more stressful physical conditions. The next major advance in subsea trees came in 2007 with the introduction of an all-electric tree.[29]

Well Control Technology

Blowout preventers have been used for nearly a century in control of oil well drilling on land. The onshore BOP equipment technology has been adapted and used in offshore wells since the 1960s. A key difference in surface and subsea BOPs is in the remote control technology required for subsea BOP operation. Because BOPs are meant to be fail-safe devices, efforts are made to minimize their complexity to ensure ram BOP reliability and longevity. As a result,

28 H. B. Skeels, B. C. Hopkins, and C. E. Cunningham, "The Horizontal Subsea Tree: A Unique Configuration Evolution," OTC 7244, prepared for the Offshore Technology Conference, May 3–6, 1993.

29 L. Bouquier, J. P. Signoret, and R. Lopez, "First Application of the All-Electric Subsea Production System: Implementation of a New Technology," OTC 18819, prepared for the Offshore Technology Conference, April 30–May 3, 2007.

despite the ever-increasing demands placed on them, state-of-the-art ram BOPs are conceptually the same as the first effective models and resemble those units in many ways.

Recently, underwater remotely operated vehicles (ROVs) have been employed to assist in well control. These unoccupied, highly maneuverable vehicles are operated by a person on board a vessel. They are linked to the ship by a tether (umbilical cable), a group of cables that carry electrical power, video, and data signals between the operator and the vehicle. High power applications often will use hydraulics in addition to electrical cabling. Most ROVs are equipped with at least a video camera and lights. Additional equipment may include sonar, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration, and temperature.

Arctic Baseline Science

The compilation by Westlien documented scientific knowledge of the Arctic Ocean surrounding Alaska that has accrued through studies dating from 1900 through 2010.[30] Over the last 100 years, scientists, using ever-advancing technology, have refined our knowledge of the Arctic resulting in a detailed understanding of the physical environment, biological resources, various ecosystem processes, as well as its human inhabitants. The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) Environmental Studies Program Information System contains 700 technical summaries of BOEMRE-sponsored environmental research projects as well as over 2,000 entries for research reports, studies, workshops, and seminars for Alaska. In addition to BOEMRE-supported studies, other federal agencies and organizations conducting science programs with implications for the Arctic marine ecosystem include the Bureau of Land Management, Department of Defense, EPA, NASA, National Oceanic and Atmospheric Administration (NOAA), National Park Service, and Marine Mammal Commission. These government programs are further enhanced by industry-supported science, as well as international programs like the Russian-American Long-Term Census of the Arctic.

30 Shell Exploration & Production Company, *Science of the U.S. Arctic Outer Continental Shelf*, vol. 1, November 2010, accessed June 29, 2011, http://www-static.shell.com/static/usa/downloads/2010/alaska/215723_booklet_spreads_rs.pdf.

The 2011 Presidential Oil Spill Commission recognized that significant scientific knowledge exists for Arctic regions and supported the proposition that Arctic natural gas and oil developments should be qualified on individual merit. Specifically, it was stated that:

> The existing gaps in data also support an approach that distinguishes in leasing decisions between those areas where information exists and those where it does not, as well as where response capability may be less and the related environmental risks may therefore be greater. The need for additional research should not be used as a de facto moratorium on activity in the Arctic, but instead should be carried out with specific time frames in mind in order to inform the decision-making process.[31]

The case can be made that the scientific data currently available are more than adequate and complete to identify, assess, and minimize the potential impacts of limited offshore natural gas and oil operations of the types previously proposed for the Beaufort Sea and the Chukchi Sea. The Ocean Research and Resources Advisory Panel, a collaborative group consisting of government agencies, academia, nongovernmental organizations, and the private sector, found that knowledge of the Arctic Ocean has further increased in recent years through additional efforts of the Department of Defense (Navy), the National Research Council, the CIA-funded MEDEA project (Measurements of Earth Data for Environmental Analysis – an information-sharing program to declassify certain information gathered for military intelligence purposes to be used for science), and other U.S. government activities that have not been widely publicized.[32]

Although there are ample opportunities to add valuable knowledge through selected studies, the currently available physical and biological science studies from the many scientific research programs have been incorporated into numerous impact assessments

31 National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water: The Gulf Oil disaster and the Future of Offshore Drilling*, report to the President, January 2011, 303, accessed June 27, 2011, http://www.oilspillcommission.gov/sites/default/files/documents/DEEPWATER_ReporttothePresident_FINAL.pdf.

32 Ocean Research and Resources Advisory Panel (ORRAP), "Key Findings and Recommendations Related to Arctic Research and Resource Management," ORRAP of the National Oceanographic Partnership Program, December 16, 2010.

conducted to assess the potential negative impact and positive benefit of natural gas and oil exploration activities in the U.S. Arctic.

Future Expectations

Technology advancements over the past century have enabled production of natural gas and oil from non-traditional resources, decreasing costs of recovery while effectively shrinking the footprint of operations, protecting the environment, and safeguarding workers' health. In the coming decade, even smaller physical operational footprints are envisioned through the deployment of such technologies as microbore drilling, advanced imaging of reservoirs in a non-intrusive surface view, and borehole imaging. Tools and rigs are expected to become lighter, decreasing surface impacts and operating profiles. Advances in computer processing will be harnessed in high-power diagnostics and risk-based data interpretation, leading to fewer wells and reducing the chance of dry holes.

Equipping drilling tools with implanted sensors will enhance the accuracy of searches for hydrocarbons, leading to a higher rate of recovery in reservoirs and, in turn, reducing cutting wastes and increasing recovery or reuse of produced water. Muds will become more advanced and environmentally friendly. Planning will take the forefront to ensure mitigation and anticipation of activities that could impact the environment and operations. Visual, noise, and emissions impacts will be reduced through technological advances of monitoring and reduced energy consumption of equipment. These improvements will all contribute to a more efficient operation.

HISTORY OF NATURAL GAS AND OIL ENVIRONMENTAL LAWS

Key Points:

- There is a comprehensive set of state and federal regulations in place that govern all aspects of oil and natural gas production and environmental protection.
- Many state agencies have been involved in regulating oil and gas development for longer than the federal government and have unique knowledge and expertise relative to the local geological, hydrological, environmental, and land use setting, and are responsible for regulation and development of private and state natural gas and oil resources, as well as for implementing certain federal laws and regulations.
- Effective regulation balances prescriptive requirements with performance-based requirements that encourage innovation and accommodate changing technologies and practices.

The evolution of water and environmental resource protection regulations governing natural gas and oil exploration, production, and well abandonment has followed a unique pattern. Most producing industries, including those related to oil refining and other "downstream" operations, developed controls for preventing pollution to air, water, and land resources primarily in response to federal pollution control acts passed by Congress between 1972 and 1990. In contrast, the "upstream" (production) sector of the petroleum industry began to initiate water protection measures in response to individual state statutes and regulations enacted in the early part of the 20th century.

Most of these early regulations on well construction and plugging were not designed to protect ground or surface water from the impacts of natural gas and oil production. Rather, the regulations were meant to prevent waters from adjacent non-productive formations and upper aquifers from flooding the oil-producing reservoir during drilling and production. The influx of alien waters could be of such a volume that drillers "lost the hole" before penetrating the target oil horizon. Thus, casing and cementing activities were incipient oil conservation measures to prevent "loss" of a saleable product. This kind of thinking was evident in the technical books of the period. For example, in 1919, geologist Dorsey Hager wrote a book called *Practical Oil Geology*. In Chapter 9, entitled "Water – Enemy of the Petroleum Industry," Mr. Hager states: "The danger of water in oil fields must not be underestimated. Water flooding is a danger often present where care is not taken in advance to protect the wells." In these early years, the principal focus was on protection of the petroleum resource from the effects of water incursion and not on protection of water resources themselves.

Most oil producers of the early period (prior to 1935) believed that royalty payments to the landowner for the privilege of extracting oil or natural gas from beneath their land adequately compensated the landowner for any surface and water resource damages caused to the property. These damages included accidental spillage of oil or saltwater, leakage of produced water from storage and disposal pits, and loss of agricultural land taken out of production by the occupancy of property. Pollution to groundwater from activities at individual tank battery locations sometimes rendered freshwater aquifers unusable for a long period of time; yet even landowners who had experienced considerable damage to their farms first viewed surface pollution as a necessary evil and an inherent part of the oil or natural gas production process.

Prior to 1935

Through the early 1930s, regulation of the exploration and production industry was irregular rather than systematic. New York required the plugging of abandoned wells as early as 1879. Ohio reported enacting the first law for regulating methods used to case and plug natural gas and oil wells to prevent water from penetrating and contaminating the oil-bearing rock in 1883. In 1890, Pennsylvania passed the first law requiring non-producing wells to be plugged in order to protect the integrity of the producing formation. Texas legislature passed a law relating to protection of groundwater, well abandonment, and conservation of natural gas in 1899. In 1915, the Oil and Natural Gas Division of the Oklahoma Corporation Commission was given exclusive jurisdiction over all wells drilled for the exploration and production of natural gas and oil, and in 1917, the Commission was given authority over related groundwater protection and mandated to develop procedures for plugging and abandonment. The Texas Railroad Commission was given similar authorities in 1917 and 1919, respectively. California enacted a plugging program in 1915 and added a groundwater protection component in 1929. Other states set up natural gas and oil regulatory commissions, often without specific authority to promulgate regulations and where enforcement authority was only available under the general statutes and civil or county control.

Around 1931, a barrel of oil, which cost about 80 cents to produce, sold for as low as 15 cents. This differential between supply and demand improved somewhat in ensuing years through the early 1930s. However, the potential for serious gluts of unmarketable oil remained and several governors – over the objections of oil producers, some state legislators, and landowners – felt that some framework of government controls over the production of oil was necessary. The United States was then, and still is, the only oil-producing country in the world where minerals rights can be privately owned and the owner of the natural gas and oil rights can make a lease agreement with a company to extract hydrocarbons in return for a royalty payment based on a percentage of each barrel produced and sold.

Initiation of Natural Gas and Oil Conservation

In 1935, after several aborted attempts to come up with an acceptable concept for government intervention into the supply-demand roller coaster, six states – Oklahoma, Texas, Colorado, Illinois, New Mexico, and Kansas – formed the Interstate Oil Compact Commission (IOCC). In 1991, the organization changed its name to the Interstate Oil and Gas Compact Commission. The purpose of the IOCC was to promote conservation of oil resources through an orderly development of oil reservoirs. Companies would predict a market demand for their product and the state agency would then set an annual or semi-annual extraction allowable for each producing field (or producing horizon) based on the market prediction. Governor Marland of Oklahoma supported a concept addressing "economic waste" and believed that government should prorate production to obtain a fair price for crude oil. This concept was eventually changed to embrace the term "physical waste" and the six states ratified the Compact agreement.

One of the early efforts of the Compact was the development of a set of model regulations that the states could use as a pattern to establish their own regulatory framework. Even though the model established a format for natural gas and oil conservation, the protection of groundwater from pollution was carried as a secondary consideration in most regulations, particularly as the regulations applied to well construction and plugging. In the early 1960s, the IOCC also developed a model for natural gas regulation similar to that created for oil in 1935.

From 1941 through the end of World War II, several state legislatures enacted moratoriums on the enforcement of environmental regulations and conservation practices controlling supply and demand due to the increased need for oil for the war effort.

In late 1941, the beneficial effect of conservation in the late 1930s had been proven and the United States had a surplus capacity of about 1 million barrels of oil, approximately 80% of which was produced from Compact states. By 1945, the IOCC had grown in membership to 17 states and was a sustaining force in providing models for natural gas- and oil-producing states to follow in promulgating regulations.

U.S. Oil Production Dominance

From 1946 to 1960, most oil- and natural gas-producing states established a regulatory agency to enforce oil and natural gas conservation practices. Still, the environmental protection aspects of the oil regulatory picture developed sporadically. State statutes regarding pollution abatement and control of oil field practices and waste emanated from individual events rather than from an overall "welfare of the nation" impetus. Kansas, for example, gave its board of health (not the Corporation Commission) authority in 1946 to issue orders against oil field brine disposal pits that were causing saltwater pollution; but it was not until January 1958 that the board could issue permits for acceptable pit usage and deny permits for those deemed to cause potential pollution.

Texas adopted "no-pit" rules in the late 1960s and several other states placed stricter limits on how long produced fluids could be retained in pits. The concern over pit usage stemmed from a realization that these so-called "produced water evaporation pits" were little more than unsealed seepage pits and, as a result, domestic water wells were being contaminated with saltwater.

Environmental Movement

The 1970s brought the nation's environmental consciousness to the forefront. The passage of the Federal Water Pollution Control Act (FWPCA) in 1972 sent the message that discharges of pollutants to the nation's waterways, estuaries, and drainages, even intermittent ones, were no longer acceptable and discharges of specific inorganic pollutants were to be regulated either by state or federal permit. Congress authorized formation of the U.S. EPA to implement the FWPCA and successive environmental and water resource protection acts. Section 311 of the FWPCA and its successor, the Clean Water Act (CWA) of 1977, elevated the consequence of accidental spillage of oil from a producing lease to a finable offense when the oil entered a flowing stream. The non-reporting of an oil spill was also a finable offense. Another part of the CWA required containment dikes around tank batteries and oil storage facilities to prevent releases of oil to "navigable streams," which by definition included almost every intermittent upper reach of a stream if it connected to a potential flowing watercourse. This program, called the Spill Prevention, Control, and Countermeasures program, was administered under the direct implementation authority of the EPA. Prior to the FWPCA, most state natural gas and oil regulatory agencies required operators to contain, report, and clean up serious oil spills on water. However, few operators were fined unless they refused to obey a state agency directive. The CWA marked the first time that the natural gas- and oil-producing industry was subject to direct dealings with a federal agency on environmental protection issues. In 1974, Congress passed the Safe Drinking Water Act (SDWA), which authorized the EPA to promulgate regulations for wells used to inject fluids into subsurface formations. This section of the SDWA was called the Underground Injection Control Program, and included wells used for either disposal of excess produced water or for injection of produced water to increase recovery of oil. Between 1982 and 1990, 20 oil-producing states applied for and received primary enforcement authority (primacy) from the EPA to administer the program under Section 1425 of the SDWA. (Additional states received primacy under Section 1422 of the SDWA.) Delegating authority to the states allowed those with longstanding natural gas and oil regulatory programs to demonstrate that their programs were as effective in protecting groundwater as those promulgated and administered by the EPA. The major initial impact of the UIC program was that operators had to verify the mechanical integrity of each of their injection wells once every five years. Prior to the UIC program, most regulatory agencies only required operators to test an injection well if it was known or suspected to be leaking.

In the 1970s, domestic oil production began to decline. Some landowners, who were actively engaged in agriculture, came to view the oil production on their acreage as a nuisance, rather than a benefit. Landowners and tenants increased demands that state natural gas and oil regulators direct operators to plug idle and non-productive wells. In response, many states set up "temporarily abandoned" or "idle" well programs that required operators to monitor the mechanical integrity of these wells and certify annually that idle wells had a future purpose.

In the 1980s, particularly after the 1986 depression in the industry, several states (Kansas, Texas, California, and others) received legislative authorization to establish dedicated funding to contract the plugging of abandoned or "orphan" wells. These well plugging funds resulted in the permanent closure of thousands of wells that might have posed a threat to the environment.

Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976, which gave the EPA authority to regulate the disposition and disposal of hazardous substances. Fluids produced during the exploration and production of natural gas and oil were originally excluded from RCRA and set aside for further study. In 1988, the EPA administrator issued a regulatory determination that wastes produced in connection with natural gas and oil exploration and production operations would remain under state regulation and would be "exempt" from the RCRA Subtitle C regulatory regime. In response to this decision, IOGCC committees developed environmental program guidelines for states to strengthen their natural gas and oil waste management programs (excluding those under the UIC program). Beginning in 1991, the IOGCC asked state committees to systematically review state natural gas and oil environmental regulatory programs against the guidelines. These review committees were comprised of state natural gas and oil regulators, state environmental regulators, major and local natural gas and oil producers and members of environmental advocacy organizations. This work is carried forward today by the State Review of Oil and Natural Gas Environmental Regulations (STRONGER).

Environmental Regulation Refinement

The last two decades have provided new environmental regulatory challenges to natural gas and oil producers. Many states formed separate departments to administer overall environmental regulations in response to a programmatic shift in emphasis towards protection of water and land resources and to the special technical knowledge needed to implement programs. Such changes provided better coordination of environmental permitting and field inspection activities and improved documentation of accountable actions to state legislatures, the public, and the petroleum industry. Several states revised existing regulations concerning pits, tanks, and well construction to reflect the latest technological, environmental, and public policy needs of the state. There has also been increased scrutiny of operators who fail to maintain compliance standards. During this period, several states, including Kansas, Oklahoma, Indiana, and Louisiana, set up formal penalty schedules and operator suspension procedures to address habitual or flagrant noncompliance. Penalties that had applied only to Class II (natural gas and oil related) injection wells were now adopted for a whole range of environmental programs.

Operators have also been subject to increased well and performance bonding and financial assurance requirements. Since 1990, intensified environmental awareness has resulted in the implementation of several new environmental programs. Some of these programs are listed below.

- The discovery of CBNG in Montana, Wyoming, the Four Corners area, and the Black Warrior Basin of Alabama, brought the search for gas into some areas previously unexplored for hydrocarbons. In Colorado and California, which had always regulated natural gas and oil at the state level under home rule statutes, citizens now exerted pressure to regulate them through county or city ordinance. In 2008, Colorado revised its regulations to allow for expanded public participation in the permitting and environmental assessment of oil field sites. This participation included review by other state water protection agencies.
- In the mid-1990s, citizens became concerned over the amount of naturally occurring radioactive material produced at some natural gas and oil lease locations. Sufficient radium and other radioactive isotopes in some produced water caused a coating of precipitate to develop in tubular goods and at pump connections. Operators were concerned when loads of salvage pipe were rejected by prospective buyers and were returned to them for disposal. As a result, some states, such as Louisiana and Texas, developed regulations governing the disposition of this pipe and other naturally occurring radioactive material and wastes.
- The Community Right-To-Know portion of Superfund (Section 312 of SARA Title III) of 1988 required oil operators to submit Material Safety Data Sheets reporting how much hydrocarbon was stored onsite at a lease facility. The state level administration of this program is usually administered by the principal state environmental agency rather than

the natural gas and oil regulatory agency. This law also has a provision under Section 304 whereby the operator has to make changes in the facility design if a large release of hydrocarbons occurs.

- The Oil Pollution Act of 1990 has had a huge impact on offshore natural gas and oil production operations, shipping, pipeline, and terminals primarily throughout the U.S. coastal areas of Louisiana, Texas, Mississippi, and Alabama. The Oil Pollution Act began as a reaction to the Exxon Valdez incident in Alaska in 1988 and required the use of double-hulled vessels to transport oil.

Transformation of Public Confidence

Environmental protection technologies, practices, and regulations have evolved along with natural gas and oil production technologies. The direction of change has been movement from conservation for the economic protection of natural gas and oil resource operators to a multidimensional approach involving citizens' rights, government regulation, and the rights of developers. As operators, citizens, and governments became more aware of the ways in which production could affect the environment, they developed a new perspective on environmental stewardship. In the early years of this process, which originated in energy-producing states decades before the environmental movement of the 1960s, the primary emphasis was on conservation and efficient production of the resource with a focus on economics. The term "conservation," in fact, initially served as a legal term of art to describe measures to avoid physical and economic waste of natural gas and oil resources. State regulations were developed to address well spacing, pooling, and unitization in producing natural gas and oil fields, among other issues, recognizing a public interest in orderly development of natural gas and oil resources, and in balancing the interests of those holding rights to those resources. The governing assumption was that those interests were primarily economic in nature.

During this period, conflicts over surface uses and occasional controversies over surface or groundwater pollution incidents were most often resolved by the legal system under principles of tort law or nuisance – and in the case of surface use conflicts, occasionally through local zoning ordinances. Natural gas and oil drilling and production operations were broadly seen as legitimate industrial activities. The postwar development of metropolitan Los Angeles provides evidence of this early social consensus: historic oil fields are interspersed with urban and suburban development in Baldwin Hills, a number of the beach communities, and even Beverly Hills.

In the postwar decades, several changes have influenced the regulatory processes governing natural gas and oil development – and in some cases, the achievability of such development on a field-wide scale in economic and practical terms. Among these changes are:

- The emergence of grassroots networks able to influence local community opinion
- The shift of some regulatory agencies from a historic pro-development mission to a position of adjudicating the interests of opposing parties
- The emergence of a strong interest by the public to manage, restrict, or prevent projects they see as affecting them
- The erosion of a social consensus that development of energy resources is at all times in the public interest.

Controversy in the 1950s and early 1960s over development of the portion of California's Wilmington Oil Field that extends under much of the City of Long Beach and out into Long Beach Harbor augured this change in social consensus. Development of the original section of the Wilmington Field north and west of Long Beach underneath the communities of Wilmington and Carson caused extensive surface subsidence and a proliferation of surface production equipment and pipelines. When the state of California, which owned the mineral rights to the Wilmington Field under tidelands in Long Beach Harbor, first proposed development of the resource, the city of Long Beach vigorously opposed the state's proposal with the strong support of city residents. The outcome of years of litigation and administrative delay resulted in a historic decision in which the state committed to develop the Long Beach portion of the field using water injection to control subsidence and to increase oil recovery. That this dispute occurred in the middle of a dynamic and growing metropolitan area ensured substantial media coverage, and led many in the public to recognize that an energized citizenry could influence not only local government, but oil field development promoted by state government.

The seminal event that shifted public perception about natural gas and oil drilling was the Santa Barbara oil spill in 1969. A drilling accident at an offshore oil rig sent almost 3 million gallons of oil into the Santa Barbara channel. As volunteers rushed to the beach and harbor to assist with cleanup, the day's events spurred a new environmental movement – beginning that evening in Santa Barbara and soon extending throughout the United States. Public clamor over the spill led Congress to pass, and President Richard Nixon to sign, the National Environmental Policy Act (NEPA). Similar public pressure led to the passage of the California Environmental Quality Act (CEQA). The spill was used again and again as a justification for passage of other environmental statutes or the adoption of new regulations intended to address pollution and environmental risk.

The spill and its aftermath were among the factors leading to passage of the Coastal Zone Management Act (CZMA). The state of California imposed a moratorium on further exploration drilling in state tidelands that was not lifted until 1981, and which was reimposed several years later. Many major environmental groups focused their position statements on opposition to offshore natural gas and oil drilling and production. Over time, many in the general public developed a distrust of the competence and credibility of the natural gas and oil industry that has never fully abated.

In the early 1980s, the California State Lands Commission cautiously lifted the moratorium on drilling from new locations in state tidelands (drilling from existing offshore structures had been allowed with state permit approvals). At the same time, the Reagan administration, through then-Interior Secretary James Watt, proposed an ambitious plan of new federal natural gas and oil lease sales in the Pacific Outer Continental Shelf (OCS). Natural gas and oil companies proposing to drill or to develop federal OCS leases promptly found themselves challenged by energized and resourceful community groups, not just in Santa Barbara County, but up and down the California coast from San Diego to Humboldt County. These groups proved adept at using early generation telecommunications and computer networks and a web of personal relationships to exchange strategies and lessons learned on grassroots organization, local referendum campaigns, and other methods to mobilize community opposition to offshore natural gas and oil projects. They recruited activists to attend public hearings to speak out against oil projects, particularly those of the California Coastal Commission, the State Lands Commission, and the Board of Supervisors of Santa Barbara County. As a result, administrative hearings that two decades before might have taken place in relative obscurity were forums for creative acts of "street theatre," notably at Minerals Management Service scoping hearings for OCS lease sales proposed off the coast of Northern California in the mid-1980s. In time, grassroots opponents of new projects in the California Pacific offshore found funding to sustain their efforts.

The natural gas and oil industry adapted slowly to this transition in the regulatory environment in California. Nor was the industry nimble in forming coalitions and mustering its supporters at public hearings. While the industry debated the percentage of the public represented by opponents of offshore natural gas and oil development, it could not deny their energy. Declining oil prices in the mid-1980s, the complexity of a post-NEPA, post-CEQA regulatory environment, and the efforts of opposition groups in California's coastal counties combined to discourage many of the major companies from further pursuit of new projects in the California offshore. Most have since sold or decommissioned their assets there.

The lessons of California for the environmental movement have been discussed frequently and at length. Their effects elsewhere on regulatory processes governing the development and production of natural gas and oil have been significant. California became the proving ground for use of administrative processes to express public opposition to (or at least skepticism of) natural gas and oil projects, and for the use of administrative requirements to subject project proposals to rigorous third-party scrutiny. Whereas agencies in the early decades of regulating natural gas and oil development were often in the position of encouraging development (and in many cases were statutorily charged to do so), beginning with California and the West Coast states, some agencies took on the role of arbiter between the interests of those advocating and those opposing natural gas and oil projects. Also, the experience of California spread through the broader public to nurture an expectation that administrative processes existed not merely to resolve the interests of owners of mineral rights, but to recognize and address the interests of those who were potentially affected by natural gas and oil development.

This transition in purpose and expectation for administrative processes has not been linear, and it has varied in pace and in outcome from state to state. But to some extent, underscored by media coverage of controversies over energy projects of many types and in many locations, this transition is occurring everywhere in North America.

Historically, development of a natural gas or oil field was grounded in property transactions and in the administrative adjudication of the rights of participants in those transactions. Companies acquired natural gas and oil leases through negotiation with mineral rights owners, then voluntarily farmed out or pooled their leasehold acreage to assemble sufficient working interest and capital to drill. Subsequently, companies would negotiate, or work within the framework of state regulatory processes to form units to optimize the development and production of the resource discovered through drilling. Over time, as state (and later, federal) laws were enacted to ensure safe and environmentally responsible operations, companies would also obtain necessary permits and approvals. In the early years of enforcement of these laws, issuance of such permits and approvals most often occurred on strictly technical grounds. A company would submit an application demonstrating its ability to comply with the law in question, and upon review by agency staff, sometimes accompanied by a largely technical hearing, the permit or approval would be issued. Sometimes companies would need to obtain site construction permits, zoning variances, or similar approvals from local governments, but these were likewise based on technical and factual showings.

Affected Populace Opinion

The contemporary approach to development of a natural gas or oil field adds to this transaction-based history an evolving emphasis on the rights and interests of those who are potentially affected by the transactions. The potential for controversy is greatest where large numbers of people consider themselves affected by natural gas and oil development, but have no direct economic interest in the development. This was, and to a certain extent remains, the case along the California coast, where many residents felt they were at the mercy of decisions made between the federal government and oil companies. This potential also exists where an ownership of the surface rights has been separated from ownership of the mineral rights, known as "split estate." Examples include both fee land states like Texas and public lands in the Intermountain West, where the U.S. government issued patents and deeds to the surface while retaining the minerals. It is also the case in natural gas plays such as the Barnett Shale near Fort Worth, Texas, where severance may exist, or where mineral interest ownership may be so fragmented into small lots that owners of mineral rights may not see an economic benefit that outweighs the inconvenience of having a large drilling operation nearby.

Similar controversy has more recently emerged where a critical mass of local citizens becomes a stakeholder in the maintenance of intangible but nonetheless strongly held values such as landscape or lifestyle. Many Santa Barbara residents in the offshore oil debates of the 1980s feared that their community and region could take on an unwanted industrial character if offshore oil projects proliferated. They fought to preserve vistas free of offshore platforms (though some 20 platforms could be found in Santa Barbara Channel at the time). Opponents of natural gas exploration in the Intermountain West have fought to preserve the undeveloped character of Colorado's Roan Plateau, Wyoming's Red Desert, and New Mexico's Galisteo Basin. Currently, in New York State, controversy surrounds proposed natural gas development in the Catskill portion of the Marcellus Shale, which supplies drinking water to New York City. Many local residents, as well as customers of the New York City Water Supply System and the city's government, oppose plans to develop this resource.

Controversy and opposition to energy development projects can also find fertile ground in situations where the scale of development – or perceptions and fears about future development – exceed the capability of existing regulatory processes to resolve the issues in dispute. The state of New York is again a good example. Many members of the public opposed to any development of the Marcellus Shale natural gas resource in the state have petitioned the New York Department of Environmental Conservation not to approve a new regulatory scheme for drilling and production of the shale gas, even though the department is statutorily directed to issue such regulations. This has resulted in protracted delays in the issuance of revised New York Department of Environmental Conservation regulations and in a suspension of new project activity in the New York Marcellus region.

The transaction-based framework for natural gas and oil development, guided by a regulatory process supporting conservation and efficient production of the resource, has evolved into a new framework that is open to the influence of parties who may not be directly involved in the underlying transactions. These parties express interests that often fall outside the scope of agencies with traditional authority over natural gas and oil drilling and production operations, and may even fall outside the authority of other state or federal agencies with an environmental mission. In the breadth of ongoing public debate over subjects pertaining to energy and the environment, a consensus that existed in support of developing energy resources, and that recognized their economic and general social value, no longer exists. With this change, long-prevalent assumptions about what rights a party holds to the development of minerals acquired through ownership, lease, or contractual arrangement are being questioned.

This leaves to mineral rights owners, their lessees, and operating companies, along with administrative agencies and governments at every level, the challenge of addressing public perceptions and responding to public concerns in order to foster a decision-making environment in which resource development can proceed. The need to secure the legal right to drill through the appropriate sequence of property transactions has not changed. The need to secure the appropriate permits and regulatory approvals to be able to drill in compliance with applicable laws and regulations has not changed. What has changed is the need to identify and engage with those who are potentially affected, broadly defined, by a proposed project. Not only must they be identified, but also the prudent operator must make best efforts to understand and to provide means to address their convictions, questions, and concerns within the budget and scope of his project. It has long been understood that natural gas and oil projects take place within boundaries of economic feasibility and rate of return, and in the context of legal title and geologic, logistical, and site surface characteristics. Over the past few decades, the enactment of new laws and regulations have also clarified that such projects must be considered in the context of their environment; that is, project plans must address their effects on air quality, on surface environment and the uses to which that environment may be put, on soils, on surface water and groundwater, on habitat and wildlife, and in some areas, on impacts to traffic and other infrastructure, and on community character and quality of life. Figure 2-11 illustrates the extensive process required for permitting a shale gas well in Pennsylvania, which addresses this variety of environmental impacts.

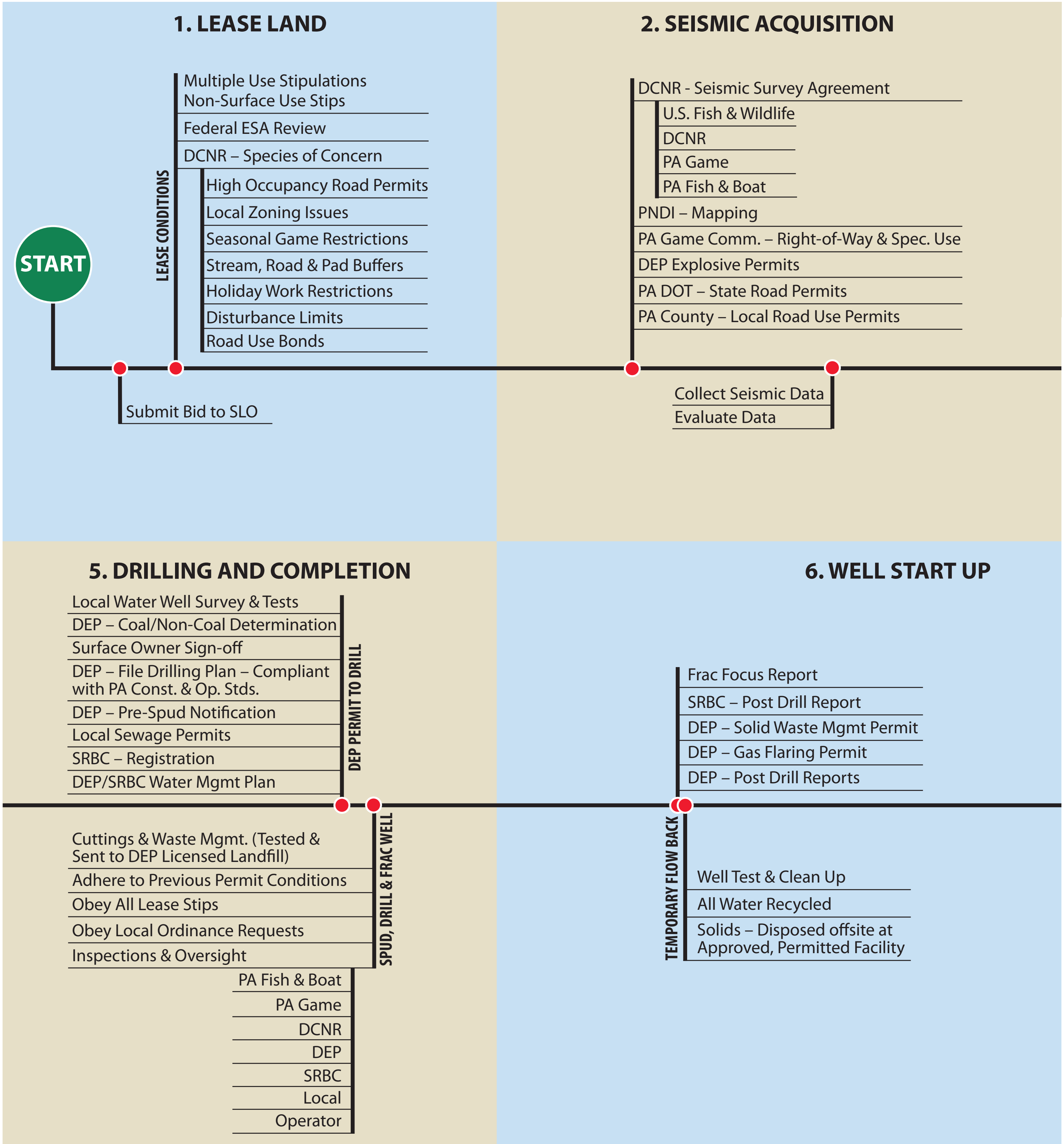
Now the task of effective project planning has expanded to include measures to address concerns of people who live in the community or region in which the project is proposed to take place. Project success or failure, timely completion, or uneconomic delay, increasingly depends on the degree to which issues of public concern are recognized and addressed in the project plan. Likewise, the pace of development of our natural gas endowment will be influenced by the ability to accomplish this project by project, field by field, and region by region. The specific approaches will vary greatly across the universe of projects. But as has been the case with many other attributes of successful natural gas and oil development projects, resolution will depend upon informed observation, thoughtful consideration of past experience, and adaptability to circumstance.

Hydraulic Fracturing

Hydraulic fracturing stimulates production in oil or gas wells and provides the industry a means to increase recovery of the hydrocarbon resource and lessen the environmental footprint from the development of natural gas and oil resources. Individuals and organizations concerned about the environmental and social consequences of hydraulic fracturing cite air emissions, surface- and groundwater withdrawals, produced water management, surface disturbances, invasive vegetation, habitat fragmentation, seismic vibrations, amplified noise, visual alterations, and community changes as potential problems. These environmental concerns have influenced legislative and regulatory policies as they relate to hydraulic fracturing. However, as hydraulic fracturing technology has progressed, operators and regulators have identified and developed extensive mitigation measures to reduce the probability of impacts.

The Safe Drinking Water Act was enacted in 1974, 25 years after the commercial onset of hydraulic fracturing operations. Hydraulic fracturing was not considered for federal regulation under the SDWA during drafting. However, opponents to the technology and existing regulatory framework have emerged over the last decade to bring hydraulic fracturing into the forefront of the current environmental regulatory debate. Table 2-4 outlines the drivers of hydraulic fracturing since the passage of the SDWA.

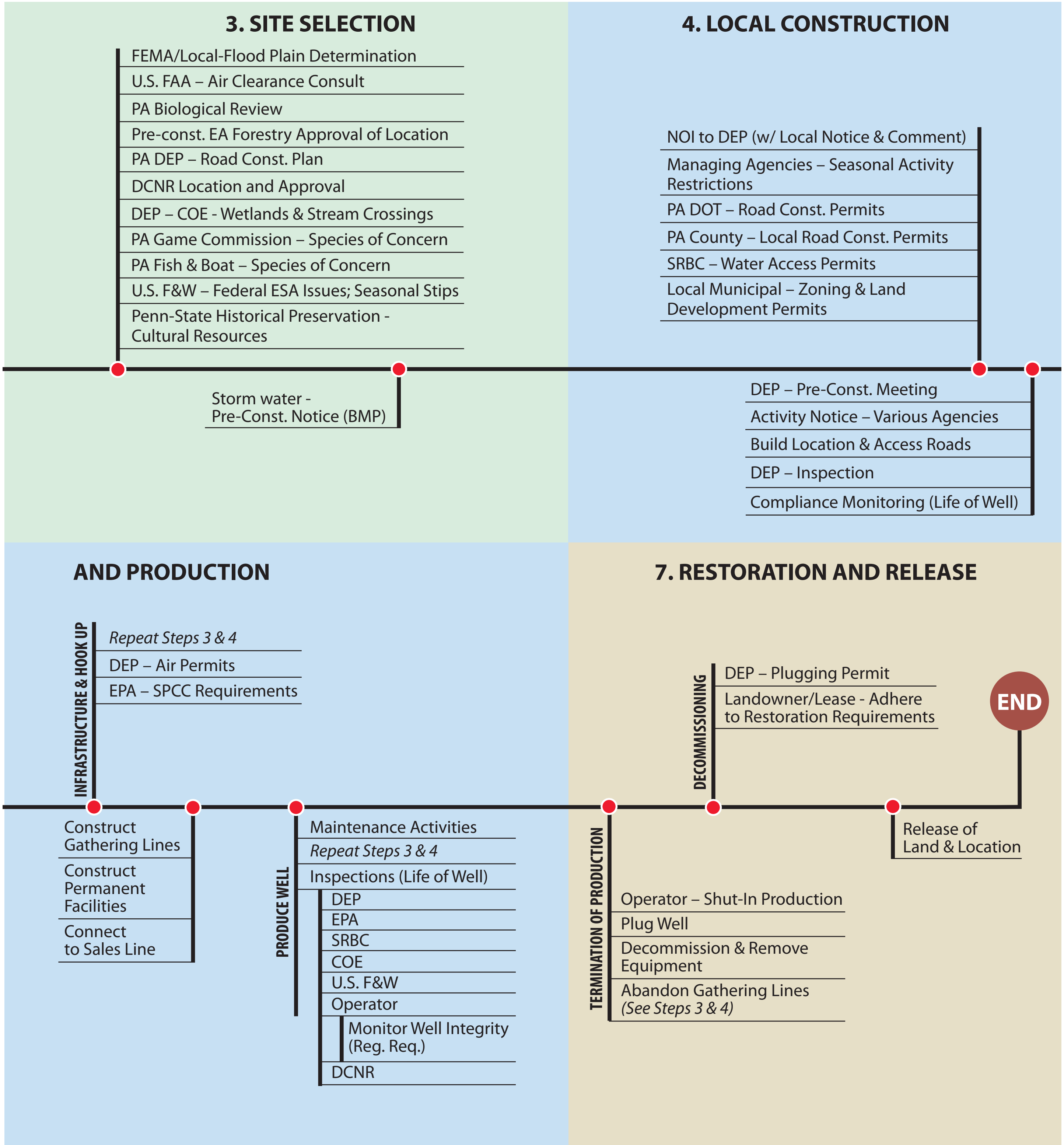
Figure 2-11. The Natural Gas and Oil Industry is Well Regulated: Project Development Requirements in Pennsylvania



LEGEND:

BMP – Best Management Practice
COE – U.S. Army Corps of Engineers
DCNR – PA Dept. of Conservation & Natural Resources
DEP – PA Dept. of Environmental Protection
EA – Environmental Assessment
EPA – Environmental Protection Agency
ESA – Federal Endangered Species Act
FAA – Federal Aviation Administration
NOI – Notice of Intent
PA DOT – PA Dept. of Transportation
PNDI – PA Natural Diversity Inventory
SLO – State Lands Office
SPCC – Spill Prevention, Control & Countermeasure Plan
SRBC – Susquehanna River Basin Commission
U.S. F&W – U.S. Fish & Wildlife Service

Figure 2-11. The Natural Gas and Oil Industry is Well Regulated:
Project Development Requirements in Pennsylvania (continued)



Source: Adapted from "Governor's Marcellus Shale Advisory, Commission Report" by Jim Cawley, Lt. Governor, Commonwealth of Pennsylvania, July 22, 2011. Full Report Found at http://www.pa.gov. Also see Pennsylvania Public Records for Grugan development: Gathering Line - Permit #ESX10-035-0002, GP0518291004, GP0818291001; COP Tract 289 Pad E - Permit #ESX10-081-0076, API #37-081-20446 (Well #E-1029H); COP Tract 285 Pad C - Permit #GP0718291001, ESX10-035-0007. Additional reporting and oversight required for exceptions to permitted activity not shown.

As hydraulic fracturing is applied to unconventional resources, it has become the focus of many regulatory modifications at the federal, regional, state, and local levels. Although hydraulic fracturing is currently regulated at all of these levels (most prominently the state), many groups and individuals have called for additional federal regulation under the UIC program.

Table 2-4. History of Hydraulic Fracturing Regulation

Year	Action	Entity	Comments
1940s to Present	Adoption of state natural gas and oil regulatory programs	All natural gas- and oil-producing states, including OK, TX, LA, CO, WY, PA, etc.	States have adopted their own comprehensive laws and regulations to protect drinking water supplies, including the regulation of hydraulic fracturing. These states' programs have been refined over the years, as necessary, to address industry changes.
1974	Safe Drinking Water Act (SDWA)	U.S. Environmental Protection Agency (U.S. EPA)	Act drafted to protect health by regulating nation's public drinking water supply.
1996	Legal Environmental Assistance Foundation, Inc. (LEAF) vs. U.S. EPA	U.S. EPA	Alabama regulation of hydraulic fracturing in coalbed natural gas stimulations under the Underground Injection Control (UIC) program.
2003	Memorandum of Understanding (MOU) between U.S. EPA and service companies	U.S. EPA	Major service companies agree to refrain from using diesel fuel in hydraulic fracturing fluids in stimulations involving underground sources of drinking water (USDWs) associated with CBM wells.
2004	Evaluation of Impacts to USDWs by Hydraulic Fracturing of Coalbed Methane (CBM) Reservoirs Final Report	U.S. EPA	Study evaluated potential threat to USDWs from injection of hydraulic fracturing fluids into CBM wells. Concluded that injection of hydraulic fracturing fluids into CBM wells poses minimal threat to USDWs.
2005	Energy Policy Act	U.S. House	Clarified that hydraulic fracturing (exception for diesel fuel) was not underground injection as defined in the SDWA.
2009	Frac Act Introduced	U.S. Congress	Act would require chemical disclosure of hydraulic fracture fluid additives.
2010	Wyoming natural gas and oil Regulations	State of Wyoming	Full chemical disclosure of fracturing fluids regulations put into place.
2010	State Regulations	Various	Multiple state regulatory bodies and legislators studying or enacting regulations on disclosure of hydraulic fracturing fluids.
2010	Hydraulic Fracturing Study	U.S. EPA	EPA announces commencement of a new study investigating the possible relationships between hydraulic fracturing and drinking water.
2011	Establishment of Secretary of Energy Advisory Board (SEAB) Natural Gas Subcommittee	U.S. DOE	The frac panel was established to provide recommendations to the SEAB on how to improve the safety and environmental performance of natural gas hydraulic fracturing from shale formations.
2011	EPA Regulation Review	U.S. EPA	EPA initiates process to develop guidance for diesel use in UIC operations.

SUSTAINABLE STRATEGIES AND SYSTEMS FOR THE CONTINUED PRUDENT DEVELOPMENT OF NORTH AMERICAN NATURAL GAS AND OIL

Key Points:

- Environmental sustainability can be accomplished by individual companies adopting business strategies that meet the needs of the company and stakeholders, while enhancing human and natural resources for the future.
- To support informed energy decisions, an objective assessment of the environmental footprint (benefits, adverse impacts, and risks) of each potential energy source is essential.
- Stakeholder engagement can provide valuable insights that lead to better decisions and strategies.
- Public-private partnerships have proven to be a successful tool to collaborate with stakeholders and to drive environmental sustainability goals within a sector.
- An environmental management system is a tool that can be used to drive environmental sustainability in a systematic manner.
- Information sharing, transparency, and continued environmental stewardship are prerequisites to gaining public confidence.

Prudent development of secure and reliable domestic sources of energy includes protecting the environment and public health, and is essential to maintain our quality of life and economic strength in North America. Along with renewable energy sources, domestically produced oil and natural gas are positioned to provide electricity and fuel for many decades to come. The future role of natural gas and oil within the North American energy portfolio hinges on the ability of companies to demonstrate their ability to sustainably produce such energy resources. For any industry, achieving the goal of environmental sustainability is an aspirational goal.

The idea of sustainably producing natural gas and oil resources is not yet well defined (see "Definitions of Sustainable Development" at the end of this chapter). Sustainable development is defined by the Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Conceptually, sustainable development within the natural gas and oil industry may be driven by a vision for global leadership by the North American industry in setting the standard for technological and environmental performance. It may be reflected in: regional, state, and provincial strategies; pace of development; management of community impacts; investment of revenues in sustainable businesses, infrastructure, assets for the future; and public-private partnerships for sustainable development. Sustainable development goals, which are aspirational in nature, include:

- Continually decreasing the surface footprint, working towards zero air emissions during production, achieving a positive water balance, and moving towards materials management not waste generation
- Measurable benefits to and reduction of impacts on communities and ecosystems where production occurs
- Ensuring development occurs at a rate where a high level of environmental compliance is consistently achieved
- Economic success of sustainable energy companies.

Ultimately, environmental sustainability can be accomplished by individual companies adopting business strategies and activities that meet the needs of the company and stakeholders while protecting and enhancing human and natural resources for the future. A number of natural gas and oil companies already have incorporated environmental sustainability goals into their business.

A sound framework for sustainable natural gas and oil resource recovery would include a **regulatory program that drives ongoing environmental improvement**, allows operational flexibility to drive innovation in technologies and practices, and requires measurement of key environmental and social impacts. Other essential elements include:

- Realistic sustainability comparisons of energy sources (social, environmental, and economic metrics) using **life-cycle assessments (LCAs) and footprint analyses**
- Use of industry-developed **environmental management systems** to systematically drive environmental sustainability

- **Public-private partnerships** (of industry, nongovernmental organizations, and government) that engage stakeholders in defining and supporting sustainable outcomes
- An effective **data management system** that provides data standardization to regulatory agencies with appropriate and standard information (via uploads from operators), and allows operators and regulators to maintain the system via a single data portal for effective data extraction and sharing of solutions and lessons learned.

Each of these four elements is discussed below.

Life-Cycle Assessments and Footprint Analyses

Numerous decisions by a host of players will determine the energy economy of North America in future decades. Questions of investments, research and development expenditures, policy priorities, and legislation and regulatory requirements all influence these decisions. While most energy decisions ultimately are economically driven, environmental implications are increasingly important. Virtually any form of energy development and generation can result in both adverse and beneficial effects to air, water, land, community, and quality of life. These impacts can be realized on the environment at the global, national, regional, state, and local levels.

Environmental matters can affect energy projects and companies in many ways and may delay or even halt projects, including:

- Operational economics may be affected, for example, when compliance requirements and negative environmental externalities not included in the original plan increase project costs.
- Operational changes may be required, such as increasing efficiencies, implementing recycling, encouraging conservation, implementing efforts to reduce GHG emissions, and designing criteria for more sustainable generation, extraction, and transportation methods.
- Project feasibility and access to resources may be limited by permit moratoria, land use restrictions, and timing restrictions on development activities.
- Changes to the "social license" and perception of the domestic energy industry may affect public trust.
- Markets accounting for the above factors will affect valuations and responses.

To ensure environmentally responsible development of North American energy resources, it is important that energy policy decisions rest on science-based, consistent, comparative information on the environmental impacts of each, otherwise known as the environmental footprint (EF). The EF can be defined as the breadth of incremental impacts necessary to adequately compare the footprint of source types.[33] It is the sum of positive and negative environmental impacts of developing, processing, transporting, and using an energy resource, considering all aspects of extracting, developing, processing, and transporting an energy source. Therefore, the EF can be assessed following principles developed for life-cycle assessments.

Use of an LCA approach will result in the evaluation of all stages of development and use of an energy source, with the understanding that stages are sequential and interdependent. By analyzing each natural medium (air, water, and land) in connection with each resource input (energy, water, or other resource), LCA facilitates the appraisal of cumulative environmental impacts accruing during all stages in development and transport of an energy source (e.g., raw material extraction, material transportation, material processing, ultimate material use).[34] Capturing impacts not contemplated in more established examinations is one benefit of adopting an LCA. A challenge is combining the LCA for each medium and resource into a single EF analysis for each unique area. Decisions are needed on how to balance and compare various impacts – for example, determining whether water use is valued at a higher level than air emissions. At this time, there is a need for a standard method for creating an overall EF for energy sources across all media and all resource use.

To be of greatest value, the EF would present impacts in a common set of metrics, under a series of main categories, such as resource consumption, land utilization, discharges (air and water), risk assessment,

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33 Science Applications International Corporation (SAIC), *Life Cycle Assessment: Principles and Practice*, EPA/600-R-06-060, prepared for the National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, May 2006, accessed June 29, 2011, http://www.epa.gov/nrmrl/lcaccess/pdfs/600r06060.pdf.

34 SAIC, *Life Cycle Assessment: Principles and Practice*.

toxic potency, and energy expenditure. Decision makers will then have information to weigh against social factors such as job creation, job retention, national security, energy independence, wealth exportation, resource depletion, and other considerations to select the energy resource appropriate for the specific circumstance in accord with national, regional, and local priorities.

An objective understanding of impacts can enhance the decision-making process. For instance, policymakers may wish to evaluate the requirement that by a specified date, 20% of the nation's electrical needs must be provided by wind power. An LCA can be used to compare the EF of the necessary amount of wind power to the EF of other energy sources. The increase in the desired power type could then be evaluated to predict the likely environmental consequence of the contemplated development compared to that of an alternative energy source.

Additional benefits of an EF analysis include involving stakeholders in planning and implementing transparency into the process. A collective, transparent approach increases all stakeholders' understanding of the issues and encourages objectivity in both public and private decision-making. A recent National Research Council study, entitled *Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use*, specifically reports findings about health and environmental externalities from various energy types and calls for a life-cycle analysis of full fuel cycles.[35] Additionally, an independent research study issued by the Applied Energy Studies Foundation, titled *The Environmental Cost of Energy*, identified the need for further in-depth analysis of environmental implications associated with the development of various renewable and nonrenewable energy sources.[36] An LCA for energy[37] can include, but is not limited to, an examination of the following subjects:

- Extraction of the raw resource, including:
  - Drilling natural gas or oil wells and transportation to a processing facility or the end user
  - Mining of coal or uranium and transportation to a processing facility
  - Constructing a solar or wind farm and transmission to the end user
  - Farming of biofuels feedstocks (e.g., algae, corn, soy, switch grass, wood) and transportation to the end user.
- Processing, manufacturing, and conversion, including:
  - Ethanol from corn
  - Biodiesel from soy
  - Uranium ore into fuel rods
  - Oil or natural gas into commercial fuels.
- Energy end use, reuse, and maintenance, including use of:
  - Coal to generate electricity and transmission of electric-power to the end user
  - Natural gas to generate electricity and transmission of electric-power to the end user
  - Nuclear fuel to generate electricity and transmission of electric-power to the end user
  - Biodiesel or compressed natural gas to power vehicles
  - Petroleum-derived gasoline or diesel to power vehicles
  - Electricity to power vehicles.
- Management of emissions, effluent, and waste, including:
  - Produced water and hydraulic-fracture-produced water from oil or gas drilling and production
  - Spent nuclear fuel wastes
  - Spent semiconductor solar panels
  - Spent lubricating and cooling oils from wind turbines
  - Mine tails and spoils.

In developing an LCA, the baseline year and level of comprehensiveness to adequately define a life cycle must be determined. The baseline year can be established based upon the validity of the historical data. The appropriate level of detail could include the primary life-cycle parameters including the energy necessary to drill the well or mine the coal. A primary

35 National Research Council of the National Academies, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* The National Academies Press, 2010, accessed June 29, 2011, http://www.nap.edu/catalog.php?record_id=12794.

36 Applied Energy Studies Foundation (AESF), *The Environmental Cost of Energy*, September 2010, accessed June 29, 2011, http://energydecisions.org/Downloads/ECOE-Report-AESF.pdf.

37 SAIC, *Life Cycle Assessment: Principles and Practice*.

life-cycle parameter is the "sequence of activities [that] directly contributes to making, using, or disposing of the product or material."[38] The primary assessment includes an evaluation of the environmental impacts from extraction to final end use, including processing, transportation, distribution, and waste streams generated along the way.

Secondary life-cycle parameters include activities such as the manufacture of the blades for a wind turbine, the manufacture of the drilling rig for a natural gas well, or the manufacture of semi-conductor panels for a solar farm.[39] Performing a secondary life-cycle assessment can be extremely complex. Deciding which factors to include or exclude may be subjective and difficult to apply consistently across energy sources.

An LCA using primary life-cycle parameters is the most realistic approach for obtaining a comparable assessment level. Figure 2-12 presents process-based primary LCA of energy resources, including inputs (raw materials, energy, and water) and outputs (air emissions, water discharges, surface impacts, biological changes, and noise and visual impacts). Each energy source must be evaluated to the same level of detail. The policymaker must define and justify the limits of the analysis and ensure an appropriate peer review.

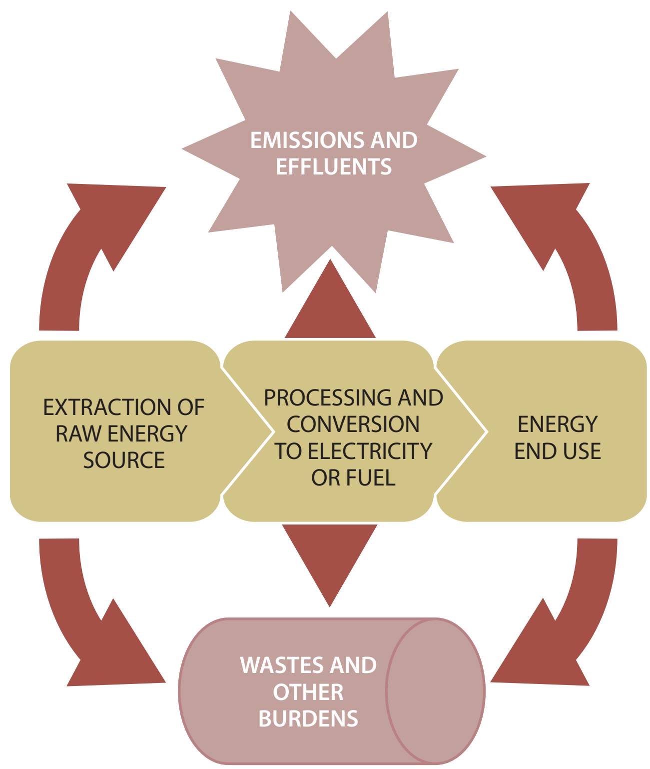
A comprehensive, objective EF analysis will ensure that public policy decisions are based on sound and comparable information. Determining the appropriate methodology and establishing a system to collect the necessary information would provide sound analytic results on environmental impacts for policy decisions. This process would involve interested stakeholders in public forums and enable discussion of a variety of viewpoints and issues. The following sections suggest an approach for conducting such a process and provide an EF analysis example, including the issues and gaps involved.

Fundamentals of Energy Life-Cycle Assessments

A standard methodology is key to comparing the EF of energy types. While each energy type involves unique characteristics specific to location, four fundamental considerations apply to all energy LCAs: scalability, metrics, regulatory compliance, and unique considerations. The methodology must include:

- A scalability filter to avoid making comparisons that are inappropriate
- A primary life-cycle approach to defining the limits of factors to be included and those that are excluded
- Consistent and compatible metrics to facilitate comparative analyses, including risk so that both probable and consequential impacts are assessed
- Recognition that not all criteria for comparison are quantitative and that qualitative or semi-quantitative data must be analyzed in some cases
- An assumption that energy development is performed in substantial compliance with applicable environmental regulations
- An accounting for unique situational or location factors
- The temporal nature of the impacts.

Figure 2-12. Life-Cycle Assessment



Source: National Research Council of the National Academies, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* The National Academies Press, 2010, accessed June 29, 2011, www.nap.edu/catalog.php?record id=12794.

38 SAIC, *Life Cycle Assessment: Principles and Practice*.

39 SAIC, *Life Cycle Assessment: Principles and Practice*.

Those factors must be equitably analyzed within and among energy development scenarios to objectively describe and compare the various energy resources. An EF analysis can become complex due to the myriad of factors, variations, and methodology issues. The analysis needs defined boundaries and documented assumptions. A comprehensive EF analysis has not been conducted for energy resources at this time. Some of the needed data exist in various sources, but it is not comprehensive or in the required form.

Scalability

Meaningful comparison of energy sources must include scalability. Scalability means an energy source can contribute to the current North American electrical or fuel needs (i.e., grid, industrial combustion, routine daily heating, and transportation). Energy sources that are not yet scalable and exist only in an experimental capacity (e.g., hydrogen cell technology) or are limited to local application (e.g., rooftop solar power) cannot realistically be compared to other scalable sources. It is most appropriate to compare one scalable source to another scalable source.

Metrics

A consistent, objective, and quantitative set of measurements or units (i.e., metrics) is important to ensure an effective comparison of dissimilar energy sources. Most of the energy sources included here are capable of generating electricity, with the exception of corn-ethanol and biodiesel. Therefore, the unit of 1,000 megawatt-hours (MWh), which is commonly referenced in the electric-power industry, is a useful comparative metric. The impact (e.g., surface disturbance, air emissions) associated with generating 1,000 MWh from various energy sources can be compared using a metric such as acres disturbed per 1,000 MWh generated, or tons of CO_2 emitted per 1,000 MWh generated. For heating fuels, environmental impacts assessed on a basis of 1 million British thermal units (MMBtu) also would be appropriate. For transportation, assessment units for environmental impacts per mile driven (for example, pounds of CO_2 emitted per 100 miles driven) would be appropriate.

The use of these assessment units allows for scaling and facilitates the comparison of evolving technologies to existing technologies. Because some renewable sources produce energy in specific forms (e.g., electricity or transportation fuels), comparisons should be made by determining the EF associated with delivering that form of energy based on its end use.

These calculations could also account for the relative quality of fuels. Different grades of coal will have different Btu contents. Measurements based on heat or electrical power produced account for the thermal or thermal-equivalent energy content of each energy source.

Some impact types cannot easily be quantified and some assessments may be constrained to semi-quantitative or even qualitative terms. That constraint may be especially true for impacts related to quality of life. Not all environmental impacts are similar nor can all environmental impacts readily be placed into quantifiable terms. However, where quantitative assessments are possible, they should be associated with a standard metric, or measure, in order to make valid comparisons.

Environmental Regulatory Compliance

Industries differ in compliance requirements, levels of compliance attained, and environmental impacts resulting from noncompliance. For purposes of the EF analysis, an assumption of compliance is essential since it would be difficult to assign a level of noncompliance and then evaluate the environmental impact of those noncompliant activities across industries. If that reality is to be reflected in the EF analysis, a consistent methodology for including risk must be identified and accepted.

Federal and state laws, regulations, mandatory controls, and mitigation measures govern most practices. These requirements regulate the degree or intensity of the environmental impacts of these practices. For example:

- Natural gas and oil extraction and coal and uranium mining operations are subject to federal, state, and local regulations that are intended to limit the environmental impacts from those activities.
- The Clean Air Act regulates emissions from electrical power generating facilities and industrial manufacturing plants.
- The Clean Water Act and Safe Drinking Water Act address impacts to surface and groundwater.
- Emissions from automobiles and other motor vehicles are regulated at the federal and state levels.

These regulations are assumed in the footprint analysis to be effective in achieving the goals of protecting human health and the environment. However, it would be beneficial to include a risk factor in the EF analysis to account for the differences in noncompliance-caused impacts to assess the effect of anthropogenic actions.

Unique and Additional Considerations

Not all energy sources are appropriate in all locations. The sun does not shine with the same reliability in all parts of the world. Likewise, the distribution of consistent, forceful wind is not uniform. Soil type and weather conditions affect areas where biomass plants can be grown under natural conditions. Oil, gas, and coal deposits are only found in certain geographical locations. These natural variations mean that energy sources may have greater, lesser, or simply different environmental impacts depending upon where that resource is or can be located. Such factors must be considered when comparing different energy sources to each other or in comparing one energy source in different locations. For example, the environmental impacts and challenges of oil drilling in the offshore Arctic are different from those of oil drilling in the offshore Gulf of Mexico. Different land types or locations will have different sensitivities to impacts; for instance, some desert, tundra, and wetland landscapes may be more sensitive to impact and so may require a longer period of time to recover.

Impacts to freshwater and clear air can also be magnified in high population density areas where the number of receptors is maximized. For instance, changes to air quality may push pollutant levels over critical non-attainment thresholds in areas with high population densities where other anthropogenic impacts already exist. However, it is also the case that small changes in air quality may be very noticeable in pristine areas such as Class I airsheds.

The temporal nature of impacts should also be considered. Environmental impacts can vary over time and be short-term, long-term, temporary, or permanent. Temporary visual impacts associated with drilling for natural gas and oil differ from the permanent visual impacts associated with wind farms. The time dimension of changes to the chemistry of the atmosphere from combustion of fossil fuels is also a consideration. Impacts on the global environment that are essentially permanent in the scale of human existence are driving a host of energy policy decisions at the state and federal levels that will have a growing influence on energy choices. Other impacts are reversible or can be remediated. A photovoltaic solar array constructed in an open landscape can easily be reclaimed when the solar array's productive life has ended while the impacts of mountaintop mining are often not reclaimable due to preexisting conditions. The environmental impacts of biofuels and biomass include land use for farming. This requires a continual land disturbance causing loss of soil, surface runoff, sedimentation buildup, and continual chemical use in fertilizers and pesticides. Wind and gas development creates an initial disturbance to the land that may be more permanent (i.e., roads and site construction), but may be partially reclaimed, have a more minor ongoing impact (i.e., traffic), and have limited recurring replacement requirements (i.e., wind turbines).

The nature of the resource being developed and the technology that will be used to develop it must be taken into account when doing an EF analysis. Shallow conventional natural gas and oil development involves different drilling and production techniques than the development of unconventional petroleum reservoirs (e.g., CBNG, shale gas, shale oil). Resource extraction methods are different and waste byproducts can also differ in both quantity and quality.

Some natural resources can be accessed from remote locations. Oil or gas wells can be drilled directionally to reach reservoirs located under sensitive environments (e.g., wetlands, tundra, lakes, or deserts) or under sensitive locations (e.g., historic landmarks or parklands). Similarly, underground mining can take place beneath areas where direct surface mining may not be acceptable (e.g., under towns and cities).

It is evident that unique and sometimes intangible variables must be included in a comprehensive analysis of energy-source alternatives. It is also apparent that in some cases, those variables can be defined by quantitative metrics, whereas in other cases, qualitative comparison may be the only means possible.

A measurement of environmental consequences should be assessed at a common end point and from a common form, such as assessing the environmental consequences for sources used to generate electricity to the point where the electricity is ready to be placed on the grid. Understanding of the boundary issues to be included in an analysis is critical to the development of an assessment producing comparable results. This becomes particularly evident when assessing highly dissimilar sources of energy (e.g., concentrated versus dispersed generation and use, direct generation and use versus energy that requires intermediate processing to use). Hence, the varied nature of the resources used to generate energy creates a need to develop common methodologies for assessment.

The level of data detail and quality of the data that can be obtained for analysis may be a limiting factor. Data may be varied or nonexistent, depending on the energy source or environmental media being analyzed. Activities associated with the development of non-renewable resources have been studied and assessed in various documents developed by federal agencies such as the Bureau of Land Management and the U.S. Forest Service. Such assessments do not appear to be available for other resources or for all of the impacts of interest.

Data exist regarding environmental impacts for specific locations in which resource development is occurring. The data are maintained by a variety of regulatory authorities and for various purposes, but those data cannot always be applied or extrapolated to other locations. For instance, assessments of environment impacts for development of natural gas and oil resources in the Rocky Mountain Front region of the United States would not necessarily be applicable to the Gulf Coast region. Data sources also can become outdated due to changing technologies, resources, and regulations. Each of those data-related factors will influence the level of detail possible for a data-driven assessment.

Example of EF Calculations

To illustrate why a standard environmental footprint methodology is needed, as recommended here, it is useful to examine existing studies on the subject and their similarities and differences. Some of those studies are referenced here and in the associated topic papers.

The fundamental assumptions and organization of any EF analysis deeply influence its quantitative results and the validity of comparisons to other studies. One basic set of assumptions involves the boundaries of the analysis, including which phases of energy development and use are included. For example, a comparison of the footprint of raw fuels will not take into account the relative efficiency of end-use technologies, such as electric power generation or automobile technologies, and the impacts associated with those end uses. There is also a methodological decision to make on how far back in the life cycle to go, such as whether to include the impacts of producing construction and equipment materials. There are many other large and small assumptions that go into arriving at the final result. Every EF analysis is performed within such a structure of methodology, assumptions, and data.

Estimating the EF requires findings from many other types of studies, including air quality modeling, ground and surface water analyses, production reports, efficiency analyses, studies of environmental emissions and discharges, fuel transport, and risk assessment, to name a few. Due to the large scope of these requirements, EF analyses face a wide assortment of analytical issues that arise from research in other fields such as geology, biology, health sciences, chemistry, engineering, climate studies, and social science. Almost all studies are careful to specify the uncertainty involved in their estimates. Some present a range of results. Some arrive at point estimates then discuss or attempt to quantify the uncertainty around those estimates. Those ranges or uncertainties can be large and this can also make inter-study comparison difficult to interpret.

Since most EF analyses use previous studies as the source for their data and assumptions, the body of literature on environmental footprint represents an evolving set of related estimates rather than a set of independent analyses. The assumptions, estimates, and methods of one study are often used in subsequent studies, sometimes in modified form. The relationship between studies, therefore, should be taken into account in comparing them. Estimates from different studies cannot necessarily be seen as independent and their agreement cannot be taken as evidence for the reliability of the results if they are interdependent.

Adding to the difficulty of comparing the results of several studies is the fact that EF studies are not always assessing the same thing. Each study has its definition of what represents an environmental impact and its assumptions about how those impacts should be estimated. As a result, studies that are being compared may actually be estimating quantities whose definitions only partially overlap.

A comparison of two such studies serves to illustrate a few of these issues. The *Bonneville Power Administration Fish & Wildlife Implementation Plan Final*

Environmental Impact Statement (BPA study) and *The Environmental Cost of Energy*, prepared by the Applied Energy Studies Foundation (AESF), took different approaches to determining the EF for a range of energy sources. While the former focused on health effects and monetized those effects, the latter analyzed a broader range of environmental impacts and did not assign dollar values. The BPA study assessed a variety of energy sources but did not evaluate a full life cycle, neglecting to include transportation and production impacts. The AESF study addressed a wider range of energy sources considered under a full primary life-cycle assessment, including extraction, processing, transportation, and generation. There were also many methodological differences.

Figures 2-1 and 2-2, found earlier in this chapter, display some of the results from the two studies on water and land resources. The figures show that the results of the two studies vary widely, for the reasons stated above. Such differences argue for the development of a sound, consistent approach to footprint analysis that is vetted through the various stakeholder groups and would result in a comparable set of estimates for the impacts of the various energy sources.

In developing the EF examples above, numerous data deficiencies became apparent. First, much of the information and data needed for an EF analysis may exist, but not in the form required, or in forms that are not easily accessible. Second, most attempts at EF analysis did not include risk-assessment scores as indicators of the likelihood of future environmental catastrophes involving individual energy sources. Last, none of the examples of EF analysis included criteria for peer review of the outcomes.

Although EF results are informative and instructive, they are limited to quantitative data and environmental impacts. Challenges remain for including qualitative data and community impacts. The Key Findings and Policy Recommendations section of this chapter contains recommendations for developing EF LCA inputs for making sound, science-based decisions that affect the future energy mix of North America.

Environmental Management Systems

Perhaps one of the most important developments in the environmental performance of natural gas and oil operations has been the adoption of Environmental Management Systems (EMSs). A management system can be defined as "the framework of policy and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives."[40] In the environmental and sustainability context, a management system is "a tool that provides a systematic approach for managing those components of an operation, function, or business that are both critical to achieve a desired level of environmental performance and to enhance regulatory compliance."[41]

Companies in many sectors have adopted EMSs over the last 20 years as a means of systematically and continuously improving environmental performance. An EMS is typically premised on a "plan-do-check-act" approach and involves the development of a systematic approach to manage operational activities in ways that meet environmental performance goals and support regulatory compliance.

Companies with an effective EMS profess a host of benefits, including improved environmental performance, better environmental compliance, reduced cost of compliance, improved operating performance, increased accountability, and improved profitability. For example, a leading energy company that implemented a safety and environmental management system showed reductions of 34% in safety and environmental paperwork and cut 20% in annual training costs in its first three years of operation.[42]

An effectively implemented EMS can reduce spills, releases, and other environmental incidents by focusing on prevention and risk mitigation rather than reaction. This improved performance benefits public health and environment, provides social benefits, and presents a more positive company image. Financial rating agencies may factor the use of an EMS into assessing a company's environmental and safety performance for financial performance and stability. Reducing incidents can improve profitability and reduce overall costs. A sound overall goal for operational and environmental management is to invest enough into prevention and appraisal to significantly drive down failure costs, which can include spill response, remediation, repair or

40 International Organization for Standardization, ISO 14001:2004, *Environmental Management Systems – Requirements with Guidance for Use,* 2004.

41 John H. Statzer and Michael J. Baldwin, "Environmental Management Systems, Key Issues on Design, Value & Implementation," February 2011.

42 Statzer and Baldwin, "Environmental Management Systems."

replacement of equipment, litigation, and medical costs for injured employees. Prevention includes encouraging employees to decrease overall impacts, including assessing in-process activities and integrating environment into operational standard operating procedures.

A properly implemented EMS can enhance efficiencies through developing and using consistent practices across the company,[43] and support institutionalization of knowledge, benefitting the company over the long term. Systematic approaches in developing processes can improve corporate-wide understanding of environmental goals and objectives. An EMS can streamline alignment of cultures, procedures, and corporate standards during mergers and acquisitions, reducing associated risks and costs.

An EMS will vary significantly between companies. But the standards for consideration of implementation follow some notable examples:[44]

- United States: Standards for compliance assurance programs in the U.S. Department of Justice Prosecutorial and U.S. Sentencing Commission Guidelines; OHSAS 18001 Occupational Health and Safety Management System; Environmental Protection Agency National Enforcement Investigations Center – 12 key elements of an Environmental Management System. ANSI:Z10-OHSMS U.S. Bureau of Ocean Energy Management, Regulation and Enforcement – 30 CFR Part 250 – Safety & Environmental Management Systems
- European Union: Community Ecomanagement and Audit Scheme Great Britain: BS (British Standard) 7750 Specification for Environmental Management Systems
- International: ISO 14001:2004 Environmental Management System Standard
- Industry associations also recognize this trend with their own standards:
  - American Petroleum Institute Model EHS Management System and Recommended Practice 75
  - American Chemistry Council Responsible Care® (RC 14001 or RCMS)
  - E&P Forum, Guidelines for the Development and Application of HSE Management Systems.

43 Statzer and Baldwin, "Environmental Management Systems."

44 Statzer and Baldwin, "Environmental Management Systems."

One of the most widely recognized management system standards is ISO 14001:2004, Environmental Management Systems (ISO 14001). ISO 14001 is designed for use by organizations to minimize harmful effects on the environment caused by its activities and to achieve continual improvement of its environmental performance. This standard contains 17 elements as shown in Table 2-5.

The ISO 14001 standard provides a framework for companies to consider when developing an EMS. Many natural gas and oil companies have developed unique EMSs.

Important factors influencing the success of an organization[45] in implementing an EMS are executive management attention and commitment; allocation of appropriate time and resources; multi-functional

45 Statzer and Baldwin, "Environmental Management Systems."

Table 2-5. ISO14001 Elements*

• Environmental Policy
• Environmental Aspects
• Legal & Other Requirements
• Objectives & Targets
• Environmental Management Programs
• Structure & Responsibility
• Training, Awareness & Competence
• Communication
• Environmental Management System Documentation
• Document Control
• Operational Control
• Emergency Preparedness & Response
• Monitoring & Measurement
• Non-Conformance, Corrective & Preventative Action
• Records
• Environmental Management System Audit
• Management Review

* See, for example, International Organization for Standardization (ISO), "ISO 14000 – Environmental Management," ©2011, accessed April 15, 2011, http://www.iso.org/iso/iso_catalogue/management_and_leadership_standards/environmental_management.htm.

internal involvement; organizational willingness to change; establishing goals and monitoring progress; employee communication; and simplicity. It is critical that upper management is a visible and active champion of the EMS and all levels of the organization are committed to and involved in implementation. Necessary culture changes can include integrating environmental considerations and operational controls into daily work tasks; repeatedly communicating with employees and contractors on planning, prevention, and continuous improvement; and incorporating environmental objectives, initiatives, and activities into employee performance evaluations and compensation.

Mandating the use of an EMS has been shown to be ineffective in motivating environmental performance. But government agencies can incentivize and recognize companies that are implementing effective, performance-based EMSs. For example, agencies can provide regulatory flexibility based on a company's performance, and can work with an industry sector to develop incentives and programs based on member companies' environmental performance and use of EMSs.

Public-Private Partnerships[46]

A key aspect of environmental sustainability for any corporation is to adopt business strategies and activities that meet the needs of the company and internal and external stakeholders while protecting and enhancing human and natural resources for the future. One method of engaging key stakeholders is through the use of what are known as public-private partnerships. These arrangements typically focus on relatively narrow issues identified as company development plans and activities that are being scrutinized either during or before operations commence. As the name suggests, regulatory agencies, community leaders, and nongovernmental organizations (NGOs) are typically engaged to ensure all relevant views are captured. Public-private partnerships provide a less confrontational method to share concerns and have them resolved when compared to enforcement and litigation. Often, public-private partnerships yield results beyond what were initially anticipated by the parties.

46 This does not refer to a public-private partnership where government services are being funded by a partnership between industry and government. This refers to a partnership between government and industry.

Frameworks for the development of public-private partnerships can be described generally by asking the four key questions of why, where, who, and what.[47]

Depending on the issue and scope of the engagement, the answers to those questions will vary greatly. Some of the more recognizable public-private partnerships through which the petroleum industry has engaged in recent years are summarized as follows:

- EPA Natural Gas STAR program[48] – voluntary, cost-effective methane reductions by the gas production and transportation sectors
- STRONGER[49] – a collaborative process by which review teams composed of stakeholders from the natural gas and oil industry, state environmental regulatory programs, and members of the environmental and public interest communities review state natural gas and oil waste management programs against a set of Guidelines developed and agreed to by all the participating parties

Federal agencies, including EPA,[50] have a long history of partnering with industry sectors on specific goals or challenges. The natural gas and oil industry is well positioned to engage in a discussion with agencies and stakeholders to develop a partnership that drives environmental best practices, enables the industry to actively engage with stakeholders on key issues, and enhances effective environmental performance reporting.

For example, EPA created the program Design for the Environment[51] to incentivize the chemical industry to "put green chemistry to work for people and the planet." Members can use a label on products. For

47 International Petroleum Industry Environmental Conservation Association, "Building NGO Capacity for Pipeline Monitoring and Audit in Azerbaijan," *Partnerships in the Oil and Natural Gas Industry,* 2006.

48 U.S. Environmental Protection Agency, *Natural Gas STAR Program,* updated April 13, 2011, accessed April 15, 2011, http://www.epa.gov/gasstar/.

49 State Review of Oil & Natural Gas Environmental Regulations (STRONGER), Inc., Homepage (n.d.), accessed April 15, 2011, http://www.strongerinc.org/.

50 U.S. Environmental Protection Agency, "Partnerships and Programs," updated February 2, 2011, accessed April 15, 2011, http://www.epa.gov/oppt/pubs/opptprg.htm.

51 U.S. Environmental Protection Agency, "Design for the Environment: An EPA Partnership Program," updated January 5, 2010, accessed April 15, 2011, http://www.epa.gov/opptintr/dfe/pubs/about/index.htm.

natural gas and oil operators, the greatest value may be achieved during regulatory and permitting processes. Such a partnership can result in a label or recognition that companies can use in permitting and other regulatory settings that are recognized by agencies.

Public-private partnerships are just an example of a tool available to drive the industry towards greater environmental sustainability to benefit communities and the environment. An industry-driven program closely aligned with the regulatory agencies and allowing stakeholder engagement is a possible strategy to be considered and implemented.

Data Management Systems

Data management, as described by DOE in 2004, is as relevant today as it was then.

What constitutes data, how data are collected, who owns the data, how data are organized and stored, how data sets may be reused, and what ultimately happens to data are significant issues that are surfacing and demanding attention. New challenges have arisen because of exponential growth of data and the capability to collect, organize, store, and reuse it for future scientific endeavors. Sharing of data in multidisciplinary and international collaborations has blurred traditional lines of scientific communication. New issues have arisen as technology enables new kinds of analyses and as numeric data and text data are integrated. End users of scientific data are demanding better access to more collections and expecting better quality. Information organization and retrieval issues, once considered essential for published research findings, now also apply to data.[52]

Modern computer systems have provided a means for more data to be readily available to operators, regulators, and the public for analysis. Use and analysis of these data has provided a means for the development of new technologies. These new technologies are in turn more complex and generate more detailed information to be managed, and provide data to perform more complex environmental assessments, which may increase regulatory requirements. This has a "Catch 22" effect in that the increased complexities of new technologies developed require that operators and regulators have access to and quickly assess larger and more complex data sets so they can advance new technologies that require more complex data. Widespread access to the Internet has also increased the opportunities for more efficient data sharing in the areas of regulatory reporting, data sharing between partners, and an increased demand for public access to operational and compliance information maintained by public agencies.

An issue commonly seen when evaluating data management is that organizations have not created standard data management processes or common programs across their own enterprises. Non-centralized data limits the ability of users to share information and make more effective use of the information gathered. It is common that data management was done at a local level with each office defining their process and technology. The end result has been many fragmented technologies and data sources that don't work to provide a cohesive picture of the resource being tracked. Today organizations have recognized the importance of data sharing and are optimizing their data management across the entire organization, either by introducing common technologies and processes or linking the current systems. In the future, data management conduits and standards should be developed for exchange of information between the industry stakeholders. Care should especially be given to providing a means to report to regulatory agencies so that common data and information are easily transferred from the lease operators to the various regulatory organizations and among the regulators. Providing a means to accomplish this goal could streamline reporting and potentially reduce duplicative efforts of dual reporting.

Because historically many agencies and companies developed their data management systems in relative isolation, much of the data are not easily shared. Different software packages and data standards have been used over the years, which made it difficult for agencies to receive data from companies and also difficult, if not impossible, to share operational and environmental data. In some cases, revising these systems would require massive capital outlays, not to mention operational disruptions, in order to change systems for which there has already been a substantial

52 U.S. Department of Energy, Office of Scientific and Technical Information, "The State of Data Management in the DOE Research and Development Complex," Report of the Meeting "DOE Data Centers: Preparing for the Future," held July 14–15, 2004, Oak Ridge, Tennessee, November 5, 2004, accessed April 15, 2011, http://www.osti.gov/publications/2007/datameetingreport.pdf.

investment. Efforts have been underway in light of providing better means of sharing information moving into the future, and many software development platforms have recognized the need for this option, which is providing hope for the advancement of data collection.

The fragmented approach to data management is influenced by the current requirements in the United States from multiple regulatory agencies, as well as by a rich variation in resource plays and individual operator priorities.

As illustrated in Table 2-6, data collected by the industry and regulatory community as a whole are used in a diverse manner. There are also many standards being implemented across the industry to manage the information. These diverse requirements of reporting and data collection can limit the effective and efficient management of resources, and until a unified approach to collecting and presenting the data from the diverse streams is realized, the true benefits of the data may not be seen. The benefits are expected to provide a better means for the prudent development of resources and take advantage of past knowledge inherent in the collected data. Other countries have started developing or have developed data portals to assist in this collection and dissemination of information, making for more efficient and environmentally sound decision making.[53,54,55]

One highly visible example representing the importance of robust data management in assisting the protection of human health and the environment was seen in the explosion of PG&E's natural gas pipeline in San Bruno, California (a suburb of San Francisco), on September 9, 2010. Preliminary investigations from this tragedy, which resulted in the deaths of eight people and the destruction of 38 homes, identified the adequacy and accuracy of records as one of several possible factors contributing to the pipeline failure.[56,57,58] A safe, reliable, expanded natural gas pipeline delivery system is critical to meet growing gas demand. The U.S. natural gas infrastructures, while robust and reliable, are facing operational challenges.

Future efforts are needed to accomplish the goals of prudent development of the U.S. natural gas and oil natural resources relative to data management. These efforts include the standardization of data, and its communication between entities is seen as the most advantageous benefit to the future. This standardization is expected to provide benefits to the public in environmental and health, and could also provide industry with cost-saving benefits. These cost-saving benefits are seen to come from making the data easier to communicate with others, report to regulators, streamline regulations, reduce duplicative reporting, and provide means to review past incidents so mistakes may not be repeated or find more successful ways to develop a resource.

Several efforts are underway to overcome some of the identified limitations of data management. For example, the U.S. Department of Energy, through the Ground Water Protection Council, has created the Risk Based Data Management System that allows natural gas and oil state regulatory agencies to more easily collect, manage, and analyze data. In addition, the Ground Water Protection Council and the IOGCC, through funds from DOE, have recently released the "FracFocus.org" website that provides for the voluntary collection, sharing, and disclosure of hydraulic fracturing chemical data that were previously either unavailable or difficult for regulators and the public to access. This website is the first step in an effort to provide public disclosure of hydraulic fracturing reported data and the first step in an even broader

53 C. Makrides (Canada Nova Scotia Offshore Petroleum Board), "Review of the Canada Nova Scotia Offshore Petroleum Board's Digital Data Management Centre," OTC 19089 (2007), presented at the Offshore Technology Conference, Houston, Texas, April 31–May 3, 2007, accessed April 15, 2011, http://e-book.lib.sjtu.edu.cn/otc-2007/pdfs/otc19089.pdf.

54 UK Department of Energy & Climate Change, UK Oil Portal (n.d.), accessed April 15, 2011, https://www.og.decc.gov.uk/portal.htm.

55 UK Department of Energy & Climate Change, "The Aims of the UK Oil Portal" (n.d.), accessed April 21, 2011, https://www.og.decc.gov.uk/portal_files/aims.htm.

56 California Public Utilities Commission, "Report of the Independent Review Panel: San Bruno Explosion," rev. ed., June 24, 2011, accessed June 30, 2011, http://www.cpuc.ca.gov/NR/rdonlyres/85E17CDA-7CE2-4D2D-93BA-B95D25CF98B2/0/cpucfinalreportrevised62411.pdf.

57 Cynthia L. Quarterman (U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration), letter to Deborah A.P. Hersman, Chair of National Transportation Safety Board, January 5, 2011, accessed June 30, 2011, http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/To%20NTSB%201%205%202011.pdf.

58 National Transportation Safety Board (NTSB), "Natural Gas Pipeline Explosion and Fire Investigation" (n.d.), accessed June 30, 2011, http://www.ntsb.gov/investigations/2010/sanbruno_ca.html.

effort to create a public "Digital Oil Field" that would allow both operators and agencies to realize significant efficiencies and improve environmental performance and compliance.

The development of a data portal from the currently available public data sources could be a huge first step to help in the realization of a new digital oil field era that could benefit development of resources in the United States as a whole. A new cohesive digital oil field is where the benefits of data management in the pursuit of prudent development will be most realized. Future efforts from expansion of the data portal to migrate from a data gathering and dissemination tool, of publicly available data streams, would be its evolution into a data collection tool that could collate information from the operators and push it back to the necessary regulatory agencies. This effort in today's regulatory climate may appear to be a daunting task, but the benefits to regulatory review and streamlining of permitting and reporting could be seen as a major step in efficiency and prudent development of resources. In addition, it would provide a consistent interface to managing the environmental and compliance data necessary for the protection of health and human life.

OFFSHORE SAFETY AND ENVIRONMENTAL MANAGEMENT

Key Points:

- Offshore Leases:
  - The Gulf of Mexico provides 97% of federal Outer Continental Shelf (OCS) production and has nearly 7,000 active leases, 64% of which are in deep water.
  - The Pacific OCS has 49 active leases off the coast of Southern California, 43 of which are producing. There have been no Pacific OCS lease sales since 1984.
  - Alaska has 675 active leases and production from a single, joint state-federal field.
  - The Atlantic does not have any active leases or production.
- Offshore Production: Gulf of Mexico provides 31% of U.S. oil and 11% U.S. gas, with the majority of Gulf of Mexico production from deep water (25% oil and 5% gas).
- Offshore Regulation: Offshore development in federal waters is regulated by a variety of agencies including the BOEMRE (within the Department of the Interior), U.S. Coast Guard, Department of Transportation, Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Federal Energy Regulatory Commission, U.S. Fish and Wildlife Service, and U.S. Army Corps of Engineers. Additionally, coastal development includes state regulatory agencies. Conflicting statutory mandates make it difficult to achieve a balanced and predictable federal offshore policy.
- Scientific understanding of environmental conditions in sensitive environments in deep Gulf waters, along the region's coastal habitats, and in areas proposed for more drilling, such as the Arctic, must be enhanced in order to meet the expectations of stakeholders.
- Seismic noise is recognized as a concern for whale populations and other marine life, including fish.
- Decommissioning offshore platforms includes beneficial options such as "Rigs to Reefs" that have been underutilized.

Any technological endeavor involves risk and there are risks associated with developing offshore natural gas and oil resources. While the benefits of development include the assured supply of energy, it is important to ensure the energy recovery process is conducted in a manner that is safe and environmentally responsible. As discussed in the previous section, an effectively implemented EMS can reduce spills, releases, and other environmental incidents by focusing management and employee attention on prevention and risk mitigation rather than reaction. Furthermore, each of the many complex activities needed to develop offshore energy resources must identify and incorporate appropriate safety-sustainability elements into plans and procedures. To address safety concerns, the offshore natural gas and oil industry manages and reduces potential risk through the integration of key planning requirements for hazards management, which are categorized into four principal elements:

- Prevention (P) – Preemptive measures to reduce the likelihood of a hazardous event

Table 2-6. Summary of Data Management Efforts

Sector	Entity	Type of Data	Publicly Available	Issues
Standards:	Energistics*	Standards for Data	Yes	NGO-developed standards not enforceable for adoption, Wellsite Information Transfer Standard Markup Language (WITSML), Production Markup Language (PRODML), and Reservoir Characterization Markup Language (RESQML).
	State Oil & Gas Regulatory	Regulatory Requirements/ Operations	Yes	Many state natural gas and oil regulatory agencies, through a collaborative effort, have developed "de facto" standards to natural gas and oil regulatory data.[†]
	EMS – ISO 14001[‡]	Environmental Standard	Yes	Standards for the development of Environmental Management Systems.
	Nongovernmental organizations (NGOs)	Various Standards for Data	Yes	Other NGOs have assisted in the development of standards used by various industry sectors. These have ranged from efforts to generate industry-wide standards by the American Petroleum Institute through the Petroleum Industry Data Exchange (PIDX)[§] and Professional Petroleum Data Management Association (PPDM)[¶] to pipeline specific standards by Pipeline Open Data Standard (PODS).[#]
Regulatory:	Federal Agencies	Regulatory Requirements/ Operations	Yes – FOIA (Freedom of Information Act) Request and Websites Provide	Multiple federal agencies requiring submission of regulatory and operational data on natural gas and oil activities. Standards between agencies may not have been adopted on same data elements, limiting ability to exchange.
	State Agencies (Oil & Gas, Environmental Protection, Department of Transportation, etc.)	Regulatory Requirements/ Operations	Yes – Many State Websites Provide	Many individual state agencies require the submission of data. These data may be stored in paper files not readily accessible to the public or industry as a whole.
Industry:	Operators	Regulatory Requirements/ Operations/ Business	No	Individually housed industry data management operations that are specific to the needs of the operator. May not be based on standards-based development, making it difficult to communicate and collaborate with other operators and regulating communities.
	Service Companies	Operations	No	Data are maintained as private intellectual property.

Table 2-6. Summary of Data Management Efforts (continued)

Sector	Entity	Type of Data	Publicly Available	Issues
Other Data:	Data Vendors	Various	Yes – Purchased	Data vendors have existed for many decades in the upstream market. These vendors collect and collate data available and provide tools to the industry for the retrieval and presentation of the data. Many times, they are a more efficient means to get analyzable data.
	NGOs	Various	Yes - Membership, Public Domain	Many NGOs are involved in support of distribution of data to the industry or by providing access to specific information. Examples include Air Emissions by Western Regional Air Partnership (WRAP)** or the disclosure of hydraulic fracturing chemical by the Groundwater Preservation Council and the Interstate Oil and Gas Compact Commission (GWPC/IOGCC).††

* Energistics, Homepage (© 2011), accessed March 21, 2011, http://www.energistics.org/home.

† Ground Water Protection Council, Risk Based Data Management System (1992–present), accessed April 15, 2011, http://rbdmsonline.org/GWPC/.

‡ International Organization for Standardization (ISO), "ISO 14000 Essentials" © 2011, accessed March 21, 2011, http://www.iso.org/iso/iso_14000_essentials.

§ PIDX International, website © 2011, accessed June 27, 2011, http://www.pidx.org/.

¶ Professional Petroleum Data Management (PPDM) Association, website (n.d.), accessed June 27, 2011, http://www.ppdm.org/.

\# Pipeline Open Data Standard (PODS) Association, website © 2011, accessed June 27, 2011, http://www.pods.org/.

** Western Regional Air Partnership, "Oil/Gas Emissions Workgroup: Phase III Inventory" © 2009, accessed June 27, 2011, http://www.wrapair.org/forums/ogwg/PhaseIII_Inventory.html.

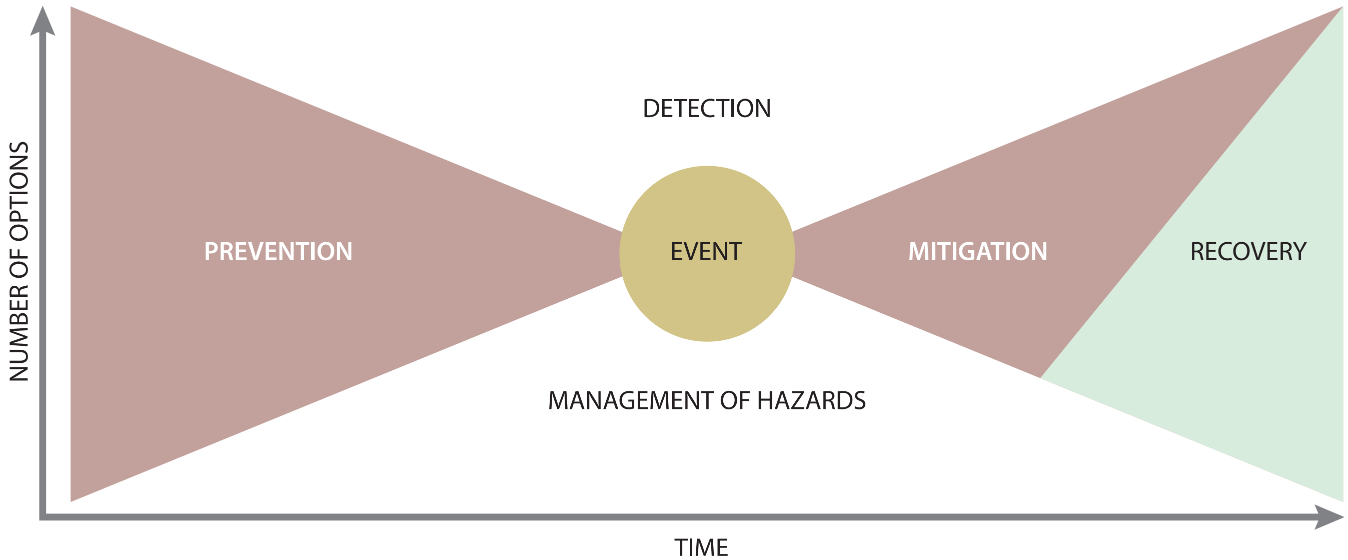
†† Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission (IOGCC), FracFocus Chemical Disclosure Registry website © 2011, accessed June 27, 2011, http://fracfocus.org/.

- Detection (D) – Early identification of a hazardous event
- Mitigation (M) – Effective measures to arrest and control a hazardous event
- Recovery (R) – Restoring normalcy after a hazardous event.

As shown graphically in Figure 2-13, a menu of options that changes with time takes the shape of a bowtie. Early planning for prevention of hazardous events preserves the largest numbers of response options; in contrast, during a crisis event, options are reduced as urgency overtakes systematic analysis, planning, and thought. Options become more abundant again only long after the event and as the latter stages of the recovery mode lead to detailed retrospectives and root-cause analysis. Thus, early and comprehensive planning (or the P-D-M-R approach) is important to sustaining safety during offshore operations.

P-D-M-R safety-sustainability elements receive different relative proportions of emphasis within different offshore activities, depending on which hazards are being managed. While all offshore operational activities must include planning for the Prevention (P) of hazards, not all combinations of activities and issues would necessarily require Recovery (R).

Figure 2-13. The Safety and Sustainability Model Featuring the P-D-M-R Elements



Notes: Safety – Responsible management of risks and hazards for human health.
Sustainability – Responsible management of risks and hazards for natural environmental quality, including water, air, animals, and plants.

Source: Modified based on "Offshore Technology Report 2001/063 - Marine Risk Assessment," prepared for Health and Safety Executives by Det Norske Veritas, 2002, of London Technical Consultancy. ISBN 0 71762231 2.

Table 2-7. P-D-M-R Safety-Sustainability Elements and Risk Management

Offshore Operational Topic Area	**Safety-Sustainability in Offshore Development: Planning Emphasis P = Prevention, D = Detection, M = Mitigation, R = Recovery**			
	Human Health & Safety (Immediate)	**Disturbance of Marine Mammals & Fish**	**Oil & Gas Spills into Marine Environment**	**Other Pollutant Releases into Air or Water**
Environmental Footprints and Regulatory Reviews	P, M	P, D, M, R	P, D, M, R	P, D, M, R
Environmental Management of Seismic and Other Geophysical Exploration Work	P, D, M	P, D, M	P, D, M, R	P, D, M, R
Subsea Drilling, Well Operations, and Completions	P, D, M, R	P, M	P, D, M, R	P, D, M, R
Well-Control Management and Response	P, D, M, R	P, M	P, D, M, R	P, D, M, R
Offshore Production Facilities and Pipelines, Including Arctic Platform Designs	P, D, M, R	P, M	P, D, M, R	P, D, M, R
Offshore Transportation	P, D, M, R	P, M	P, D, M, R	P, D, M, R
Data Management	P, D	P, D, M	P, D, M	P, D, M

Table 2-7 summarizes one view of how the safety-sustainability elements are incorporated into risk management and indicates combinations of P-D-M-R emphasis for different intersections of seven topical areas and four hazard categories. For example, core topic 7 (Data Management) enables the dissemination of essential information used in oil-spill planning, recovery and restoration operations, but data management alone cannot implement hazard Recovery measures. Fieldwork required for Recovery from an oil-spill hazard remains the purview of core topic 4 (Well Control Management and Response). Therefore, Table 2-8 indicates an "R" for Well Control Management and Response under the "Oil & Gas Spills into Marine Environment," but not so for Data Management.

Center for Offshore Safety

To realize the intended benefits of P-D-M-R mapping into development plans, a credible infrastructure is needed to ensure that effective planning tools are available and that operators accept and demonstrate accountability. The Presidential Oil Spill Commission (2011) endorsed the role of a new Ocean Energy Safety Institute within the U.S. Department of the

Table 2-8. U.S. Government Agencies Involved in Offshore Natural Gas and Oil Regulations

Regulatory Authority	Federal Statute	Offshore Natural Gas and Oil Project Phase			
		Predevelopment Phase (Exploration)	Development Phase (Design, Construct)	Production Phase (Operations)	Divestiture Phase (Decommissioning)
Bureau of Ocean Energy, Management, Regulation and Enforcement	OCSLA, NEPA, NFEA, CAA, NHPA	•	•	•	•
U.S. Coast Guard	OPA, PWSA	•	•	•	•
U.S. Department of Transportation	HMTA			•	
U.S. Environmental Protection Agency	CWA, CAA, RCRA	•	•	•	•
National Oceanic and Atmospheric Administration	CZMA	•		•	
National Marine Fisheries Service	MMPA, ESA, MFC	•		•	•
Federal Energy Regulatory Commission	NGPA			•	
U.S. Fish and Wildlife Service	ESA	•		•	•
U.S. Army Corps of Engineers	CWA, RHA			•	

Note: CAA = Clean Air Act; CWA = Clean Water Act; CZMA = Coastal Zone Management Act; ESA = Endangered Species Act; HMTA = Hazardous Materials Transportation Act; MFC = Marine Fisheries Commission; MMPA = Marine Mammal Protection Act; NEPA = National Environmental Policy Act; NFEA = National Fishing Enhancement Act; NGPA = Natural Gas Policy Act of 1978; NHPA = National Historic Preservation Act; OCSLA = Outer Continental Shelf Lands Act; OPA = Oil Pollution Act; PWSA = Ports and Waterways Safety Act; RCRA = Resource Conservation and Recovery Act; RHA = Rivers and Harbors Act.

Interior (DOI), but separately called upon industry to embrace the potential for an industry safety institute to supplement government oversight of industry operations.[59] Based on an industry-led study, which included review of five other safety programs including the Institute for Nuclear Power Operations and the Occupational Safety and Health Administration Voluntary Protection Program, the Center for Offshore Safety was formed. The Center for Offshore Safety is administered by the separately funded standards and certification arm of the American Petroleum Institute and is open to companies exploring and producing natural gas and oil offshore.

Outer Continental Shelf Safety Oversight Board

The OCS Safety Oversight Board was established by Secretary Salazar (Order No. 3298) on April 30, 2010. The purpose of the board was to provide recommendations regarding interim measures that could enhance OCS safety and improve the BOEMRE's overall management, regulation and oversight of OCS operations.[60]

59 National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling*, report to the President, January 2011, page 272, accessed June 27, 2011, http://www.oilspill-commission.gov/sites/default/files/documents/DEEPWATER_ReporttothePresident_FINAL.pdf.

60 National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling*, page 4.

On September 8, 2010, the Safety Oversight Board issued a report providing recommendations for improving the Bureau of Ocean Energy Management's operational and management policies, notably:

- Enhance personnel training and recruitment to address the lack of technical expertise.
- Increased fines and civil penalties to deter risky industry practices.
- Address real and perceived conflicts between resource management, safety, and environmental oversight and enforcement, and revenue collection responsibilities.
- Take steps to improve inter-agency coordination with federal agencies related to oil spill response and the mitigation of environmental effects of offshore energy development.

Regulatory Framework on the Outer Continental Shelf

The 1953 Outer Continental Shelf Lands Act (OCSLA), as amended, governs the development of offshore mineral resources, including natural gas and oil. The OCS consists of submerged lands lying between the seaward extent of state jurisdiction and the seaward extent of federal jurisdiction. OCSLA provides the authority to the U.S. Coast Guard (USCG) and BOEMRE to exercise control over the "exploration, exploitation, or development" of OCS mineral resources.

Regulatory Framework on the Outer Continental Shelf

Regarding references to BOEMRE, on October 1, 2011, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), was replaced by the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) as part of a major reorganization. BOEM is responsible for managing environmentally and economically responsible development of the nation's offshore resources. Its functions will include offshore leasing, resource evaluation, review and administration of oil and gas exploration and development plans, renewable energy development, National Environmental Policy Act (NEPA) analysis and environmental studies. BSEE is responsible for safety and environmental oversight of offshore oil and gas operations, including permitting and inspections, of offshore oil and gas operations. Its functions include the development and enforcement of safety and environmental regulations, permitting offshore exploration, development and production, inspections, offshore regulatory programs, oil spill response and newly formed training and environmental compliance programs. Due to this NPC report's completion and approval on September 15, 2011, the following discussion references the regulatory framework prior to the October 1 reorganization.

The complex regulatory processes that affect offshore developments involve at least nine federal statutes, as well as nine different federal agencies. After the Macondo blowout and oil spill in April 2010, the Minerals Management Service was replaced by BOEMRE in June 2010, which in turn is subdivided into the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement, effective October 1, 2011. Along with the U.S. Coast Guard, BOEMRE is a key agency in regulating all OCS development phases. Other federal agencies involved with offshore development include: the U.S. Department of Transportation, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Federal Energy Regulatory Commission, U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers. Table 2-8 provides a summary of federal agencies (and their associated statutes) that are involved with administering offshore regulations, and which phase of offshore development they are principally involved with.

BOEMRE regulations are contained in 30 CFR, Chapter II, with operations regulations at Part 250.[61] Specific reviews of possible environmental impacts from routine events and accidents are required for plans for exploration, development, and production. Separate from these requirements, there is also specific permitting of proposed discharges, cooling water intake entrainment (for new facilities), and implementation of various best management practices plans required under the EPA's National Pollutant Discharge Elimination System permits. All waste transport and onshore disposal/reuse is regulated under RCRA and DOT regulations, as well as specific state regulations.

USCG regulations are contained in 33 CFR, Subchapter N.[62] USCG regulations contain provisions for occupational safety and health and citizenship of workers on the OCS, firefighting and lifesaving equipment on OCS facilities, and operational requirements. USCG regulations also contain many references to other requirements in 46 CFR, which is related to shipping, as well as the navigational rules and pollution prevention pertaining to oil, hazardous materials, and human waste.

For state and local government involvement, the Coastal Zone Management Act requires federal agencies to provide them the opportunity to review leasing and permit proposals. If a state disagrees with a proposed project, there is a process for resolving inconsistencies with the state's coastal management plan or an appeal can be filed. The OCSLA requires the Secretary of the Interior to accept the recommendations of state and local governments on leasing proposals unless it is determined that they do not balance federal and state interests. The OCS support facilities that are located onshore are regulated by numerous state and local statutory regimes.

One problem faced by the BOEMRE is the conflicting goals of OCSLA and other federal statutes. Table 2-9 provides current examples of these conflicting issues. At a minimum, clarifications are needed for certain overlapping authorities and responsibilities among the BOEMRE, U.S. Coast Guard, National Oceanic and Atmospheric Administration, and Department of Transportation.

Lease Sale Planning Process

BOEMRE has a five-year evaluation process that takes place during the OCS planning process, lease sale, and exploratory and development project phases. A component of the process also includes the performance of an environmental impact statement, which is conducted pursuant to the National Environmental Policy Act (NEPA), and is designed to identify risk-producing factors at a level appropriate for the different stages of development. As the process moves from a regional perspective to a very specific location for a project, stipulations to minimize and mitigate potential for harmful impacts to the environment as well as avoid conflicts between different user groups are implemented. Before the project phase is implemented, a number of different mechanisms are used to ensure extensive oversight and intensive environmental review. Some of these mechanisms are highlighted below:

- **Statutory Requirements** – Energy and mineral activities on the OCS are governed by numerous statutory obligations and operations may not proceed unless the process requirements satisfy applicable laws.

61 Code of Federal Regulations. Title 30, Mineral Resources. Chapter II, Minerals Management Service, Department of the Interior. Part 250, Oil and Natural Gas and Sulphur Operations in the Outer Continental Shelf.

62 Code of Federal Regulations. Title 33, Navigation and Navigable Waters. Chapter I, Coast Guard, Department of Homeland Security.

Table 2-9. Examples of Conflicting Goals between the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and Other Agencies

Examples of Conflicting Goals	Purpose or Issue	BOEMRE Regulatory Authorities
Memorandum of Understanding between Minerals Management Service/ BOEMRE and U.S. Coast Guard (January 15, 1999)	Identifies the division of responsibilities and communication process for these two agencies. Annex 1 of the Memorandum of Understanding includes a responsibility matrix for systems and subsystems related to Mobile Offshore Drilling Units.	30 CFR Part 250
Notice to Lessees (NTL) No. 2009-N11 (December 4, 2009)	This NTL clarifies air quality jurisdiction on the OCS in the Gulf of Mexico. However, timing of EPA approvals of air emissions is a prolonged process in Alaska. The timing should better coincide with the BOEMRE permit and plan approval process.	30 CFR Part 250.302, 303, and 304
Memorandum of Understanding between Department of the Interior and Department of Transportation (August 17, 1998)	Implements the regulation of OCS pipelines. BOEMRE regulations apply to all OCS oil or gas pipelines located upstream of the points at which operating responsibility for the pipelines transfers from a producing operator to a transporting operator.	30 CFR Part 250
U.S. Coast Guard and BOEMRE	Certain security procedures limit the BOEMRE's ability to conduct unannounced inspections.	30 CFR Part 250

- **Consultation Requirements** – Proposals for potential uses of the OCS must be published for public review and comment pursuant to specified statutory and regulatory provisions.
- **NEPA Compliance** – Each successive step in the process is subject to NEPA analyses, for five-year program proposals, lease sale proposals, Marine Mammal Protection Act authorizations, seismic exploration proposals, exploration proposals, and development and production proposals.
- **State and Local Government Roles** – The CZMA requires federal agencies to provide state and local governments the opportunity to review leasing and permit proposals. If states disagree, an elaborate mechanism for ensuring consistency with state coastal zone plans is provided.
- **OCSLA Programmatic Process** – Pursuant to Section 18 of the OCSLA, no area of the OCS may be offered for leasing unless the Secretary of the Interior complies with the requisite scientific, analytical, and deliberative process requirements.
- **OCSLA Lease Sale Process** – Once a 5-Year OCS Leasing Program is approved in accordance with Section 18 (above), specific lease sale proposals are subject to the process provisions of Section 19 of the OCSLA.
- **OCSLA Exploration Process** – Once a lease is obtained, site-specific exploration proposals (seismic and exploratory drilling) must be subjected to further analysis.
- **OCSLA Development and Production Process** – If oil or natural gas is discovered in commercial quantities during the exploration process, site-specific development and production plans must be subjected to further analysis, NEPA compliance, state and local government CZMA review, Marine Mammal Protection Act authorization, Clean Air Act compliance, CWA discharge permitting, and public consultation and review prior to plan approval.

To provide checks and balances in its regulatory program, the DOI and other agencies have the opportunity to review and comment on proposed rules and the 5-Year OCS Leasing Program. There are existing Memoranda of Understanding and Memoranda of Agreements with other agencies (e.g., U.S. Coast Guard, U.S. Fish and Wildlife Service, Department of Energy, and Department of Transportation), with states, and with other countries to accomplish this. The DOI is also held accountable to the White House, and Congress via multiple avenues such as: (a) the 5-Year OCS Leasing Program's planning documents and press releases on specific lease sales; (b) forms that are submitted to the House, Senate, and the Government Accountability Office alerting them of imminent final rules; (c) information collection packages (new and updates) that are submitted to the Office of Management and Budget for approval and that provide cost and hour burdens of new and existing rules; (d) an annual publication notice in the Federal Register listing civil penalties; and (e) annual appropriation reports to Congress on the agency's performance over the past year and its future goals.

Coastal Marine Spatial Planning

On July 19, 2010, President Obama signed an Executive Order that led to the creation of a National Policy for the Stewardship of the Ocean, our Coasts, and the Great Lakes. The policy will be guided by the National Ocean Council, which met for the first time in November 2010. The National Ocean Council has begun developing draft strategic action plans and held a public comment period from June 2 to July 2, 2011. These plans will address the nine priority objectives that relate to the most pressing challenges facing the ocean, coasts, and Great Lakes. One of the priority objectives is for Coastal and Marine Spatial Planning (CMSP).

CMSP is an integrated ecosystem-based management strategy with the goal of maintaining the marine ecosystem in a healthy, productive and resilient condition. The intent of CMSP is to identify areas most suitable for various types or classes of activities to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives. In addition, the National Ocean Policy states that one of the guiding principles of CMSP is for multiple existing uses (e.g., commercial fishing, recreational fishing and boating, subsistence uses, marine transportation, sand and gravel mining, and natural gas and oil operations) and emerging uses (e.g., offshore renewable energy and aquaculture) to be managed in a manner that enhances compatibility among uses and with sustained ecosystem functions and services, provides for public access, and increases certainty and predictability for economic investments.

It is still unclear whether CMSP will result in the creation of and strict adherence to "planning or systematic zoning areas" in the ocean environment that might preclude natural gas and oil development, or how BOEMRE must use regionally developed coastal and marine spatial plans to inform the statutory development process under OCSLA.

Consideration of Studies on the Deepwater Horizon Incident

This report's recommendations were developed through independent research and analysis. Nonetheless, they bear some similarities with, and are complementary to, recommendations from external studies focused on the Deepwater Horizon incident and the associated Macondo well blowout. The following external studies and investigations were considered, although some were not yet complete when the review was conducted and only preliminary public information may have been available.

- The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Safety
- The Bureau of Ocean Energy Management, Regulation and Enforcement and U.S. Coast Guard Joint Investigation
- The National Academy of Engineering Macondo study
- The Chemical Safety Board study
- The Outer Continental Shelf Safety Oversight Board
- BP's and Transocean's Company Investigations
- Industry Study Group Investigations, and Congressional Investigations by: (1) the House Oversight and Government Reform Committee; (2) the House Natural Resources Committee; and (3) the House Energy and Commerce Committee.

Many of the external study findings generally align with findings and recommendations reported in this study that are aimed at prudent offshore natural gas and oil development. Specifically, the key aims for sustainable future offshore operations must include better coordination among regulatory agencies and industry attention to honing best practices both in equipment and operational risk management.

Offshore Operations and Environmental Management Findings

- Seismic methods will continue to be the primary geophysical tool used to discover, evaluate, and enable responsible production of offshore oil and gas resources.

- Seismic noise is recognized as a concern for whale populations and other marine life, including fish.
- Pipelines have proven to be the safest, most reliable, economical, and environmentally favorable way to transport oil and gas from well to shore. The aging of the pipeline infrastructure is a concern.
- Decommissioning offshore platforms includes beneficial options, such as "Rigs to Reefs," that have been underutilized.
- Scientific understanding of environmental conditions in sensitive environments in deep Gulf waters and coastal habitats in areas proposed for more drilling, such as the Arctic, must be enhanced in order to meet the expectations of stakeholders.
- Oil-spill response must include multiple methods/tools such as: (1) oil sensing and tracking; (2) dispersants; (3) in situ burning; (4) mechanical recovery; and (5) shoreline protection and cleanup. All of these methods/tools must be properly developed, available, and preapproved to effectively respond to a large event.
- The multiplicity of U.S. government regulatory agencies involved in setting data reporting requirements has led to inefficiencies.
- Conflicting statutory mandates make it difficult to achieve a balanced and predictable federal offshore policy.
- Federal regulatory agencies lack technical expertise to oversee complex technical systems and operations.
- DOI/BOEMRE has implemented a NEPA policy that limits the use of categorical exclusions. This leads to preparation of more time-consuming environmental assessments, which has further slowed the commencement of drilling in the Gulf of Mexico.

KEY FINDINGS AND POLICY RECOMMENDATIONS

Key Findings

Sustainable Strategies and Systems

Sustainable development was defined by the Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." The concept of sustainability is often used to refer to a company's objective to achieve goals related to social, environmental, and economic needs.

There is not one correct approach to encouraging or implementing environmental sustainability within the industry. It can be accomplished by individual companies adopting business strategies and activities that meet the needs of the company and stakeholders while protecting sustainability and enhancing human and natural resources for the future. A number of natural gas and oil companies already have environmental sustainability goals incorporated into their business.

An environmental management system strategy is an industry-developed tool that can be used to drive environmental sustainability in a systematic manner. In addition, collaboration among companies, government, and other stakeholders is often essential to the success of industry-wide efforts. Due to the complexity of environmental sustainability issues, no one group (government, stakeholders, or business) can master the concept of environmental sustainability alone.

A properly implemented EMS can provide greater efficiencies as consistent practices are developed and used across the implementing company. Stakeholder engagement can provide valuable insights that lead to better decisions and strategies. It can also increase the trust and support of government and citizens. Such discussions can more effectively incorporate local environmental sustainability priorities and concerns. Environmental sustainability is often seen as first a local matter, then regional, and finally national and international. Stakeholder discussions at a local level can easily be incorporated into public-private partnerships and overall environmental sustainability goals and objectives. These can, in turn, be addressed on a regional basis, whether by state or on a multistate basis that may include all jurisdictions involved in a geologic basin or resource play.

Listening to these concerns can support a company in staying ahead of issues that can impact reputation, production delays, lawsuits, and regulatory actions.

Public-private partnerships have proven to be a successful tool to collaborate with stakeholders and to drive environmental sustainability goals within a sector. These partnerships put the regulator in a different role. Instead of implementers of programs as dictated by legislators, they are managers working for outcomes that result in public benefit by navigating the various strategic choices. Public-private partnerships, if properly designed and implemented, are an effective tool to drive environmental sustainability objectives consistently throughout an industry. It can also enhance the ability to engage stakeholders and incorporate input. Below are two examples of public-private partnerships through which the natural gas and oil industry has engaged in recent years, but none are focused on overall industry stewardship:

- **EPA's Natural Gas STAR program** – voluntary, cost-effective methane reductions by the gas production and transportation sectors.
- **State Review of Oil and Natural Gas Environmental Regulations (STRONGER)** – a collaborative process of the natural gas and oil industry, state environmental regulatory programs, and members of the environmental/public interest communities to review state natural gas and oil waste management programs against a set of guidelines.

Finding:

Industry's and government's commitment to an enhanced partnership focused on promoting and using systems-based strategies to drive environmental sustainability goals and outcomes can minimize the environmental impact of recovering North America's natural gas and oil resource.

Recommendations:

- Industry and government should work with stakeholders to implement public-private partnerships focused on achieving environmental sustainability goals, sharing best practices, and measuring outcomes.
- Government should recognize continuous improvement within the regulatory and permitting processes in a manner to promote innovation within the industry.

Building Public Confidence

One element of building public confidence and demonstrating the necessary environmental performance is assuring the public that industry adheres to a set of operational performance standards or principles that minimize risk and are protective of the environment. Much of this assurance is provided by the regulatory agencies and programs that govern natural gas and oil operations and require compliance with environmental laws and regulations. Additional assurance is provided by industry organizations and public-private partnerships that develop industry standards, recommended practices, and guidelines, such as those cited above, and industry associations, professional societies and organizations of states such as the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council.

However, there may be a need for additional efforts to coordinate systems, activities, and programs within industry and between industry and government, to collect and disseminate state-of-the art practices, technologies, and management systems on a regional or resource play specific basis. Such a set of repositories would give industry and regulators easy access to the latest information on environmentally protective practices, applicability, and effectiveness in different areas and settings, and costs and benefits. It would also provide the public with transparency for those practices and with confidence that the principles of excellent environmental performance are being followed by those companies that use these practices and systems. The repositories should be open to companies, regulators, policymakers, NGO stakeholders, and the public.

One recent example of the natural gas and oil industry's efforts to build public confidence is found in FracFocus, the hydraulic fracturing chemical registry website. A joint project of the Ground Water Protection Council and the IOGCC, FracFocus provides information about the chemicals used in the hydraulic fracturing of oil and gas wells along with educational materials on hydraulic fracturing, groundwater protection, and regulation. Many natural gas and oil companies participate in FracFocus, but not all companies do so. Increasing the participation in FracFocus to all natural gas and oil companies that engage in hydraulic fracturing and adding into the system all wells currently in drilling or production would be an important step in building public confidence.

Finding:

Broad systems (i.e., operational, management, technological, and communications) within the industry and government must work together to achieve efficient, sustainable, and prudent development.

Recommendations:

- The leaders of companies set the expectations for organizations and focus attention on the critical nature of environmental safeguards and practices. Therefore, commitment must be maintained to excellent environmental performance and continuous environmental improvement at both the leadership level of companies and throughout the organization.
- Industry and government should work together to establish centralized and play-specific repositories that collect, catalog, and disseminate standards, practices, procedures, management systems, etc., from all appropriate private and government sources.
- This will not take the place of standards-setting bodies, but rather serve as a central repository where industry, the public, and government may review and have free access to the most current standards and practices and a description of their applicable uses.
- Every natural gas and oil company that uses hydraulic fracturing should participate in FracFocus and comply with applicable state-mandated registries. The Department of the Interior should require every natural gas and oil company that uses hydraulic fracturing on federal lands to participate in FracFocus.

Planning and Risk Assessment

Operators and regulators have long recognized that operations in extreme or sensitive environments, such as arctic climates, deepwater offshore settings, and wetlands, require careful planning to ensure operational success, worker safety, and environmental performance. As operations have moved into deeper, more challenging plays in more conventional settings, the need for more careful planning of these operations has been highlighted as well. The new paradigm for planning involves not only careful operational and logistic plans, but also requires that those plans be developed specifically to accomplish clear environmental protection goals as well as worker safety and public safety goals. In addition, risks must be identified and assessed.

Finding:

Prudent development of North American natural gas and oil resources requires enhanced predevelopment planning.

Recommendation:

- All levels of the oil and gas industry should be encouraged to use appropriate and comprehensive predevelopment planning, stakeholder engagement, risk assessment, and the innovative applications of technology, which must be adapted to the variability of resource plays and regional differences.

Regulatory Framework

There is a comprehensive set of state and federal regulations in place that govern all aspects of natural gas and oil production and environmental protection. The U.S. EPA administers most of the federal environmental laws, although development on federally owned land is regulated primarily by the Bureau of Land Management (part of the Department of the Interior) and the U.S. Forest Service (part of the Department of Agriculture) while offshore development in federal waters is regulated by a variety of agencies, including the BOEMRE (within the DOI), U.S. Coast Guard, Department of Transportation, Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Federal Energy Regulatory Commission, U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers. In addition, each state in which natural gas and oil is produced has one or more regulatory agencies that permit wells – including the design, location, spacing, operation, and abandonment – as well as environmental activities and discharges, including water management and disposal, waste management and disposal, air emissions, underground injection, wildlife impacts, surface disturbance, and worker health and safety. Many of the federal laws are implemented by the states under agreements and plans approved by the appropriate federal agencies.

To deal with the limitations of prescriptive regulations, some agencies have developed performance-based requirements that allow the use of new practices and new technologies so long as environmental protection goals are met. This approach allows greater flexibility and innovation while ensuring environmental protection, but both operators and regulators have recognized that this is not the best approach in all cases. Operators, regulators, and the public are in a near-constant dialogue to ensure that regulations are in place to effectively balance the need for natural gas and oil production, and the need for flexibility and innovation, with the need for regulatory certainty and environmental protection.

Finding:

A balanced and optimized regulatory process is critical to prudent development of resources.

Recommendations:

- Regulators at the federal and state level should have sufficient funding to ensure adequate personnel, training, technical expertise, and effective enforcement to properly regulate natural gas and oil companies.
- State and federal agencies should seek a balance between prescriptive and performance-based regulations to encourage innovation and environmental improvements while maintaining worker and public safety.
- Federal agencies should undertake efforts to better coordinate and streamline permitting activities on federal lands and in the OCS.

Environmental Footprint

The U.S. economy depends on a reliable, affordable, and abundant supply of energy. A key element of a reliable energy supply is one that can be developed prudently – i.e., one that is sustainable environmentally, economically, and socially. As the United States considers its energy sources for the future, assessing the environmental impacts of the various energy sources will be a significant factor in the choices that are made.

One useful approach for this is an environmental footprint analysis that, to the extent possible, quantifies the potential environmental impacts of each source on a per unit of energy basis. The footprint analysis does not attempt to provide a single score to indicate that one source is better than another. Instead, it provides an objective, science-based assessment of the potential positive and negative impacts of each source so that trade-offs can be evaluated and the relative importance of different impacts can be weighed.

In practice, however, environmental footprint analyses tend to remain in early stages of development, with analyses exhibiting different techniques for measuring impacts and widely varying assumptions that often end up producing apples-to-oranges comparisons across fuels and energy resources. There are technical issues such as incomplete data and the lack of consensus around quantification of impacts and risks. This latter fact complicates the ability of this potentially important technique to provide policymakers with useful information to evaluate the relative importance of the different impacts. Moreover, the different resource types for the same fuel may have different impacts, such as with shale gas versus conventional gas. Environmental footprint results, however, are not intended to be a rationale for not mitigating the impacts of any fuel.

Policymakers should refine their understanding of the life cycle and environmental footprint of energy sources, including natural gas and oil, as part of providing a high-quality information base for making decisions about energy choices that reflect the different nature and intensity of impacts. Information from environmental footprint analyses could be incorporated into analyses used in making investment and purchasing decisions by consumers, producers, and state and federal governments.

With a high energy density and relatively low air emissions, the overall footprint of natural gas and oil appears to be smaller than most other energy sources and compares favorably with all sources in available analyses. In particular, shale gas, with higher than average production per well, has an even smaller environmental footprint on an energy unit basis according to some studies. Coupled with other factors such as domestic abundance, reliably consistent production, and its versatility as a fuel for many uses, the environmental footprint of natural gas, especially shale gas, makes it an attractive energy source that can fuel the U.S. economy both now and in the future.

Finding:

When compared with other energy sources, natural gas (and shale gas in particular) has a comparable or better overall environmental footprint across the full life cycle than most other energy sources.

Recommendations:

- The federal government should support the development of methodologies for assessing environmental footprint effects such as impacts on water and land.
- As sound methodologies are established and vetted, regulators and others policymakers should use environmental footprint analysis to inform regulatory decisions and in implementing other policies where energy resource choices involve economic and environmental trade-offs.

Technology Innovation

The history of natural gas and oil development has been one of continuous technology advances, improved systems management, and improved regulatory processes that have allowed production of new and more challenging resource plays, while at the same time improving environmental performance. These advances have led to production of resources that until recently were not considered to be technically recoverable and have resulted in levels of environmental performance that could not have been envisioned just a few years ago.

Improvements in environmental performance have occurred in every phase of natural gas and oil development for both offshore and onshore operations, from construction, drilling, completion through production, plugging of the well, and final reclamation. New technologies and innovative practices have been implemented to better control water use, reduce air emissions, and ensure groundwater protection. Additional performance improvements have been developed for hydraulic fracturing, materials management, and overall operation and management.

As we move forward, we can expect to see even more technology advancements that will allow production of ever more challenging resources while continuing to improve environmental performance. Such advances must continue to be accompanied by regulations that provide effective environmental protection based on sound science while allowing innovative changes that can lower costs and improve protection.

Continued support for research and technology development is a necessary condition to enable development of our natural gas and oil resources. Much research and technology development is conducted by private companies and it is important to not jeopardize this private enterprise system of innovation. However, sometimes the payoff period for such research is too long to attract private support. Therefore, private investment cannot be counted on to perform this work. In other cases, the intellectual property developed by research is better held as a public good rather than being held privately. This can occur when the benefits of the research would accrue to the United States as a whole, yet do not meet the criteria of any individual company to justify the investment.

Finding:

Advances in technology, continuous operational and environmental performance improvements, and the appropriate assessment and mitigation of risks are essential to ensure continued prudent development of North American natural gas and oil resources.

Recommendations:

- Even as natural gas and oil companies continue to fund their own proprietary technology and other research, federal government agencies should also perform important roles in supporting the development of new technology. While different federal agencies may be appropriate homes for a range of research and technology development efforts, the Department of Energy should lead in identifying, in some cases funding, and in other cases supporting public-private partnerships for research and development on energy and certain environmental issues of national interest. Examples where federal involvement is needed include:
  - The environmental impact of oil spills and cleanup, including residual effects of chemical dispersants, and science-based risk assessments
  - Science and pre-commercial technology relating to methane hydrates
  - Technology and methods for understanding, quantifying, and mitigating the environmental impacts and other risks of natural gas and oil development to continue to improve the environmental performance of exploration and development activities.

- State and federal agencies should continue working to develop regulations that ensure environmental protection and encourage technology advancement and innovative environmental practices.

Public Education

The importance of informing the public, maintaining transparency concerning operations and risks, and gaining public confidence through excellent environmental performance is a recurring theme. This information and understanding is critical to achieving the public's permission to operate in many parts of North America. Public education can take many forms, including information libraries, K-12 curricula, media campaigns, speakers bureaus, web sites, and studies of risks in areas of special concern, such as hydraulic fracturing. Continuously improving environmental stewardship is a prerequisite to gaining public confidence. The importance of this undertaking merits highlighting through a separate finding.

Finding:

Public knowledge and confidence needs to be built through open information sharing and transparency about operations, impacts, risks, and availability of mitigation strategies.

Recommendations:

- The oil and gas industry must maintain and publicize continuous effective environmental performance and transparency.
- The industry and state and federal agencies must disseminate science-based information on practices and risks to inform the public and build public confidence.

Definitions of Sustainable Development

Sustainable development was defined by the Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."[63] The concept of sustainability is often used to refer to a company's objective to achieve goals related to social, environmental, and economic needs. Sustainable development for industry can be referred to as the triple bottom line,[64] a three-legged stool,[65] or corporate social responsibility.[66] The triple bottom line was introduced by John Elkington in 1997 in order to demonstrate that to reach sustainability, economic, environmental and social performance must be achieved.[67] The Global Reporting Initiative (GRI),[68] a widely recognized sustainability measurement organization, introduced draft Sustainability Reporting Guidelines for organizations in 1999.[69] GRI is currently developing a tool specifically designed to measure the different environmental aspects of the natural gas and oil industry.[70] This effort can be further defined once the GRI tool is released.

Sustainability within business is not a clearly defined concept for industry.[71] Most companies have

63 United Nations General Assembly, "Report of the World Commission on Environment and Development: Our Common Future," transmitted to the General Assembly as an Annex to document A/42/427 – Development and International Co-Operation: Environment (1987), accessed April 15, 2011, http://www.un-documents.net/wced-ocf.htm.

64 Timothy F. Slaper and Tanya J. Hall, "The Triple Bottom Line: What Is It and How Does It Work?" Indiana Business Review 86, no. 1 (Spring 2011), accessed June 29, 2011, http://www.ibrc.indiana.edu/ibr/2011/spring/article2.html.

65 United Nations General Assembly, "Report of the World Commission on Environment and Development."

66 Cynthia A. Williams and Ruth V. Aguilera, "Corporate Social Responsibility in a Comparative Perspective," University of Illinois at Urbana-Champaign (2007), accessed June 29, 2011, http://www.business.illinois.edu/aguilera/pdf/Williams%20Aguilera%20OUPfinal%20dec%202006.pdf.

67 William R. Blackburn, *The Sustainability Handbook: the Complete Management Guide to Achieving Social, Economic and Environmental Responsibility,* Environmental Law Institute, 2007, page 4.

68 Global Reporting Initiative, Homepage (n.d.), accessed April 15, 2011, http://www.globalreporting.org/Home.

69 Global Reporting Initiative, Homepage (n.d.), accessed April 15, 2011, http://www.globalreporting.org/Home.

70 Global Reporting Initiative, "Oil and natural gas" (n.d.), accessed April 15, 2011, http://www.globalreporting.org/ReportingFramework/SectorSupplements/OilAndGas/.

71 Blackburn, *The Sustainability Handbook*, page 9.

Examples of Economic, Environmental, and Social Topics*

Examples of Economic Topics

- Brand strength
- Capital expenditures
- Cash flow
- Community donations
- Credit rating
- Debt and interest
- Dividends
- Liabilities
- Local purchasing
- Market share
- Profits
- R&D investments
- Retained earnings
- Return on investment
- Sales
- Taxes
- Tax subsidies
- Wages

Examples of Environmental Topics and Impacts (Benefit or Impact)

- Air pollution
- Biodiversity (wildlife or habitat)
- Chemical spills
- Compliance
- Cultural resources
- Energy use (conservation or consumption)
- Greenhouse gases
- Invasive species (increase or decrease)
- Land disturbance (soil erosion, construction)
- Natural resource use (consumption or conservation)
- Noise and odors
- Product energy use
- Renewable energy
- Soil contamination
- Spills (prevention or occurrence)
- Waste disposal (hazardous, solid, liquid)
- Water quality (surface water or groundwater)
- Water use (consumption or conservation)
- Wetlands

Examples of Social Topics

- Surface owner concerns or benefits
- Visual changes
- Community concerns, including environmental justice
- Changes in reputation
- Indoor air pollution
- Access to healthcare
- Charitable donations
- Labor issues
- Community education and outreach
- Corporate governance
- Employee benefits
- Disaster relief
- Emergency preparedness
- Employee assistance programs
- Employee diversity
- Employee wellness programs
- Employment
- Ethics
- Human rights
- Impacts on local cultures and communities
- Industrial hygiene
- Legal compliance
- Occupational health
- Product safety
- Securities regulation
- Support for community services
- Workplace safety
- Transparent public reporting

* William R. Blackburn, *The Sustainability Handbook: the Complete Management Guide to Achieving Social, Economic, and Environmental Responsibility,* Environmental Law Institute, 2007, pages 25–27.

activities that further the cause of environmental sustainability. Financial success and long-term employment can be part of a sustainability equation. Strong corporate governance and business ethics are other common sustainability successes for companies. Sustainability does not mean that a company can achieve no negative impacts to society and the environment. It is a process that supports companies moving towards a more sustainable outcome. Companies can be perceived by society as being environmentally and socially conscious, or not based on perceived or actual past occurrences. Jeffrey Immelt, Chief Executive Officer of General Electric, was noted for stating: "The world's changed. Businesses today aren't admired. Size is not respected. There's a bigger gulf today between the haves and have-nots than ever before. It's up to us to use our platform to be a good citizen. Because not only is it a nice thing to do, it's a business imperative."[72]

72 Marc Gunther, "Money and Morals at GE," Fortune (November 15, 2004), accessed April 15, 2011, http://money.cnn.com/magazines/fortune/fortune_archive/2004/11/15/8191077/index.htm.

Organizations can engage with stakeholders to improve goals, metrics, monitoring systems, and reports. To achieve superior performance, a business will continually challenge itself. James Collins, former Stanford University business professor, indicated that a common characteristic of great companies is that they understand and confront "the brutal facts."[73] Companies and industries often have dialogues within their organizations, which can lead to discussions based on hope rather than reality. Great companies have the courage to listen to stakeholders and ask for alternative views.[74] Such companies will reflect stakeholders' views in strategic objectives and communications. Listening to these concerns can support a company to get ahead of issues that can impact reputation, production delays, lawsuits, and regulatory actions.[75]

Stakeholder engagement can provide valuable insights that lead to better decisions and strategies. It can also increase the trust and support of government and citizens. For example, Art Gibson of Home Depot stated: "A company can't realize the full potential of environmental sustainability unless the organization and its stakeholders are aligned on the important aspects of that concept in a way that brings mutual benefit. A good way to achieve that alignment is through an engagement process. And from our experience, a proactive, well-planned process is much easier than a reactive one."[76]

In the sectors involved in land development, public comment and hearings are often required for permitting and other government approvals. There are also a number of laws requiring disclosures to agencies or shareholders.

Such discussions can also more effectively incorporate local environmental sustainability priorities and concerns. Environmental sustainability is often seen as first a local matter, then regional, and finally, national and international. Stakeholder discussions at a local level can easily be incorporated into public-private partnerships and overall environmental sustainability goals and objectives.

73 Blackburn, *The Sustainability Handbook*, page 373.

74 Blackburn, *The Sustainability Handbook*, page 373.

75 Blackburn, *The Sustainability Handbook*, page 373.

76 Blackburn, *The Sustainability Handbook*, page 375.

Stakeholder engagement and partnerships have not always proven successful. There are a few commonly stated reasons for such engagements to be less than successful, including:

- Individuals in the organization are concerned about the outcome of the engagement
- Poor understanding of engagement techniques
- Failure to effectively scope purpose of discussions and partnership
- Lack of evaluation of outcomes
- Lack of resources.[77]

Any partnerships or engagements could focus on an open dialogue with clear goals and purpose. These lessons can be taken into consideration for developing public-private partnerships.

Public-private partnerships have proven to be a successful tool to drive environmental sustainability goals within a sector. These partnerships put the regulator in a different role. Instead of implementing programs as dictated by legislators, they are managers striving for outcomes that result in public benefit by navigating the various strategic choices. This can enhance accountability of public managers and provide a greater source of regulatory and voluntary tools. As the National Academy of Public Administration's 1995 report on the U.S. EPA states: "At present, EPA is hobbled by overly prescriptive statutes that pull the agency in too many directions and permit managers too little discretion to make wise decisions. Congress should stop micromanaging EPA."[78] The report continues to press for a coherent integrated governing statute and indicates that "EPA should promulgate a mission statement of its own."[79]

Public-private partnerships, if properly designed and implemented, are an effective tool to drive environmental sustainability objectives consistently throughout an industry. It can also enhance the ability to engage stakeholders and incorporate input.

77 Blackburn, *The Sustainability Handbook*, page 377.

78 National Academy of Public Administration, "Setting Priorities, Getting Results: A New Direction for the Environmental Protection Agency," Report to Congress (Washington, D.C., 1995), page 1.

79 National Academy of Public Administration, "Setting Priorities, Getting Results," page 1.