

INTRODUCTION

The Shale Dilemma

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The unlocking of shale resources using the twin technologies of high-volume hydraulic fracturing (HVHF) and horizontal drilling deep underground has raised hopes for an inexpensive and abundant energy resource that will spur broad-based economic development. At the same time, it has sparked fears about potential risks to human health, the environment, and local communities. US exploitation of its shale resources has been both heralded as an energy revolution and denounced as an environmental catastrophe. Worldwide, countries with shale resources, contemplating following in US footsteps, have embraced shale development, proceeded with ambivalence, remained undecided, or rejected shale development outright. How and why have individual countries decided to follow such different paths? What can we learn about the promises and perils of shale development from these divergent positions on shale development? Why do perceptions of the benefits versus costs of shale development differ so markedly within and across countries? This volume addresses these and related questions.

A VERY SHORT HISTORY OF SHALE DEVELOPMENT

The United States leads the way in shale development. From January 2007 through July 2017, US shale gas production increased tenfold,¹ from 0.12 billion cubic meters per day (bcm/d) to 1.28 bcm/d (US Energy Information Administration 2017a).² The growth in shale gas production, alongside a rise in tight oil production, has transformed the United States from a significant energy importer to near self-sufficiency, meeting 86.2 percent of its

energy consumption in 2016 (US Energy Information Administration 2017b). The United States was a net exporter of natural gas in three of the first four months of 2017; and it is projected to become a net exporter of natural gas in 2017 and 2018 (US Energy Information Administration 2017c).

Thanks to US gas prices being largely decoupled from world prices, the expansion of shale gas production has cut the price of gas in the United States. Gas prices per gigajoule (GJ) declined from \$7.74 in January 2001 to \$5.52 in January 2010 (US Energy Information Administration 2017d). These prices declined further to \$2.16 in January 2016 before rebounding to \$3.13 in January 2017 (US Energy Information Association 2017d). Cheaper gas yielded \$48 billion in consumer and producer surplus in 2013, around 0.33 percent of US gross domestic product (GDP) (Hausman and Kellogg 2015), and spurred the growth of downstream manufacturing industries (Baily and Bosworth 2014). A fall in the price of gas has also contributed to the shift in US electricity generation from coal to gas; the share of gas increased from 20.1 percent in 2006 to 33.8 percent in 2016, while that for coal declined from 49.0 percent in 2005 to 30.4 percent in 2016 (US Energy Information Administration 2017e). This shift from coal to gas improved air quality at the point of combustion and yielded significant health benefits.

However, local communities in areas where shale gas is produced have borne significant costs, despite enjoying benefits such as jobs and public goods financed by tax revenue from shale. In cases where residents do not own mineral rights, they do not benefit directly from lease or royalty payments that could offset some of these costs. These towns and rural municipalities face increased traffic and noise as well as the financial burdens of repairing roads used by heavy trucks, providing emergency services to the shale industry, and offering social and health services to workers' families (Ward, Polson, and Price 2014). Shale development has contributed to documented cases of adverse environmental impacts. For example, water extraction by the shale industry (added to the extraction for agriculture and municipality use) has contributed to the diminution of the Carrizo Aquifer in semiarid Texas (Nicot and Scanlon 2012). Surface and groundwater has been contaminated by surface spills and leaks, improper wastewater treatment, and gas migration to aquifers through improperly cemented gas wells (Vengosh et al. 2014). Air quality has deteriorated in several shale-producing regions (Moore et al. 2014), and lawsuits against companies brought by landowners who allege nuisance and contamination from shale operations are on the rise (Meadow, Saiers, and Thompson 2013).

The successful extraction of shale resources in the United States has induced several countries with shale resources to attempt to replicate this experience. Figure I.1 shows the location of shale gas and shale oil basins assessed

in the study by the US Energy Information Administration and Advanced Resources International (2013). Central governments in the United Kingdom, Poland, China, Argentina, and South Africa have pressed forward with shale development. However, disruptions to local communities and pollution incidents in the United States have prompted other countries to declare a moratorium on shale development (as in Germany) or to ban HVHF for shale development (as in France). In countries that pursue shale development, several subnational entities have chosen to restrict or ban shale development. Examples include New York State, Scotland, and Northern Ireland, along with a growing number of municipalities in Argentina and the United States, including several in Texas, the birthplace of the shale industry. Some local restrictions, however, have been quashed by a number of state governments in the United States (Wiseman 2016).

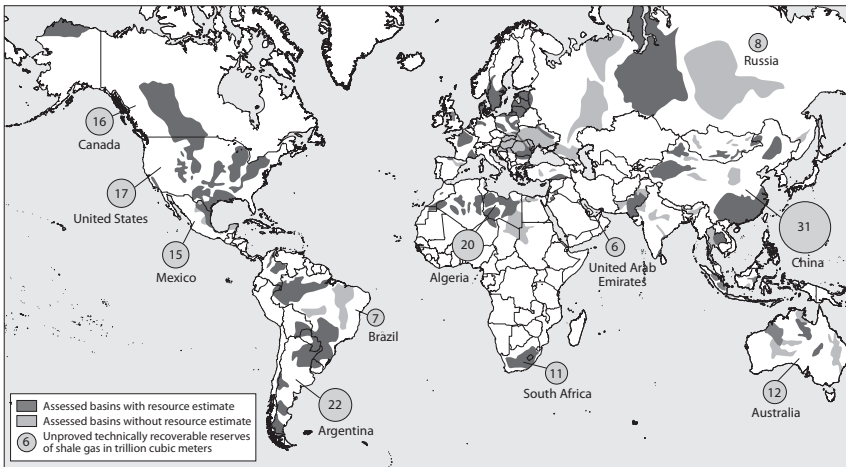


Figure I.1. Worldwide location of shale gas and shale oil basins that have been assessed. *Source:* This map is redrawn from the original map as published in US Energy Information Administration and Advanced Resources International, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Washington, DC: US Energy Information Administration, 2013), and the estimates are from US Energy Information Administration and Advanced Resources International, *World Shale Resource Assessments* (Washington, DC: US Energy Information Administration, 2015), https://www.eia.gov/analysis/studies/worldshalegas/archive/2013/pdf/fullreport_2013.pdf.

GETTING TO GRIPS WITH THE SHALE DILEMMA

The decision to undertake or forgo shale development poses an inherent dilemma. The heart of this dilemma is that shale development promises benefits but also threatens to incur costs, and these potential benefits and costs are unevenly distributed across society. On the benefits side of the ledger, domestic shale exploitation can provide a secure source of energy. Furthermore, ben-

efits can be broadly distributed if countries implement policies on resource taxation and distribution, on the management of potential boom-bust cycles at the local level, and on the development, if appropriate, of downstream industries. On the other side of the ledger are the costs of shale development, such as noise, traffic, and the possibility of environmental contamination, all of which are concentrated in the localities where production and waste disposal occur. In addition to their uneven distribution within society, potential benefits and costs are fraught with uncertainties because of knowledge gaps on the size of economically recoverable reserves and on the health and environmental impacts of shale development.

Optimistic projections of the economic benefits from shale development, such as job creation and government royalties, have been used to justify the pursuit of shale development, while pessimistic projections are held up to question such a pursuit. In reality, these projections vary widely because they rely critically on the assumptions made about the economically recoverable shale resources. However, the economically recoverable resources remain highly uncertain until substantial exploration has taken place. Estimates of physically recoverable resources alone—the oft-cited figures—do not provide a firm basis on which to estimate the economically recoverable resources. A substantial downward revision of US technically recoverable reserves was not made until 2012, five years after shale production began its significant growth in the United States (US Energy Information Administration 2012).

Weighing benefits against costs is also difficult because promised economic benefits may not materialize and costs may be higher than anticipated unless shale development proceeds under certain conditions. For instance, without appropriate taxation and redistribution policies, revenue from shale development may not spur significant, broad-based economic development. Similarly, without appropriate planning, environmental regulations, and legal protections for local communities, shale development is likely to inflict costs on local communities and adversely affect human health and the environment.

Terminological imprecision accentuates the problem of weighing benefits against costs. The term *economic benefits* (and its opposite, *economic costs*) should include the spectrum of financial, environmental, health, and social benefits (or costs). But several studies that estimate the economic benefits from shale development have cautioned that they omit environmental costs due to data limitations, including Hausman and Kellogg (2015), which examines the United States, and Wait and Rossouw (2014), which analyzes South Africa. Often, benefits/costs on the financial yardstick are easier to estimate than those on the human health and the environmental yardsticks. Moreover, environmental and health impacts of shale development, under industry's

current practices, are only gradually emerging. The shale industry, it must be remembered, is a new industry, distinct from the historical conventional oil and gas industry. The historical use of hydraulic fracturing in the conventional oil and gas industry does not provide a definitive understanding of the environmental impacts of today's shale industry.³

For shale development to achieve a number of goals its proponents promise, the adoption and effective implementation of complementary policies are needed—whether they are carefully developed, closely embraced, and fully implemented remains uncertain. For example, for shale development to contribute to climate protection, countries that are developing shale resources need to control methane leakages and to use shale gas as a substitute for coal instead of expanding overall fossil fuel combustion. Another challenge is for countries to prevent carbon leakage; that is, any coal displaced by shale gas should not be burned elsewhere in the globe. (When the United States reduced coal-fired power generation and increased gas-fired power generation, it exported coal that would have been burned in its coal-fired plants to Europe, where that coal was burned.) Likewise, for shale to contribute to broad-based economic development, planning for and mitigating the boom-bust cycles in the shale industry are essential. The rapid expansion in the shale industry leads to an influx of transient workers that places stress on local services, while the rapid contraction of the industry leads to abrupt loss of jobs and local government revenue. Additional policies are needed to protect against environmental damage that destroys long-term productivity and undercuts long-term economic benefits. Moreover, these policies and their associated regulations not only need to be introduced, they need to be enforced. However, the political economy of government's reliance on shale gas revenues and the stronger influence of the shale industry relative to that of competing industries, civil society, and local communities can limit the effectiveness of the regulatory framework.

More broadly, the debate on shale development brings to the fore competing visions of pathways on how to achieve economic development, energy security, climate protection, and environmental quality. Those who are more confident in the implementation of policies to secure benefits and mitigate costs from shale development and who weigh more heavily the opportunity costs of delaying shale development take the position that shale development provides a potent strategy to achieve these goals. Others, who are more doubtful of the implementation of these policies and weigh heavily the potential environmental risks from shale development and the potential for sunk costs in shale development to delay long-run renewable energy adoption, support a direct focus on renewable energy to enhance economic development, energy security, climate protection, and air quality.

Countries vary on the strategies that have gained prominence to achieve these goals. In the United States, shale development has commanded much attention as a key strategy to achieve these goals—unsurprisingly, given its large shale production. In contrast, in Germany, France and the United Kingdom, which have committed to transition to a low-carbon economy, have prioritized other strategies, such as increasing the adoption of renewable energy, enhancing energy efficiency, and reducing fossil fuel consumption. Even in the United Kingdom, where the central government strongly supports shale development to make up for the decline in North Sea conventional gas production, renewable energy and nuclear energy have featured more prominently than shale in the policy debates on how to achieve the low-carbon transition.

The variation in viewpoints about pathways to achieve goals such as economic development is evident not only across countries but also within countries. Some energy experts have argued that shale development in emerging economies such as South Africa and Argentina can improve the well-being of local communities. Other experts, focusing on the historically adverse impact of mining on these communities, gaps in protection for local communities, and the lack of broad-based development from mining activities, urge the pursuit of alternative development pathways. In Argentina, both the conventional and the unconventional oil and gas industries have contributed to pollution incidents, fueled land conflicts between oil companies and indigenous communities, and spurred the growth of poorly planned boomtowns with social problems. In South Africa, the mining industry provided job opportunities for local communities and migrant workers, but at the cost of adverse health and environmental impacts.

Social and environmental groups in South Africa have called for the development of renewables as an energy source and for further land reform in the Karoo region (an area located in south-central South Africa that overlays shale resources) to support emerging black farmers as an alternative to shale development. Groups in Argentina have similarly urged the development of renewables to meet Argentina's energy needs and have pressed the government to support the existing economic activities of farming and ecotourism as an alternative to shale development. These viewpoints, however, have failed to win over most of the South African and Argentinian public, who have been more impressed by the potential for shale to relieve pressing energy needs.

EXPLORING THE SHALE PUZZLE

What explains such diversity and polarity in public and governmental attitudes toward shale development? This book is the first to apply a common analytical framework to case studies of shale development by experts from

around the world. It simultaneously brings together an international cast of researchers who are active in deliberations on shale development and the broader energy and environmental policies in their countries *and* uses the same analytical framework across all the case studies, thereby creating a truly comparative study of global dimensions. We—the editor of and the contributors to this volume—apply analytical tools from political science, economics, and risk analysis to examine why the United States, the United Kingdom, Poland, China, Argentina, and South Africa are pursuing shale development and why France and Germany are not.

We argue that two sets of issues are relevant to this puzzle. The first set pertains to a country's energy mix, economic profile, and climate commitments that shape the goals articulated for and against shale development. The second set of issues pertains to the decision-making process within a country that determines if and how shale resources are exploited.

The decision-making process determines the extent to which concerns about shale development are taken into account, whose concerns (e.g., civil society's or the extractive industry's) are given most weight, if and how policies are introduced and adjusted to address these concerns, and the level of consideration given to alternative strategies to achieve energy security, economic development, and climate protection. By examining the decision-making process across countries, we seek to identify what features a process should possess if it is to help a society arrive at a course of action that reflects a genuine consideration of the various viewpoints on shale development, accounting for the benefits and costs, their uncertainties and uneven distribution and various worldviews on how best to achieve energy security, economic development, and environment protection. We also acknowledge that people differ in what they value, their appetite for risks and rewards, and their vision of progress (US National Research Council 1989; National Research Council 2008). That course of action may be to proceed with shale development with policies that address the concerns of local communities and the public or not to proceed with shale development.

Accordingly, this book sets out to do three things. First, we examine how each country's national characteristics shape the goals articulated by its government for and against shale development or for a faster pace of shale development than acceptable to environmental groups but at a slower pace than advocated by industry. These national characteristics, such as energy mix and security of supply, economic profile, and climate commitments, are the product of countries' historical actions (or lack of actions) undertaken to address energy security, economic development and environmental protection. These national characteristics shape the viewpoints that eventually dominate the debate on whether shale development is likely to contribute to or negate

the stated goals of achieving energy security, economic development, climate protection, and air quality improvements. And when the stated goals come into conflict, these viewpoints determine which goals—energy, economic, or environmental—are given greater weight in trade-offs.

For example, countries' energy mix determines whether shale development can serve as a strategy for climate protection (with caveats) at least in the short term. The central governments of the United States, Poland, China, and South Africa, where coal makes up a significant share of the energy mix, have argued that domestic shale development, which enables the switch from coal to gas in their power generation, would reduce their greenhouse gas (GHG) emissions and thus protect the climate. In contrast, France's reliance on nuclear energy and the United Kingdom's shift from coal to gas in its power sector in the 1990s means that the coal-to-gas shift, facilitated by shale development, does not serve as an option for these countries to further decarbonize their economies.

Second, we examine individual countries' decision-making processes that produce policies on shale development. More particularly, we examine how actors that vary in their perception and experience of the costs and benefits of shale development and that differ in their support for various strategies to achieve energy security, economic development, and environmental protection interact to arrive at a country's set of policies governing shale development. Most central governments, with the support of the oil and gas and downstream industries, have pursued shale development. Opposition to shale development has tended to come from local communities, competing industries such as agriculture and tourism, environmental nongovernmental organizations (NGOs) and, in some countries, the general public. We review the extent to which central governments are constrained politically to consider and respond to the view of the majority of the electorate, NGOs, local communities, and industrial interests and constrained legally by local governments' authority to restrict shale development. We also examine the extent to which local communities and NGOs can learn about the potential and actual impacts of shale development. Countries differ in their conduct of scientific assessments of the potential impact of shale development. Their laws vary in effectiveness in facilitating access to and dissemination of information on the operations and impacts of the shale industry and on regulators' enforcement actions.

Third, we compare policies across countries to examine why countries reach different decisions about how to weigh and balance the goals of energy security, economic development, and environmental protection. For countries that are developing their shale resources, we draw lessons—both positive and negative—from the US experience. The rapid growth of shale develop-

ment in the United States initially outpaced regulatory responses to environmental risks and adverse effects on local communities. However, countries that are in the early stage of shale licensing, exploration, or production, such as the United Kingdom, Poland, China, Argentina, and South Africa, have the lead time to put in place more effective policies to ensure broad-based benefits and to mitigate costs to communities, health, and the environment.

We suggest that countries' development of alternative energy plays a pivotal role in whether countries decide to opt out of shale development until more is known about benefits and costs or to press ahead with the exploitation of shale resources despite health and environmental risks. In countries that face a less pressing need to develop a new energy supply (e.g., Germany, which has embarked on an energy transformation program and France, which relies on nuclear), the majority of the public has been able to oppose shale development. Despite a number of scientific reports in France and Germany concluding that effective regulations can be implemented to minimize risks (although other scientific reports challenge this view), the majority of the public perceives that the benefits will not be large enough to offset nontrivial risks to the local environment and to the global climate. In contrast, the central governments in Poland, China, Argentina, and South Africa, which view shale as providing an urgent new energy source, have proceeded with shale development, even at the cost to local communities and potential risks to the environment. For China, Argentina, and South Africa, which perceive high opportunity costs by forgoing shale development, undertaking shale development poses nontrivial risks if their institutional capacities to address these risks are not developed.

The review of the decision-making processes across countries reveals the need for improvements. The needed improvements are (1) enhancing research on the impacts of shale development and access to and dissemination of this knowledge; (2) providing more political space for concerns about shale development to be expressed; and (3) improving information disclosure and regulatory responsiveness to mitigate potential environmental impacts. Countries have taken compensatory approaches to encourage local communities to accept shale development, such as providing revenue for or investing in local communities in the United States, the United Kingdom, and Argentina and are improving the regulatory framework to ensure community and environmental protection in the United States, the United Kingdom, and South Africa. However, several countries—Argentina, for example—have also taken the approach of rolling back public participation in the shale decision-making process. The ability of local governments or local communities to shape shale development has been restricted in the United States, the United Kingdom, Argentina, and Poland. Such moves shift the cost of shale

development to local communities without attempting to compromise and bury these communities' concerns about traffic, noise, public health, and the environment but without striving to mitigate these potential impacts.

TAKING A COMPARATIVE APPROACH

This book takes a global comparative approach, examining three sets of countries: those with commercial production, those in the exploratory stages, and those not pursuing shale development.

The Choice of Case Studies

Most of the countries we examine rank high globally in their estimated technically recoverable shale reserves. If a significant fraction of these reserves could be profitably extracted (an unknown at present), the pursuit of shale extraction would have substantial impacts on the energy balance, the economy, and the environment at the national, regional, and global levels. China, Argentina, the United States, and South Africa rank first, second, fourth, and eighth in the global rankings of estimated technically recoverable resources. France and Poland rank first and second among European Union (EU) countries. While the United Kingdom and Germany rank only fifth and seventh in the EU, they serve as valuable case studies on how countries that have committed to climate protection and a transition away from carbon-intensive energy resources grapple with the shale dilemma.

Our array of case studies includes countries that are at various stages of shale development. The studies feature three out of the four countries that are producing commercial quantities of shale gas: the United States, the largest producer of shale gas, and China and Argentina, far smaller producers in the distant third and fourth spots globally. The United Kingdom and Poland have undertaken shale exploration, and South Africa's government is assessing permit applications for shale exploration. France has enacted a ban on HVHF and Germany has implemented a moratorium on shale development.

These countries reflect the significant variation in the characteristics that shape the goals articulated for and against shale production. They vary in their levels of economic development, their energy profile (i.e., their energy mix), their dependence on imported gas, and their perceived energy security, as well as to the extent they have embarked on a transition from fossil to nonfossil fuels and to the extent they have committed to climate-change policies. The case studies also reflect significant variation in the factors that influence the political decision-making process. The countries vary in the degree to which central government is constrained by the political process to respond to political parties out of government, local communities, NGOs, and the general public. At one end of the spectrum is the French government,

which responded to the electorate's pronounced opposition to shale development by banning HVHF; at the other end is the Chinese government, which has been able to press ahead with shale exploitation without accommodating local communities' needs. These countries differ in legal requirements for conducting scientific assessments. They also vary in the legal rights for local communities, environmental NGOs, and the general public to participate in shale deliberations and to have access to relevant information and for local communities or local governments to restrict or veto shale development.

Three of the four countries engaged in commercial shale production are covered; Canada has been omitted. Instead of spending a chapter on each of the North American countries that produce shale, the volume devotes two chapters to the United States. This approach allows for in-depth coverage of the country with the longest experience in shale production and by far the greatest output.

Among the top nine countries with large shale reserves, four, in addition to Canada, are omitted: Algeria, ranked third in technically recoverable reserves but for which information on its decision-making process has been limited, and Mexico, which is ranked sixth and which, in the near term at least, has chosen to pipe in cheaper gas from Texas rather than face higher costs and uncertainties in developing its shale resources (Stillman 2014). Also omitted is Australia (ranked seventh), whose most promising basin in the Northern Territory lies far from population centers and therefore reflects a risk profile uncommon to most shale basins under consideration today. Finally, Russia (ninth in reserves) is not covered because the rationale behind its decision on shale exploitation is highly unlikely to arise in other countries contemplating shale development. Russia has chosen not to pursue shale because its conventional resources are abundant and extractable at lower cost than shale and because it perceives shale development globally as a competitor to its conventional resources.

An Overview of the Case Studies

Chapter 1 examines the evolution of shale development in the United States, from the technological experimentation stages in the 1990s to a rapid boom in 2000–2015, followed by a contraction in this cyclic industry in late 2015. This volume outlines how the shale industry grew within a supportive political, economic, and legal environment in the United States, with evidence on benefits amassing early whereas data on costs emerged more slowly, in part because of limited disclosure and research. Successive US administrations focused on expanding domestic oil and gas extraction to ensure energy security and promote economic growth, both of which shale development promised to support. Except for New York and Maryland, which declared a morato-

rium on HVHF, state governments permitted shale development to proceed under existing oil and gas regulations. The shale industry was therefore able to negotiate directly with private owners of mineral rights and proceed with shale extraction largely unimpeded.

This book describes the significant benefits that the industry has yielded since shale resources began to be exploited in the early 2000s: low gas prices for consumers; lease and royalty income for owners of mineral rights; job creation in the shale and related industries; domestic energy supplies to meet short-term energy needs; and reduced air pollution when power generation switched from coal to gas. But the first chapter also describes the economic, health, social, and environmental costs from shale development—costs that in many cases have taken time to emerge and that in some instances call into question earlier claims made by proponents of shale development. For example, the argument that shale can contribute to climate protection has been undercut by methane leakage during the production and distribution of natural gas and by carbon leakage from the combustion of US coal, displaced by gas, in Europe.

While it is too early to weigh the costs of shale development against its benefits, this volume notes that costs are being accentuated by inadequate regulation, monitoring, and enforcement; the rapid pace of development, which has impeded government planning to tackle the challenges the industry presents (ranging from traffic to waste management to the boom-bust nature of the cyclic industry); and the reluctance of the industry to share the information it has about the impact of its operations. Tensions and conflicts within communities arise from uneven benefits and costs from shale development and varying worldviews on whether shale development should proceed, with some local governments choosing to restrict or even ban shale development.

Chapter 2 examines the political battles fought in response to the uneven distribution of benefits and costs. The benefits are diffused across the economy, but the costs are concentrated in the local communities where shale operations take place. Some local governments and NGOs have pushed for stricter regulation, more disclosure, and greater local government controls to protect local communities and for higher levels of resource taxation to generate funds that could be used to benefit society as a whole. Such efforts, however, have been vigorously opposed by a number of state governments and a subset of industry players.

State governments that are in favor of shale development have contested federal regulations on the shale industry and the actions of local governments that restrict or ban shale development. While the Bush administration and Congress supported exemptions for the shale industry from several federal

environmental regulations, such as the Safe Drinking Water Act, under the Obama administration, federal agencies have enacted a number of shale-specific regulations that set the minimum baseline regulations across US states. A number of state governments have contested these regulations—for example, by filing a lawsuit against the federal Department of the Interior's rules on hydraulic fracturing on federal lands. States have also fought against local-level efforts to limit shale development. In response to local governments restricting or banning shale development, state governments in Pennsylvania, Texas, and Oklahoma have enacted legislation that preempts the powers of local governments to impose such limits.

This volume describes the push by NGOs for stricter regulations, more effective enforcement, and more disclosure in the shale industry. NGOs argue that in light of the scale of the industry and its environmental footprint, exemptions enjoyed by the oil and gas industry from certain provisions of environmental regulations that apply to other heavy industries should be reassessed. Likewise, NGOs argue, given water scarcity due to population growth and climate change, US regulations enacted decades ago need to be reassessed to ensure they strike a balance between encouraging energy extraction and protecting drinking water. Lack of disclosure and research has been detrimental to the industry itself, with New York governor Andrew Cuomo banning HVHF based on the lack of public health studies about its effects. Greater transparency in regulators' investigation and reporting of pollution incidents, greater disclosure by shale operators on their chemical use and waste treatment and disposal, and greater disclosure of legal settlements in contamination cases would provide a clearer picture of shale's impact. The uneven benefits and costs from shale development, this book notes, has spurred vigorous public debates on tax issues, such as the tax rate on resources and the share of tax revenue distributed to local governments versus state governments.

In chapter 3, Jim Skea writes about the United Kingdom, illustrating how a central government's strong push for shale development has been met with strong pushback from local communities, NGOs, and some members of the general public. Reasons enumerated by opposition include the traffic, noise, and urbanization of the rural landscape; health and environmental risks; and climate impacts. Skea writes that the central government has supported shale development to replace declining North Sea production in order to generate government royalties, reduce imports, and sustain the petrochemical industry. Energy security has not figured in the debate, as the United Kingdom has diversified its energy supply and has been developing its renewable resources. The government has sought to win public support by emphasizing the United Kingdom's regulatory capacity to address risks and promising financial bene-

fits to communities that host shale development, but it has also attempted to influence the permitting process. Skea draws attention to the political space for debate and opposition, legal protection for local communities, and use of the scientific information that has enabled NGOs and local communities to counter the government's position. For example, the Lancashire county council rejected local planning permission for the shale company Cuadrilla, a necessary step in the shale permitting process. The United Kingdom's legal commitments to binding carbon budgets have made the climate issue central in its shale debate. NGOs, drawing on an article published in *Nature* in 2015, have advocated that protecting the climate would require leaving substantial amounts of fossil fuels, including unconventional gas, unburned in the ground. NGOs have received support from those members of the public who perceive fossil fuels as polluting, archaic, and associated with global conflicts. Skea concludes that the government and NGOs have staked opposing positions that will be hard to reconcile, with the government firmly committed to pushing forward with shale development and NGOs staunchly opposed to even exploratory drilling, which is necessary to estimate the size of the resource.

In chapter 4, Michael LaBelle describes the Polish case, which shows how the argument of energy security within a country concerned about energy dependence on a powerful neighbor can dominate the national debate and leave limited political space to address concerns about shale development. LaBelle notes that the government has taken the position that exploiting shale, just like mining coal—Poland's other main fossil resource—is critical for the country's energy security because it will help to reduce dependency on Russian gas. In reality, gas accounts for only 14 percent of Poland's energy mix, and most of this gas is used as raw material for industrial processes, not for home heating or electricity generation. Russia supplies 70 percent of Poland's gas demand. LaBelle points out that with public concern about dependency on Russian gas, local opposition to shale development, primarily in rural Poland, has not won nationwide support. NGOs have chosen not to oppose shale but to focus on strengthening shale regulations. LaBelle highlights that political and legal avenues at the EU level have provided only limited opportunities for Poles to address environmental and social concerns, as shale regulation has been left primarily to member states. The hearing of the petitions of Polish opponents of shale development at the European Parliament did not change the reality on the ground that local communities face significant difficulties in accessing information on proposed shale development. Arguing that it has examined the risks of shale development and designed an effective regulatory framework, the Polish government contested the European Commission's charge that its removal of the requirement of environmental impact

assessments for drilling above five thousand meters is contrary to a European directive. Nevertheless, the prospects for shale development in Poland has dampened significantly with the departure of foreign shale companies, which are concerned about the economic viability of their involvement given poor initial drilling results and a draft proposal for shale development from the Polish government that assigns a smaller-than-expected share of the profits to companies.

In chapter 5, Patrice Geoffron examines how the French national government's failure to consult local governments and local communities in the initial approval of exploration permits (in 2010) during a period of national consultation on decisions affecting the environment (2007–2010), within a country with a strong tradition of political activism at the local level, snowballed into fierce opposition to shale development. Opposition by local communities, local politicians, and the general public culminated in a ban on HVHF in 2011, known as Jacob's law. The permitting process—which did not require full reporting of technical processes or consultation with local governments and communities and which did not disclose emerging information on the risks of HVHF as seen in US operations—first provoked public concern and then solidified opposition. Opposition centered on risks from water contamination and the land surface disturbances that undermine agriculture and tourism, the core economic activities in French regions that overlay shale reserves. Moreover, France does not face any urgency in developing shale, having met its energy needs by relying on nuclear power and by diversifying its sources for gas. Geoffron explains that the French Energy Transition Law does not envision a role of shale in this energy transition but is focused instead on raising the share of renewables, improving energy efficiency, and reducing fossil fuel combustion. Geoffron opines that the public debates did not consider the role of shale in this transition for two reasons; first, the French public staunchly opposed shale development. Second, France hosted the Conference of Parties of the United Nations Framework Convention on Climate Change in Paris in 2015. The French government did not want to consider the possibility of expanding fossil fuel production domestically at a time when it was focused on getting countries to agree on a global climate agreement to limited GHG emissions. Nevertheless, Geoffron notes that while the debate on shale in France is not over, it has become more politically polarized. Politicians on the left support the continuation of the ban. In contrast, politicians on the right, including the former president Sarkozy, who supported the ban while he was in office, are calling for the reassessment of the ban.

In chapter 6, Miranda Schreurs examines the German case, which illustrates the debate on whether shale contributes to or contradicts the goals of

transitioning to a lower-carbon economy, protecting the climate, and enhancing energy security. Shale debates take place within the context of Germany's *Energiewende* ("energy transformation"), a process designed to achieve energy security, boost economic vitality and innovation, and mitigate climate change. Germany's oil and gas industry and its manufacturing sector support shale development; standing opposed are industries such as beer, agriculture, and renewable energy, NGOs, and the general public. Proponents of shale development argue that it supports the *Energiewende*, particularly with the phasing out of nuclear energy. Gas can serve as backup power for renewable energy; domestic shale development, by reducing the price of gas, would encourage the switch to gas from coal and lignite. Opponents argue that shale development contradicts the goals of the *Energiewende* and advocate instead that the government focus on direct strategies to support renewable energy, such as improving grid connections among producers and consumers of electricity across large geographical spaces and enhancing research into more efficient batteries and a smarter electrical grid. Despite the major challenge Germany faces to reduce its reliance on coal, shale opponents argue that a system based on energy-efficient, renewable energy is best for securing long-term energy security. Schreurs notes that the German coalition government has passed a law that would permit HVHF for shale for research purposes only, subject to the permission of the state government where the test drilling is to be performed. According to Schreurs, several state governments that have developed their own renewable programs oppose shale development, including the state government of North Rhine-Westphalia that hosts the largest shale deposits in Germany.

In chapter 7, Alvin Lin examines the China case, showing how shale development, pursued to address pressing needs such as dealing with the air pollution crisis in Chinese cities and reducing China's GHG emissions, can shift significant health and environmental risks to rural communities where shale development is proceeding unless China improves its institutional capacity to address these risks. Shale production has reached commercial levels in some fields in the Sichuan Basin. The Chinese government views shale development as facilitating its shift from coal- to gas-fired power plants. Lin highlights the need to address regulatory weaknesses and lack of transparency in the industry. China has yet to undertake a strategic environmental assessment on the risks of drilling for shale gas or to enact the necessary mitigation measures and introduce regulations that address risks specific to the shale industry. Moreover, without independent bodies reporting on shale operations, regulators' activities, and pollution incidents, it has not been possible to determine the industry's true impact. The few investigations in the field have highlighted the lack of redress for local communities that face pollution

or land encroachment. Lin also looks at the political challenges of improving enforcement when the responsibility for local environmental enforcement rests with the local government, which generally favors companies' pursuit of economic activity even at the risk of creating environmental hazards for local communities. Lin notes that although the Chinese government has moved toward improving transparency (it has, for instance, published a report documenting China's poor air quality) and NGOs have disseminated information on polluting companies, access to information is still tightly restricted in the shale industry.

In chapter 8, María Florencia Saulino writes that Argentina, reliant on gas for 52.4 percent of its primary energy consumption in 2014 (Argentina Secretaría de Energía 2015), has pursued shale development to address its declining conventional gas production and to reduce its gas imports. The Argentinian case illustrates how the three levels of government—federal, provincial, and local—that share the regulation and monitoring of shale development have not fully addressed local concerns about the costs of shale development. The federal government, which has the responsibility of setting baseline regulations, has not enacted shale-specific regulations that would provide minimal protection across provinces. The provincial governments, which serve as the primary regulator of the oil and gas industry, have taken some steps to address local concerns, but conflicts persist. The province of Neuquén has enacted regulations to address shale-specific risks, though gaps remain. It has also required that shale companies invest in local communities; information is scarce on these investments, however. And, although several local governments have attempted to ban shale development, at least one provincial court has overturned this ban. Contrary to legal requirements, the provincial governments have issued exploration and drilling permits, and shale companies have conducted operations without prior consultation with local indigenous communities, resulting in land conflicts. Saulino argues that Argentina needs to better address the concerns of local communities by filling regulatory and enforcement gaps, instituting conflict resolution procedures to address local communities' concerns about encroachment on their land and pollution incidents, and improving transparency on shale operations, pollution incidents, and regulators' enforcement actions.

In chapter 9, Barry Morkel and Maarten de Wit examine the South African case, focusing on how an emerging economy has placed high hopes in shale development to meet pressing energy demands and to address poverty and high unemployment levels. At the same time, however, the country faces significant challenges in implementing effective taxation of natural resources, stricter regulations, and improved enforcement capacity to achieve broad-based economic benefits and environmental protection. Morkel and de Wit

describe government efforts to increase the state's share of the profits in the face of opposition from the business community. The South African National Assembly is reconsidering a bill that would give the state the right to acquire a 20 percent interest in shale exploration and production operations without financial obligations and to acquire additional interests at costs. Morkel and de Wit point out how the government's actions reflect the tension between its push for more rapid shale development, supported by the Karoo Shale Forum, which is lobbying for a share of the shale revenues to return to the communities where shale is produced, and the pushback from Karoo landowners, some emerging black farmers, and NGOs that have used legal tools to combat shale development. In 2011, the government imposed a moratorium on shale development, in part because of scathing criticism of the inadequacy of environmental plans submitted by companies seeking exploration licenses, but lifted the moratorium based on a limited, two-month study by a government task force. The government enacted shale-specific regulations without sufficiently addressing the criticisms leveled at the draft regulations. In 2014, the government agreed to undertake a two-year strategic environmental assessment that would provide more detailed information on the risks from shale development and the needed mitigation measures, but it also decided to allow concurrent shale exploration. Morkel and de Wit highlight the importance of engaging low-income black communities in the Karoo region, many of whom have not been given access to information on the shale development plans nor have they been consulted during the public consultation process required of companies that apply for permits for shale exploration. Yet, as the authors note, addressing local concerns is critical given that mining has long provided job opportunities to local communities but at a cost to their health and to the environment.

In the book's conclusion, Shanti Gamper-Rabindran draws two key lessons from the preceding case studies and offers a variety of practical recommendations for mitigating the adverse effects of shale development. The first lesson is that the anticipated contribution of shale development to energy security has been a very powerful argument in countries that have decided to pursue development, such as the United States, Argentina, China, South Africa, and Poland. The overriding focus on energy security, alongside the promise of economy-wide benefits, has made it more challenging for concerns about the costs from shale development to receive equal hearing. In contrast, in countries that have invested in alternative energy resources, such as Germany and France, anti-shale coalitions have blocked shale development, arguing that the economic benefits are not large enough to justify costs to local communities and the global climate.

The second lesson that Gamper-Rabindran draws is that a key issue

remains unresolved in countries pursuing shale development: how to balance the interests of local communities, which bear the brunt of costs from shale development (despite their receipt of some benefits such as jobs), with the interests of the larger society, which can enjoy benefits from shale development. Across countries, local communities have limited access to the decision-making process, limited information on shale operations and impacts, and limited ability to press for greater protections and compensation. Such is the reality even in the United States and the United Kingdom, where local communities enjoy a number of political and legal rights. The chapter recommends several practical measures so that countries can improve their decision-making processes on whether and how to undertake shale development, thereby enabling a more reasoned decision—be it for or against shale development—to be reached.

The final section of the chapter recommends practical steps that would help to mitigate adverse effects on local communities. These steps include providing more information to local communities about risks and compensation, introducing more effective regulations and enforcement, creating more transparency in the operations of the industry and government regulatory agencies, delivering promised investments to local communities, and, ultimately, giving local communities the choice of whether or not to pursue shale development, given their perception of costs versus benefits.

ABOUT THIS BOOK

All of the contributors to this book are researchers who are engaged in national-level reviews and regional-level discussions of the potential benefits and risks of domestic shale development. Our in-country experience and engagement in both the shale and the broader energy debates anchor our analyses in the context of countries' energy, economic, and environmental challenges. That is not to say that we all share the same views on the wisdom or otherwise of shale development; we do not. But we do share a commitment to be as evenhanded, objective, and dispassionate as possible; to present relevant and reliable facts and figures rather than to perpetuate misconceptions and cherry-pick data; to point out where those facts and figures are unreliable, unproved, or incomplete; and to subject the arguments of various players in the national debates to equal scrutiny.

Jim Skea, at Imperial College, London, is a member of the United Kingdom's Climate Change Committee, which has a legal responsibility to report on how shale gas exploitation would affect the country's climate change targets. Miranda Schreurs, at the Technische Universität München, serves on the German Advisory Council on the Environment, which published its statement on the role of shale development in the broader energy and envi-

ronmental context. Patrice Geoffron, at Université Paris-Dauphine, has been engaged in the debates on France's energy transition law, which was adopted by the National Assembly in July 2015. Michael LaBelle, at the Central European University, authored a report for the European Parliament on public debates on shale in Poland and Bulgaria. Alvin Lin, at the Natural Resources Defense Council's Beijing office, has been working with China's Ministry of Environmental Protection on identifying regulatory gaps. María Florencia Saulino, at the Universidad de San Andrés in Buenos Aires, has been engaged with legislators and environmental lawyers in Argentina addressing regulatory gaps in shale development. Barry Morkel and Maarten de Wit, at Nelson Mandela Metropolitan University, are undertaking baseline monitoring in the Karoo region in South Africa and have contributed to the Academy of Science of South Africa's study on the technical capacity of South Africa to undertake shale development. As for myself, I am at the University of Pittsburgh. I participated in the shale workshop in Chengdu, China, organized by Sichuan University and Natural Resources Defense Council, and in the US-UK workshop on Improving Understanding of Potential Environmental Impacts Associated with Unconventional Hydrocarbons, organized by the US National Science Foundation and UK National Environment Resource Council.

Remarkably, until the publication of this book, and despite the enormous interest in cross-country comparisons of shale development evidenced by numerous international conferences on shale development, researchers had not applied a common analytical framework that would facilitate understanding of the variation in the decisions and decision-making processes across countries. Conference proceedings and edited books—such as the special issue of the journal *Oil and Gas Energy Law* (vol. 3, 2014); the special issue of the journal *Energy Research and Social Science* (vol. 20, 2016); Yongsheng Wang and William Hefley's edited book *The Global Impact of Unconventional Shale Gas Development: Economics, Policy and Interdependence* (Springer, 2016); and Quentin Grafton, Ian Cronshaw, and Michal Moore's edited volume *Risks, Rewards and Regulation of Unconventional Gas: A Global Perspective* (Cambridge University Press, 2017)—typically feature compilations of independent papers that are driven by authors' individual foci. Such publications can thus offer rich variety and detail, but they thus miss the opportunity to conduct a comprehensive and interdisciplinary comparative study.

Despite its strengths, Wang and Hefley's volume misses the opportunity to bring together voices of in-country experts who can contribute insights from their participation in the shale and the broader energy and environmental debates and policy making. Grafton, Cronshaw, and Moore's volume, which focuses on regulations, examines only countries that have pursued shale

development and does not, therefore, delve into the question of why other countries have chosen to eschew shale development.

Shale development and the debates it engenders are dynamic affairs; the shale landscape changes continually. One of the major changes in that landscape occurred in mid-2015, when the US shale industry went into a downturn. Earlier publications could not, of course, reflect on this change in the shale industry's fortunes, but fortunately this volume covers the industry up until early 2017 and thus can reflect on the specific and wider implications of the downturn. Examining both the boom and the bust phases of shale development is critical to understanding the industry's overall balance sheet of economic benefits and costs, including the challenges for local governments and companies in the shale and complementary industries of navigating the cyclical nature of the industry and the consequences for workers and local communities of failing to do so.

This book also captures influential changes in other countries since mid-2015. China and Argentina have achieved commercial levels of production and have announced new joint ventures with multinational oil and gas companies that could boost their production levels. However, reports have emerged about major pollution incidents and land conflicts between local communities and shale companies. In South Africa, the government announced that shale exploration will commence in 2017. However, the strategic environmental assessment report warns of the lack of infrastructure and administrative capacity to mitigate adverse impacts from shale development, boosting the antishale position of NGOs and Karoo landowners. In the United Kingdom, the North Yorkshire county council approved for the first time planning permission for a shale company, thus paving the way for shale exploration. However, the UK Climate Change Committee reported that shale development, without achieving three difficult-to-meet conditions, would cause the United Kingdom to exceed its legally binding carbon budgets. NGOs, citing this report, have doubled down on their opposition to shale.

Other comparative analyses have been centered on narrower aspects of shale development. The International Energy Agency's *Golden Age of Gas* (2011) focuses on estimates of shale gas worldwide, and its *Golden Rules for a Golden Age of Gas* (2012) zeroed in on policies necessary to address potential environmental and social impacts from development. The World Resources Institute's *Global Shale Gas Development: Water Availability & Business Risks* (2014) examines water risks posed by shale development across shale basins worldwide. Michael Stephenson's *Shale Gas and Fracking: The Science behind the Controversy* (Elsevier, 2015) is valuable insofar as it provides a detailed account of the scientific arguments on the potential environmental benefits and risks of shale development. Our book reports on the scientific findings as

of early 2017, updating the reader on the rapidly evolving state of the science and analyzing policy responses to scientific findings.

This book is aimed at two audiences. The first is made up of policy makers, regulators, NGO staffers, and academics (from both the developed and the emerging economies) who are wrestling with the design of policies under which shale development might proceed. The second consists of members of the general public who are interested in, and may be actively participating in, the shale debate. Some may be focused on the debate within their country, but others may seek an international perspective, conscious that each country's decision on shale development can affect the economy and environment not only of the host country. Additionally, large-scale shale gas production across countries (whether it would occur remains a topic of debate and is explored in this book) can affect the economy and environment of regions and the world as a whole through its impact on regional gas and other energy markets and through its emissions of GHGs and its displacement of other energy sources.

The analyses in this volume assist readers in navigating the shale debate. The shale debate has become polarized, with one side arguing that shale development is crucial for energy security, economic development, and climate protection, and the other side contending that shale development negates these goals. This book offers an evenhanded review of these arguments, counter-arguments, and caveats. Our assessment of the decision-making process provides insights on how to improve that process so that competing sides of the debate can be considered and weighed to arrive at a reasoned course of action. Armed with information, some countries may choose to pursue shale development and accordingly undertake effective planning and regulations to mitigate potential economic, environmental, and social costs and to provide fair compensation for local communities that bear the brunt of the costs of shale development. Other countries may opt not to pursue shale development because of their collective judgment that costs outweigh benefits and that alternative strategies, such as renewables-led economic development, can better meet their goals of energy security, economic development, and climate protection.

A NOTE ON PROVENANCE, METHODOLOGY, AND TERMINOLOGY

This book project emerged in part from observations in southwestern Pennsylvania, the home of the University of Pittsburgh. This region has served as a microcosm of the competing visions of economic, energy, and environmental policies as reflected in the worldwide shale debate. This region, with its long history of oil and gas production, has seen the rapid development of the shale industry in the Marcellus Shale. The Pittsburgh region has transformed

itself from a heavily polluted rust-belt city to a tech city with high scores on green livability, hosting a growing sector in R&D in green technologies. A few miles outside of Pittsburgh, several farming areas have been economically rejuvenated, thanks to incomes from the leasing of gas rights. However, other communities are facing economic contraction from the rapid decline in shale production. Several communities have voiced fear and anger in the face of traffic, noise, and pollution incidents caused by the shale industry (Amico et al. 2015; Hurdle and Phillips 2017).

Given the ever-present energy-environment-economic dilemma in Pittsburgh and worldwide, the need to understand the difficult issues raised, and the urgency to craft policy responses, I, the editor, organized the first University of Pittsburgh Environment and Energy Conference (the “Pitt conference”) in March 2014. Experts from the University of Pittsburgh and academics and policy makers from the United States and Europe examined US and European energy policies, including issues pertaining to domestic shale development. I am grateful to Miranda Schreurs and Jim Skea, presenters at this conference, for their early support of this book project. After the conference, I reached out to researchers working on the issue of shale development in France, Poland, China, Argentina, and South Africa. Together, we agreed on a common analytical framework that allowed us to capture the common threads across countries and yet highlight the unique aspects of our study countries. We met in March 2015 at the second Pitt conference to present our research. Our book workshop, following the conference, helped us solidify the lessons learned from this comparative study. We continued working on this volume, taking into account events that unfolded until early 2017 in our analyses.

In our research for the chapters in this volume, the authors and I used several sources of information. On the politics and economics of shale development, we drew on peer-reviewed research, reports by international organizations such as the Energy Information Administration (EIA), reports written for national governments and regional organizations, reports in the news media, and conversations with various actors in the shale debate. In using these sources, we have been careful to distinguish between facts and perception. We have also highlighted the uncertainties in these reports. For example, the EIA reports provide estimates of technically recoverable reserves, but we noted in our analyses that such figures suffer from uncertainties, even in countries with extensive production.

For the scientific assessment of risks, we have turned to reviews by national scientific panels and peer-reviewed research studies. The deliberations by scientists on these panels and the peer-review process ensure that the scientific knowledge presented is as reliable as possible and that known short-

comings in data and analyses are acknowledged. On the legal framework regulating shale in each country, we have read the relevant laws or draft laws and consulted legislative reviews. We have also examined ongoing research and reports by environmental organizations that are well regarded for their expertise in science, law, political science, and economics.

When examining countries with commercial shale production, we have consulted reports on pollution incidents. For the United States, this information is based on peer-reviewed research and government reports on pollution impacts from shale development. For Argentina and China, where such sources on pollution information are harder to find and access, we have relied on reports written by well-respected media organizations and NGOs. In these two countries, where transparency and accountability for pollution incidents are limited, NGOs play an important role in spotlighting pollution incidents and, therefore, providing valuable information to the public. Government agencies are constrained by scarce resources to keep track of these incidents and by political considerations to publicize these incidents (Bercovich and Rebossio 2015).

A final note should be made regarding terminology, which has to some extent become a casualty of the polarized nature of the shale debate. When we refer to “environmental risks” from the shale industry, we follow the approach of national scientific review panels, which is to consider risks from the entire life cycle of shale development (US National Research Council 2014; Council of Canadian Academies 2014). These risks are involved in site preparation, drilling (including, but not exclusively, the HVHF stage), production, transportation of gas, and the management and disposal of waste products. Members of the public, who commonly use the term “fracking,” refer to the range of activities in the life cycle of shale development; similarly, the “antifracking” protests focus on these same activities. We do not take the narrower approach of some members of industry, who focus their discussion of risks on the one stage of hydraulic fracturing within the drilling process.

NOTES

1. Even though shale development also includes tight oil production, particularly in the United States and Argentina, this book focuses primarily on shale gas for two reasons. First, unlike other fossil fuels, shale gas promises environmental benefits, such as protecting the climate and improving air quality. Second, the economics of natural gas and oil are distinct. Natural gas markets are segmented regionally, in contrast to the global nature of crude oil markets (Bradshaw, Dutton, and Bridge 2015).

2. Expressed in cubic feet, this production grew from 4.27 billion cubic feet per day (bcf/d) in January 2007 to 45.78 bcf/d through April 2016.

3. As noted by Jackson et al. (2014), Moore et al. (2014), the Health Effects Institute (2015), and Neville et al. (2017), current technology—that is, a combination of HVHF and horizontal drilling to release gas from shale rocks—is significantly different from hydraulic fracturing technology applied in the past in the conventional oil and gas industry. In particular, this technology requires greater volumes of water applied under greater pressure and often requires directional or horizontal drilling. Subjecting wells to greater injection pressure can affect the well integrity, and the greater amounts of water required for hydraulic fracturing can place significant demands on local water resources. The faster decline of production in wells creates a more rapid dynamic of well abandonment and new drilling of wells, contributing to economic boom-and-bust cycles in local communities.

REFERENCES

- Amico, Chris, Danny DeBelius, Scott Detrow, and Matt Stiles. March 2015. "Natural Gas Drilling in Pennsylvania: Violations." *StateImpact Pennsylvania*. <http://stateimpact.npr.org/pennsylvania/drilling/violations/>.
- Andrews-Speed, Philip. 2014. "OGEL Special: Governance of Unconventional Gas outside the United States of America." Special issue, *Oil, Gas and Energy Law* 3.
- Argentina Secretaria de Energia. 2015. *Balance Energético Nacional 'Año 2014 Revisión'—Provisorio*. Buenos Aires: Secretaria de Energia.
- Baily, Martin Neil, and Barry P. Bosworth. 2014. "US Manufacturing: Understanding Its Past and Its Potential Future." *Journal of Economic Perspectives* 28(1): 3–26.
- Bercovich, Alejandro, and Alejandro Rebossio. 2015. *Vaca Muerta. El Sueño de un Boom Petrolero Argentino*. Buenos Aires: Planeta.
- Bradshaw, Michael, Joseph Dutton, and Gavin Bridge. 2015. "The Geopolitical Economy of a Globalizing Gas Market." In *Global Energy: Issues, Potentials and Policy Implications*. Edited by Paul Ekins, Michael Bradshaw, and Jim Watson. Oxford: Oxford University Press.
- Centner, Terence J., ed. 2016. "Risks, the Social Sciences, and Unconventional Hydrocarbons." *Energy Research & Social Science* 20: 1–178.
- Council of Canadian Academies. 2014. *Environmental Impacts of Shale Gas Extraction in Canada. Ottawa: The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction*. Ottawa: Council of Canadian Academies.
- Grafton, R. Quentin, Ian G. Cronshaw, Michal C. Moore, eds. 2017. *Risks, Rewards and Regulation of Unconventional Gas: A Global Perspective*, Cambridge: Cambridge University Press.
- Hausman, Catherine, and Ryan Kellogg. 2015. "Welfare and Distributional Implications of Shale Gas." N.B.E.R. Working Paper No. 21115. Cambridge, MA: National Bureau of Economic Research.

- Health Effects Institute. 2015. *Strategic Research Agenda on the Potential Impacts of 21st Century Oil and Natural Gas Development in the Appalachian Region and Beyond. Special Scientific Committee on Unconventional Oil and Gas Development in the Appalachian Basin*. Boston: Health Effects Institute.
- Hurdle, John, and Susan Phillips. 2017. "Data Trove Offers New Details on Complaints to DEP during Shale Boom." *StateImpact Pennsylvania*, January 31. <https://stateimpact.npr.org/pennsylvania/2017/01/31/data-trove-offers-new-details-on-complaints-to-dep-during-shale-boom/>.
- International Energy Agency. 2011. *Golden Age of Gas*. Paris: International Energy Agency.
- International Energy Agency. 2012. *Golden Rules for a Golden Age of Gas*. Paris: International Energy Agency.
- Jackson, Robert B., Avner Vengosh, William Carey, Richard J. Davies, Thomas H. Darrah, Francis O'Sullivan, and Gabrielle Petron. 2014. "The Environmental Costs and Benefits of Fracking." *Annual Review of Environment and Resources* 39: 327–62.
- Meadow, Stephanie, James Saiers, James Thompson. 2013. "Shale Related Litigation and Regulatory Developments: The Future of Hydraulic Fracturing Litigation," April 24–26. American Bar Association Section of Litigation Annual Conference, Chicago.
- Moore, Christopher W., Barbara Zielinska, Gabrielle Pétron, and Robert B. Jackson. 2014. "Air Impacts of Increased Natural Gas Acquisition, Processing, and Use: A Critical Review." *Environmental Science and Technology* 48(15): 8349–59.
- National Research Council, Division on Engineering and Physical Sciences, Committee on Risk Perception and Communication 1989. *Improving Risk Communication*. Washington, DC: The National Academies Press.
- National Research Council, Division of Behavioral and Social Sciences and Education, Committee on the Human Dimensions of Environmental Change. 2008. In *Public Participation in Environmental Assessment and Decision Making*. Edited by Thomas Dietz and Paul C. Stern. Washington, DC: The National Academies Press.
- National Research Council, Division of Behavioral and Social Sciences and Education, Board on Environmental Change and Society, and Paul C. Stern, Rapporteur. 2014. *Risks and Risk Governance in Shale Gas Development: Summary of Two Workshops*. Washington, DC: The National Academies Press.
- Neville, Kate J., Jennifer Baka, Shanti Gamper-Rabindran, Karen Bakker, Stefan Andreasson, Avner Vengosh, Alvin Lin, Jewellord Nem Singh, and Erika Weinthal. 2017. "Debating Unconventional Energy: Social, Political and Economic Implications." *Annual Review of Environment and Resources* 42.
- Nicot, Jean-Philippe, and Bridget R. Scanlon. 2012. "Water Use for Shale-Gas Production in Texas, U.S." *Environmental Science and Technology* 46(6): 3580–86.

- Stephenson, Michael. 2015. *Shale Gas and Fracking: The Science behind the Controversy*. Amsterdam: Elsevier.
- Stillman, Amy. 2014. "Economic and Practical Obstacles Limit Mexico's Shale Ambitions." *Financial Times*, November 12. <https://www.ft.com/content/2ac592a0-586c-11e4-a31b-00144feab7de>.
- UK Department of Environment Climate Change. April 2016. *Public Attitudes Tracker—Wave 17. Summary of Key Findings*. London: UK Department of Environment Climate Change.
- US Energy Information Administration. 2012. *Annual Energy Outlook 2012*. Washington, DC: US Energy Information Administration. [http://www.eia.gov/forecasts/aeo/pdf/0383\(2012\).pdf](http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf).
- US Energy Information Administration. 2017a. *Natural Gas Weekly Update*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/naturalgas/weekly/>.
- US Energy Information Administration. 2017b. *Monthly Energy Review: July 2017*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/totalenergy/data/monthly/archive/00351707.pdf>.
- US Energy Information Administration. 2017c. "United States Expected to Become a Net Exporter of Natural Gas This Year." *Today in Energy*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/todayinenergy/detail.php?id=32412>.
- US Energy Information Administration. 2017d. *Henry Hub Natural Gas Spot Price*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/dnav/ng/hist/rngwhhdM.htm>.
- US Energy Information Administration. 2017e. *Electric Power Monthly: February 2017*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/electricity/monthly/pdf/epm.pdf>.
- US Energy Information Administration and Advanced Resources International. 2013. *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*. Washington, DC: US Energy Information Administration. https://www.eia.gov/analysis/studies/worldshalegas/archive/2013/pdf/fullreport_2013.pdf.
- US Energy Information Administration and Advanced Resources International. 2015. *World Shale Resource Assessments*. Washington, DC: US Energy Information Administration. <https://www.eia.gov/analysis/studies/worldshalegas/>.
- Vengosh, Avner, Robert B. Jackson, Nathaniel Warner, Thomas H. Darrach, and Andrew Kondash. 2014. "A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States." *Environmental Science & Technology* 48 (15): 8334–48.
- Wait, Requier, and Riaan Rossouw. 2014. "The Economic Benefits of Shale Gas Extraction in the Southern Karoo." *Southern African Business Review* 18(2): 1–34.

- Ward, Sharon, Diana Polson, and Mark Price. 2014. "Measuring the Costs and Benefits of Natural Gas Development in Tioga County, Pennsylvania: A Case Study." Harrisburg, PA: Pennsylvania Budget and Policy Center.
- Wiseman, Hannah J. 2016. "Disaggregating Preemption in Energy Law." *Harvard Environmental Law Review* 40: 293–347.