MAY 2018

Workshop HIGHLIGHTS

Onshore Unconventional Hydrocarbon Development:

Legacy Issues and Innovations in Managing Risk

The oil and gas industry has been transformed in recent years by the development of new technologies that allow access to shale oil and shale gas. The subsequent rapid expansion of oil and gas infrastructure has sparked public concern over potential impacts to surface- and groundwater, air, and land where the resources are extracted. At a December 2016 workshop, representatives of federal and state government, industry, non-governmental organizations, and academia gathered at the National Academies of Sciences, Engineering, and Medicine to discuss opportunities and challenges to ensure the successful management of oil and gas fields throughout their lifecycle—from initial development through decommissioning and reclamation—in ways that minimize risk to the environment.

Over the past decade, the development of oil and gas extraction technologies, such as combining horizontal drilling with hydraulic fracturing to stimulate the flow of oil or gas to the well bore, has allowed new access to shale oil and shale gas (Figure 1). Since 2005, the extraction of these types of so-called "unconventional" hydrocarbons has helped the United States reduce crude oil imports by more than 50 percent and become a net natural gas exporter.

The boom in unconventional hydrocarbon development has brought jobs, infrastructure, and population growth in the communities where the resources are located. However, the rapid expansion of the infrastructure associated with oil and gas extraction has also sparked public concern about the long-term environmental impacts that may result. These concerns fall into one of three main categories:

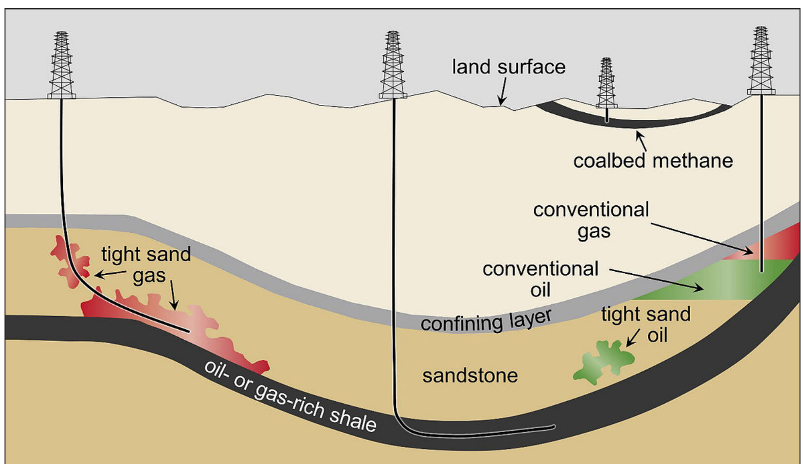

Figure 1. This figure shows oil and gas development via a vertical well on the far right (so-called "conventional" well), and several wells producing from other types of oil and gas formations: a vertical coalbed methane well (second from right); a horizontal well producing from a shale formation (center); and a well producing from a tight sand formation (left). The latter two rock types—tight sand and shale—have low permeability which hinders the flow of oil or gas to the wellbore. Horizontal or directional drilling, together with hydraulic fracturing, is a technology which injects a mixture of water and specific chemicals to generate additional fractures in the rock to increase its permeability and improve the flow of oil and gas to the wellbore. Source: EPA, 2015; presented by Kyle Murray of Oklahoma State University.

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Figure 2. A drilling rig operation for a shale formation in Texas shows the extent and scale of some of the infrastructure. CREDIT: Shuttershock via Photographer: Jeffrey M. Phillips.

Contamination of Groundwater, Land, and Surface Waters. Because the water brought to the surface during oil and gas extraction (produced water) can contain contaminants such as salt, oil and grease, and chemicals that have leached out of the surrounding rock or were introduced during drilling, leaks or spills of such waters raise public concern regarding potential risks to underground drinking water supplies and the surface environment. At present, most produced water is managed by underground injection for permanent disposal into rock formations that lie below drinking water aquifers. However, produced water managed in this way also has to be collected and transported prior to disposal, which can elevate the risk of accidental surface spills. The prevention of underground leaks of fluids from active or abandoned oil or gas wells into the surrounding rock formation or aquifers is also a focus of well operators, regulators, researchers, and the public.

Surface Disturbances. The development of the infrastructure for oil and gas fields may include new roads and increased truck and heavy equipment traffic as well as disturbance of landscapes to establish the well pad and other infrastructure (Figure 2). Concerns about these issues may be particularly evident in areas where such development has not previously taken place or where it occurs close to population centers.

Methane Leaks. Unconventional hydrocarbon development has yielded a plentiful supply of natural gas that is cheaper than coal, and is also considered to be cleaner than coal from a climate perspective, because when burned, natural gas emits less carbon dioxide than coal does. In 2016, natural gas surpassed coal in the mix of fuels used for power generation in the United States. However, natural gas is made up mostly of methane, which is itself a greenhouse gas 25 times more potent than carbon dioxide. Methane can leak from pipelines during gas extraction, from gas storage tanks, or from plugged and abandoned gas wells.

Unconventional oil and gas production will likely remain an important part of the U.S. energy economy for many years to come. Exploring ways to minimize environmental impacts like these is thus important to mitigate the potential for leaving negative environmental legacies in the regions where such development is taking place.

MANAGING OIL AND GAS DEVELOPMENT TO AVOID NEGATIVE ENVIRONMENTAL IMPACTS

Several workshop participants noted that technologies exist to help mitigate many of the environmental risks related to oil and gas production. For example, constructing the well from steel pipes that are cemented in place—a practice known as casing—helps prevent the geological formation surrounding the pipe from collapsing into the bore hole, and prevents the leakage of oil, gas, or produced water from the well into the surrounding rock formation.

Participants noted the importance of emphasizing science-, engineering- and data-driven operational decisions at the well sites that minimize environmental risks. Because unconventional well pads are larger in surface area than conventional well pads due to the hydraulic fracturing equipment that is placed on the site, operators can choose to drill multiple wells from one well pad, which is less disruptive to the landscape. Further, one presentation at the workshop highlighted a GIS-based tool developed by The Nature Conservancy to help operators plan and site well pads, roads, and pipelines to minimize impacts on land, water, and wildlife.

Natural gas leaks can occur at every stage of the production process, from the well to the pipeline to the infrastructure that carries the gas into homes. However, the data gathered so far indicate that emissions from wells are a small portion of the estimated annual emissions from upstream natural gas production. Taking better measurements of methane emissions could help control emissions further—for example, by instrumenting wells with new nanotechnology devices to detect methane. Another new use of technology that could help with natural gas leaks is fiber optics to look at fluid flow in the well casing and to monitor well integrity.

Factors such as the location of the oil or gas field, the geologic formation from which the water was produced, and the type of product being extracted can all influence the environmental impacts a well may have. Assessments of the unconventional resource plays across the United States that gather data on the types of resources in place, the portion of the resource that is technically recoverable, and the long-term production outlook will be important in considering legacy impacts from resource development. Collecting data on well integrity, gas leaks, surface emissions, pipeline integrity, and the chemistry and toxicity of wastewater will also help better understand risks and ways to manage them.

INVENTORIES AND MANAGEMENT OF INACTIVE WELLS

Although the hydraulic fracturing boom has brought economic growth in the communities where the resources are located, there are concerns about how communities that have come to rely on the income from oil and gas production will manage abandoned wells and efforts to reclaim landscapes when the wells are no longer productive or oil or gas prices fall.

After oil and gas production has ceased, properly decommissioning wells by plugging the well and dismantling surface well infrastructure is important to reduce the potential for leaks of methane to the air or for contamination of groundwater. However, this can be a time-consuming and costly procedure, and many wells are abandoned without proper decommissioning, several participants said. In some cases, operators want the flexibility to cease production when there is a drop in oil prices or a problem with equipment, and to resume production when conditions improve. In other cases, companies may be reluctant to permanently abandon wells because of the expense of decommissioning. A study cited at the workshop found that 46 percent of Louisiana wells were in a temporarily abandoned status for 10 years or more. A 2014 study that was also cited found methane emissions from inactive wells in Pennsylvania constituted about four to seven percent of the state's human-caused greenhouse gas emissions. However, data on the number of inactive wells in the United States are scarce, and understanding the scale of the problem will require better data on the status of these wells.

Several presentations and discussions noted that in the future there will be tens to hundreds of thousands of new wells but no coherent funding mechanism for reclamation and cleanup at well sites. States require oil and gas companies to obtain bonds to ensure that their wells are properly decommissioned at the end of their usable lives. A recurring theme during the workshop was the fact that this financial bonding can be inadequate to fund reclamation efforts. Because drilling a well carries an inherent financial risk, bonding requirements must be sufficiently reasonable for oil and gas companies to be able to carry that risk. However, in some cases where well owners have gone bankrupt, bonding requirements may not have been high enough to cover the decommissioning costs, with the cost of decommissioning the well then left to the state.

Several states have established legacy funds that require operators to put aside money for well site cleanup. North Dakota puts a portion of its oil and gas revenues and penalties incurred by the industry into a legacy fund to help mitigate negative environmental impacts in the state. On an annual basis, the state selects five to ten sites and cleans them up using the legacy fund.

After oil and gas operations have ceased, surface restoration efforts help replace soil and vegetation at well sites in order to restore ecosystems and natural habitats. One workshop presentation highlighted an example of restoration in a sagebrush grassland in Wyoming, where restoration work is particularly difficult because the landscape was previously undisturbed. That means operators are attempting to restore native plant communities, a more challenging task than simply revegetating cropland. Further, Wyoming has a stressful environment for plants, with a semiarid climate, salty arid soils, and invasive species. Collecting data on restoration methods, environmental conditions, and restoration progress is important to build a database of best management practices. This view was echoed later in the workshop, when a workshop discussion highlighted the need for ongoing monitoring of decommissioned wells to ensure they don't begin to leak. These data should be stored in accessible repositories, participants noted. Workshop participants also emphasized the importance of communication among state and federal regulators, the research community, industry, and non-governmental organizations to share data and best practices to help manage risks to the environment.

PLANNING COMMITTEE FOR THE WORKSHOP ON ONSHORE UNCONVENTIONAL HYDROCARBON DEVELOPMENT: LEGACY ISSUES AND INNOVATIONS IN MANAGING RISK: Brian J. Anderson (*Co-Chair*), West Virginia University; **Julia Hobson Haggerty** (*Co-Chair*), Montana State University; **Melissa Batum**, Bureau of Ocean Energy Management, Department of the Interior; **Susan L. Brantley** (NAS), The Pennsylvania State University; **Jeffrey J. Daniels**, The Ohio State University; **Paul Doucette**, Baker Hughes, a GE Company; **David Glatt**, North Dakota Department of Health and Environmental Council of the States' Shale Gas Caucus; **Steven P. Hamburg**, Environmental Defense Fund; **Joe Lima**, Schlumberger Services, Inc.; **Jan Mares**, Resources for the Future; **Kris J. Nygaard**, ExxonMobil Upstream Research Co.; **Amy Pickle**, Duke University; **Elizabeth A. Eide** (*Senior Board Director*), **Ed J. Dunne** (*Program Officer; up to June 16, 2017*), **Nicholas D. Rogers** (*Financial and Research Associate*), **Yasmin Romitti** (*Research Associate*), **Courtney R. DeVane** (*Administrative Coordinator*), **Eric J. Edkin** (*Senior Program Assistant*), **Raymond Chappetta** (*Senior Program Assistant*), National Academies of Sciences, Engineering, and Medicine

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ABOUT THE ROUNDTABLE ON UNCONVENTIONAL HYDROCARBON DEVELOPMENT
Launched in 2015, the Roundtable provides a neutral forum where representatives from government, industry, academies, and nongovernmental and international organizations can critically examine the facts about the scientific, engineering, health and safety, regulatory, economic, and societal aspects of unconventional hydrocarbon development.

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For more information, contact the Board on Earth Sciences and Resources at 202-334-2744 or visit http://www.nationalacademies.org/besr. *Onshore Unconventional Hydrocarbon Development: Legacy Issues and Innovations in Managing Risk – Day 1: Proceedings of a Workshop* can be purchased or downloaded from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; (800) 624-6242; http://www.nap.edu.

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