The Science and Technology of Hydraulic Fracturing
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Hydraulic fracturing, or fracking, is a method of oil and natural gas extraction involving injection of a fluid under high pressures in order to crack the rock formation containing the hydrocarbon. The composition of the fluid varies with the type of formation being fractured, but generally consists of mostly (90-98 percent) water, a “proppant” such as sand to keep the fractures open, and a small percentage of chemical additives.

Hydraulic fracturing was invented in the 1940s and is now used in more than 90 percent of U.S. drilling operations. Until recently, the technology has not been the focus of public concern. However, the widespread adoption of horizontal drilling technology, coupled with hydraulic fracturing for both oil and natural gas production, has broadened the scale and geographical scope of hydraulic fracturing significantly and aroused concern about the technology’s environmental impact.

Horizontal drilling and hydraulic fracturing have had a significant impact on natural gas and oil production in the United States. As the technologies are adopted worldwide, they will exert a major influence on energy economics. Already, the dramatically increased supply of natural gas and concomitant global reduction in natural gas prices have resulted in natural gas replacing coal in almost all new U.S. electricity generation. As a result, U.S. greenhouse gas (GHG) emissions from burning fossil fuels have been reduced to levels not seen since the mid-1990s.

The increased supply and reduced cost of crude oil and natural gas have also had a major impact on chemical production in the United States. Propagation of this resource through the chemical manufacturing supply chain may provide new opportunities for innovation leading to improved product portfolio and lifecycle impacts.

The U.S. Environmental Protection Agency (EPA) is the federal agency responsible for underground injection of liquids from hydraulic fracturing in oil or natural gas production. By statute, EPA has delegated its authority to regulate to qualified state agencies. Over the past several years nearly every oil and gas producing state (except New York) enacted legislation regulating specific aspects of hydraulic fracturing. The Department of the Interior (DOI) issued a final rule on March 20, 2015, that regulates oil and gas activities, including hydraulic fracturing on public and tribal lands. The implementation of this final rule has been stayed pending the outcome of related information. While hydraulic fracturing is a well-understood part of hydrocarbon fluid production technology with a long and successful history, its use in areas of high population density has raised significant questions of human and environmental impact. The potential development of production wells in areas of high population states, such as Pennsylvania and New York, has resulted in disharmony. The ACS urges increased communication among all of the parties to balance the concerns of the affected populations with the long-term economic and energy needs of the nation.
The use of large quantities of water in hydraulic fracturing raises questions of conservation and sustainability. “Flowback” and formation water produced after hydraulic fracturing may be stored in tanks or open pits (usually lined) before being disposed of by deep well injection, treated in a waste treatment facility, or recycled for use in future oil field operations. The water may contain naturally occurring radioactive elements such as radium, radon, and strontium, high salinity and small amounts of chemical additives from the original hydraulic fracturing fluid. Recovered water management practices for re-use in subsequent hydraulic fracturing operations operate under regulatory guidelines, including those related to the health and safety of workers, the environmental management of chemical constituents removed to render the water suitable for re-use, as well as the transfer and storage of the treated water intended to be used for the next frack. Sustainable hydraulic fracturing operations are coming to depend upon treated recycled water as a way to mitigate fresh water consumption, particularly in drought-stricken areas. Whereas the combustion of natural gas is known to yield less carbon dioxide (CO$_2$) per kilojoule of energy produced than the burning of coal, the environmental picture for the use of natural gas is not well established. A full life-cycle analysis that takes into account activity beyond combustion should be considered in assessing its true environmental impacts. For example, methane emissions from natural gas production and transportation facilities, if not responsibly managed, may be high enough to be significant. EPA recently enacted comprehensive methane emissions standards for all wells drilled in the U.S., which include environmental impacts associated with emissions from drilling equipment at the well head, as well as spills at the well site.

Concerns have been raised that recent increases in seismic activity are related to hydraulic fracturing. Both drilling and deep injection disposal wells have been implicated. Similar wells are used extensively in many industrial, government and military applications including agriculture, chemical manufacturing, and petroleum production. Detailed scientific study evaluating the relationship between drilling, injection well disposal, and induced seismicity would be extremely helpful in determining if there is a cause and effect.

The complex chemical mixtures used during hydraulic fracturing and hydrocarbon production have raised questions in many communities. The ACS urges the hydrocarbon production industry to disclose the chemicals used during hydraulic fracturing and production, as long as protections are provided to safeguard key intellectual property and confidential business information or trade secrets. The ACS further urges the companies to work cooperatively with communities to explain the hazards and risks and to jointly develop risk reduction and emergency response programs.

DOI regulations address some of these concerns on public and tribal lands. The regulations assist in protecting groundwater by monitoring well construction such that wells are properly constructed besides promoting the use of best practices so that fracking fluids are managed in an environmentally sound manner. It also improves public awareness of the chemicals used and the surrounding geological conditions, aligns state and tribal authorities with respect to water zone protection, and provides opportunities for state and tribal cooperation on well regulation.

**Recommendations**

The American Chemical Society (ACS) recognizes that hydraulic fracturing is, and will remain, a significant element in the U.S. energy production landscape. ACS and industry partners are working to address this challenge and others by applying green chemistry principles and practices to hydrocarbon development. It is important that research continues to ensure that hydraulic fracturing is carried out in a responsible fashion and that the public is made confident that any risks to the environment or their health and safety are being properly managed. To
this end, ACS recommends the following research initiatives and possible regulatory actions on hydraulic fracturing:

1. Hydraulic fracturing is a process through which oil and natural gas can be extracted from tight geological formations. As such, any analysis of the impacts of the extraction process should be conducted from a life-cycle perspective, including considerations of the geologic, hydrologic, and seismic characteristics of the area where drilling is being contemplated. It is inappropriate to consider the extraction process in isolation. ACS supports continued analyses of the uses of fossil resources obtained through hydraulic fracturing relative to alternative resources, both fossil and renewable, that could be used in their place.

2. In some locations where hydraulic fracturing has been conducted, evidence has been found that methane, ethane, and other organic gases from wells have contaminated groundwater. Research should continue to determine the extent and causes of such contamination and to develop methods to evaluate the impact of leaking wells.

3. For electricity generation, natural gas has significant environmental benefits over other hydrocarbon alternatives. Specifically, burning natural gas emits roughly half the CO₂ that burning coal emits, reduces SOₓ and NOₓ emissions, and eliminates the release of mercury. However, these emissions benefits would be greatly offset if natural gas wells or natural gas handling facilities emitted a significant amount of methane to the atmosphere. EPA estimates that, pound for pound, the comparative impact of methane on climate change is more than 30 times greater than CO₂ over a 100-year period. Research on emissions of methane from hydraulic fracturing sites should continue to establish the amount of methane being released from wells and facilities and methods to minimize such releases.

4. Hydraulic fracturing a single horizontal well can involve injection of several million gallons of hydraulic fracturing liquid. Research should be continued by EPA and others to determine whether hydraulic fracturing liquids are contaminating groundwater or have the potential to contaminate groundwater in the variety of geological formations where hydraulic fracturing is being done or may be carried out in the future. Recovery and recycling of produced water to minimize the depletion of critical fresh water sources should be considered at the state level.

5. To facilitate the responsible handling of hydraulic fracturing fluids, best management practices must continue to be developed that will reduce fresh water requirements, disposal challenges, and environmental impacts including truck traffic, site congestion, and exposure to harmful chemicals by promoting recovery and re-use of produced water for well drilling and completion applications using best practices. Guidelines that hold industry accountable and government responsible are best formulated by representatives from all stakeholders including the public, government, and the oil and natural gas service and production industry. Regulations that ensure safe disposal, treatment, or recovery and recycling, should continue to be reviewed and adopted.

6. Some portion of the injected hydraulic fracturing liquid returns to the surface with the oil and natural gas being produced. Research should continue to further characterize these returned liquids and establish safe methods for treating/disposing of them.

7. Less hazardous hydraulic fracturing fluids should continue to be explored iteratively, with their use potential characterized within a lifecycle framework.