A New Sustainability Challenge: Water Management in Unconventional Shale Oil & Gas Operations

Meeting Emerging Needs of the Water-Energy Nexus

Examination of Key Issues by The Dow Chemical Company

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Executive Summary

The economic benefits of the shale boom have been widely reported in a variety of mainstream business and trade media, including lower natural gas prices in the United States (U.S.), economic growth in oil and gas producing regions, direct and indirect job growth, and competitive advantages for U.S. manufacturing.[1]

Unconventional sources of natural gas and oil, such as shale, make previously untapped energy reserves available, and are an important resource for meeting increasing energy demands in the next several decades. These resources will help satisfy three key factors:

- **Economic growth:** In 2012, the shale energy industry created 2.1 million jobs, with an estimated 3.9 million jobs created by 2025. Likewise, shale energy contributed $284 billion to U.S. Gross Domestic Product (GDP) in 2012, which is projected to nearly double by 2025.[2]
- **Security of energy supply:** Shale gas has increased domestic gas production by 26 percent since 2007, which is expected to double by 2035. Comparably, net oil imports in the U.S. are expected to reduce by nearly 50 percent by 2020, decreasing international oil imports by $185 billion.[3]
- **Improved environmental performance by reduction of CO_2 emissions when compared to coal:** Natural gas releases less than half the amount of carbon dioxide compared to coal, and lower amounts of pollutants, such as nitrogen oxide, sulfur dioxide, and mercury.[4]

Concerns from environmental groups around the globe have also been raised and are being investigated: one of the biggest issues voiced is groundwater contamination and overuse of scarce water resources. This document will shed light on current hydraulic fracturing water issues, address policy and regulations, and frame the larger public discussion, focusing on the need to expedite the implementation of existing, cost-effective technology – especially those that help reuse and recycle flowback and produced water – to ensure safe, sustainable water management in hydraulic fracturing practices.

The hydraulic fracturing process is beneficial and can be a safe operation through environmental and product stewardship coupled with effective legislation and regulatory requirements. Government must explore the various ways to encourage and accelerate the adoption of available water treatment technologies to ensure sustainable industry practices, especially those for recycling and beneficial reuse of flowback and produced water.

In addition, it is critical for energy companies to be forthcoming and transparent with data articulating the cost versus investment of hydraulic fracturing operations so government, industry and community stakeholders can clearly see the value and benefits derived from economically and environmentally sustainable hydraulic fracturing operations.

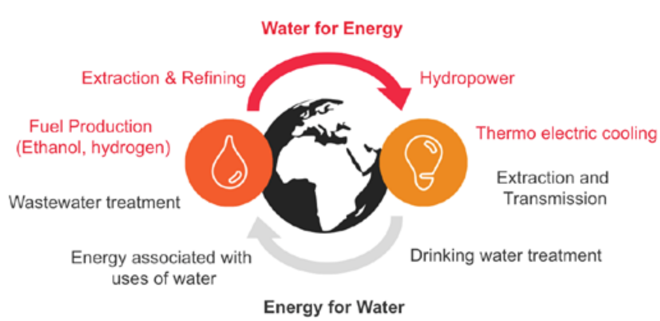
Unconventional Shale Extraction: A Growing Source of Energy

The U.S. and many other regions of the world have abundant natural resources, both tapped and untapped. Recent innovations like hydraulic fracturing – combined with horizontal drilling in shale formations – have led to a rise in unconventional oil and gas extraction, unlocking natural resources to help meet the energy needs of today and tomorrow.

Hydraulic fracturing and other unconventional techniques have doubled North American natural gas reserves to three quadrillion cubic feet — the rough equivalent of 500 billion barrels of oil or almost double Saudi Arabia's crude inventory.[5] The same techniques work for oil extraction – Oil and Gas Journal reported in April 2013 that a well that can produce 70 barrels a day using conventional drilling can yield upwards of 700 barrels through hydraulic fracturing. In fact, a new projection from the US Energy Information Agency shows that the United States will likely become the world's largest producer of petroleum products and natural gas hydrocarbons in 2013.[6]

Oil and natural gas drilling is booming in places like the Permian Basin in West Texas and the Bakken formation in North Dakota. With U.S. oil and gas production growing rapidly, a recent Citigroup report [7] indicated that in just five years the U.S. may no longer need to import oil from any source except Canada. The report also suggests that combined U.S. and Canadian oil output could be in surplus of projected needs.

Lower natural gas prices in the U.S., economic growth in gas producing regions, direct and indirect job growth and competitive advantages for U.S. manufacturing have been identified as key economic benefits of the hydraulic fracturing boom in mainstream, business and trade media. On the other hand, hydraulic fracturing and horizontal drilling also raise concerns from environmental groups around the globe. As these concerns are raised, it is important for industry to inform and engage in the conversation and ensure the accuracy of shared information.



Source: Dow Water & Process Solutions

Among the biggest hydraulic fracturing issues voiced is groundwater contamination and overuse of scarce water resources, among other concerns. Concerns such as these have been sufficient to cause several countries and three U.S. states—Vermont, New Jersey and New York—to enact bans or temporary moratoriums on hydraulic fracturing. At least three EU member states—France, the Czech Republic and Romania —have also adopted temporary moratoriums on hydraulic fracturing as well.

With 32 percent of the total estimated natural gas resources globally in shale formations and 10 percent of estimated oil resources in shale or tight formations,[8] it is imperative to understand the issues and work toward safe, sustainable water management in hydraulic fracturing so the most can be made of the abundant hydrocarbon resources available for development. The hydraulic fracturing process can be an effective and safe operation through environmental and product stewardship coupled with effective legislation and regulatory requirements that encourage and expedite the adoption of water treatment technologies and ensure sustainable industry practices.

While shale oil and gas is game-changing for the U.S. energy market and beyond, concerns around the environmental impact of the process threaten to thwart industry growth. Many of these concerns are tied to water issues, which means there is a significant opportunity for the public and other stakeholders to gain a better understanding of the process.

The water-energy nexus refers to the dynamic, connected nature of water and energy. They are inseparable; water is used to extract energy sources, and energy is required to produce useable water. The water-energy nexus can become a vicious cycle, as lack of technology, poor management or inefficiencies in use in one area can affect the sustainability of the other.

Dow believes that hydraulic fracturing can be an efficient and environmentally sound process to extract shale oil and gas, if the correct procedure is followed and the most appropriate technologies are used. One must consider the entire process, from start to finish, an environmentally-contained process where no materials are exposed to people or the environment.

Shale fracturing flowback refers to the portion of injected hydraulic fracturing fluids that return to the surface before and during initial production. The large quantities of flowback and formation water generated during the fracturing process must be treated before recycling, beneficial reuse or disposal. Typically 10 – 20 percent returns within 7 – 14 days with a rapid decline in quality and quantity.

Shale produced water typically refers to water produced during the production phase of the shale wells longer term, and has significantly lower flow rates and more consistent quality than flow back.

Below is an overview of how water is used in hydraulic fracturing operations and addresses priority concerns with the public, regulators and the oil and gas industry:

- Drinking water contamination from fracturing operations
- Overuse of fresh water resources
- Availability of technologies to properly manage water in fracturing operations
- Expense of water management
- Chemical use in hydraulic fracturing operations

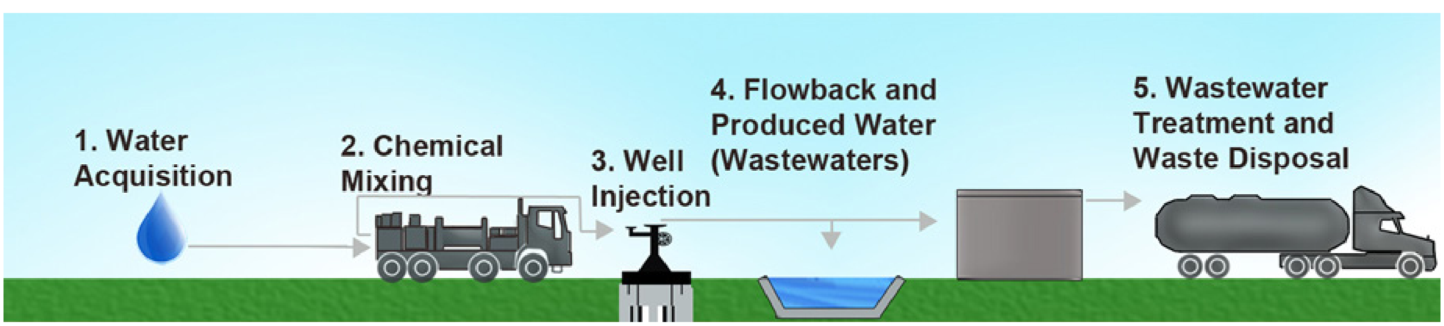
Overview: Water Use in Hydraulic Fracturing Operations

The hydraulic fracturing process can use more than 5 million gallons of water per well. A variety of organic and inorganic compounds are used in fracturing fluids to optimize formation fracture and proppant transportation. Consequently, it is of the utmost importance that the correct water quality is used during operations to ensure unwanted salts and compounds do not interfere with the performance of the fracturing fluid. Additionally, deep gas seams are often associated with hyper-saline, deep aquifers, which generate hyper-saline formation water.

Water management decisions within shale oil and gas production fall into three primary categories: water acquisition, water utilization within hydraulic fracturing operations, and the disposal of wastewater from drilling and production.

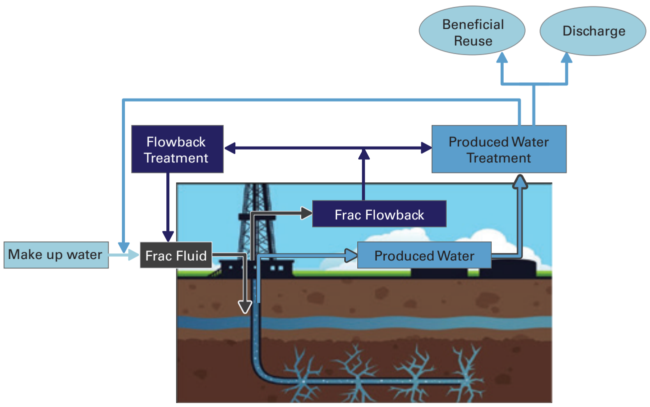
Concern #1: Water Contamination and Hydraulic Fracturing

States, local governments and shale oil and gas operators seek to manage water produced during the fracturing process in a way that protects surface and ground water resources, and eliminates the potential for contamination. According to research conducted by the Congressional Research Service in January 2013, data thus far suggests that hydraulic fracturing—particularly in deep zones—is unlikely to contaminate underground sources of drinking water.



Source: EPA

Schematic of water flow in fracing process



Source: EPA

The average depth of a horizontal shale well is more than 7,700 feet, nearly 1.5 miles below the Earth's surface and thousands of feet below fresh water formations, with thick layers of rock separating aquifers from natural gas formations.[9]

The vertical portion of a shale oil or gas well is exactly the same as any vertical well drilled into the Earth for other reasons. Like most deep vertical wells, a shale oil or gas well will likely pass through one or more underground aquifers. Current well construction requirements consist of installing multiple layers of protective steel casing surrounded by cement that are specifically designed and installed to protect freshwater aquifers and drinking water aquifers from contamination attributable to hydraulic fracturing.

After the process of hydraulic fracturing is complete and the gas reservoirs are opened, the micro-fractures in the shale rock pressurize and push a percentage of the hydraulic fracturing fluid back to the surface. This flowback water contains fracturing fluid, hydrocarbons, minerals and other substances that flowback from the deep sub-surface and must be securely contained in tanks for further treatment.

Several technologies exist today to treat flowback water. These advancements remove contaminants and enable flowback water to be recycled into the next hydraulic fracturing job without harming the water supply.

Concern #2: Amount of Water Used in Hydraulic Fracturing

The process of hydraulic fracturing requires quantities of water to be used to break up shale rock several kilometers below the surface of the Earth. However, the amount of water in the horizontal drilling process is small in comparison to other uses.

Water consumption in the fracturing process generally ranges from less than 0.1 – 0.8 percent of total water use by basin, but can seem like a large amount especially when fracturing takes place in areas that are facing drought, like Texas. Assuming 20,000 new shale gas wells are drilled each year, water demand for fracturing would require approximately 120 billion gallons per year. While this is less than 0.03 percent of total water used in the U.S.,[10] it is still a substantial amount when you consider the average U.S. residence uses approximately 100,000 gallons of water indoors and outdoors each year. Taking a bath requires up to 70 gallons of water, whereas a five-minute shower uses only 10 to 25 gallons. An Olympic-size swimming pool contains 660,000 gallons of water. [11]

According to the National Renewable Energy Lab, electricity production from fossil fuels and nuclear energy requires 190,000 million gallons of water per day or 69 trillion gallons per year, accounting for 39 percent of all freshwater withdraws in the nation.[12] The amount of water used to produce shale gas is significantly lower than the amount used to produce other common fuel sources.[13] In the Marcellus Shale, for example, it takes 1.3 gallons of water to produce 1MMBTU of energy, whereas it can take anywhere from 2 – 8 gallons of water to produce 1MMBTU of energy from coal without a slurry transport.[14]

Despite the quantities of water needed, there is no reason that water used for fracturing must be of pristine, drinking water quality. Water sources to support oil and gas production can come from a variety of sources, including fresh or brackish water from surface or groundwater withdrawal, treated industrial or municipal wastewaters, and recycled water produced along with oil and gas.

Water recycling is widely seen as a potential means of reducing the impact on local water resources, particularly in areas where hydraulic fracturing is new or water is relatively scarce. Recycling also reduces the need for long-range trucking of fresh water for hydraulic fracturing liquids and subsequent wastewaters – providing both an economic and environmental win. Technology advancements allow for the reduction of wastewater requiring disposal and increased recycling of water recovered from producing oil and gas wells, which can reduce costs, preserve fresh water resources, and improve the sustainability of the hydraulic fracturing operation.

All that said, shale energy producers and regulators are working to find ways to keep water flowing to the industry without impacting farmers, municipalities and growing populations, particularly in regions of the country where water scarcity is a challenge. For example, the state of Texas is in the midst of a historic drought, has little surface water and many of its groundwater aquifers are drying up. However, hydraulic fracturing operations in the Permian Basin and Eagle Ford Shale are booming – producing at 1,560,000 barrels of oil per day (BOPD)[15] – in large part due to sustainable water management and the availability of innovative water treatment technologies.

Dow is committed to working with states, local governments and shale gas operators to manage produced water in a way that protects surface and ground water resources. For example, the Company worked with an oil and gas company in the Eagle Ford Shale and Permian (Delaware) Basin areas in Texas to create a mobile system to pre-treat a high-pressure nanofiltration (NF) system. The new robust NF membranes enable the recycle and reuse of high salinity produced waters by selectively removing ions like Calcium, Magnesium and Sulfate that interfere with fluid and formation chemistries. For very high salinity waters, combinations of NF and reverse osmosis may be used to clean and concentrate the brines – essentially splitting the waste streams into reusable heavy brines and fresh water. The recovered brine is reused for drilling fluids and hydraulic fracturing while the low-salinity permeate may be beneficially reused as service water.

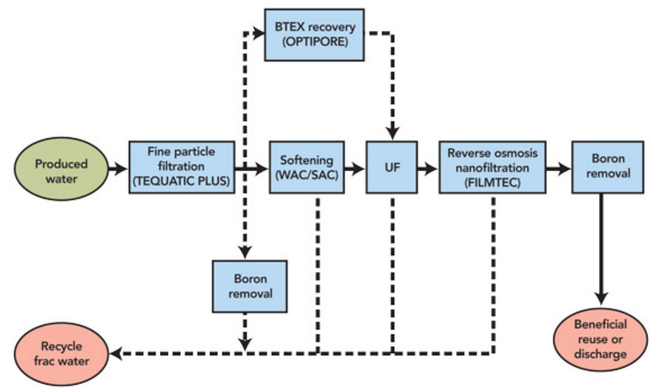
Concern #3: Availability of Technology for Sustainable Hydraulic Fracturing

Among the concerns from an industry perspective is the availability of sustainable water management solutions. Numerous technologies are available today to enable complete or tailored removal of ionic, organic and particulate contaminants from source waters for injection or produced waters for discharge.

A variety of water treatment technologies help take the lowest water quality available in the region and upgrade the water by treating it to a suitable level for use in hydraulic fracturing operations. Salinity and water composition must be compatible with the hydraulic fracturing fluid chemistry and formation to maximize shale gas recovery. Ultrafiltration can be used as a pre-treatment, and then reverse osmosis, nanofiltration and ion exchange technologies tailor the salinity of injection water to the formations into which they are injected and help provide particulate-free water to help maintain permeability.

Advanced water treatment technologies beyond traditional methods such as settling tanks and bag filters open up opportunities to help remove contaminants from flowback water before disposal and improve water quality to a level where it can be recycled into the next hydraulic fracturing job. From fine

Available Shale Gas Produced Water Treatment Processes (For < 30,000 ppm TDS Water)



Source: http://www.dowwaterandprocess.com/en/industries-and-applications/oil_field_water/produced_water/shale_gas

particle filtration to remove suspended solids and selective ion exchange for boron removal to polymeric adsorbents for organic compound removal, numerous water management solutions are available to ensure flowback and produced water is properly treated for recycling, reuse or disposal. These advanced treatment technologies have been used extensively in other industries where water scarcity drives reuse. Measures are also taken to ensure there are no circumstances in which flowback or produced water is discharged to the environment or to municipal wastewater treatment plants prior to significant treatment. Use of these processes or any of these unit operations will be dependent on the water composition for the given area.

Dow has a large range of advanced chemistry and technology solutions for water treatment to help operators improve shale oil and gas recovery, while helping minimize environmental impact throughout the hydraulic fracturing process.

Concern #4: Economic Impact of Treating Fracturing Water Flowback

Another industry concern is the cost associated with treating flowback water. Hydraulic fracturing flowback disposal is typically costly due to lack of infrastructure, not costly treatment technologies. In areas like the Marcellus Shale, economic drivers associated with hauling water have already led to most (90+ percent) of the available fracturing flowback being recycled.[16] Material science expertise enables providers, such as Dow Water & Process Solutions, to develop water treatment components, including membranes, which can help lower costs and increase production of oil and gas resources.

Concern #5: Chemical Use in Hydraulic Fracturing Operations

Water and sand comprise more than 99 percent of the hydraulic fracturing fluid mixture. Less than one percent of the total mix is additives. The hydraulic fracturing process has been available for more than 60 years, but only started to reach its potential when chemical additives were used during the process. These chemical additives help unlock hydrocarbons from shale rock, making their use essential for a cost-effective and sustainable hydraulic fracturing process. It is the use of the entire fracturing fluid mixture that allows for a proper proppant transportation, reduced friction, and increased fluid flow necessary for the process. While chemical additives make sustainable hydraulic fracturing possible, the application and handling of these chemical additives must comply with legislation and regulations. Using the right type and amount of additives allows for more efficient and effective fractures, which in turn means reduced water use.

In the U.S., there are oil and gas industry regulations, as well as federal and state regulations. Most shale-producing states have more rigorous standards that take primacy over federal regulations, as well as additional regulations that control areas not covered at the federal level. These include:

- Different depths for well casing
- Level of disclosure of drilling and fracturing fluids
- Requirements for water storage
- Water supply/quantity/withdrawal limits
- Management of flowback and produced water
- Disposal of wastewater by underground injection

The European Union has its own set of regulations, including the REACH Regulation.

The process of hydraulic fracturing introduces water and organics into an already organic-rich layer deep in the biosphere where shale formations are found. These shale formations have not seen water or viable micro-organisms for 100 to 200 million years.

The presence of water combined with the rich supply of organics (a food source for microbes) can lead to microbial growth. To avoid microbial control problems deep in the Earth's biosphere, fracturing fluid must be treated to ensure it remains microbe-free throughout the fracturing process. Microbial control technology can be used to control the introduction and growth of troublesome and harmful micro-organisms during hydraulic fracturing to preserve well integrity.

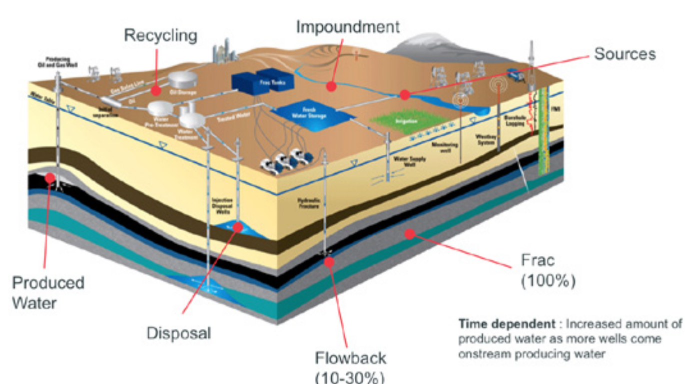
Dow strongly supports and encourages 100 percent transparency and disclosure for all materials used in the hydraulic fracturing process.

The Rise of Recycling

There is a common trend that emerges when addressing the concerns above in order to ensure a sustainable hydraulic fracturing process – the need for water reuse and recycling. Water recycling is widely seen as a potential means of reducing the impact on local water resources, particularly in areas where hydraulic fracturing is new or water is relatively scarce. Recycling also reduces the need for long-range trucking of makeup water to the well pad and subsequent wastewaters to remote disposal facilities – providing both an economic and environmental win. Technology advancements allow for the reduction of water withdrawals and increased reuse of water recovered from producing oil and gas wells.

However, fracturing operators are still facing challenges when it comes to recycling of water. Most challenges are coming from recycling back into the process itself, including understanding the chemistry and the needs of the formations better and the water requirements. As operators increase recycling and reuse in hydraulic fracturing, more will be understood to help overcome the challenges of advanced water treatment.

The industry, along with companies who offer treatment solutions such as Dow Water & Process Solutions, is working towards making existing technologies better suited for oil and gas uses. Use of reverse osmosis membranes for treating



Source: Schlumberger Water Services

condensed produced waters is a relatively new use of those well-established products. Dow is providing new technologies and developing current technologies further to provide new applications in this market. As the industry moves forward, advanced treatment systems are going to need to work together to provide and share the work. There are efforts to solve the challenge of how to treat waters with high variability, and how to put the pieces together to develop a treatment system that will work reliably.

Policy and Regulation

The hydraulic fracturing process can be done safely and effectively while protecting the environment. Around the U.S., government entities at all levels are working to address questions and concerns raised by the significant growth in hydraulic fracturing. Regulatory frameworks based on industry best practices can help ensure the sustainability of operations.

At the request of Congress, there is currently a comprehensive study underway at the U.S. Environmental Protection Agency (EPA). The goal is to better understand the potential impacts of hydraulic fracturing on drinking water and ground water. The scope of the research includes the full lifespan of water in hydraulic fracturing, from water acquisition to wastewater treatment and waste disposal.

The first progress report,[17] released in December 2012, describes progress made as of September 2012 on 18 research projects underway to answer questions associated with each stage of the hydraulic fracturing water cycle. Three of the fundamental research questions under investigation are:

- How might large volume water withdrawals from ground and surface water impact drinking water resources?
- What are the possible impacts of releases of flowback and produced water on drinking water resources?
- What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?

Following a series of technical seminars, roundtables and webinars in 2013, a draft report is expected to be released for public comment and peer review in 2014. Given the long history of hydraulic fracturing—more than 60 years and over a million wells drilled in the US[18] —it seems unlikely that the EPA will recommend a ban or moratorium. However, a central issue is whether the EPA should have full jurisdiction to regulate the underground injection of fluids for hydraulic fracturing of oil or

Four pillars to ensure sustainable industry practices

Source: Dow Water & Process Solutions

gas wells under the Safe Drinking Water Act (SDWA).

Growing public concerns and the large number of federal and state regulatory initiatives suggest that new regulations will drive demand for improved water treatment and management, including reuse. In fact, the Bureau of Land Management has put out a proposal for hydraulic fracturing regulations, which was finalized in 2013.[19] The proposal includes three main components:

- Requiring operators to disclose the chemicals they use in fracturing activities on public lands
- Improving assurances of well-bore integrity to verify that fluids used during fracturing operations are not contaminating groundwater
- Confirming that oil and gas operators have a water management plan in place for handling fluids that flow back to the surface

With the shale industry mobilizing at a rapid pace, government, working with industry, needs to spend more time considering how they can accelerate the adoption of available water treatment technologies, especially those for fracturing water recycling and reuse.

For example, Eagle Ford Shale oil production has surpassed Alberta Oil Sands SAGD production in just three years, and Dow believes it is conceivable that Eagle Ford will produce 10 percent of U.S. oil in the next couple years. Three years is also about how long it takes to pilot, permit, construct and commission a decent-sized potable water desalination plant—assuming everything goes perfectly. Regulators need to focus on how they can accelerate the adoption of sustainable water technology and provide guidance on reuse and secondary use for operators. Offering incentives that encourage industry to take advantage of existing solutions will help drive adoption of technologies that increase the reuse and recycle of flowback water.

Investment vs. Cost to Treat and Manage Water in Shale Oil and Gas Extraction

In unconventional plays across North America, the industry is facing the challenge of managing hydraulic fracturing water in environmentally and economically sustainable ways. According to a report by the Joseph M. Katz Graduate School of Business at University of Pittsburgh, the cost of procuring water for hydraulic fracturing operations is relatively small, averaging $3.00 per 1,000 gallons in the Marcellus region.[20]

Wastewater management is the primary driver of water-related costs. In Pennsylvania alone, approximately 4,700 unconventional oil and gas wells have been drilled.[21] The active wells in this region will yield more than 10 billion gallons of flowback and produced water during their operational life.

A recent IHS report suggests that decisions made about water management will have an impact, not only on the industry's costs and profitability, but also on regional water supplies, infrastructure and local economies.[22]

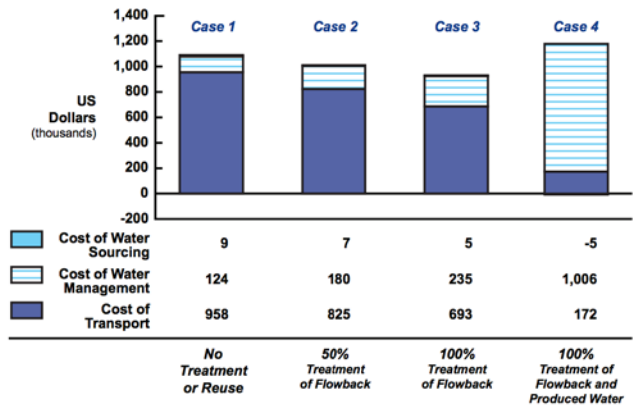
IHS preliminary models show that freshwater withdrawal accounts for less than one percent of total water management

Cost Model

Cases	Percent of flowback treated	Percent of produced treated	Cost of water treatment per 1,000 gallons
1	0	0	NA
2	50	0	$95
3	100	0	$95
4	100	100	$190

Table 1: Cost model for hypothetical Marcellus Shale gas well. Primary drivers changed through four possible water management cases include percent of flowback and produced water treated and cost of treatment. Source: IHS

Lifetime Cost of Water Management: Hypothetical Marcellus Shale Gas Well



Source: IHS

costs. Water sourcing, treatment, transport and disposal combine to account for approximately 10 percent of a well's operating expense, leaving the industry vulnerable to escalating and variable water management costs in a time of low prices and slim profit margins.

IHS has developed a cost optimization model to explore how decisions about water treatment, transportation and disposal impact total cost. Using a hypothetical well in the Marcellus play with an ultimate recovery of 4.4 billion cubic feet of natural gas over a 20-year lifetime and operating costs estimated at approximately $2.30 per thousand cubic feet, the IHS model considers four cases for treatment and disposal of flowback and produced waters:

- Case 1 – All flowback and produced water are trucked offsite for disposal
- Case 2 – Half of flowback water is treated for reuse in drilling and fracturing operations on site, but produced water is transported offsite for disposal
- Case 3 – All flowback water is treated for reuse in drilling and fracturing operations on site, but produced water is transported offsite for disposal
- Case 4 – All flowback and produced water are treated to a level that could be reused in agriculture or discharged to surface water under a permit

IHS concluded that Case 3, in which 100 percent of flowback was treated, but produced water was transported offsite for treatment, was the most cost-effective approach. This strategy yields over $150,000 in savings per well, compared with the no-onsite treatment case, due to a 38 percent reduction in transportation costs. It is important to note that these operating costs are highly variable from region to region, and optimization of well economics must be conducted on a well-by-well and play-by-play basis.

Looking to the future, it is likely that compliance with regulation and satisfying public demands would require an approach akin to Case 4, where all flowback and produced water is treated onsite for recycling or secondary use. In this case, IHS assumes the water would be treated to a level appropriate for surface discharge or for beneficial use in agriculture or other applications. This would increase the total water management cost of IHS' hypothetical well 26 percent over the optimal costs of Case 3 and more than eight percent over a no treatment scenario where flowback and produced water is trucked offsite, as illustrated in Case 1. However, the volatility and potential upward trend of transportation and disposal costs, coupled with increased public focus, could necessitate a shift in this direction.

Further data on the cost versus investment aspect of hydraulic fracturing operations is not publicly available today due to the private nature of data collection information by energy companies. It is critical for companies to collect and share this information so government, industry and community stakeholders can clearly see the value and benefits derived from economically and environmentally sustainable hydraulic fracturing operations.[23]

Dow strongly believes and encourages an environmentally contained water management system that begins with the treatment of impaired water, followed by the proper handling of flowback water according to standard rules and regulations. If the investment to extract shale oil or gas, compared to the cost of executing an environmentally contained water management system for hydraulic fracturing operation is not fiscally sound, then companies should not use hydraulic fracturing. Dow firmly believes there are no shortcuts on proper water management in hydraulic fracturing operations. Operators should only hydraulic fracture if they can do it in a sustainable manner via an environmentally contained process.

Conclusion

Hydraulic fracturing can be an efficient and environmentally sound process to extract shale gas, provided the correct procedure is followed and the most appropriate technologies are used. A sustainable hydraulic fracturing process is one in which the entire process from start to finish is a closed loop where none of the materials are exposed to people or the environment.

Economic Development From Shale Development Value Chain

	2012	2020	2025
Jobs (in millions)	2.1	3.3	3.9
GDP (in billions)	$284	$468	$533
Gov Revenuess (in billions)	$74	$126	$138
Increased Household Disposable Income	$1,200	$2,700	$3,500

Source: Institute for 21st Century Energy, http://www.energyxxi.org/sites/default/files/file-tool/ihs_two_pager.pdf

To achieve this, best practices, including the measuring and monitoring of shale operations, and sustainable technologies must be implemented in several key areas including water sourcing; chemicals management; containment, treatment and recycling of flowback water; and gas/methane capture; as well as ensuring well casings provide a durable, impenetrable barrier between the well bore and the aquifer. Continuously improving and adopting advanced water treatment technologies and best operating practices is critical to ensuring the sustainability of hydraulic fracturing operations.

States are in the best position to develop regulatory requirements and procedures for projects that involve hydraulic fracturing, given that each formation has unique properties. Each state, however, must allocate the proper resources to develop, oversee and enforce proper rules and regulations. Of the 27 U.S. states that support 99.9 percent of all natural gas exploration activities nationwide, all 27 have permitting requirements in place that govern the siting, drilling, completion and operation of wells, including hydraulic fracturing.

Dow believes the increased supply of natural gas and oil from unconventional sources such as shale will be an important resource for the next several decades. These resources will help satisfy three key factors:

- Economic growth
- Security of energy supply
- Improved environmental performance by reduction of CO_2 emissions

Economic growth will depend on the development of all sources of energy—including oil, coal, natural gas, nuclear power, wind, solar and geothermal, among others. Without an effective, sustainable effort to drive the development of energy sources and management of demand, the global economy will struggle to grow and create the jobs of the future. Leaders in the public sector need to turn their attention to how they can help accelerate adoption of water technology and provide guidance to operators on reuse and secondary use, in order to ensure a sustainable hydraulic fracturing process that stimulates economic growth.

Maintaining a social license to operate requires paying attention to regulatory trends and changes in public sentiment. If the cost of properly treating the water going into the well, and disposing or treating the flowback water outweighs the investment of extracting shale gas, then companies should not do it. There should be no shortcuts in this process. Proper water management is vital to sustainable hydraulic fracturing.

As the global population continues to grow, balancing the need for clean water and energy will remain a focus for industry, regulators and communities alike. With effective product stewardship, clean-burning natural gas and oil from shale reserves can be produced in a safe, responsible and effective manner.

Dow is committed to collaborating wherever possible to increase transparency around the hydraulic fracturing process and continuously improve advanced water technologies offered into the market in order to help producers and service companies operate in a manner that minimally impacts the environment.

Additional Information

More information about available technologies to support sustainable water management in oil and gas operations can be found at the following links:

- Unconventional Shale Gas Extraction
  http://www.dow.com/microbial/shalegas.htm
- Increased reuse and recycling of water
  http://www.dowwaterandprocess.com/en/products/d/dowex_optipore_l493
- Microbial Control Technology
  http://www.dow.com/microbial/applications/ma_go_products.htm
- Shale Gas and Oil Technologies and Applications
  http://www.dowwaterandprocess.com/en/industries-and-applications/oil_field_water/produced_water/shale_gas

Glossary of Terms

The following terms are referenced throughout this paper.

Beneficial Reuse: Secondary use or reuse of produced water outside of hydraulic fracturing operations

Disposal: Transporting produced water offsite or disposing of it via deep well injection

Flowback: Fluids returned to the surface following hydraulic fracturing. In addition to the original fluid used for fracturing, flowback can also contain fluids and minerals that were in the fractured formation

Hydraulic Fracturing: The process of creating fissures, or fractures, in underground formations to allow natural gas to flow

Produced Water: Water produced along with natural gas longer term after the drilling and fracturing of the well is complete

Recycle: Reusing flowback and produced water in subsequent hydraulic fracturing operations

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