The Changing Value of Water to the US Economy: Implications from Five Industrial Sectors

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Executive Summary

Water plays a key role in industrial production. Today, with increasing demand for water resources and uncertainty about the amount and quality of supply, the competition for water resources is being felt across all sectors of society. Awareness of the ways water-related risks can disrupt business has also increased. Although the cost and price of water varies tremendously across the United States, corporations are increasingly assessing and reporting their water use and improving water process efficiency. In addition, companies are seeking economic and technological innovations. Many companies are also forging partnerships to improve efficiency and derive maximum value from the water they and the surrounding community use.

Introduction

This paper examines the changing value of water in five industrial sectors: semiconductor manufacturing, thermal power generation, mining, chemicals, and oil and gas. The case studies for the five sectors analyzed draw on a number of information sources, including economic information published by the Bureau of Economic Analysis. In addition, the authors have conducted interviews with representatives of firms engaged in water policy decisions in each of the sectors and have reviewed a variety of company documents.

Water is a critical component in all sectors of the U.S. economy and serves a range of different uses, from direct input to supporting operations. Where it is not part of or the end product itself (as in the agricultural and food and beverage sectors), water is used in production processes in varied ways, ranging from its use as a transportation medium (carrying copper concentrate, for example) to ultrapure cleaning (as in semiconductor fabrication). Water's value in these uses is determined both by its available quantity and quality. Prevailing environmental regulations may further influence the decision to discharge or reclaim process wastewater.

Historically, the industries examined in this paper relied on and assumed they would have an ample supply of quality water. Today, the availability of water is changing because of climate change (reducing inflow and increasing depletion), governmental policy, deteriorating quality of fresh water supplies, and increasing competition for water resources. As a result, water issues are garnering increased attention from all interested parties, from government to consumers. Water remains a local resource, and companies located near an ample, clean supply have an advantage. Companies that operate in arid regions have had to adopt innovative approaches to ensure the availability of adequate water supplies. These innovations range from increasing efficiency to investing in water delivery and water treatment infrastructure, creating reservoirs, monitoring water quality, or relying on mobile water supply, such as the use of water trailers. Not surprisingly, the value of water increases dramatically once adequate-quality water supplies become scarce.

The price of water and wastewater treatment varies across the United States and is influenced by a number of factors, including direct and indirect regulations, industry best practices, and agreements with different local groups. In some states, such as Wisconsin and Indiana, public service commissions (PSCs) directly regulate rates set by most public water and wastewater utilities; in these situations, the states often use rate-setting models established by the PSCs that are based on specific protocols that typically employ cost of service (COS) principles. In contrast, in states where most public water and wastewater utility rates are not directly regulated, such as Virginia, rates are based on local agency discretion unless cases are filed with either the public service commission or other court systems.

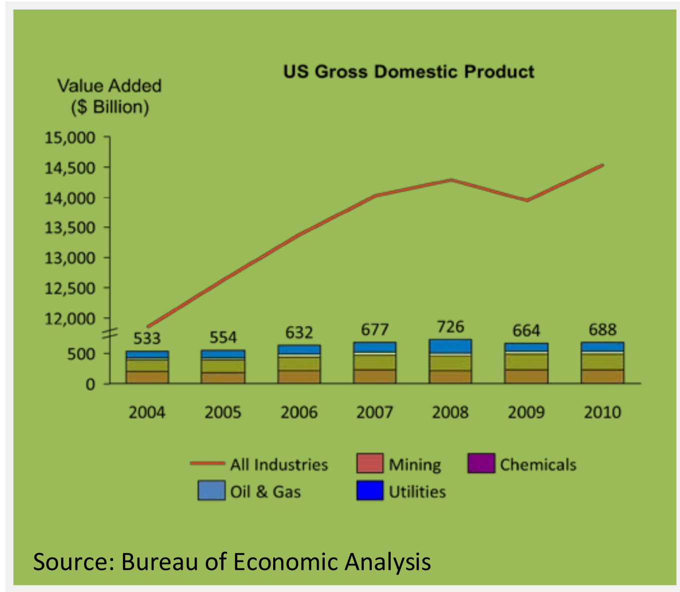


Exhibit 1: U.S. Gross Domestic Product in Industries of Focus

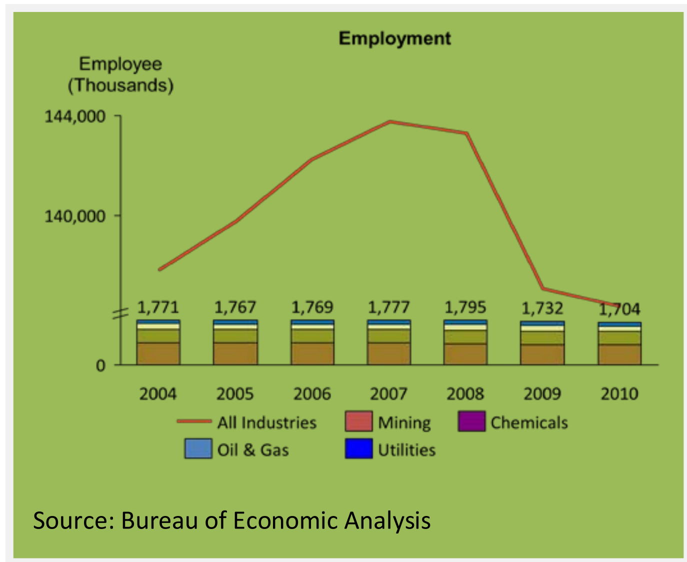


Exhibit 2: U.S. Employment in Industries of Focus

In general, guidance documents by water industry associations such as the American Water Works Association (AWWA) define the cost of providing service as one of the primary factors in setting fair and equitable rates. While the guidance documents, such as AWWA's *Principles of Water Rates, Fees, and Charges*[1,] provide reasons for deviation in some cases from strict COS principles. Examples include negotiated and economic development rates for large volume or targeted new customers, particularly in situations where such rates do not adversely affect existing customers or to provide rate discounts to low-income customers in line with community affordability goals. In such situations, the guidance documents recommend that there still be a significant linkage to COS principles.[2] As a result, regional and local variations in input costs and system-specific factors, such as the age of assets, availability of natural water resources, and opportunities for scale economies, result in significant variations in rates. Industries also source water through agreements with groups such as local landowners, reservoir authorities, and river basin authorities, which can result in different prices.

Most companies in the five industries we examine have global operations. As shown in Exhibits 1 and 2, these industries account for approximately 5 percent of U.S. gross domestic product (GDP) and approximately 1 percent of U.S. employment.[3] Increasingly, water is one of the factors influencing decisions by these

[1] Manual of Water Supply Practices - M1, Sixth Edition: Principles of Water Rates, Fees, and Charges, American Water Works Association, 2012.

[2] Ibid., page 209.

[3] Based on data from the Bureau of Economic Analysis, Release Date: December 13, 2011.

industries to maintain or expand operations in the United States. Increased awareness of related issues has brought water to the boardroom, forcing companies to recognize that effective management of water is necessary to the long-term viability of their operations.

Role of Water in the Five Sectors

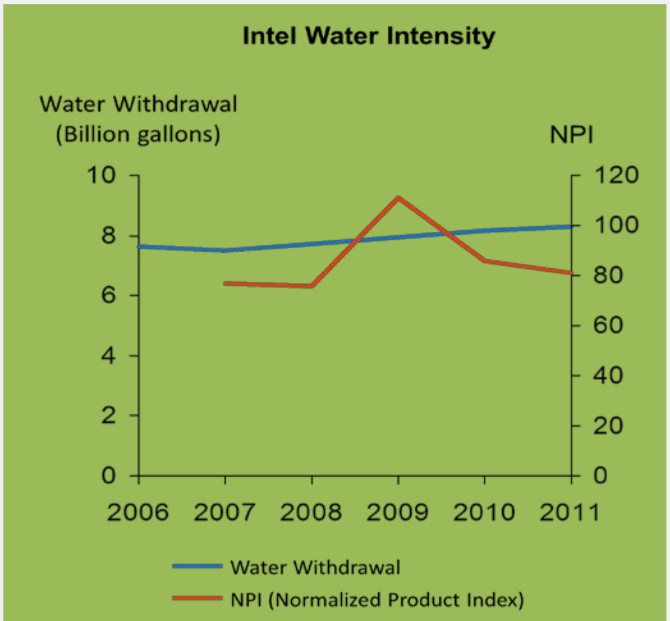
Water's influence on corporate decisions varies by sector. In the semiconductor, thermal power generation, downstream oil and gas, and chemical sectors, companies have a choice in where new operations will be located. Several factors influence the decision; however, availability of water can play a role. Conversely, for the mining and upstream oil and gas sectors, geology determines the location of the resource and hence the location of extractive operations; in these sectors, the impact of water–and in particular, the challenge of supply and disposal–depends on the water resources in the area. In either case, the choices made by companies in these sectors may affect the water utilities serving the area.

The quality of water is classified by different parameters, including pH, turbidity, dissolved solids, trace contaminants, and temperature. The quality and the supply of water available influence the value of the water to the user. For example, corrosion from highly saline source water can degrade the performance and longevity of assets; this can have a significant impact, increasing maintenance costs or requiring an earlier upgrade or re-investment in the asset. In either case, companies incur losses from additional capital and operational costs in addition to loss of revenue from disruptions in production. Given the sensitivity of certain industrial processes to water quality, degradation of water quality may require additional investment and operational costs for pre-treatment. Furthermore, more stringent environmental regulations related to wastewater discharge are leading communities to consider reclamation and reuse options, because cost of treatment to reach discharge limits might exceed that of treatment for reuse. That, coupled with frequent delays involved in securing discharge permits, has driven industry increasingly to adopt zero liquid discharge practices in certain areas.

Semiconductor Industry

The semiconductor industry was born in the United States. Over the years, much of its manufacturing has gravitated to Asia, with new fabrication facilities being built primarily in China. However, **Intel** is developing the world's most advanced high-volume chip manufacturing plant (Fab 42) in Chandler, Arizona, at an existing location, and it is a fine example of water management practices by an industry leader.

Fab 42's goal is to enable Intel to stay ahead of the competition in chip miniaturization. The $5 billion factory will begin by making chips with circuits just 14 billionths of a meter (14 nanometers) in width.[4] These tiny chips will reduce power requirements, enable Intel to compete in additional markets such as smart phones, and allow the firm to remain a leader in chip technology.



Reproduced with permission from the Intel Corporate Responsibility Report[5]

Exhibit 3: Intel Water Use from 2006 to 2011

The new plant will provide social and economic benefits to the local economy. Plant development will create an estimated 14,000 temporary jobs, including spinoff jobs created by construction activity. Beyond the construction jobs, about 1,000 people will be needed to run Fab 42.[5] On average, Intel employees in Arizona earn over $130,000 per year,[6] so the new plant will provide a payroll in excess of $130 million when it is fully operational.

Water, in the form of ultrapure water (UPW), plays an essential role in manufacturing semiconductor chips, acting as a solvent to remove impurities that can short out the hundreds of circuits in each chip. Water has always been critical to Intel's operations, some of which are located in water-constrained and arid areas such as Israel, China, New Mexico, and Arizona. Beyond considering water availability when choosing a site, Intel considers other factors such as taxes, incentives, transportation, educated workforce, cost of living, proximity to existing facilities, and infrastructure, in addition to the cost, availability, and reliability of electricity. As a result, the company has had a long-standing focus on water sustainability. In particular, Intel has taken measures to improve the efficiency of processes used to produce UPW. Today, Intel needs 1.25 to 1.5 gallon of water to make 1 gallon of UPW, down from almost 2 gallons in the recent past.[7] Intel factories are equipped with complex rinse-water collection systems that process contaminated wastewater for reuse. Furthermore, some campuses use gray water from the local municipal water treatment operation instead of fresh water.

For its operations in Ocotillo, Arizona, Intel has partnered with the City of Chandler to implement water usage technologies that benefit both the company and the local community. For example, Intel is spending

[4] "Intel's Chip Plans Bloom In Arizona Desert," Chris Nuttall, *Financial Times*, January 22, 2012.

[5] "New $5 Billion Intel Facility Planned for Chandler," Ryan Randazzo, Edythe Jensen, and Mary Jo Pitzl, *The Arizona Republic*, February 19, 2011.

[6] "Intel's $2.4 Billion Economic Impact," Arizona, Intel Flyer. 2012

[7] "Intel: Exploring Market Opportunities in Water," *Harvard Business School Case Study 9-412-100*, p. 3, April 2012.

more than $200 million on public infrastructure,[8] including water and wastewater facilities. For example, an addition to a previous investment will enable construction of an advanced reverse osmosis plant that treats process wastewater back to drinking water standards for Intel's use in its production processes, thus reducing Intel's demand on scarce fresh water supplies. The Ocotillo campus also receives a direct feed of water not suitable for drinking from the City of Chandler's wastewater treatment plant; the company uses this water for irrigation and cooling. This was a factor in Intel's ability to earn a Leadership in Energy and Environmental Design (LEED) Silver certification for the Ocotillo facility.

Fundamental to its impact on operations, water has become a strategic issue for Intel. The company has taken various steps to maintain access to adequate supplies, while also ensuring that water is available to the local community. In 2009, as a first step in identifying better water management opportunities and best practices, Intel completed a water footprint analysis. In 2010, the company formally published its water policy, which supports safety, sufficiency, transparency, physical accessibility, and responsibility in communities where it operates. In 2011, the company began working on "water equivalency" analysis, which adjusts total water use based on a location's water stress level.

In the future, Intel aims to harness technological innovation to improve efficiency and derive maximum value from the water it uses in the following ways:

- Reducing the company's operational footprint by looking at options to reduce water use through recycling
- Improving the environmental footprint of Intel's products by producing chips that use less energy, thus reducing the power demands and associated demands on water supplies
- Developing new products for water management, such as water-sensing devices to identify leaks, satellite imagery, and other "smart water" technology
- Using the web and social media to encourage increases in the amount of wastewater recycled in communities

Chemical Industry

As with other sectors, water is critical to the chemical industry, which uses it for a variety of purposes. Volumes vary considerably from plant to plant, but water is essential throughout the production process for cooling, cleaning, dissolving, diluting (sometimes constituting part of chemical products), and generating steam. While water might not currently be a high-cost item, the availability of ample, clean water is critical for the industry and a key component of its investment decisions.

While the importance of water to the production process has not changed, the industry is becoming increasingly aware of and concerned about the liability associated with water and the competition for water. In response to societal pressure for greater transparency, companies are reporting on water use and their efforts to reduce water consumption. As competition for water increases, companies are considering a range of different options. Policy action could at least partially alleviate the issue by managing the allocation of water. In the meantime, companies' contingency plans range from leasing water treatment trailers to investing in infrastructure to ensure adequate supply. Therefore, the value of water to the chemical industry can be articulated in terms of the impact that curtailed water availability would cause, both in the short term and long term. Once again, the risk lies in both the quantity and quality of water. A drought can slow or stop operations, leading to revenue loss. Changing water quality can reduce the life of productive assets and result in significant costs for a company.

The Dow Chemical Company (Dow) is one of the largest global chemical companies. It maintains a significant presence in the United States, where it generated 32 percent of its revenues in 2011. The company's 22 U.S. manufacturing sites employ more than 20,000 workers. Effective water management has long been an

[8] "League of Arizona Cities and Towns Is Upset Over 'Intel Bill'," Luci Scott, *The Republic*, May. 23, 2012.

important consideration for Dow's operations. The company began to report its total water intake and water sources in 2005, and it has embedded water conservation into its 2015 sustainability goals. As the world's leading supplier of reverse osmosis membrane filters for desalinating seawater, the company has specific commitments to reduce the cost for desalination and water reuse by 35 percent between 2005 and 2015, and to serve treated water to 60 million people through residential applications by 2015. Because Dow is a global company, the entire world will benefit from Dow's commitments to increase water availability[9].

Today, Dow is adopting a range of new technologies and approaches to reduce water consumption and design more efficient facilities. By implementing advanced cooling water technology in 2010, Dow is saving 1 billion gallons of water and $4 million annually[10]. In addition, the company has taken a collaborative approach with neighboring communities to reduce its intake of fresh water. In Texas, Dow's Freeport operations recently began recycling treated wastewater from Lake Jackson, a neighboring community. By reusing approximately 1.3 billion gallons of treated wastewater each year, Dow reduced its fresh water demand in Freeport by 2.5 percent. This initiative contributed to the 10 percent overall freshwater demand reduction achieved by the site in 2011. Through ongoing projects, the site is targeting an overall 20 percent reduction in freshwater demand by 2013.

In addition, Dow engages in public-private partnerships related to water conservation at various manufacturing sites across the world, by reusing water multiple times before a final discharge. Similar to Dow's Freeport operations treating effluent water from the community for use in its plants, at Dow's second largest manufacturing site in the Netherlands, the company has partnered with the local government and a local provider to turn community wastewater into energy. At that site, Dow purifies more than 70 percent of its effluent to generate steam and feed manufacturing plants.

Dow is also exploring several extraordinary approaches to manage water more effectively. For example, in 2011, Dow's Freeport operations purchased a 2,200-acre parcel of land in Texas as a site for development of a reservoir.[11] The reservoir will improve the reliability of water supplies both for Dow's business in Freeport and for Brazoria County residents, to whom Dow will provide fresh water during dry spells and droughts.

In addition, in a first-of-its-kind collaboration, The Nature Conservancy recently announced plans to partner with Dow (and others in the business community) to recognize and incorporate the value of nature into global business goals, decisions, and strategies[12]. As part of this initiative, Dow will apply The Nature Conservancy's scientific knowledge and experience to examine the ways in which its operations rely on and affect nature. One area of focus at the collaboration's first pilot site in Freeport is fresh water. The Dow Freeport manufacturing site receives its fresh water supply from the Brazos River. By forecasting changes in the future flow of water in the river and changes in demand in the Brazos River Basin, Dow and other water users can plan more effectively for future water scarcity. Both "green" and "gray" (traditional) infrastructure options that could help maintain flow in the river are being explored. The pilot project will evaluate the economics of these options to understand which will provide the most value for all users.

In the future, Dow aims to be able to apply its innovative and effective water conservation and management products and practices globally to realize the following goals:

- Reduce the company's operational water footprint
- Develop products that help customers reduce their own water footprint
- Provide access to better-quality water by developing products that improve water quality

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[9] *The Dow Chemical Company Annual Report, 2011*

[10] *Provided by The Dow Chemical Company*

[11] *The Facts: Dow Gets Prison Land*, Dow News Clip, December 02, 2011.

[12] *The Nature Conservancy Press Release*, January 2011,

- Ensure adequate water supplies for both Dow's operations and neighboring communities through multi-party collaboration that supports conjunctive use of ground and surface water

Mining Industry

Mining operations use water to mill ores, process concentrates, and mineral products; cool or wash equipment; manage waste tailings; suppress dust; and supply onsite needs for drinking and culinary supplies. At many sites, the operations make use of non-potable water, thereby avoiding the use of high-quality (potable) water and helping to conserve local water supplies. Although the minerals and metals industry is a small user of water on a national scale, it can be a large user at a local level. Some sites are located in water-scarce locations where mining companies compete with other water users, including local communities, agriculture, and other industries, while in some locations companies need to manage significant water flows resulting from precipitation or groundwater sources. Many mining operations recycle significant amounts of water onsite, and water management, discharge, and use are subject to comprehensive regulatory and legal requirements.

Rio Tinto, an international mining company with a number of operations in the United States, adopted a water strategy that provides a framework for managing water and improving business performance across the social, environmental, and economic aspects of water management.[13] The strategy has three main components: improving performance, accounting for the value of water, and engaging with others on sustainable water management.[14] A key focus is to identify ways to minimize the amount of water removed from the environment, reusing it when possible, and returning it to the environment while meeting, at a minimum, regulatory limits.

Rio Tinto has decided to invest in water conservation (for example, by making processes more efficient or using poorer-quality water in place of potable water) because it understands the value of water. The company looks beyond the cost of water to take into account the nonmonetary aspects such as the social and environmental values. Rio Tinto has observed that perceptions of value may also change; for example, communities, governments, and business place great importance on water conservation during droughts. This concern often quickly diminishes when the drought ends. A longer-term approach that takes the full value of water into account would support decision-making on sustainable water use. While these approaches are still being developed and tested, two of Rio Tinto's companies are taking creative approaches to valuing water.

Kennecott Utah Copper's (Kennecott) operations are located near Salt Lake City, Utah, where its business has been operating for 110 years. Increasing population and other factors are placing more pressure on water resources within the region, making sustainable water management critical to Kennecott. In 2011, total in-state spending by Rio Tinto's businesses was $1.2 billion, which included $270 million in wages, salaries, benefits, and pensions; $765 million in purchases from Utah firms; and $140 million in payments to state and local government (including taxes).[15]

Greater than 90 percent of the water used at Kennecott is characterized as poor-(low) quality water,[16] and an average of 60 percent of the water withdrawn is recycled to minimize importing additional water resources.

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13 Rio Tinto Sustainable Development 2011, Water

14 See *Rio Tinto and water* (PDF), www.riotinto.com

15 Kennecott and Rio Tinto directly employed 2,810 people in Utah during 2011, with an annual payroll of $253 million (including benefits) and an average payroll per job of $90,000, which makes these among the highest-paying jobs in the state. The companies were responsible for another 14,971 indirect jobs during this period. Provided by Rio Tinto (see also http://www.kennecott.com/economy). Based on research *performed and submitted by:* Pamela S. Perlich, Ph.D., senior research economist Bureau of Economic and Business Research University of Utah Released June 2012.

16 Rio Tinto categorizes water as either freshwater or poor water. Freshwater is defined as potable water or good-quality raw water with total dissolved solids less than 1,500 milligrams per liter. Poor water is defined as raw water with total dissolved solids greater than 1,500 milligrams per liter.

More than 90 percent of the water used at the largest water user at Kennecott, the concentrator (which concentrates the copper after it is finely ground), is from recycling. To drive water performance improvements, Kennecott is developing a water management approach that recognizes that different waters have varied benefits and costs that support using different waters for different purposes,. This water hierarchy approach recognizes the need to balance a number of considerations including availability of water and water quality; the location and type of infrastructure required to transport or treat water; energy use; and regulatory or legal requirements. Kennecott's water hierarchy approach aims to do the following:

- Use poorer-quality water first in operations to minimize the amount of new, clean water required for use
- Recycle process water where practicable
- Separate waters of different quality to optimize water use within the process
- Maintain direct involvement and support with the scientific community in advancing technologies and education in improving best practices and methodologies
- Educate the workforce in best water management practices

For example, when a groundwater source for the concentrator became unavailable, Kennecott applied the water hierarchy approach to select a replacement source. Kennecott assessed several possible alternative sources, including: (i) potable quality groundwater; (ii) surface water suitable for irrigation, and (iii) recycled water sources from its operation. The three replacement sources each carried distinct costs and benefits. No source was adjacent to the concentrator, so each source carried transportation infrastructure and operational costs, which differed according to relative proximity. Although recycling required transportation across 13 miles compared to 3 miles for potable groundwater, existing infrastructure was available for recycling. The need for new infrastructure for the groundwater and surface water sources increased the "costs" of these water sources. Additionally, using recycled water preserved potable groundwater to meet existing and future culinary purposes and saved the surface water for agricultural use. Capital and operational costs, however, were not the only considerations. Poor water quality can impact metals recovery during the milling process; therefore process changes were also needed to limit inhibited metal recovery. Kennecott ultimately replaced the original groundwater source with the lower quality recycled water. The decision considered tradeoffs among operational needs, energy requirements, new infrastructure, and the economics of each option. However, the water hierarchy approach was the primary guide that led to the decision to use the recycled water source.

The **Resolution Copper** (Resolution) project is located near Superior, Arizona. The large world-class copper resource lies 1 or more miles below the surface, near but deeper than an old mine that was closed in the mid-1990s. The proposed underground mine is projected to produce more than 1 billion pounds of copper per year over approximately 34 years. A 2011 economic and fiscal impact study[17] estimated "that the total economic impact of the Resolution project on the State of Arizona will be over $61.4 billion or nearly $1 billion each year."[18]

To begin developing the new mine, more than 2 billion gallons of water that naturally accumulated in the old mine had to be removed. Resolution constructed a $20 million water treatment facility to prepare the water

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[17] Operations are projected to "support over 3,700 jobs annually, equating to $220.5 million in annual wages. The copper mine will directly employ approximately 1,400 individuals when the mine reaches full production with payroll of roughly $105 million. . . The ripple effect of direct operations will support an additional 2,300 jobs each year over the life of the mine earning wages of $113.3 million. From beginning to end, over $14.1 billion in wages will be generated." The project also is estimated to generate total federal, state, county, and local tax revenue of nearly $20 billion. (*Resolution Copper Company Economic and Fiscal Impact Report, Superior, Arizona*, prepared by Elliott D. Pollack & Company, September 2011.) http://securearizonasfuture.com/benefits/economy.php

[18] Ibid.

for discharge once it is pumped to the surface. Initial draining of the old mine took nearly 3 years to complete. One of the challenges was determining where the removed groundwater should go once treated, to ensure the water is fully used and the environment is not negatively affected.

Resolution worked with the New Magma Irrigation and Drainage District (NMIDD) to supply the extracted water for agricultural use in Arizona. The project involved constructing a 44-kilometer pipeline to transport the water from Resolution's treatment facility in Superior to Magma Junction. NMIDD will combine this water with Central Arizona Project (CAP) water for irrigation purposes. CAP delivers water from the Colorado River by canal to central and southern Arizona so surface water can be used instead of depleting groundwater for agricultural, municipal, and industrial uses.

In parallel with draining the old mine, Resolution has had to plan for operational needs of up to 20,000 acre-feet (approximately 6.5 billion gallons) per year, principally for the flotation process used to separate the valuable ore from the waste minerals. While groundwater is the most readily available and least expensive water source for the mine, the company sought alternative, more sustainable resources. In total, Resolution identified 25 potential sources and ranked them according to social, environmental, and economic criteria.

Resolution identified three sources as future supply options for water:

- **Groundwater that was previously affected by mining:** this would only satisfy about 10 to 20 percent of the new mine's ultimate need.
- **Banked water with the CAP:** Resolution is purchasing and "banking" excess CAP water with the irrigation districts for future use, minimizing its impact on water supply.
- **Treated municipal wastewater effluent:** Resolution is working with the Science Foundation Arizona, the University of Arizona, and Freeport-McMoRan on technology to use treated municipal effluent in the flotation process, thereby lessening demand on other sources, such as groundwater.

Mining companies in the United States, and globally, are exploring proactive approaches to water that consider how to account or demonstrate the value of water taking into account not only , economics, but also considering social and environmental factors as well.

Oil & Gas Industry

The oil & gas industry handles a larger volume of water than it does oil. It is estimated that the U.S. oil & gas industry will use 72 billion gallons of water in 2012,[19] for a range of different activities. The industry relies on water of varied quality, including fresh water, brackish water (water with a level of salinity between freshwater and seawater), and seawater. The largest volume of water is used in enhanced oil recovery (where water is injected into the oil-bearing formation to increase the yield of the reservoir), followed by use in drilling and completion of oil and gas wells. Water is also used in petroleum refineries, especially for cooling systems. Over the years, the oil industry has adopted practices to manage water effectively to meet its needs and manage water-related risks.

In recent years, the ability to develop unconventional/shale gas using hydraulic fracturing has led to a dramatic increase in the industry's demand for water in the United States. In some instances, companies are paying more than the local market rate to secure water for their hydraulic fracturing operations. In July 2012, the City of Aurora, Colorado, reached a 5-year agreement with Anadarko Petroleum Corporation to sell an annual volume of 1,500 acre-feet of wastewater (reclaimed and sanitized, but not rendered drinkable) for $9.5 million. Therefore, Anadarko is paying $1,200 per acre-foot of water, which is nearly 3.5 times the market rate of $350 an acre-foot for Aurora water.[20] The impact of water in terms of the volume required, discharge impact, and cost on unconventional gas production is much higher than is the case with

[19] "Water: The Next Great Investment in the Oil Patch," Keith Schaefer, *Oil & Gas Investments Bulletin*, January 26, 2012.

[20] *American Water Intelligence*, page 14, August 2012.

conventional gas production. As a result, both water availability and discharge are garnering more attention at the executive level of oil & gas companies.

For nearly 60 years, hydraulic fracturing has played an important role in the development of the oil & gas resources in the United States, where an estimated 35,000 wells are hydraulically fractured each year. It is estimated that over 1 million wells have been hydraulically fractured since the first well in the late 1940s. As production from conventional oil & gas fields continues to mature and the shift to nonconventional resources increases, the importance of hydraulic fracturing will continue to escalate as new oil & gas supplies are developed.

Water requirements for hydraulically fracturing a well vary widely, but on average it requires approximately 2 to 4 million gallons per well to extract gas from deep unconventional shale reservoirs. Although these volumes may seem large, they generally represent a very small percentage of total water use in the areas where fracturing operations occur. Water used for hydraulic fracturing operations can come from a variety of sources, including surface water bodies, municipal water supplies, groundwater, or wastewater sources. Water can also be recycled from other sources, including previous hydraulic fracturing operations. Despite the increasing demand for water for shale gas development, water withdrawal for shale gas use is small compared to water withdrawals for other uses. For example, in Texas, the water use for shale gas is less than 1 percent of statewide water withdrawals,[21] although a large number of wells have high water requirements per well.

Obtaining the water necessary for use in hydraulic fracturing operations can be challenging in some areas, particularly in arid regions. The volume of water required for hydraulic fracturing challenges operators to find new ways to secure reliable, affordable supplies. In some areas, operators have opted to build large reservoirs. These reservoirs may capture withdrawals from local rivers (as permitted by state or local water resource authorities), or they may store fracture flow-back water for future use. Companies have also explored the option of using treated produced water from existing wells as a potential supply source for hydraulic fracturing operations. For example, **Chesapeake Energy**, one of the first shale gas development companies, has developed and implemented a produced water reuse program, the Aqua Renew program, which uses state-of-the-art technology in an effort to reuse produced water. The goal is to reduce the volume of freshwater used in Chesapeake's operations and thereby reduce the need to compete with other users. The Aqua Renew process is able to treat and reuse almost 95 percent of Chesapeake's Marcellus Shale-produced water.[22] Other companies are pursuing similar efforts. In all cases, the use of water and implementation of these recycling and reuse practices must conform to state and local regulatory requirements.

Water is essential to energy resource development; conversely, energy resources are needed for developing, processing, and distributing water resources. As a result, water and energy are interdependent. This balance or nexus between resources is a critical, yet often overlooked, component in evaluating energy resources. While water use varies substantially from case to case, shale gas plays make relatively efficient use of water.

In summary, the availability of water is essential to the development of shale oil and gas. It is estimated that by 2015, shale gas will account for 43 percent of U.S. natural gas production, a significant increase from 27 percent of the total in 2010. Correspondingly, the shale gas industry is expected to support 870,000 jobs in 2015, up from 600,000 jobs in 2010. In addition, the industry's contribution to GDP is expected to reach $118 billion, up from $76 billion in 2010.[23]

[21] "Water Use for Shale-Gas Production in Texas, U.S.," Jean-Philippe Nicot and Bridget R. Scanlon, *Environmental Science and Technology* 3580−3586: March 2012, p. 46.

[22] *The Play, A Quarterly Publication of Chesapeake Energy Corporation*, Spring 2010 Issue.

[23] *The Economic and Employment Contribution of Shale Gas in the United States*, prepared for America's Natural Gas Alliance, submitted by IHS Global Insight (USA) Inc., December 2011, page 5.

Thermal Power Generation Industry

Electric power generation requires large withdrawals of water, primarily for cooling systems. The amount of water withdrawn and consumed varies depending on the generation technology (for example, nuclear, coal, or combined cycle); the type of cooling system used (for example, closed cycle, once through); and other factors, including the unique characteristics of the source water. Among the external impacts potentially affecting water resource management are federal, state, and local regulatory changes as well as drought and other weather conditions. Decisions about future generation take into consideration many, and sometimes competing, factors. While some generation sources, plant types, and cooling systems are attractive for certain reasons (such as cost, fuel, or water availability), they may be less attractive for others. Therefore, the value of water to the thermal power generation sector lies in having a threshold amount of water for its operations.

With growing public awareness of the many demands on water resources and the importance of conserving water, utilities in the United States are exploring several major water management options. These options considered for power plants include advanced cooling systems that use nontraditional water sources, methods, and technologies to recover water that otherwise would be consumed or released into the atmosphere. Some utilities are also employing processes that eliminate liquid discharge from a system or are using treated wastewater for processes on plant sites.

Southern Company, which serves more than 4.4 million customers in the southeast United States and is one of the country's largest electric utilities, is pursuing several new technology initiatives at its generation plants to improve water utilization. Southern Company also has a growing portfolio of water-related research and development initiatives under way. Exhibit 4 shows the results of the company's efforts to reduce water use.[24]

In northwest Florida, the company has partnered with Emerald Coast Utilities Authority (ECUA), the local water and sanitation services provider in Escambia County, to utilize reclaimed water for its scrubber system, which needs consistent, high-quality water. Through ECUA, the plant has reduced the amount of water it withdraws from the Escambia River and avoided construction of a water pretreatment plant.

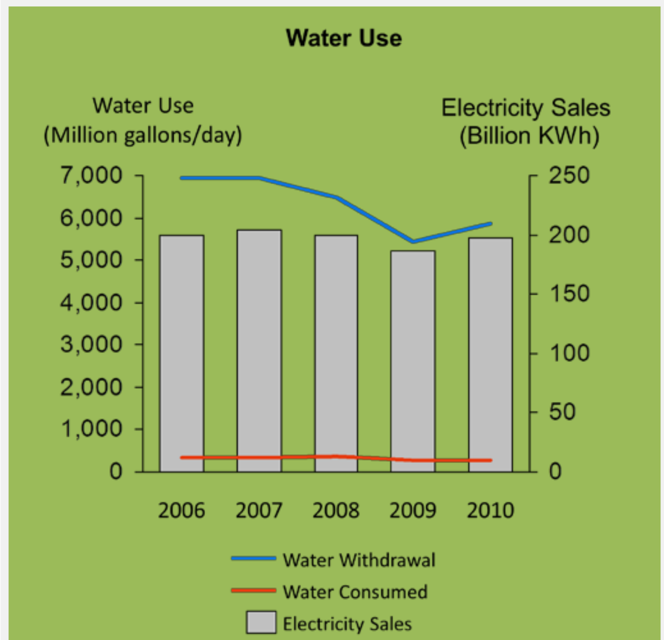
In Alabama, Southern Company researched and built a wetland to treat coal pile runoff. This passive biological treatment system provides low-maintenance, chemical-free water treatment, allowing the water to flow eventually to the Black Warrior River. The treatment process works much like natural wetlands.

[24] *Southern Annual Reports*, Southern Water Action Reports, Dec 2011

In Mississippi, the company is exploring a zero discharge option, in which no processed wastewater from its new integrated combined-cycle gasification plant, under construction in Kemper County, will be discharged into rivers, creeks, or streams. In addition, Mississippi Power will purchase and reuse the City of Meridian's treated effluent, or "gray water," for plant cooling.

Southern Company also is hosting a new Water Research Center, based in Georgia, scheduled to open in fall 2012. The center will test water conservation technologies related to power generation and allow researchers from around the world to test technologies to improve water efficiency in seven focus areas: cooling systems, moisture recovery, zero liquid discharge, solid landfill water management, wastewater treatment, carbon technology effects, and modeling/best practices.

In addition, Southern Company is seeking ways to improve water resource management in non-generation facilities and applications.



Source: Reproduced with Permission from Southern Annual Reports, Southern Water Action Reports, Dec 2011

Exhibit 4: Southern Company Water Use

Through various individual initiatives and the collective action of electric utilities to manage water resources more effectively, the power generation sector will likely continue finding ways to decrease water withdrawal and consumption per unit of electricity generation.

Cross-sectoral Perspectives

Although the use of water varies across sectors, the industries examined above face some common challenges and opportunities in managing water resources and ensuring the availability of water for their operations:

- Increasing competition for water
- Increasing awareness of water usage (measurement and reporting)
- Potential for business disruption because of changes in volume or quality of water
- Efforts to increase water efficiency and to plan for contingencies (developing engineering or economic solutions, including investing in public or private infrastructure, depending on such factors as cost and availability of water resources and rights)
- Innovation (technological, financial, and collaboration via partnerships)

Conclusion

The availability and accessibility of water is immensely important to the U.S. economy because water is critical to maintaining business continuity and supporting growth in production, both in the short term and long term. Industries are adopting best practices to maximize their position with regard to water resources, including implementing measures such as:

- Water reduction in the process (for example, less water consumed per unit produced)

- Energy reduction in operations (addressing the “water cost of energy”)
- Enhanced monitoring and automated control of water use
- Increased vigilance and control of indirect water consumption (for example, leaky pipes, running hoses, vehicle cleaning, dust suppression)
- “Fitness-for-use,” which involves treating water and wastewater to the minimum needed for the specific purpose in an industrial process, including using water in progressively less demanding processes
- Water reuse, which requires both energy and additional capital investment

This paper focused on identifying the water challenges faced by selected industrial sectors, and has showcased some of the approaches that are being taken to address them. There is every indication that with water being squeezed from both ends–climate change altering supply and population growth increasing demand–water issues will continue to increase.

Future work is needed to quantify water usage across industries in specific geographies and determine how effective these approaches are in reducing water stress.

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