02

Impact Series

The water challenge: preserving a global resource

Barclays and the Columbia Water Center explore how energy companies and public utilities can help alleviate water shortages and improve water quality through new technologies and better practices

BARCLAYS

Foreword

Welcome to the second report in our Impact Series, in which we shine a spotlight on how the energy industry – and, in particular, the oil and gas sector and public utilities – can improve the way it uses and recycles water.

March 22, 2017

Water is arguably the most important natural resource, essential both for human survival and for the effective functioning of many industries. As climate variability impacts the availability of freshwater, and economic growth puts pressure on global water supplies, households as well as industrial, energy and agriculture sectors are increasingly likely to experience supply disruptions in the near and long term.

The data point to some clear challenges. Only 2.5% of the world's water is fresh[*], yet the US depends on it for nearly 90% of withdrawals for public and industrial use[**]. At the same time, groundwater, which is present under the earth's surface and makes up 30% of all freshwater, is under wide-spread stress, with NASA reporting that a third of major water basins globally are being rapidly depleted by human consumption[***].

The human cost of water scarcity is likely to be high. The Organisation for Economic Cooperation and Development (OECD) estimates that about 1.5 billion people today live in areas seriously affected by shortages, predicting that it will rise to 4 billion by 2050, accompanied by a 50% increase in the demand on water resources.

While individuals, governments and other consumer and policy organisations are all instrumental to preserving this precious commodity, the energy industry in particular can have a positive impact on alleviating water shortages. Oil and gas companies, as well as power and water utilities, are ideally placed not only to be more efficient users of water but also to be pioneers in finding alternative water sources and introducing innovative technologies to counter wastage.

We believe this report makes a valuable contribution to the debate on the future of water.

Jes Staley, Chief Executive Officer of Barclays

"Only 2.5% of the world's water is fresh, yet in the US we depend on it for nearly 90% of our withdrawals for public and industrial use."

* Source: Food and Agriculture Organization of the United Nationsv

** Source: US Geological Survey (USGS)

*** Source: NASA http://www.nasa.gov/jpl/grace/study-third-of-big-groundwater-basins-in-distress

What this report is about

Global water stresses are not only a serious challenge for society and the environment, but can also be viewed as a sustainable investment opportunity. This report is the result of a collaboration between Barclays Research and Columbia University to explore how investment in new technologies and infrastructure can help alleviate the social, environmental and development problems associated with water shortages and increased usage.

While the report focuses on the U.S., the issues discussed can be extended globally across industries - water risk and scarcity is a universal problem.

The U.S. energy industry uses substantial amounts of water in the course of its business operations and we think new technologies and practices present an opportunity to use water resources more efficiently. While water use in the energy industry is small relative to agriculture, usage is increasingly in the oil and gas industry, and underinvestment by public utilities presents infrastructure, environmental, and public health challenges.

In the U.S. oil and gas industry, for example, fracking operators have increased their use of freshwater from 5,600 barrels per oil well in 2008 to more than 128,000 barrels in 2014 and over 300,000 barrels in some areas today. Yet we are confident that oil and gas operators can substantially increase water reuse, learning from countries such as Canada, where regulations mandate water reuse and limit fresh water acquisition for oil sands operations.

Water scarcity could also pose a financial risk to both the utility and the oil and gas sectors, while shareholders and the general public are encouraging corporations to improve their transparency around water usage.

The structure of the report

- In the first part of the report we highlight the extent of the water challenge, how the energy industry contributes to the problem and the different technologies companies can apply to reuse or recycle the wastewater they create in the course of their business.
- The second part is divided into three: the oil and gas sector, power companies, and water utilities. We investigate the issues that are particular to each industry, but also explore the commonalities. We identify opportunities for them to collaborate through shared learning and innovation, and also look at areas where more can be done to protect water resources, and how the sector can collaborate with other industries. Through several case studies, we look at examples of best practices where companies are utilizing new technologies and methodologies to lower water related costs, improve their freshwater footprint, and help the communities where they operate.

The water mandate for energy companies and utilities

Worldwide, there is growing pressure on the availability of freshwater: the effects of climate variability are becoming clearer at a time when a growing global population is placing greater demands on resources and often has to compete with industry and agriculture for access to clean, safe water.

Water is a shared resource and all users and industries can help safeguard water supplies throughout the world. Lack of access to clean water is a global problem, but low income countries generally experience the burdens of water stress more acutely than developed countries. In the United States, too, inadequate water quantity and quality disproportionately impacts low income users. This has been exemplified by the lead contamination of drinking water in Flint, Michigan, where a combination of underinvestment, inadequate water treatment and poor regulation proved catastrophic for the community in 2014. The incident remains the focus of ongoing criminal investigations.

The challenge therefore is to ensure that there is enough water for humans to consume safely and sustainably, while also safeguarding policies and regulatory support for the reuse and recycling of industrial wastewater, as well as desalination programs.

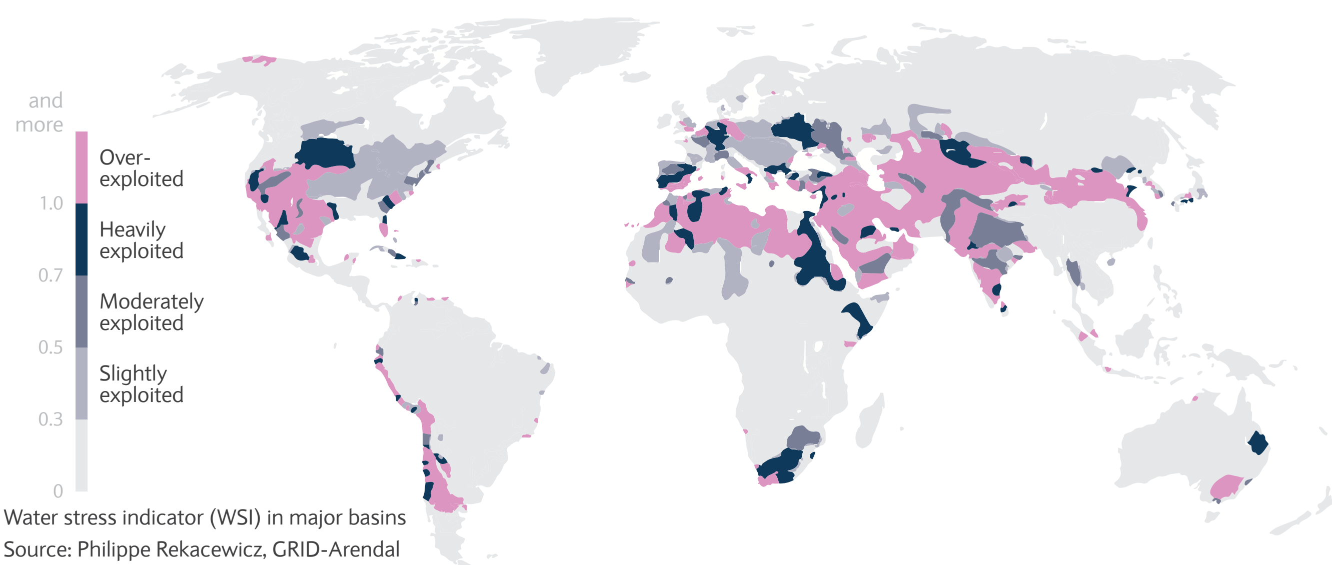
In this report we first turn to the oil and gas industry because water is crucial to its operations, and it has long been scrutinized over poor water management issues. While the industry has improved practices in recent years, more can be done to protect water supplies, and there is room for collaboration with other industries. In this report, we highlight two case studies of progressive practices by oil and gas companies.

Collective action is needed not only from oil and gas operators, but also the utility industry and government, to improve transparency around water usage, invest in innovative technologies, and to improve data collection and sharing across sectors. Robust water management, combined with innovative technologies and forward-looking practices, are not only good for the environment and society, but could also benefit companies' bottom line.

In essence, we believe the industry could consume less freshwater and do more to access alternative sources through recycling and reusing more of the waste water it produces as a by-product of its operations.

Figure 1

Global pressure: water withdrawals have steadily increased in the past century



Water stress indicator (WSI) in major basins
Source: Philippe Rekacewicz, GRID-Arendal

The importance of the water cycle

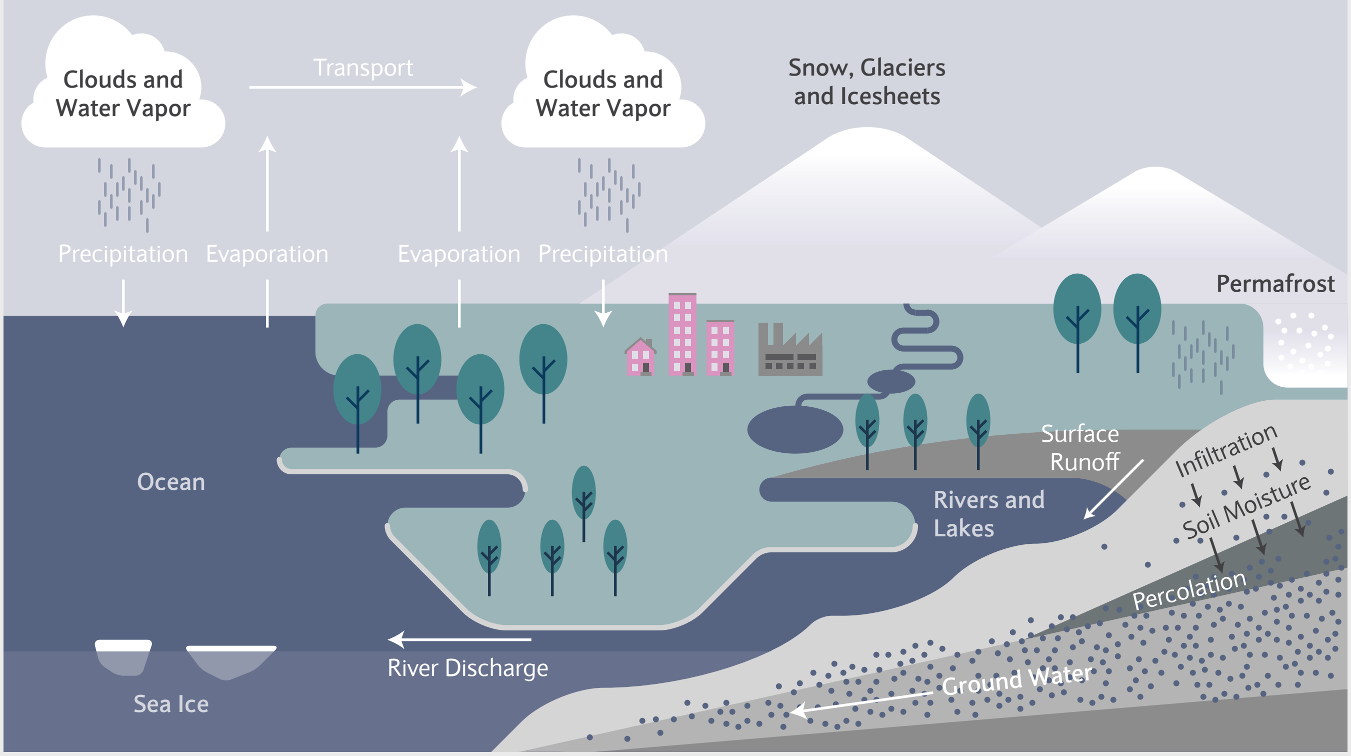
Freshwater undergoes a cycle of precipitation, evaporation and transpiration. Water evaporates from water sources, such as dams, rivers and the sea, into the atmosphere where it transforms into precipitation (rain and snow). Some of this water evaporates into clouds and returns to the atmosphere beginning the cycle again, while other precipitation is stored in reservoirs, aquifers or dams and rivers.

Subterranean water bodies, such as aquifers, are replenished at a slow rate because the water must pass through soil, gravel and other sediment. Physical water stress happens when water is depleted at rates faster than they can be recharged.

A large part of water shortages is due to inefficient use and losses from inadequate infrastructure to capture rain and snow. In urban areas, for example, between 10% and 50% of water is lost. Because rainfall is variable depending on the climate and time of year, some regions may have surplus water, while others may not have enough. “The greatest challenge is that water is not available when we need it,” according to Upmanu Lall, Director of the Columbia Water Center.

We define the main water constraints as:

- groundwater depletion
- poor water quality
- the potential for future scarcity because of droughts
- lack of storage



Source: NASA

Ripple effect: a local problem with wider repercussions

Water scarcity has a direct effect on public health, availability of food and, ultimately, public safety. In an increasingly interlinked world, with ever-expanding trade routes, water stress in one geographic region not only affects local populations, it can also have a reverberating impact in other regions.

In agriculture, for example, a shock like a drought or blight (a fungal disease that spreads rapidly in wet weather) can have a high human cost through famine, but also have global implications for food supplies. Countries that import water are especially vulnerable to such shocks.

Other industries can be impacted too. For example, in the United States several regions import hydroelectricity from Washington State. When dry years or reduced snowmelt impact Washington's capacity to generate hydropower, it reduces its ability to export electricity to other states. Climate scientists predict that by 2040, lower snowmelt in the state could decrease hydro generation by between 18% and 21%.

Taking responsibility: how the energy industry uses water, and what it can do better

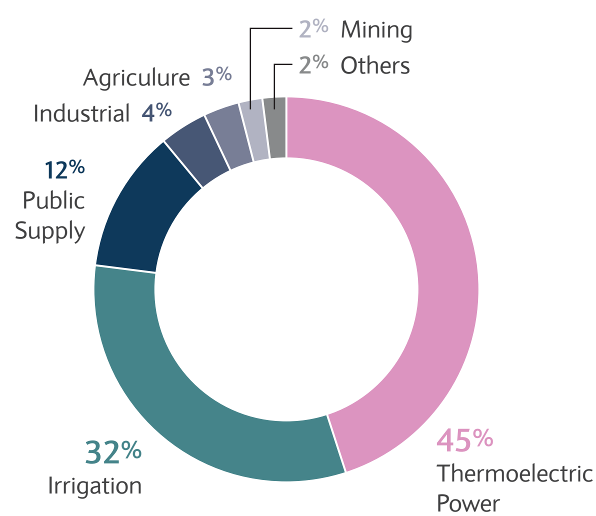
While oil and gas companies do not use as much water as other industries, including agriculture, in certain contexts their water usage may be significant. More importantly, although the industry is improving the way it deals with wastewater, in particular, it has been responsible for spillages and other problems. Companies that implement sustainable water practices, such as reusing water and building efficient infrastructure, could lessen the industry's contribution to water scarcity and quality issues, allowing them to act as water stewards.

The electric utility industry has large water withdrawals compared to other industries, but much of this water is returned to the water cycle. The problem lies not so much in contributing to water scarcity as protecting against it. However, in water-stressed regions, these withdrawals may contribute to supply and demand imbalances. We believe that when possible and economical, electric utilities could use alternative sources of water such as treated saline or recycled water for cooling purposes.

Policy and economics will be the biggest drivers of innovation for power and water utilities. In an uncertain regulatory future, we believe that utilities that incorporate water risk planning into their strategic planning and engage in integrated water resources management will be better positioned for unforeseen water shocks. Water utilities must prioritize infrastructure investments and maintenance before they can invest in new technologies and cooperate with power utilities for shared resources.

Figure 2

Thirsty business: water withdrawal by industry



Source: US Geological Survey

Practical steps to tackle water shortages

Many entities can make a difference – governments, individuals, non-governmental organizations (NGOs) and others - but crucially also the companies that are high-volume users of water.

What individuals can do

Individuals and society can begin thinking about water constraints as part of an overarching climate variability problem. Because climate variability exacerbates water-related shortages through droughts, for example, efforts to mitigate global warming could help relieve future water stresses. Individuals and society should consider their energy and food choices as directly shaping future climate scenarios and indirectly influencing their future water resources.

The role of government and water agencies

US government research and development is an important funding source for new water technologies. The government also oversees crucial accounting agencies like the United States Geological Survey, and could play a leading role in developing a national data repository that enables more shared learning and cross-industry collaboration. Enforcing and standardizing water reporting across industries can also help improve water management. Current regulation around reporting for the oil and gas industry is inconsistent and voluntary for some states, and data from the water and electric utility industries is fragmented. Because larger companies have research and development budgets for water technologies, smaller companies could receive support from government agencies to engage in more research and development. In addition, state and federal governments could standardize regulations.

Companies can step up too

Companies could accurately measure and disclose their water usage. Steps have been taken to improve accountability for water supply chain operations, and to illustrate the connection between improved water management and reduced greenhouse gas emissions. Formerly known as the Carbon Disclosure Project, CDP has a water program aimed at motivating companies to disclose their water data. In the most recent CDP survey, only 34% of energy and utility companies disclosed their water use to CDP, suggesting room for improved transparency.

Energy companies should not only consider water as a shared resource, but invest in ways to reduce freshwater usage by collaborating with other industries like agriculture, municipalities and utilities for alternative water sources for drilling and cooling activities. Companies - particularly utilities - can also consider implementing simple measures such as demand management, energy efficiency and consumer education. These strategies have worked well in drought-prone California to promote water conservation.

Collaboration, shared learning and innovation

Despite differences between the three industries we profile - the oil and gas sector, electricity providers, and water utilities - there are opportunities for them to collaborate through shared learning and innovation. The energy industry can also protect water resources by collaborating with other industries. For example, larger, well-capitalized companies in the oil and gas industry, as well as some utilities, can help finance upgrades for capital-constrained small public wastewater utilities in exchange for use of wastewater.

Glossary

Freshwater is deemed safe for human consumption, occurring naturally through precipitation and in dams, river and some underground sources.

Brackish water is a naturally occurring mixture of fresh and salt water, also known as brine.

Saline occurs naturally in oceans, has a salt content higher than brackish water, and is not drinkable.

Recycled water is wastewater that has undergone a robust treatment in order to be used again.

Reused water is wastewater reused within an oil or gas well, requiring little or no treatment.

The technologies that could make a difference

Water scarcity is a problem for all of the industries examined in this study, but there is a host of technologies and practices that can transform alternative sources of water for drinking and industrial use. Evidence shows that energy companies can be incentivized to put effort into research and development that can deliver technologies to benefit all. The following is a list of technologies that can help curb water wastage.

Desalination:
Widely used in the Middle East, desalination treats non-potable brackish (a naturally occurring mixture of fresh and salty water, also known as brine) as well as sea water to freshwater standards to be used for oil and gas drilling, irrigation, industrial use, power plant cooling and drinking water. The main technologies associated with desalination include the membrane method, whereby water is pushed through a membrane to remove the salt, and heat-based treatments. While costs and energy usage have declined, treating highly saline water remains energy-intensive and expensive. Renewable powered desalination and energy recovery technologies can reduce electricity costs.

Recycled effluent water (municipal wastewater):
Reusing wastewater is another method of reducing dependence on freshwater supplies. We look at examples of recycled municipal effluent in both the oil and gas sectors and the electric utility sector.

Indirect potable reuse (IDPR) and direct potable reuse (DPR):
These incorporate the practice of treating wastewater to drinkable standards and then either indirectly (through a natural buffer like a river or reservoir) or directly reintroducing the treated water into drinking water sources. Although the treatment technology for direct potable reuse is proven, regulatory hurdles and public acceptance are some of the largest obstacles, and only a handful of examples of potable reuse exist in the U.S.

Advanced metering infrastructure (AMI):
Also known as the smart grid, electronic metering and software is installed on customers' water or electric meters. The system utilizes automated meters (smart meters) to read energy usage in real time, and sends it back to the utilities. AMI not only shows customers how much water they consume, it also provides utilities with continuous data on water consumption through data analytics packages. Already widely practiced in the electric utility industry, water companies are beginning to adopt AMI to improve accuracy in billing and evaluate consumption. AMI systems can help utilities identify water leaks, reduce operating and maintenance costs, and communicate the value of water to customers.

Leak detecting technologies:
Technologies such as acoustic monitoring can help water utilities identify expensive pipe leakage and water loss. Acoustic monitoring uses devices to listen for leak "noise" or vibrations on a nightly basis when there is little background noise and low water usage. Usually paired with AMI, the acoustic monitors gather data and send the noise signals to the field office, where it is analyzed and the physical leak location is identified.

Dry cooling:
Thermoelectric power utilities withdraw large amounts of water for their cooling needs. Dry cooling can reduce water use significantly, but these savings may come with efficiency losses. Water-stressed regions may retrofit existing plants with dry or hybrid cooling systems or build new dry or hybrid cooling plants to reduce overall withdrawals.

What does good water management mean?

For energy companies:

- Sustainable water practices will increasingly be a part of energy companies' social license to operate in a water-constrained world.
- The economics of adopting efficient water usage, through various improved technologies and innovative practices, are compelling and could drive further adoption.
- Despite a relatively more relaxed regulatory environment under the new U.S. Administration, we think the risks (reputational, legal, and financial) are increasing, particularly in water-conscious and -constrained communities.
- Public-private partnerships can lead to "win-win" outcomes for corporations and communities by saving costs, improving infrastructure, and reducing fresh water usage.

For investors in energy companies:

- Companies that are able to lower fresh water usage and costs will be better positioned for an uncertain water future.
- Oil and gas companies are able to lower costs and water usage by utilizing more efficient sourcing methods and technologies.
- As water becomes a growing input for oil and gas and energy companies, security of supply to support growth plans will be increasingly considered.
- Water and soil contamination related liabilities represent significant investor risks, particularly with the rise of public water awareness in the wake of the events in Flint, MI.
- Smart technologies including meters and monitors can boost returns by reducing water loss and identifying damaged infrastructure.

Figure 3

Where the salt flows: sources of brackish water in the US

Source: US Geological Survey

Alternative sources of water

Recycled municipal water, as well as brackish and saline water create alternative sources of water for many industries, including the energy sector.

Developments in desalination have generated interest by the US Geological Survey and the Texas Water Development Board in better mapping brackish groundwater recharge and availability. The map above illustrates the amount of brackish water present in aquifers throughout the U.S., which are unsuitable for human consumption without treatment, and may even require additional treatment before use by some industries. However, new technologies mean brackish water can be used for power plant cooling and oil and gas operations, and could even be transformed into drinking water through desalination treatment.

The water-climate nexus: the impact of climate change on water

While demographic and economic pressures are increasing the global demand for water, a major source of increasing stress on the supply side is climate variability. Over time, the climate could have an increasing impact on the availability and quality of water that industries can access.

Climate change and water are interconnected in several ways. The Intergovernmental Panel on Climate Change (IPCC) cites robust evidence in the scientific community that increasing greenhouse gas concentrations raise freshwater-related risks, and that climate change will reduce both renewable surface water (dams, rivers, reservoirs) and subterranean groundwater. In fact, the IPCC estimates that between 7% and 20% of the global population could be exposed to reduced freshwater supply for each degree of global warming.

The IPCC also shows some evidence of additional water-related risks caused by climate change including reduced water quality and increased frequency of droughts.

Climate changes and the impact on global water supplies

In terms of the water risks expected to be exacerbated by climate change over time, the IPCC singles out in particular the following:

- Climate change is likely to lead to a significant reduction in renewable water in most dry sub-tropical regions
- Climate change is likely to negatively impact freshwater ecosystems by changing streamflow and raw water quality
- In dry areas, climate change is likely to increase the severity and frequency of droughts, both meteorological droughts (less rainfall) and agricultural droughts (less soil moisture)
- Climate-change projections imply increased flooding risk at a global level but especially in south, southeast, and northeast Asia, tropical Africa, and South America
- Climate change is likely to cause decreases in the extent of permafrost and glaciers, in turn releasing more greenhouse-gases with consequences not yet modeled by the IPCC

The key regulations governing water use

Drinking water:
Safe Water Drinking Act

Groundwater:
Ground Water Rule, Source Water Protection

Fracking:
Underground Injection Control Program

The connection with droughts

Columbia Water Center scholars have made pioneering connections between California's recent drought and climate change. In 2015, scientists argued that while precipitation acts as the primary driver of drought variability, human-driven warming has been a secondary driver of the California drought from 2012-2014. Scientists at the Lamont Doherty Earth Observatory say the evidence indicates that while droughts have cycles, over the past two centuries droughts in the American West have increasingly worsened due to climate change.

The map from Columbia Water Center illustrates water stress as a result of climate-driven drought. The red areas illustrate regions where demand exceeds average annual supply in the county.

Paying attention to groundwater depletion

A commonly cited statistic is that 97.5% of earth's water is saline, while only 2.5% is fresh. Only 0.3% of all freshwater is stored on the surface in dams and rivers; 30.8% is groundwater and the vast majority of freshwater is frozen in glaciers, snow and icecaps. The main users of groundwater include agriculture (irrigation), industry, public supply, and thermoelectric power generation.

Both pollution and natural processes lead to variations in groundwater levels but there is little data on the effects of climate change. Nevertheless, the dearth of clean fresh groundwater is likely to become a concern in the future.

Groundwater is a form of subterranean water storage that naturally recharges through precipitation like rain and snowfall. However, because the precipitation enters into the water table through pores of soil and rocks, it takes time to replenish, especially if it is withdrawn at a faster rate than it is recharged. Improvements in water recycling and treatment technologies could be used to recharge aquifers artificially.

Recent mapping from NASA shows that groundwater stress is widespread, and in fact a third of major groundwater basins show depletion.

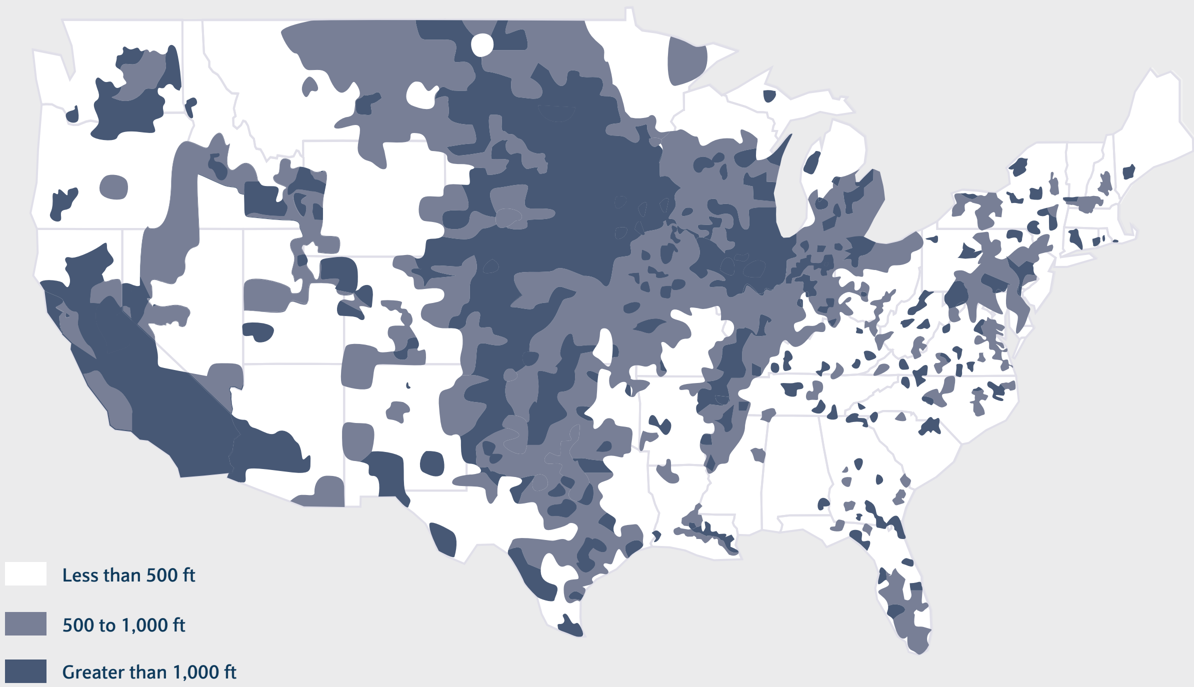
Good quality water is essential

In addition to the quantity of fresh groundwater, quality is also important for humans, animals and other living organisms as well as industries. Groundwater contains dissolved chemicals, particulates and organic materials, some of which are natural while others are caused by human activity. Of particular concern to humans is groundwater with high levels of arsenic, chloride and nitrate. Only a portion of the available groundwater in the United States is fit for human consumption and industrial reuse without additional treatment.

Jiminez Cisneros, B.E., T. Oki, N.W. Arnell, G Benito, J.G. Cogley, P. Doll,T. Jaing, and SS Mwakalila, 2014; Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate change, pp. 229-269.

Figure 4

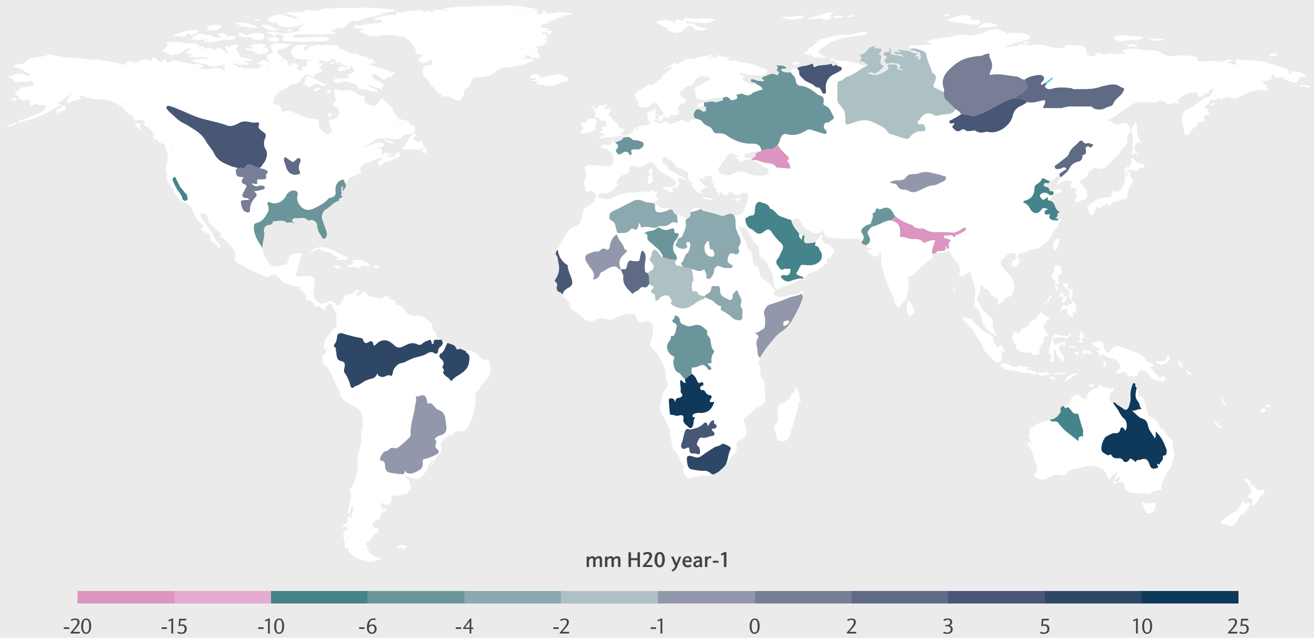
Water stress based on magnitude of water deficits and drought risks in the US relative to demand patterns



Source: America's water risk: Current demand and climate variability, Geophys. Res. Lett., 42, doi:10.1002/ 2015GL063487 and the Columbia Water Center

Figure 5

Human consumption: the depletion of groundwater basins around the world



Source: NASA

Going with the flow: How energy companies and utilities use water

Energy companies need water for most aspects of their supply chain, from pumping to treatment and cooling. For its part, the water industry requires large amounts of electricity to treat water and convey it from source to destination. In this part of the report we look at just how interconnected these two industries are, and discuss some of the most efficient solutions to water shortages that can reduce both energy and water usage.

Our research shines a spotlight on how the energy sector – and, in particular, the oil and gas, and power industries – use water in the United States. We use our findings to forecast how water constraints can act as either a barrier or a driver of investment opportunities, and make recommendations for sustainable solutions to water-related shortages. By examining industry growth, and analyzing data on water consumption by industry, we compare water consumption data from Barclays Research, the Columbia Water Center, Digital H20*, as well as publicly available information.

Improved water management can help energy companies' supply chains, and could protect resources by using alternative water sources when possible. At the same time, water scarcity also poses a financial risk[1] to companies with shareholders and the general public demanding that they improve transparency. Reputational risk and regulatory actions are also important considerations.

* Digital H20 is a digital oilfield solution company focused on developing software-based insights and solutions for the end-to-end management of water in oil and gas production

Acting together to avoid a crisis

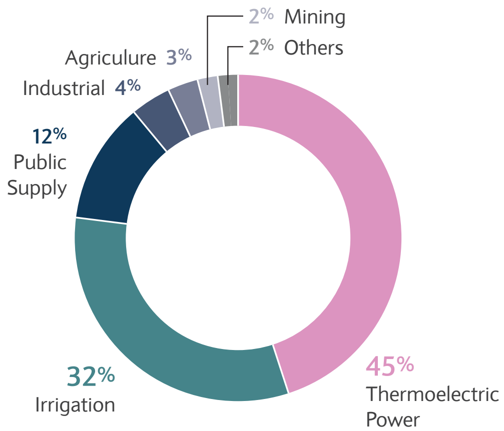
We first turn our gaze on the oil and gas sector because cost-effective water management is crucial in a low oil price environment, and is also important for companies' social license to operate. It is clear that both the oil and gas sector and the power industry can do more to find alternative forms of water and invest in new technologies. However, they also face common regulatory, logistical and economic challenges in sourcing adequate alternatives such as saline or municipal effluent water. We believe that with enabling regulations, and improvements in data management, these industries are well-placed to invest in infrastructure, enter into public-private partnerships and collaborate with other industries.

In the water utility industry, especially, the infrastructure crisis is so acute that it needs immediate attention both from a human rights and a business perspective. There is a significant opportunity for public-private partnerships and capital investment, and we believe that collective action is needed to improve transparency and encourage investment in innovative technologies. Robust water management can lead to lower operating costs and can also preserve resources for future operations.

Each industry has a unique set of challenges related to water scarcity, but some solutions can be applied across sectors. As climate variability and competition for resources put pressure on the availability of freshwater, some industries will be impacted more than others. For example, cooling for thermoelectricity - the name given to electricity that is generated by heat – has one of the highest withdrawals, while mining (including oil and gas extraction) requires far less water.

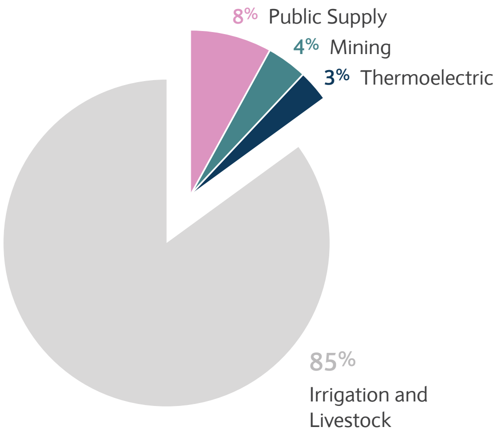
It is important to note that while withdrawals from the thermoelectric power industry are large, it is not regarded as a major water consumer. The US Geological Survey defined consumptive use as water that has been withdrawn and incorporated into a product or crop – and therefore not returned to the water cycle. By this definition, irrigation and livestock are by far the largest water consumer. This means that users with little consumptive use are not large contributors to water scarcity. However, water is essential to their functionality, and so competition with other industries like agriculture could have investment ramifications.

Figure 6
Water withdrawals by industry



Source: US Geological Survey

Figure 7
Water consumption usage by industry



Source: US Geological Survey

The oil and gas industry

One of the most controversial methods for extracting oil and gas is hydraulic fracturing, known as fracking, in which water is injected at high pressure into subterranean rocks in order to open fissures and release oil or gas. Fracking has a reputation for being a highly water intensive industry compared to other industries, but it actually uses a fraction of the available freshwater in the U.S.,[2] according to the USGS. For example, water use by the mining industry (which comprises extraction of coal and iron, and liquids like petroleum, and natural gas) in 2010 was 1% to 2% of total U.S. freshwater withdrawals.

As a whole, the oil and gas industry uses less freshwater than the electric utility industry, but in some regions it may be substantial relative to the amount of available water.[3] In addition, the amount of consumptive water used by oil and gas producers varies by operating region and basin.

What are the challenges?

Exploration and production companies in the oil and gas industry face two obstacles: 1) obtaining water for fracking (or "completing" oil and gas wells that have been drilled); and 2) finding a place to put the large volumes of wastewater produced by the fracking process.

Oil and gas operations are becoming more water intensive. While withdrawals are small compared to irrigation (32%), thermoelectric power (45%) and industrials (4%), according to USGS data, we think that future reductions in the quality and quantity of water as well as competition from other industries will create additional pressure points.

Another challenge is that increased amounts of produced water – the term used to describe water that is produced as a byproduct along with oil and gas - is problematic for surrounding communities and the environment due to its high salt content. In addition, water scarcity may drive up the price of freshwater, while disposal of produced water may increase costs and pose environmental and social stresses.

Where there are risks, there are opportunities too

The use of water for fracking varies from location to location depending on the availability of water in a particular year and the type of well drilled. Regulatory challenges, wastewater disposal options, and competition between agriculture, energy and industrials, all impose geographically specific water constraints on U.S. oil and gas producers.[4] Due to uncertainty in water availability and quality, we forecast that competition between users will increase in the future, forcing some companies to pay more for water, increase investment in water management or even face curbed usage.

The low oil prices in recent years have forced producers to cut capital spending and operating expenses, which has encouraged more innovative and efficient water management, and we expect this trend to continue.[5] Public concern over the lack of sustainable water practices could lead to state regulations, potentially impacting water handling operations associated with oil and gas. Since regulation on water disposal and acquisition varies by state, shale exploration in particular could face unique regulatory water constraints.

Given the central role of water in oil and gas production, we believe the industry will rethink conventional water acquisition and disposal methods and invest in more efficient and sustainable water technologies and practices. We also believe that the industry can substantially increase water reuse, learning from countries such as Canada, which has brought in regulations mandating water reuse, monitoring and evaluation and limiting fresh water acquisition for oil sands operations.[6] Pennsylvania has also made strides reusing produced water (reusing 80-90%, versus the industry 10-20%) due to regulations and limited saltwater disposal options.

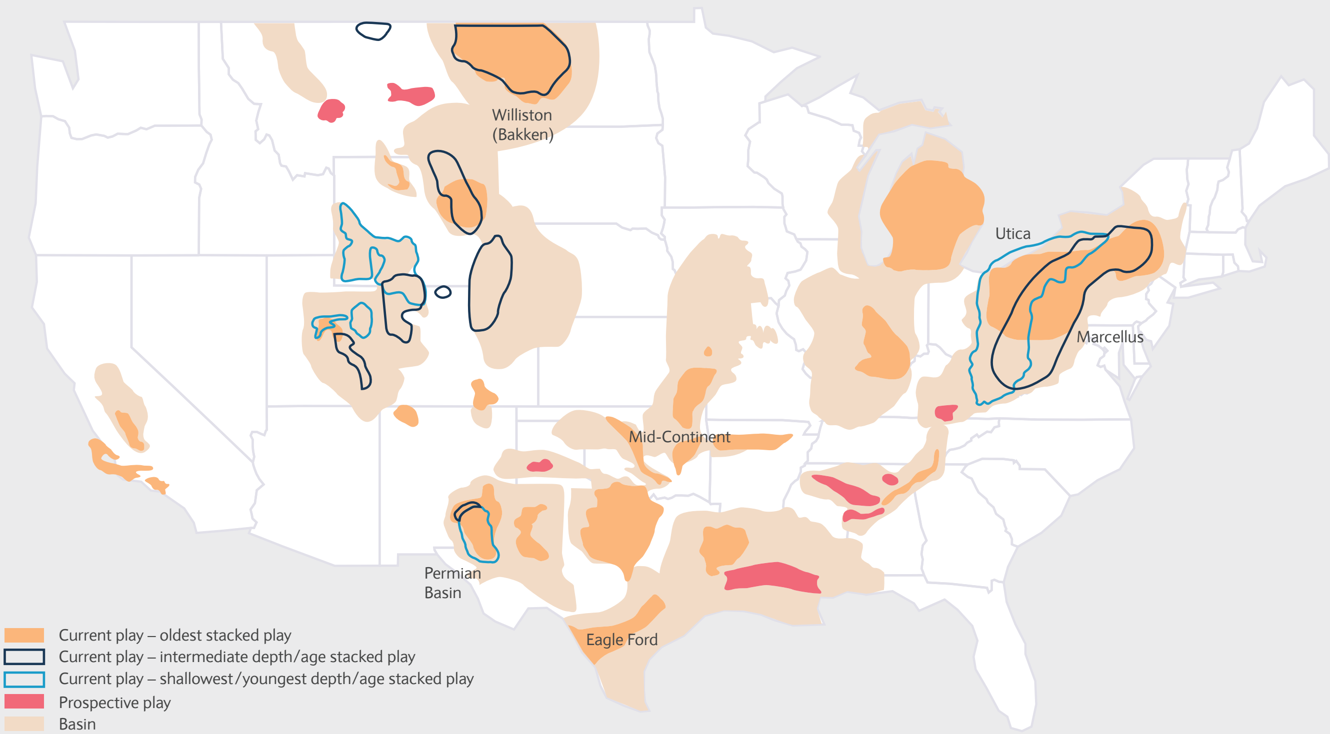
Although oil and gas market regulations under a Trump administration are uncertain, we project that the industry will show sustainable growth in parts of the United States. Based on its high oil and gas production despite lower oil prices, the Permian basin, which stretches across West Texas and New Mexico, is an example of overall water trends for shale production in the United States, and we look to the Permian for our analysis throughout this paper.

The companies that will be best positioned for an uncertain water future will be those that engage in sustainable water management practices by cutting down or eliminating freshwater usage, and treating wastewater as a resource. First, we estimate that reusing produced water in fracking operations could lower water costs by about 45% and save over 300,000 barrels of freshwater per well, improving company economics and the industry's environmental footprint, and enhancing security of supply.

The industry can help alleviate water shortages and create a new resource for other industries through the development of recycled water (which is more intensely treated than reused water and has a broader range of application). States could introduce regulations to incentivize smaller companies to finance and construct the necessary infrastructure and technologies. In addition, we believe that long-term water quality testing is important to ensure recycled water is safe for human and agriculture use.

Figure 8

The main oil and gas basins in the US as of 2016 (current and future)



This map shows the oil and gas basins throughout the U.S. as of 2016 – regions where the oil and gas industry is drilling today and in the future.

Source: EIA and Barclays Research

Rising pressure

While water use varies by play and region, overall, water use has been rising since 2008. The USGS found that between 2008 and 2014 median freshwater use for the injection stage in hydraulic fracturing increased from 5,618 barrels to nearly 128,102 barrels per oil well and 162,906 barrels per gas well, largely due to a shift to more water-intensive horizontal drilling.[7] The below chart by Digital H20, shows the increase in water use per well since 2013 broken down by the three main U.S. onshore oil plays, including the Permian Basin (up 434%), the Williston Basin (up 103%), and the Eagle Ford (up 64%).

Gradual supply constraints and regulations have also shaped how water is acquired and disposed of. In a business-as-usual scenario, operators will face gradual reductions in water supplies from both ground and surface water due to natural causes. In the context of extreme droughts or supply shocks, some local governments may prioritize the needs of agricultural producers over oil and gas operators. Each state has its own unique water rights, which determine water availability for producers in emergency situations.

Water sources for the industry

The availability and quality of freshwater both pose constraints for the oil and gas industry. For example, highly saline water may require treatment before storage and reuse. Similarly, producers may be constrained by water availability through droughts, distance to water sources, regulation around water withdrawals from river basin commissions and state water boards, and public scrutiny.[8]

If operators have diversified water sources, little competition with other industries, water infrastructure and plentiful surface water, a drought itself may not curb production activity. In times of drought users often turn to groundwater pumping, which can put pressure on supplies.[9]

The case for brackish water

The Permian Basin, which stretches underneath western Texas and southern New Mexico, is a large oil and natural gas producing region. However, a combination of multiyear droughts, low groundwater levels and competition with the agriculture industry also means it is highly water stressed.[10]

Oil and gas operators in the Permian depend on the High Plains aquifer (an underground rock formation that contains and enables the flow of groundwater) for its freshwater withdrawals. This aquifer is one of the most important yet highly depleted aquifers in the United States[11], which presents a challenge for operators.

Exploration and production companies have begun to think of brackish water (a naturally occurring mix of salty and freshwater) as a potential new source for their extractions.[12][13] In Texas, for example, almost 80% of water in many parts of Delaware side of the Permian Basin is sourced from brackish water, according to the Texas Railroad Commission, while the Midland side of the Permian uses about 30% brackish water.[14] Although brackish water can be used for drilling, it may require additional treatment and, because it is corrosive, may be subject to more transportation and storage restrictions, which will add to the costs.

In addition, pumping groundwater is energy intensive and expensive. Texas has plentiful brackish water aquifers, which can be thought of as an opportunity for future production. Recent developments in desalination have led the state of Texas to see brackish water as potential drinking and irrigation sources, which mean such aquifers may be better protected in the future.[15][16]

The role of water in hydraulic fracturing

Initial water

Water is involved in many stages of unconventional oil and gas production. At the beginning of the supply chain, a drilling company will typically acquire large volumes of freshwater to be transported to the well site, or alternatively source brackish, municipal or produced and flowback water. Producers will transport water from the source through truck or pipeline to the well, and store it in large impoundments. Once the well is ready for fracking, the water is mixed with proppants like sand and chemicals. The resulting fluid is injected into the well at high pressures with the intention of creating small cracks in the rock formation of the well. The fissures allow gas and oil to escape from the well and rise to the surface.

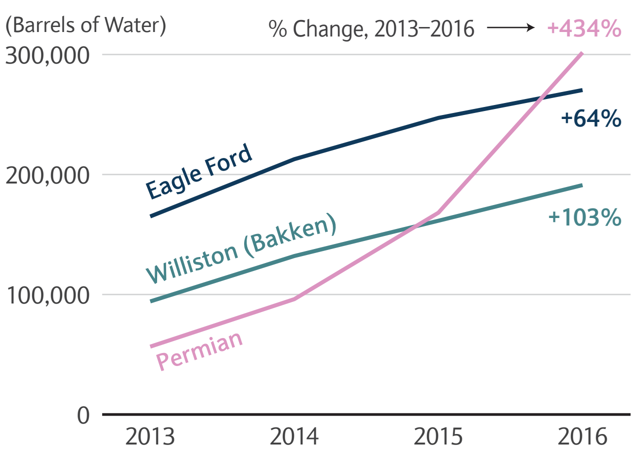
Once the pressurized fluid has been released, a combination of flowback and produced water will rise to the surface along with gas and oil. Flowback is fluid that was originally injected into the well, which flows to the surface after the frack is completed, whereas produced water is naturally occurring water in the shale formation, that typically has high salt content. Both flowback and produced water continue to rise to the surface throughout the life of the well. Because both contain oil, radioactive material, chemicals and dissolved solids such as salt, it must be handled and treated according to state regulations before disposal.[17]

Coping with ‘flowback’ and ‘produced water’

The amount of produced water and the water to oil ratio will influence water management costs and choices for the operator. The Marcellus formation is a bedrock in eastern North America that typically generates the lowest quantity of produced water of all the major shale regions in the United States.

Figure 9

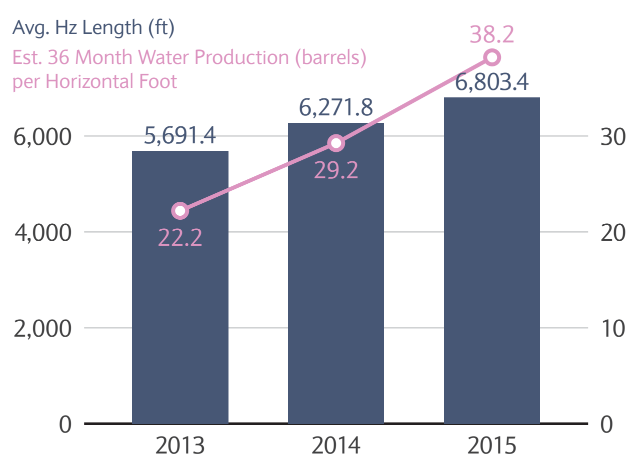
Average Water Used per Frack in the three major U.S. onshore oil plays



Source: Digital H20

Figure 10

Average Horizontal Length and 36 Month Water Production Per Horizontal Foot in the Permian Basin



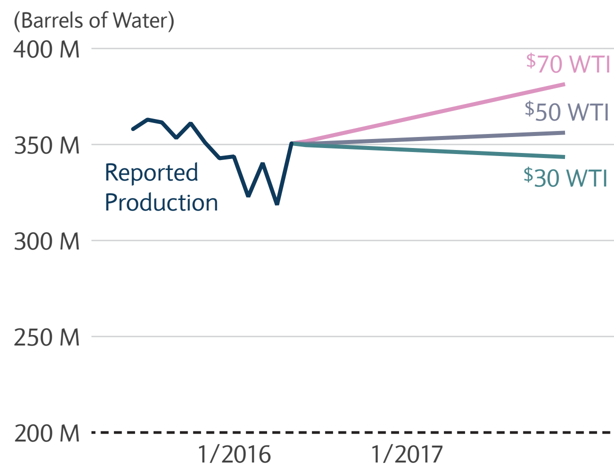
Source: Digital H20

By contrast, the Permian Basin has the highest amount of produced water among all of the U.S. oil and gas basins. On an absolute basis, produced water in the Permian Basin ranged from 358 million barrels to 286 million barrels between June 2015 and May 2016, compared with 14.8 million barrels to 11.8 million barrels in the Marcellus.[18]

The Permian Basin also has the highest water-to-oil ratio among the three major U.S. onshore oil basins. For every barrel of oil produced in the Permian Basin in 2016, over 6.5 barrels of water were produced. This compares with around 1.1 barrels of water produced for every barrel of oil in the Williston Basin (Bakken), and 0.9 barrels of water in the Eagle Ford. While Texas has hundreds of disposal wells in the state to accommodate the high volumes of produced water from the Permian Basin, disposal wells may not be sufficient and could reach capacity, and also overlooks the potential value of produced water.[19] As a result, reuse, and recycling could eventually become a necessary and attractive option.

Figure 11

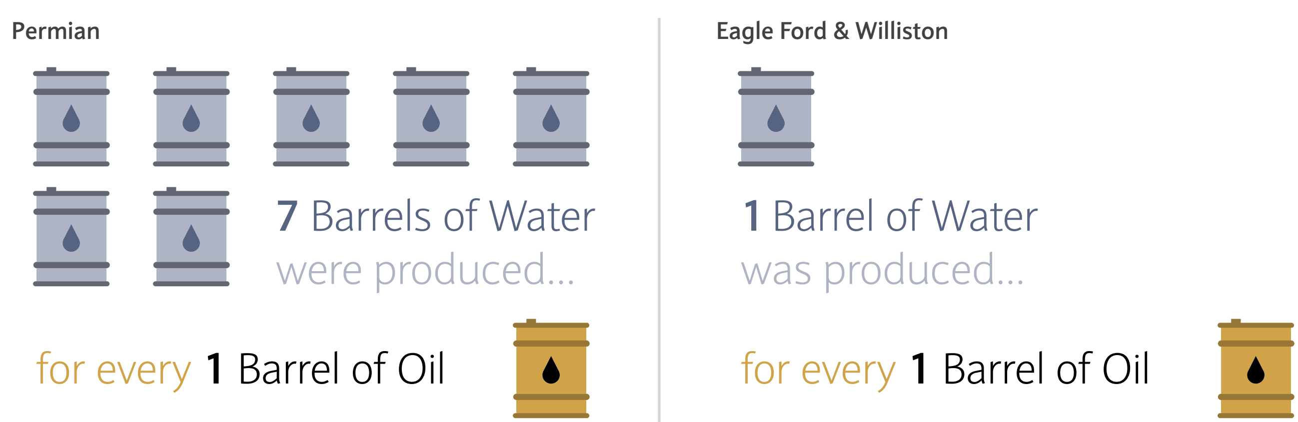
Permian Basin Total Produced Water Forecast Scenario Analysis



Source: Digital H20

Figure 12

Water-to-Oil Ratio for the three major U.S. onshore oil basins



Source: Digital H20

Putting a price on water

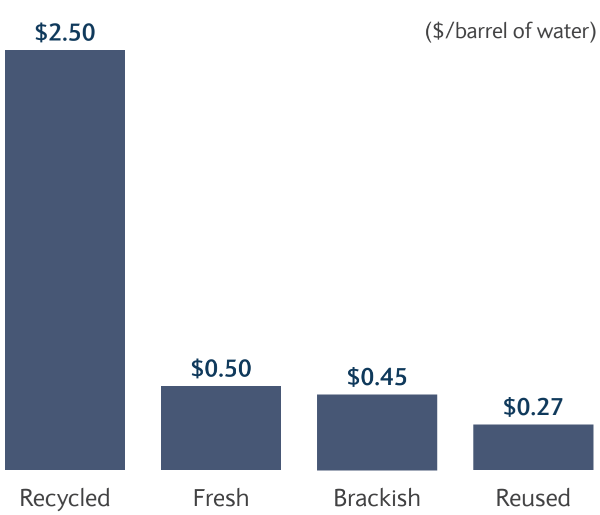
Approximately 10% to 30% of a well's capital expenditure is water related, while 40% to 55% of operating costs come from produced water management and disposal.[20] This percentage will vary considerably by basin due to factors including fresh water availability, competing uses, water quality and distance from water acquisition and disposal site, state and federal regulations and disposal and wastewater management selection.

While variable costs differ across basins, transportation of fresh and wastewater remains a universally high operating cost. According to the U.S. government's Energy Information Administration (EIA), water disposal including trucking and injection, ranges from $1 to $8 per barrel of water.[21]

The chart below illustrates water costs for fracking in the Permian Basin, excluding transportation costs for trucking, which generally ranges from $1 to $3 per barrel.

Figure 13

Average Water Costs for Oil and Gas Completions in the Permian



Source: Barclays Research

Options for wastewater management

Depending on the quantity of produced water and the water-to-oil ratio it contains, oil and gas producers have several methods for managing wastewater, including injecting it into deep underground wells, recovering some of the oil it contains, and treating for reuse and recycling. Reusing wastewater does not only cut water acquisition costs but also disposal and trucking costs, and it is also crucially an opportunity for improved sustainability and cooperation with other industries.[22] There are currently studies underway to test the selling of treated produced water for agriculture.

Water treatment

There are different levels of water treatment, and the quality of the wastewater determines to a large extent whether wastewater will be injected, reused or recycled for use in another industry. The basic level is direct reuse within a well, which requires little treatment, while recycling to fresh water standards will require several intensive steps of treatment.[23]

The next level of treatment is the most common and economic: simple filtration, which removes large organic particles, oil, and gas bubbles known as suspended solids. Another, more complex, treatment produces clean brine while a third level removes salts and naturally occurring minerals, particles and salts, collectively known as total dissolved solids (TDS).[24] Low-cost technologies exist to treat suspended solids and large particles, but removing salts is the most difficult and expensive.

The final stage of treating water to near-fresh standards is to remove bacteria, ammonia, heavy metals and other materials,[25] requiring technologies such as oxidation and biological treatment.[26] A last option is zero liquid discharge treatment, which converts wastewater into a dry solid, to be used for other purposes.[27]

Light treatment is sufficient to prepare water for injection into a saltwater disposal well, but more robust treatment methods are necessary for recycling for other purposes. Typically, producers transport their wastewater to a specialized treatment center specific to oil and gas production, which creates an additional transportation cost. However, larger companies are moving towards onsite water treatment to reduce transportation costs, discussed later in this report.

Putting a lid on disposal

We believe that a useful mechanism for incentivizing recycling and reuse is to restrict the disposal of wastewater. Two factors will create such a constraint: on the one hand disposal wells (used for storing wastewater) are reaching capacity and, on the other hand, an increase in regulation governing wastewater. Both of these factors will drive up the price of oil and gas extraction. If the oil price recovery continues, and subsequently more wells are completed, produced water volumes will increase, putting more pressure on disposal wells.

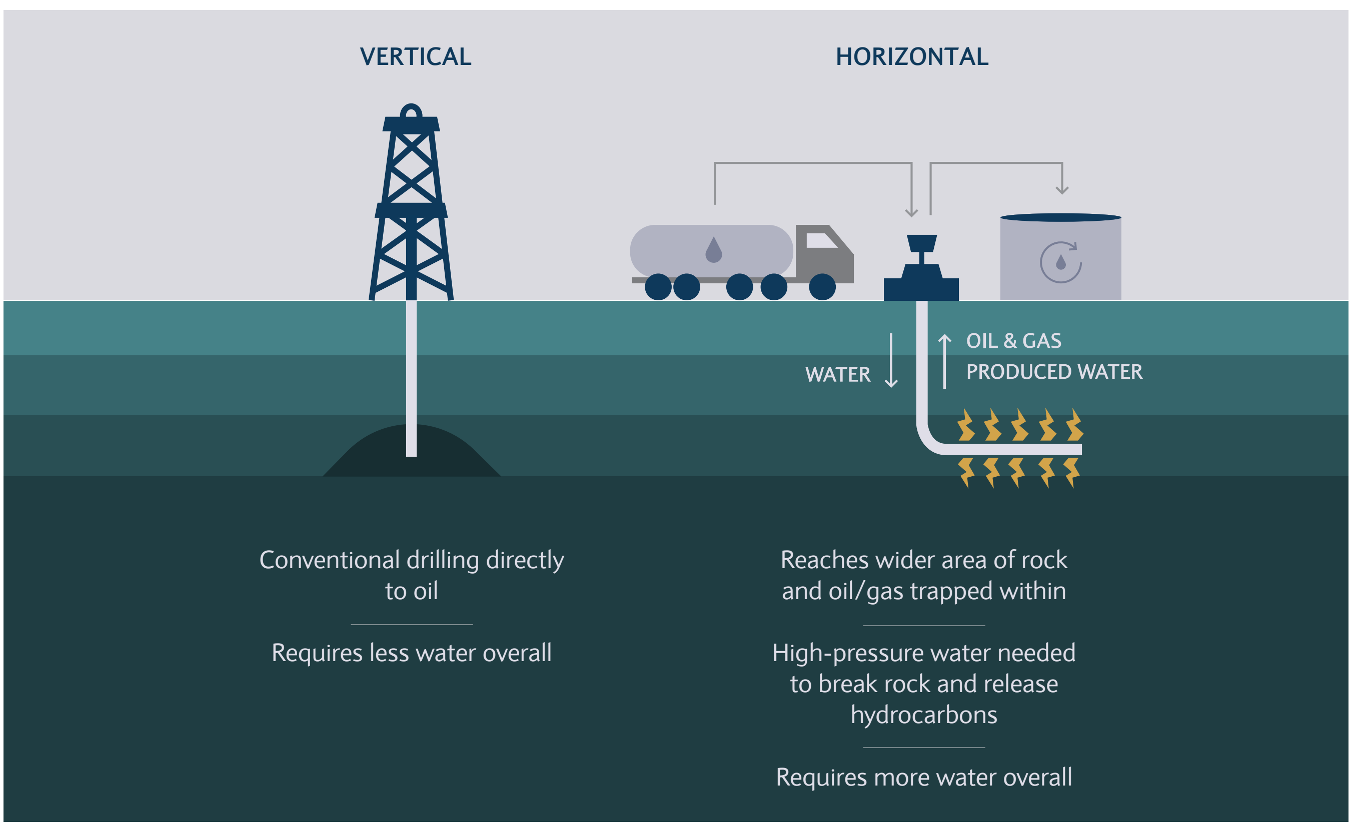
Regulations around earthquakes and new environmental rules, including potential protection of brackish groundwater, could also make disposal wells more expensive. In some parts of the United States deep-well injection has been connected with earthquakes, which could lead to regulatory limits. This could force exploration and production operators to look for other options for managing wastewater. In Oklahoma, for example, the Oklahoma Corporation Commission's oil and gas division recently issued restrictions on disposal wells in an area deemed susceptible to earthquakes, shutting down existing wells and reducing injection volumes in other ones.

Another factor that could influence the cost of disposal wells is research by the Texas Water Development Board on brackish water, which could see the Environmental Protection Agency give brackish aquifers the same protection as freshwater ones under the Safe Drinking Water Act.[28] The Texas Energy Alliance speculates that the cost of a disposal well could double, which could be a driver for reuse.

Favorable regulations such as the passage in 2015 of bill HB2767[29][30] could increase the price of wastewater injection wells by transferring the ownership and liability of wastewater from the producer to the person who takes possession of the wastewater.

Figure 14

New oil wells, new water demands



Source: EPA[31]

The two Rs:

Reuse…

While the terms recycling and reuse are used interchangeably, we define reuse as wastewater reused within a well, which requires very little additional treatment, while recycling is treating wastewater to acceptable standards through robust treatment. Economics, water availability, water quality logistics, and disposal options dictate whether an operator reuses or recycles, and so recycling and reuse rates vary across the country. Reusing water is logistically challenging for companies without enough connected land (known as contiguous acreage), because wastewater rises to the surface over variable periods (sometimes months), depending on the location and must be stored and later transported to a new well for reuse. The chance of spilling toxic wastewater increases when the water is moved and stored.

Reuse:
Wastewater reused within a well, which requires very little additional treatment

Recycling:
Treating wastewater to acceptable standards through robust treatment

… and recycling

Over the past few years, new opportunities for collaboration with industries, such as agriculture, have created sustainable solutions for water management. The industry calls these collaborations "beneficial reuse", though we refer to them as recycling.

There are many possible uses for recycled wastewater, especially for livestock watering, irrigation or industrial reuse for crops. For example, in Midland, Texas some farmers are experimenting with using recycled water from oil and gas for irrigation on non-food crops such as cotton.[32] In California, Chevron sells 21 million gallons per day of its treated wastewater to neighboring farmers for irrigation, according to the LA Times. However, such projects have not been tested long term and it is unclear whether radioactive material or metals in the recycled water has any harmful effects on soil and crops. For these reasons, many environmental groups and other public groups oppose the practice.[33]

Opportunities for the industrial use of wastewater include cooling power plants, process water and vehicle wash water. The National Energy Technology Laboratory has done several studies on using alternative sources of water for cooling including treated produced water, and we discuss their pros and cons in the chapter on power and utility companies. In addition, some states approve the use of solid wastewater for use on public roadways during winter weather. However, environmental groups are concerned that the salt and metal content could be hazardous to the ecology of roadside streams and farmlands.[34]

Our recommendations for better water use in the oil and gas industry

Barclays Research shows how the oil and gas industry could implement the following steps:

1) Operators can increase water reuse by:

a. Increased regulatory clarity, further data transparency, and enhanced industry and company coordination.

b. Additional research and development and progressive pactices and partnerships to drive costs lower.

2) Once operators substantially increase reuse the next steps for recycling include:

a. Technologies including membranes and distillation must improve and become cheaper, and storage tanks and pits must be engineered to prevent spillage.

b. Greater investment is needed around water infrastructure, to facilitate safe transportation of wastewater to centralized treatment facilities and to other operators.

c. Operators, the Government, and policy groups can coordinate research and development on long-term health and environmental effects of using produced water for alternative uses including irrigation, drinking water and industrial purposes.

Case Study

Laredo production corridors: efficient water treatment and reuse

Background:
Laredo Petroleum is an independent oil and gas company. With the primary objective of building blocked-up acreage throughout the Permian Basin, it began acquiring land in 2008, ending up with about 149,000 acres in 2015.[35] Its position facilitates the ability to construct production corridors and drill long lateral wells. In 2014, it created a long-term plan for full-scale and cost-effective development of its acreage. It decided to build four production corridors, which would help develop horizontal wells and improve efficiency and reduce costs. In addition, Laredo hoped to improve sustainability by reducing freshwater through reuse of produced and flowback water in new fracking operations.

Solution:
Laredo aimed to change its water usage through production corridors and building centralized infrastructure. The production corridors are designed to efficiently move oil, gas and water on site, process water at a centralized water treatment center, and transfer oil and gas products to market.

The largest corridor, Reagan North, holds the centralized water recycling facility, while the three smaller corridors - JECox, Reagan South and Lacy Creek - have water service lines connecting to, or the ability to build-out lines that connect to the water recycling facility. Overall, these production corridors and the treatment facilities have connected storage capacity of more than 5 million barrels of water and would be able to recycle 30,000 barrels of water per day.[36] By the first quarter of 2015, the Reagan North production corridor was fully operational. Spanning 7 miles, it was designed to provide services to 450 or more horizontal wells.[37]

Layout:
The Reagan North corridor is unique because it has a water storage facility and three different water lines to transport fresh, produced and recycled water. The corridor also has three different gas lines and an oil gathering line. By using a combination of robust 16-inch steel pipes and 10-inch poly pipes, rather than smaller pipes, the water is transported at faster rates. The buried pipelines have a monitored cathodic protection system and robust maintenance procedures to mitigate spills and leaks. An advantage of the corridor and the installed infrastructure is the efficient delivery and takeaway of water in efficient manner, minimizing spills and trucking.

The water treatment facility uses filtering and oxidation to remove solid particles and kill bacteria from flowback water that is piped to the facility. The treated water is then piped to a series of on-site storage ponds with a total capacity of 1.4 million barrels of water. The water can then be used for completions and is transported to the well-site by pipe. To date the company is recycling almost 40% of its produced and flowback water.

Cost Savings:
Laredo has currently invested around $100 million in its production corridor infrastructure, including roughly $56 million in water infrastructure assets. Additionally, Laredo has invested approximately $50 million in additional infrastructure assets not associated with the four production corridors.

Overall, Laredo estimates the production corridors provide around $1.3 million in benefits per 10,000’ horizontal well, recognizing about 25% of savings in the first six months of the wells’ life. In 2016, Laredo estimates water infrastructure generated capital and operating cost savings of $12.7 million. Recycling produced water instead of sending it to a salt water disposal well saved $0.32 per barrel of water in 2016. Gathering and transporting produced water by pipe as opposed to truck displaced around 95,000 truckloads of water, at a savings of $0.85 per barrel of water. Finally, using recycled water in well completions as opposed to purchasing freshwater saved around $0.26 per barrel of water. In the fourth quarter of 2016, Laredo estimates its production corridors reduced its lease operating expense by approximately $0.51 per barrel of oil equivalent.

Lessons:
Laredo is unique in the Permian, because of its large, contiguous acreage, which means it can effectively and safely deploy infrastructure that facilitates the reuse of wastewater. Companies with as much land would benefit from following its lead, while ones that are more spread out would gain from enhanced inter-industry collaboration, consistent regulations around water storage, and pipeline integrity to encourage safe reuse.

Case Study

City of Midland, Texas, and Pioneer: working hand in hand in a public-private partnership

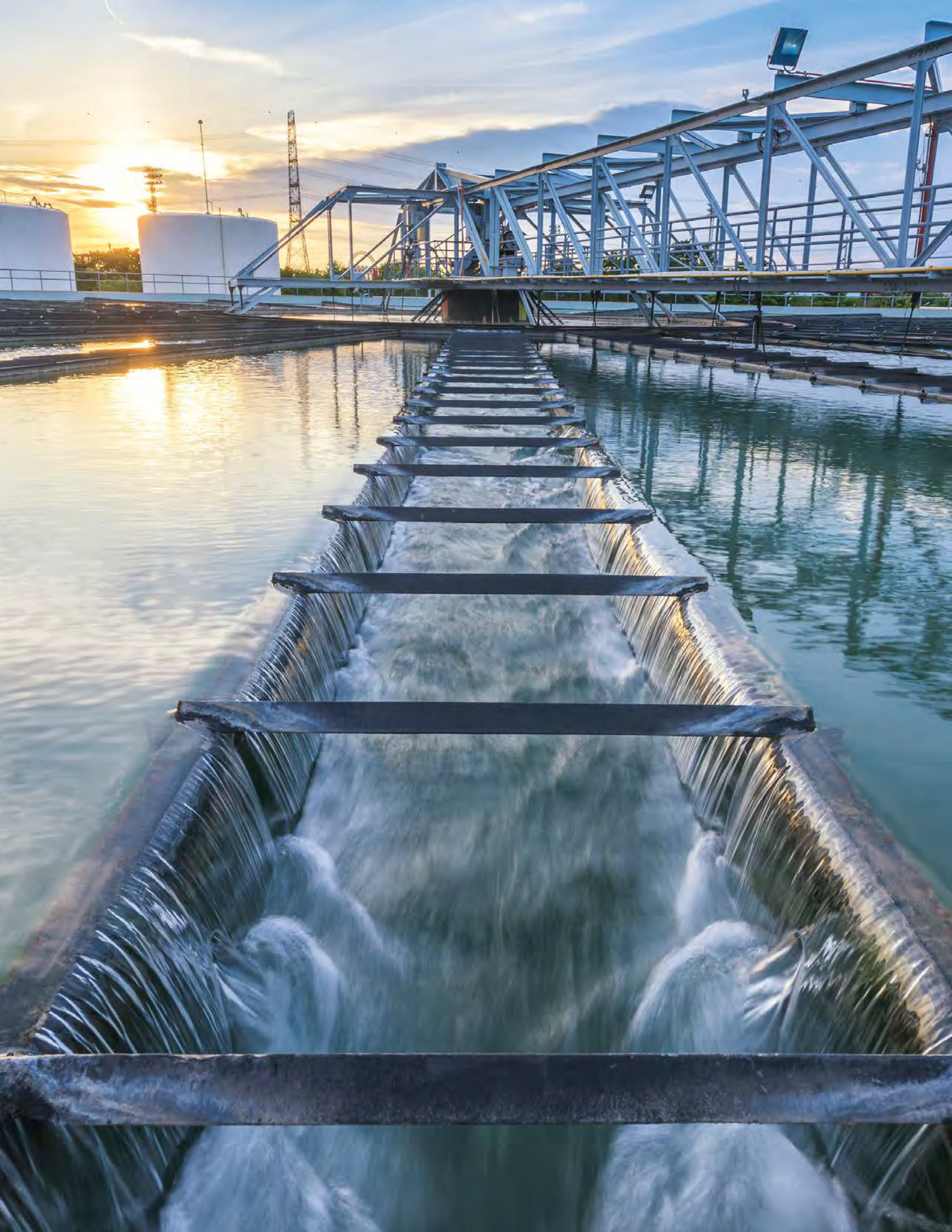
Background:
Midland County, Texas is one of the most drought-prone areas of the state. A large county in the Permian Basin, it has high oil field activity, economic growth and water scarcity. It relies on the Colorado River Municipal Water District and maintains 1,400 miles of sewage pipes serving a population of 161,077.[38] The City of Midland is part of the West Texas Water Partnership, whose mission is to "form partnerships, leverage financial capacity and knowledge, maximize existing water sources, minimize impacts to the environment and eliminate the adverse effects of competing for water."[39]

The city not only forecasts freshwater shortages in the near to long term but also anticipated environmental restrictions around municipal wastewater treatment. The City of Midland currently has a no-discharge permit, which means that wastewater cannot be moved from the collection site. It was therefore necessary to upgrade its wastewater treatment plant just to meet current standards, at a cost of $60 million to $80 million, a burden that would have been transferred to rate payers. In order to avoid raising rates, the city put out a Request for Proposal for a company to help finance the upgrades and benefit from the treated municipal water.

Pioneer Natural Resources, one of the largest exploration and production companies in the Permian Basin, also faces water-related challenges. In 2016, the company's Permian Basin operations used roughly 300,000 barrels per day on average for its 14 rigs, with plans for further growth. Considering the regional economic development, unfolding draught, and community and social considerations, Pioneer was looking for innovate solutions to achieve water security and lower its freshwater footprint.

Opportunity:
After reviewing several proposals, the City of Midland accepted Pioneer's proposal to upgrade the water system at a cost of $115 million. The city stated that what differentiated Pioneer's proposal was its use of pipelines rather than trucks to transport wastewater. The contract provides 2 billion barrels (or lasts 28 years) commencing in 2019, providing up to 240,000 barrels of water per day. In addition to paying for the capital upgrades, Pioneer will pay the city $0.029 per barrel, which equates to $2.5 million annually. The net cost to Pioneer will be $0.06-$0.10 barrel of water, or roughly 84% below the cost of freshwater in the region at $0.40-$0.60 per barrel of water.

By using municipal wastewater, Pioneer will reduce its freshwater usage, cuts water acquisition costs, save freshwater in a constrained environment, and reduce competing usage in the Texas Water Development Board Region F (West Texas), which the Texas Water Development Board predicts will have shortages of roughly 2.1 billion barrels of freshwater by 2040.[40]



Public Utilities

Coming clean on innovation in the utilities sector

This part of the report focuses on public utilities*, and in particular on electricity and water companies. It is notoriously one of the least innovative sectors in the United States when it comes to water.

While there are exceptions, such as research conducted by investor-owned utilities, the National Regulatory Research Institute has found that the industry spent only 0.1% of revenue on research and development in 2014. This is partially due to its highly regulated nature: both electric and water utilities have an obligation to provide reliable, safe, quality public goods at an affordable rate, while also complying with environmental regulations and standards. As a result, utilities tend to be more risk averse than oil and gas and other energy companies.

However, there are differences between power and water utilities. One key factor is that power companies are largely investor-owned, giving them access to a higher capital spend, while water utilities are mainly in public ownership. According to data from the Regulator Assistance Program (RAP), only 16% of water companies are owned by their investors in contrast to 75% of electric utilities.

The power industry is usually first to adopt new technologies, followed slowly by water companies. Advanced metering infrastructure, for example, has been widely used by power utilities, but is only now starting to find traction among water companies.

The Energy Information Administration (EIA) estimates that since 2015 electric utilities had installed almost 64.7 million advanced metering systems for residential, commercial, industrial and transportation use, largely driven by state policies. Exact numbers are unknown for the water sector, but we estimate the adoption rate is much lower. Because the water sector is so fragmented and also suffers from budget constraints, most public water utilities prioritize maintaining and repairing infrastructure in the short term rather than investing in new technologies.

As climate change causes increased temperatures and extreme weather events that affect the quantity and quality of freshwater, utilities could face increasing challenges to consistently deliver services and protect vulnerable infrastructure without driving up prices for ratepayers. Water and electricity companies will have to innovate and invest in new technologies and infrastructure. At the same time, a favorable regulatory environment and long-term planning through integrated water management would be beneficial.

* In this paper we focus on water consumption for power production (cooling) and not primary energy production (supply chain).

Wired for change: electric utilities

In the coming decades, electric utilities across the U.S. will likely have to carefully manage their water demands and look to alternative technologies and water sources. They use a lot of water, and will therefore be especially susceptible to climate-induced stresses in water scarce regions.

In addition to installing hybrid cooling technologies in power plants and reducing freshwater usage through saline and recycled municipal water, power companies can deploy demand-side management and energy efficiency. Like the oil and gas sector, alternative water sources used with additional treatment can be an opportunity, but they also require additional infrastructure, and are costly and energy intensive.

Changes in how electricity is generated will indirectly impact water use. Although regulations will be the strongest propeller, low natural gas prices and aging coal power plants are all contributing to the demise of coal.[41] Natural gas is less water intensive than coal, while clean energy uses less water than fossil fuel power generation. This means that state level energy mixes will determine water usage by region.

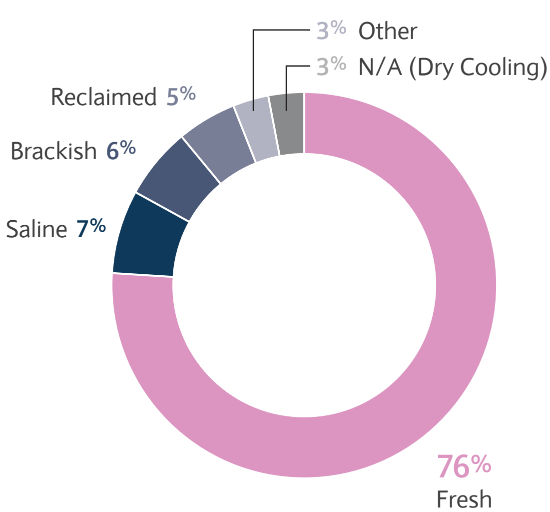
But with uncertain regulations, we believe that customer engagement, including demand-side management and energy efficiency, and careful planning and cooperation between water planning boards and other industries, could prevent long-term water stress. More importantly, there could be greater cooperation on a state and local level between water and electric utilities in managing water supplies and planning for future water scarcity, as advocated by the Department of Energy. Several utilities have already developed proposals to meet future water and energy needs through integrated resource plans in the face of supply and regulatory uncertainty.

Types of electricity generation and their relationship to water

In 2015, the United States derived about 87% of its electricity from thermoelectric (heat-generating) sources such as coal, natural gas, petroleum and nuclear. Hydropower generated about 6% of the country's electricity needs, with the remainder coming from renewable energy sources, according to data from the US Energy Information Administration (EIA). Most of the hydroelectric power comes from the Northwest, while thermoelectric power generation in the form of coal dominates in the Northern Plains, Midwest, East Coast and Rockies. Each type of power generation withdraws different quantities of water.

Figure 15

Water sources for thermo-electric cooling



Source: Argonne National Lab, Department of Energy

Thermoelectric power and water cooling

According to the United States Geological Survey (USGS), the thermoelectric power industry accounted for 45% of the nation's total water withdrawals, making it the largest water user. In its accounting, USGS does not include hydroelectric power for overall withdrawals because thermoelectric is classified as generating electricity with steam-driven turbine generators.

Unlike irrigation and mining, a large percentage of thermoelectric water withdrawals are not consumptive, so the water is returned to the water cycle. Nevertheless, water is still a crucial part of wet cooling systems for thermoelectric power generation. In water-poor environments, reduced supply will impact power plant production and efficiency. Because water use varies by electricity source, it is important that regional water groups work with transmission planning agencies, and local utilities engage in their planning discussions.

Nationally, groundwater makes up only 0.5% of the water needed for cooling at thermoelectric plants, while 99.5% comes from surface water.[42] Drought-prone states like Nevada and Arizona which depend heavily on groundwater, have introduced conservation measures, such as new dry cooling plants, encouraging the use of reclaimed water. Most of the water for power plants comes from rivers, streams, seawater and groundwater and reclaimed water.

Hydroelectricity

Hydropower generation depends on water as much as thermoelectric power, and works in a very similar way. However, hydro harnesses energy from the natural flows of a body of water rather than withdrawing it from a source.[43] Nevertheless, hydroelectricity does have high evaporation rates, making it a high consumer of water.

Renewable sources (wind and solar)

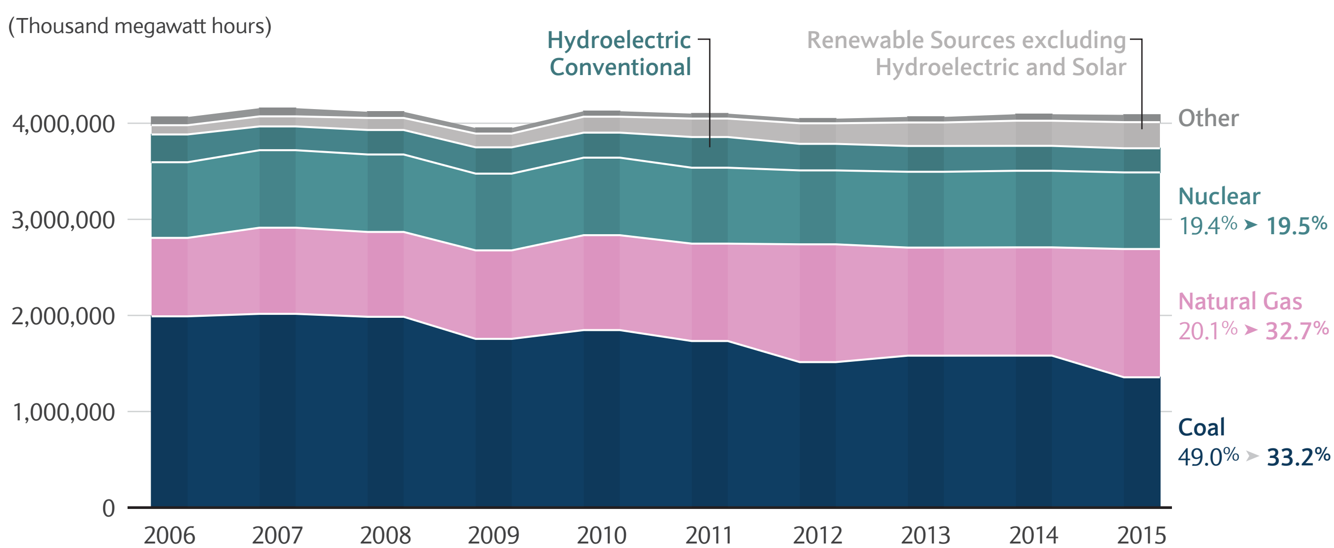
Neither wind power nor small scale rooftop solar uses large amounts of water, except for cleaning purposes. However concentrating solar, where lenses and mirrors are used to concentrate sunlight, does have high associated water use depending on the cooling technology. According to the National Climate Assessment, wet cooling on a concentrating solar plant can require between 750 and 900 gallons/MWh, which is almost as much as coal.

Finding the right mix of power sources

In the decade between 2004 and 2014, coal-powered electricity generation decreased by 22% in the United States, while natural gas increased by 151%. Why does this matter from a water use standpoint? Water use for cooling varies by fuel source and cooling type.[44] Though estimates vary widely, NREL found that withdrawals using tower cooling for nuclear had the highest withdrawals, followed by coal. Withdrawals for a combined cycle natural gas plant were almost a quarter of those of coal.[45] Apart from concentrating solar, renewables like solar and wind use no water.[46] Because renewable energy and natural gas use less water than other generation sources, a shift to these sources can help decrease the amount of water needed, which is an important consideration for planning in water stressed regions like the Western United States.

Figure 16

U.S. Electricity Generation by Fuel Source



Source: EIA Electric Power Annual

We expect that water withdrawals will increase with population growth and resulting demand for electricity. Electricity planners in water-stressed regions should not only work with statewide regulators to determine the best fuel mix for individual states, but they could also consider the impact on water supplies.

Water shortages reach boiling point

Water constraints include both shortages and regulatory restrictions from governing agencies such as water development boards, river basin commissions and state water rights. Nationally, water rights can influence how much water a permit holder can use and may result in restrictions for various users depending on the water right type in times of drought. However, the US Government Accountability Office found that even under normal conditions, 40 states anticipate fresh water shortages.

Getting on-stream with technology-alternatives to fresh water

Saline water

Treated saline water is suitable in conventional cooling towers while untreated saline or brackish water can be used in specially designed towers. Saline is therefore increasingly used for power plants' cooling needs. This practice in states like Georgia and Delaware has led to a reduced reliance on freshwater between 2005 and 2010,[47] with 97% of all saline withdrawals in the U.S. coming from the thermoelectric power industry.[48]

Recycled and reclaimed water

Power utilities can also use waste products such as produced water from oil and gas operations, treated municipal effluent or reclaimed water from mining and natural gas extraction. Using alternative sources of water gives power companies more flexibility when choosing a site for a new plant, and also eliminates the needs for water permits. Given the high volumes of produced water from fracking, as well as municipal effluent water, many energy agencies have studied the feasibility of using wastewater.

Some states are taking steps to reduce freshwater usage for cooling purposes by requiring companies to source alternatives and to improve measuring and accounting of reclaimed water usage. The California Water Board, for example, evaluates permits for freshwater sources for power plant cooling based on future water needs and compares these with the potential for the plant to use alternative water sources. The Texas Water Development Board estimates that reuse could produce 4.7 billion barrels of water per year over the next several decades. The total reuse volumes for treated effluent water to cool power plants have doubled from just over 10 billion gallons in 2009 to 20 billion gallons in 2015.[4950]

When sun and wind can alleviate water shortages

Water-scarce states and those dependent on hydropower could consider implementing Renewable Portfolio Standards (RPS) which make provision for the likes of solar, wind and storage as a form of long-term resiliency planning.[51] These recommendations will not only offer protection against water shortages, but also make provisions to smooth out the load as more solar and wind is added to the grid.

Though it will have a less dramatic impact on water use than coal shutdowns, we believe that renewables will alleviate water shortages in some regions. In order to diversify energy supplies, hydro dependent states like Washington should consider diversifying their energy mixes with more wind and solar.

However, solar and wind energy requires additional storage to smooth gaps between intermittent generation, caused by the fact that solar generation is limited to sunlight hours, while peak demand for electricity is in the evenings.

Planning for supply and regulatory uncertainty

Electricity utilities can plan for regulatory uncertainty and water supply shortages through Integrated Resource Plans, which allow investor-owned utilities to evaluate supply and demand scenarios, and to work with stakeholders to minimize environmental impacts and diversify their energy portfolios.[53] Although Integrated Resource plans are long-term, labor-intensive processes, we consider them best-practices for investor-owned utilities because the process is collaborative, inclusive and plans for uncertainty.

Low tech/cost effective solutions and policies

Reductions in electricity production result in reductions in water use for cooling, and vice versa. Like the water utility industry, the electricity industry and governments can facilitate these reductions through low-technical solutions, including demand-side management and energy conservation.

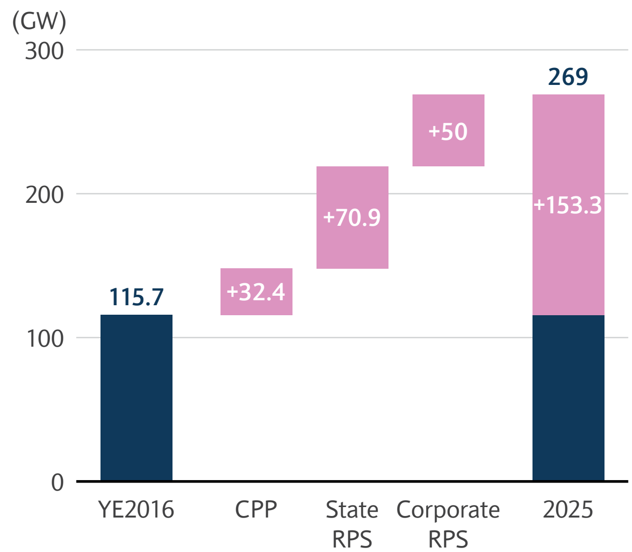
Other solutions include reducing load growth through energy efficiency, which is usually policy driven at both the state and federal level. Energy efficiency involves the deployment of technologies that reduce energy waste from transmission through building, appliance and automobile and power plant retrofits. In the United States, for example, weak economic growth and energy efficiency programs, such as low-energy light bulbs, have resulted in no electricity growth since the mid-2000s.

Energy efficiency projects have high upfront capital costs, but the availability of financing mechanisms can help offset costs through state and federal government programs.[54] Utilities can incentivize efficiency programs for residential customers through rebates.

However, while economic growth is showing signs of improvement, energy efficiency and meeting demand remain headwinds to electricity sales growth.

Figure 17

Drivers of renewable capacity demand through 2025



Source: Barclays Research[52]

Case Study

Wind-water desalination in Seminole

Background:

In 2010 the city of Seminole, Texas, began exploring strategies to reduce dependence on the Ogallala aquifer. The aquifer is over-used by farmers in the region and many of Seminole's wells were below EPA drinking water standards.[55] Ideas included treating brackish water aquifers like the Santa Rosa and Dockum aquifers. Since neither aquifer had been drilled and the depth was unknown, city planners hoped to conduct a pilot project to explore their sustainability. Located in the Texas Panhandle, with abundant wind capacity, the city saw a wind-powered reverse osmosis plant as a viable option.

The city approached Texas Tech University National Wind Institute and Water Resources Center to create a pilot grid connected to a wind powered reverse osmosis desalination project. The goal was to reduce electricity costs related to reverse osmosis, boosting water savings for the town. After securing funds from the Texas Department of Agriculture (TDA), the State Energy Conservation Office and the Texas Water Development Board (TWDB), the project began the permitting and planning process and drilled the Dockum well. By 2011 the drilling and pump testing was completed and by 2012 the construction consultants finished installing the reverse osmosis system.[56]

Costs:

The total project cost was $1.625 million sponsored by several agencies including the TWDB, the TDA and the city of Seminole. TWDB donated $300,000 to drill the Dockum well and the TDA $724,624 for other project components. Additional funding came from Texas Tech University. Although the city retained the infrastructure for the project and would manage the daily operations, the operational costs and monitoring would come from Texas Tech.

Project Layout:

The pilot project consisted of a pump, and reverse osmosis system, powered by a grid-connected 50kW wind turbine provided and installed by Entegrity Wind Systems.[57] The project would operate over a one year and five month period.

Challenges:

Although the turbine generated enough electricity to meet approximately 47% of the demand of the well pumping and the reverse osmosis system, the turbine operation and the desalination process were not timed to coincide. The project developers argue this could have been solved through long-term planning.[58]

Overall, the renewable technology was not an issue, and in fact, worked due to the grid back-up. Other short-term problems included a broken well pump and lighting strike.[59]

The biggest challenges had to do with characteristics and depth of the aquifer and problems with the membrane. The combination of the high TDS levels and challenges with pre-treatment caused the membrane to foul, a common occurrence in reverse osmosis systems.[60]

A second problem was that the Dockum aquifer produced too little water for the project to be a viable long-term water source for the city. The depth of the water decreased in the first year of drilling and ended up producing a mere 20-25 gallons per minute, short of an optimal rate of 50 gallons per minute. Although the wind power resulted in electricity cost reductions of $0.33/1,000 gallons, the town did not find the cost to be worthwhile for the amount of water the well generated.

Solutions and Outlook:

The project participants concluded that regular maintenance of the reverse osmosis system and better characterization of brackish water aquifers would lend to future brackish water desalination systems powered by any type of energy system. Future studies of brackish water systems will help municipalities understand depths, salinity and limitations of brackish water resources. In general, wind power proves to be a viable source of electricity to power reverse osmosis plants, especially when it is grid connected or backed by batteries.

Tapping into the water utilities

The biggest challenges for water utilities are forecasting demand from a growing population, planning for extreme weather events and updating aging infrastructure. At the same time, the industry has to deliver consistent and clean water to its users at an affordable rate.

Water companies tend to have more budget constraints than electric utilities and are therefore less able to invest in innovation. The industry is also highly fragmented, which means that in a disaster, responsibility is spread over many agencies and institutions.[61] Across the United States, investment in water-related solutions often comes about as a result of regulations introduced after a crisis event, and often far too long after the fact. While the lead contamination of the drinking water in Flint, Michigan, was caused by a combination of issues, budget constraints and mismanagement were primary drivers.

Many public water utilities prioritize infrastructure investments, including maintenance and upgrades, and few have sufficient funds for research and development. Investor-owned water utilities usually lead the way in the development of new technologies, such as leak detecting and advanced metering infrastructure (AMI). These technologies have high upfront capital costs but in the long term they save money and water, and also benefit public utilities.

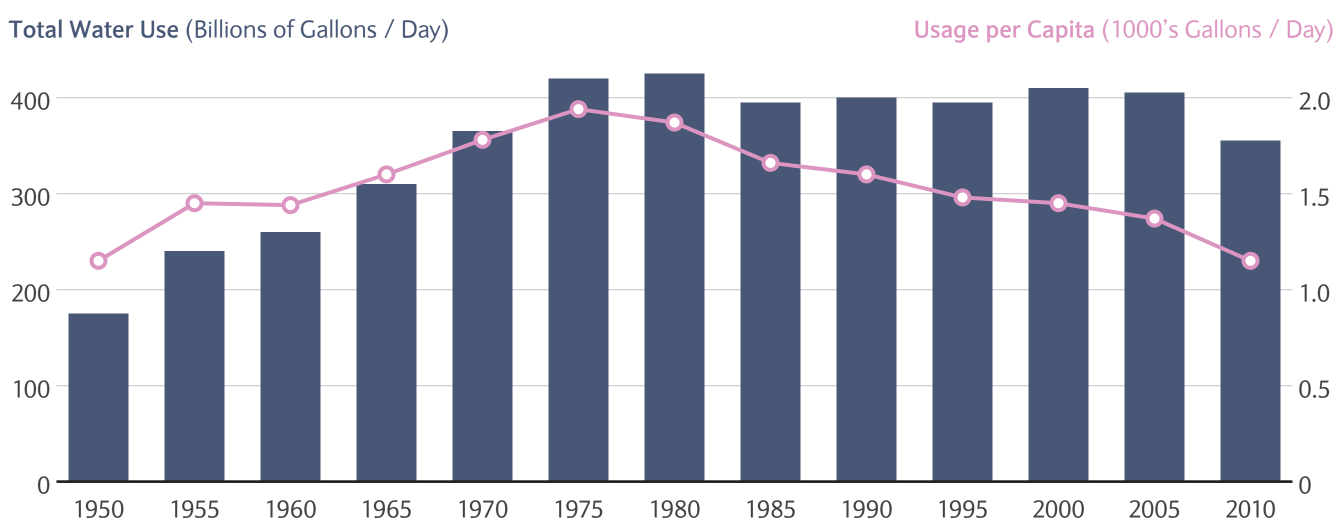
How much water does the US public consume?

Public water supply in the United States in 2010 averaged 335 billion gallons per day, a decline from 2005 when the daily average was 409 billion gallons. Average per capita water usage has been declining steadily, mostly due to improved water metering and conservation measures, and we expect this trend to continue.

However, it is expected that competition with other industries, population growth and potential climate change induced shortages will make water use an increasing concern for the utility sector.

Figure 18

Changes in Aggregate water usage and consumption, 1950-2010



Source: US Geological Survey, US Census Bureau, Barclays Research[62]

The challenges ahead

Given the integral role of water to their business, water utilities face challenges such as a decline in supply due to lower precipitation levels, reduced groundwater, and increased demand for freshwater. Other risks include extreme weather events and a rise in sea level, both of which can impact the quality of freshwater supplies and tax existing infrastructure.

Water quality and quantity

Contaminated water is a great concern for freshwater utilities, because clean water is central to their function, and treatment to remove arsenic, chloride and nitrates is expensive. Besides naturally occurring changes in groundwater, and reductions in water quality due to human, agricultural and industrial activity, other natural occurrences can compromise groundwater quality. Flooding for example, is an important risk because it can cause storm water overflow and saltwater intrusion into freshwater sources.

Water scarcity is another challenge, especially in regions that face dramatic and unplanned increases in population. Water companies also have to manage supply and demand balances with adequate storage. For example, persistent drought has plagued Southern Nevada, which relies on the Colorado River Basin and sparse groundwater for much of its supply. However, communities in the area have continued to grow at unprecedented rates, creating uncertainty for water planners.[63]

Areas with supply constraints and under-developed infrastructure must transport water over distances, which not only requires additional power, but also makes infrastructure more susceptible to failure.[64] The Southern Nevada Water Authority has reacted by prioritizing conservation efforts and developing innovative solutions including water reuse, water-smart landscaping and building standards, and implementing conservation tools such as education, and conservation rate restructuring.[65,66,67]

Where the water flows

Drinking water

Drinking water undergoes several steps before it reaches the tap. A water utility will source its water from either surface or groundwater, or in some instances reclaimed water, though this is less common in the United States. Freshwater will be pumped or transported from its source to a facility, where it is treated and tested to EPA Drinking Water Act standards.[68] The water then enters a transmission main and is distributed to residents.[69]

Wastewater utilities

There are two types of wastewater utilities: municipal and industrial, which have different standards for treatment depending on the effluent.[70] Wastewater from residential and industrial users is collected in a sewer system, along with rainwater and storm water runoff.[71] From the sewer, the water is transported to treatment plants where the water undergoes several steps before it is discharged to water sources or used for other purposes such as groundwater recharge.

Our recommendations

Infrastructure requires the most funding in the water industry, which could be solved in the following ways:

- More consolidation of utilities
- Increased funding from the private sector and/or partnerships between private and public sectors to bridge funding gaps
- There are long-term opportunities in potable reuse to alleviate water scarcity, but it requires more consistent regulations.

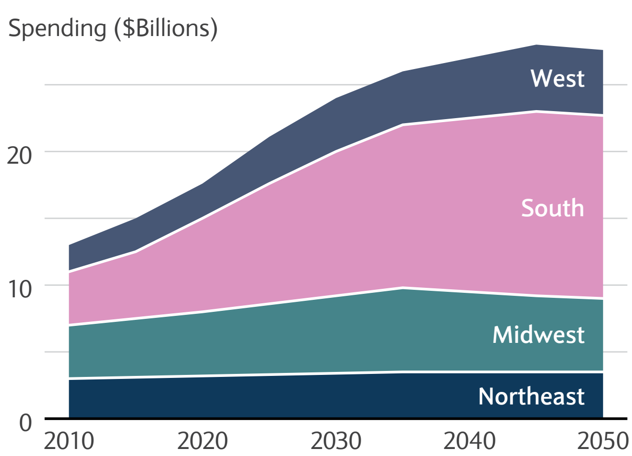
How to value the cost of water

Many users are not aware of the significant infrastructure, treatment and maintenance costs that go into delivering clean, uninterrupted water to their homes and businesses. Unlike electricity or natural gas, customers rarely consider their water consumption or the reliability or their water and waste water systems. Maintaining infrastructure, while keeping affordable rates for customers, remains one of the biggest challenges for water utilities.

Drinking water utilities spend almost 40% of their operating costs on electricity used for pumping, conveyance and treatment, according to the Environmental Protection Agency (EPA).[72] The Pacific Institute found that using conservation and efficiency measures on the customer side like replacing residential showerheads and retrofitting appliances are more cost effective than investing in new technologies such as desalination and potable and non-potable reuse.[73] Other energy efficiency methods include introducing efficiency measures into pumping and conveyance systems. For example, the EPA recommends that wastewater utilities retrofit pumps with energy efficient motors and also replace large pumps that operate infrequently with smaller pumps that operate continuously. [74]

Figure 19

Water Main Replacement
Annual Cost Forecast – 2010 to 2050E



Source: ASCE[75]

Liquid investment

Projected spending needs vary but the American Society of Civil Engineers (ASCE) estimates that drinking water investment will be more than $1 trillion in the next 25 years, while the EPA predicts that the infrastructure needs will reach $384.2 billion over the next 20 years, excluding waste water systems.

However, as water utilities are mainly owned by municipalities and publicly traded water companies have a combined market capitalization of only $18 billion to $20 billion, it is evident that investment will need to come from both the public and private sectors. The outdated water infrastructure is the main reason such large investments are needed.

The EPA estimates that the cost of replacing water mains alone could approach $25 billion annually by 2030.

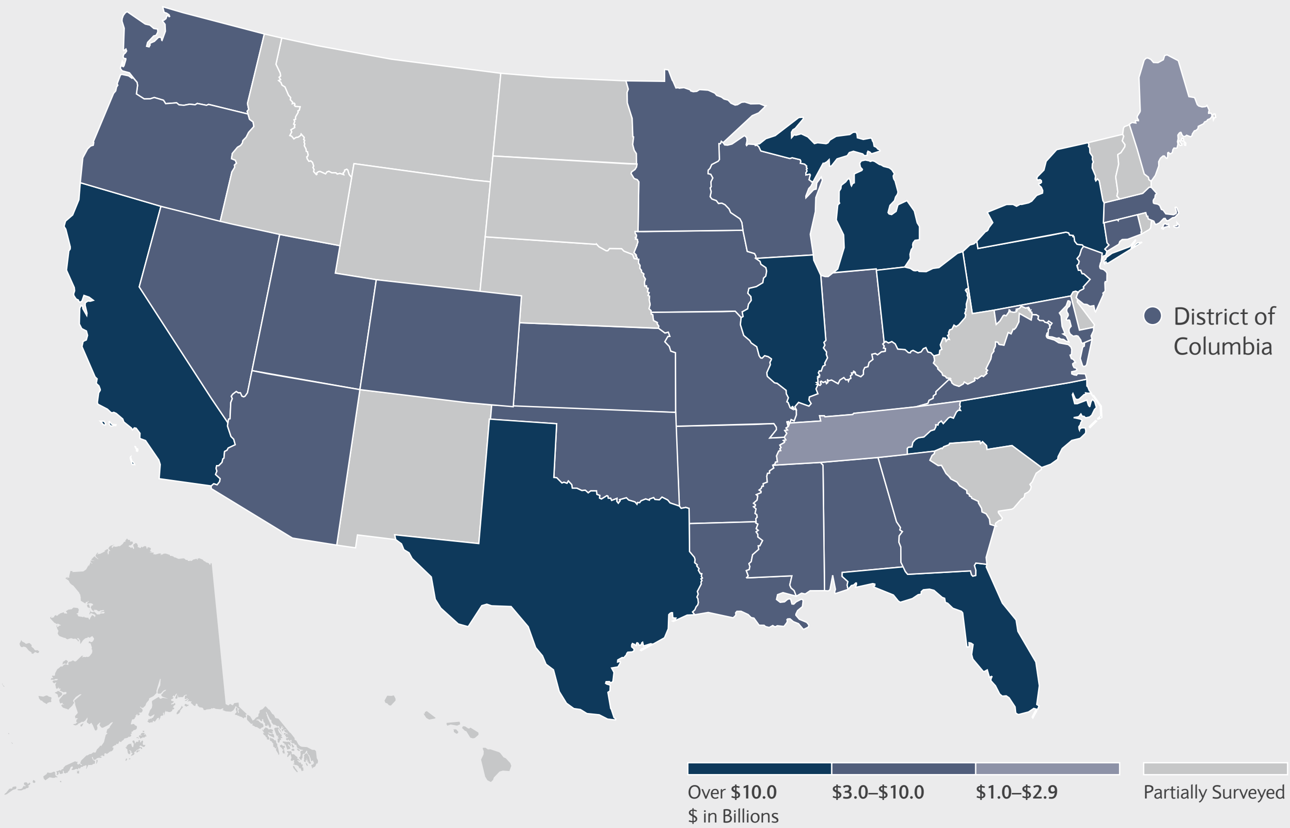
Different regions will need different levels of investment – some areas need infrastructure upgrades because they suffer from scarcity and population growth, while other states may not have had the budgets in the past to maintain their infrastructure.[76] As expected, drought prone states like California, Nevada and Texas, and states with growing populations like New York have the highest sourcing needs.[77]

Counting the losses

According to the American Water Works Association, there are two types of water losses: “real losses” from leaks in mains and storage vessels, and “apparent losses” also known as non-physical losses caused by ineffective metering or theft.[79] In 2015, the Water Research Foundation assessed water losses in distribution systems across five regions in the United States and found that the median real losses for water mains was 785.54 gallons per mile of main per day.[80]

Figure 20

Overview of 20-Year Need by State



Source: EPA[78]

Current methods for treating water

Drinking water utilities

Drinking water utilities must abide by the Safe Drinking Water Act Standards,[81] which regulate the allowable limits of microorganisms, disinfectants, organic chemicals and inorganic chemicals.[82] In addition, EPA also has secondary drinking water regulations or voluntary guidelines for contaminants that still render the water safe to drink but may have undesirable aesthetic effects.[83] Though the Safe Drinking Water Act is enacted on a federal level, states have individual standards for water quality.

Water utilities have access to several step-like treatment processes, including coagulation, flocculation, sedimentation, filtration, and disinfection.[84] In the first few steps - coagulation and flocculation - particles are suspended in the water, to later be removed through filters. The last step, disinfection, uses a disinfectant to remove bacteria and viruses.

Wastewater

The primary treatment for wastewater is to remove suspended solids, and other large items like trash, while secondary treatment breaks down organic materials. Tertiary treatment, or disinfection, usually occurs through chlorine,[85] aimed at killing organisms and pathogens that could cause disease, though the level of treatment varies by water quality and local standards.[86] Treatment levels are regulated by the Environmental Protection Agency.

New technologies and solutions as game changers

As water scarcity continues to limit existing freshwater supplies, water-scarce utilities are looking at alternatives to freshwater sources including treated brackish water, saline water and wastewater, all of which require expensive treatments. Other solutions to water shortages include managing existing supplies through conservation, smart water management and leak detection.

Thinking smart: Smart meters and advanced metering infrastructure

Smart meters and grids are a crucial investment for utilities to properly gauge how much water their customer use, track unauthorized consumption and detect leaks. Automatic metering infrastructure was initiated by the electric utility industry, and not only allows for more accurate billing, but it can also help with detecting real water losses and reduce apparent losses – and reduce labor costs associated with meter readings.[87] Meters can also communicate the value of water to customers, by increasing awareness of actual water consumption.[88]

Leak detection

Household leaks in the United States waste 1 trillion gallons of water each year, according to the EPA.[89] Much of this can be avoided by regular maintenance and leak-detecting technologies. Traditional leak detection is a slow and labor-intensive manual process conducted at night. New leak detection devices make the process faster and save money. These include satellite imagery to detect leaks, flow-sensitive meters and acoustic monitoring. Still in the pilot phase, satellite systems work by detecting unexplained puddles of subsurface water with an accuracy unavailable to acoustic monitoring.[90] They eliminate the need for metering infrastructure, but still provide comprehensive data. Flow meters detect leaks by monitoring high night flows – when users are normally inactive.[91] Lastly, acoustic monitoring detects noise or vibrations from leaks in the water pipe.[92] The most effective way to detect leaks is to use a toolbox of detecting methods, with acoustic monitoring, for example, usually paired with advanced metering infrastructure.

Treatments

Making wastewater drinkable again

Indirect potable reuse is the practice of treating wastewater to non-drinking standards and releasing into an environmental buffer, to further dilute.[93] After a period of time the water from the aquifer, lake, groundwater or reservoir is treated to drinking water standards and reintroduced as a drinking water source.

Direct potable reuse on the other hand, allows a utility to treat wastewater to potable standards and then directly introduce the treated wastewater into the drinking water system. Indirect potable reuse is successfully practiced throughout the United States, but the direct method has only had a few successful pilot projects to date. Although the treatment technology is proven, regulation, cost and public acceptance are some of the largest obstacles to wider adoption. Nevertheless, favorable regulation in some states has spurred pilot projects and small scale projects for utilities servicing small communities. California and Texas are two state leaders for such regulations, and Texas recently allowed the country's first direct potable reuse project.

Desalination

In coastal areas or regions with brackish aquifers, desalination is an alternative treatment for providing freshwater. Desalination is deployed successfully, with 18,426 worldwide desalination plants worldwide and 1,300 in the U.S., according to the American Membrane Technology Association and the International Desalination Association.[94]

As discussed in the oil and gas chapter, desalination comes in two main types of technologies: thermal and membrane technology. The majority of American desalination systems are membrane based systems, mainly for brackish water.[95] While desalination has the potential to provide alternative water supplies to water-scarce regions, barriers include its high capital cost, and the high quantities of energy it consumes.

Costs for desalination depend on variables such as the costs of building the plant, and its operating and maintenance expenses, such as electricity and labor. Compared to other water sources it remains the most expensive form of treated water. For example, water at the Carlsbad desalination facility in San Diego costs between $2,131 and $2,367 per acre foot, compared to recycling potable water at $1,200-$1,800 per acre foot,[96] according to the California Energy Commission.[97] Seawater desalination is typically more expensive than brackish water because it has higher levels of dissolved solids.[98]

Conserving water the non-technical way

In California, the cheapest form of water recycling is generally still hundreds of dollars more expensive than the cheapest water strategies like conservation, according to research by the Public Utilities Commission.[1003] The context matters of course, as well as the location. In areas with high priced water, recycling may indeed be less expensive.[1014]

The EPA has numerous recommendations for utilities to improve the value of water, including designing price structures like “time of day pricing” and “water surcharging” where any overuse would be charged a higher rate through smart water management.

Water trading is another form of conservation, and particularly transferring water from regions with abundant water supplies to arid regions. Some parts of the U.S. like California have instigated small-scale water trading markets. These could be used to transfer surplus water to users in need. However, water markets in the US are not as efficient as they could be, with obstacles including the difficulty of physically transporting water, patchwork infrastructure and bureaucracy of various agencies.[102]

Case Study

American Water- Acoustic monitoring

Background:

In 2014, American Water in Charleston, West Virginia, was suffering non-revenue water loss estimated at $500 per million gallons. Leaks present a large cost to a drinking water utility, because for every leak, the company is throwing away water and the associated costs from chemicals and electricity to treat and convey the water. It is known as "non-revenue water loss" because it is water that the customer is not paying for. Contrary to public perception, a large percentage of water loss comes from small subsurface leaks rather than large noticeable main breaks.

Solution:

After many years of piloting the software in other locations, American Water in 2015 deployed the first large-scale project of acoustic monitoring software by technology company Echologics, installing 386 sensors in Charleston.[103]

American Water, one of the few investor-owned water utilities, is a pioneer in pairing acoustic monitoring and advanced metering. In 2005 it developed continuous acoustic monitoring (CAM), a process that not only listens for vibrations, but transmits that information to a utility.[104] In 2009 the company helped to develop an acoustic monitoring software prototype through synergies between Echologics leak detecting equipment and Mueller Co's communication meter reading, which had previously been used on fire hydrants.

The result was Echologics Echo Shore DX, which works by installing sensors and communication devices in fire hydrant caps. On a nightly basis, the sensors listen for leaks and then transmit the reports remotely through the communication device to the utility. Most leak detection is conducted at night, when there is very little ambient noise from traffic, and when customer water use levels are at their lowest.

Challenge:

The main challenge for the Charleston project was that some of the sensors were installed along the Kanawha River, which made the leaks easily hidden as they flowed directly into the river. Other obstacles included the fact that as leaks are repaired, pressure in pipeline mains increases, and new leaks develop. Although it was not the result of a flaw in the software, the new leaks required additional maintenance.

Success:

Over the course of the first four months of operation, Echologics' monitors detected 45 leaks resulting in an overall reduction of non-revenue water loss of 2.3 million gallons per day for Charleston.[105] The system also found a large leak in a transmission main of 2 million gallons per day, which was identified through ground vibration.

Costs and scalability:

The high capital cost of acoustic monitoring (approximately $1,200 per unit at seven units per mile) renders the system most attractive to utilities with expensive water supplies and those who suffer large amounts of real water loss, or those located in water-scarce areas. However, the technology makes the most sense from an investment perspective in areas where water mains are buried and leaks would be harder to detect without the technology. For systems with low water costs and system leaks that could rise to the surface quickly, it would be more cost effective to reactively identify the leak manually or use options like district metering, or manual leak surveys. Echologics monitoring systems work best with metallic pipes rather than plastic pipes because they best carry sound.

Case Study

San Diego: Potable reuse demonstration project

Background:

To reduce consumption of imported water from Northern California and the Colorado River, 10909 San Diego embarked on a multi-phase project to turn wastewater into a drinking source. It aims to address water shortages caused by the drought, and planning for population growth. The project also hoped to minimize the amount of water treated and discharged to the ocean by the Point Loma Wastewater Treatment Plant, and eliminate the need for plant upgrades at an estimated cost of $1.8 billion.[107]

A multi-phase reuse project would not only contribute 83 million gallons of freshwater to the city by the year 2035, it would also divert a portion of the Ponta Loma's 240 million gallons/day of wastewater to a pure water facility and transform it into freshwater.[108,109]

Process:

In 2004, the San Diego City Council approved research on the feasibility of a water reuse project, its requirements for water recycling, and its health effects. The second step was a demonstration recycled water project from 2009 to 2013, which examined the feasibility of potable reuse in San Diego. The results showed that the technologies used to purify the municipal wastewater met all drinking water standards.[110,111]

Using a five-step toolkit of technologies including membrane filtration as pretreatment, reverse osmosis and ultraviolet light to purify the wastewater, the treated water was released into the San Vincente Reservoir, which is later used as one of the sources for a drinking water treatment plant. After a year of testing, the project proved the water met purification standards and was approved for a large-scale reuse project called Pure Water San Diego.[112]

Implemented over a 20-year period, the project will operate in two phases in two locations. The first phase is scheduled for completion in 2021 and will produce 30 million gallons per day, while the second phase, due to complete in 2035, aims to deliver 53 million gallons per day. In each project, wastewater from the Ponta Loma facility will be treated at a Pure Water facility, where it will then be released into a reservoir. After a period of time, the reservoir water will be blended with the city's imported water supplies and then treated at a drinking water plant. In total, the project will reduce Ponta Loma's wastewater discharges by 50%.

Costs:

The cost of the demonstration project was approximately $11.3 million, including the advanced water purification facility and the public outreach component quality testing, and was funded through a temporary rate increase between 2008 and 2009.[113] Pure Water San Diego is budgeted to cost $3 billion, spread out over cost-sharing agreements for wastewater agencies.

Overall, the project will save rate payers money over time by reducing the amount of water imported from other parts of California. In addition, several studies illustrate that the cost of purified water at $5.2 to $5.8 per 1000 gallons is less expensive than seawater desalination water at $6.5 to $7.3 per 1000 gallons.[114]

Challenges:

An objective of the project was garnering public support through education and public outreach. Public acceptance was the largest obstacle, which the city overcame by launching an education campaign consisting of tours at the demonstration facility, social media, and a speaker's bureau. The city said the combination of public education and awareness of water scarcity caused by the drought encouraged people to embrace the idea of wastewater recycling.[115] Opinion polls between 2004 and 2012 on the use of advanced treated recycled water found that public opposition decreased by 75%.

Challenges for the demonstration project included the many required permits and lack of standard regulations. A lack of federal regulations on direct potable reuse meant that in 2010 the California Legislature enacted Senate Bill 918, which requires the state Department of Public Health to conduct a feasibility study on developing uniform criteria for direct potable reuse.

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