The Academy of Medicine, Engineering & Science of Texas

2014 TEXAS WATER SUMMIT REPORT

Securing Our Economic Future

In May of 2012, The Academy of Medicine, Engineering & Science of Texas (TAMEST) held the 2012 Texas Water Summit: Securing Water for Texas' Future, with a program focused on the major challenges of ensuring future water resources. On May 19, 2014, TAMEST held a second water summit to gain a better understanding of the issues surrounding water use in the agricultural, industrial, commercial, and ecological sectors.

This report includes summaries of the presentations and panel discussions from the 2014 Texas Water Summit: Securing Our Economic Future, where over 250 scientists, engineers, policymakers, agency officials, and other stakeholders gathered to discuss the challenges and opportunities Texas faces in providing water to sustain the state's economic growth and stability.

Video footage and slides from both the 2012 and 2014 summits as well as digital versions of the reports can be viewed at www.tamest.org. Copies of the printed reports are available upon request.

Panel on

Sector Based Use and Conservation

UNCONVENTIONALS AND WATER USE IN TEXAS

Jean-Philippe Nicot, Ph.D.
Research Scientist
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Dr. JP Nicot's recent research efforts include the intersection of water resources with hydraulic fracturing, carbon storage, and nuclear waste disposal.

UNCONVENTIONAL OIL AND GAS WATER RECYCLING AND REUSE

Todd Langford
Senior Sales Professional
GE Power & Water
Water & Process Technologies

Todd Langford's focus is on business development for water issues surrounding the unconventional oil and gas market.

POWER GENERATION

Carey King, Ph.D.
Assistant Director
Energy Institute
The University of Texas at Austin

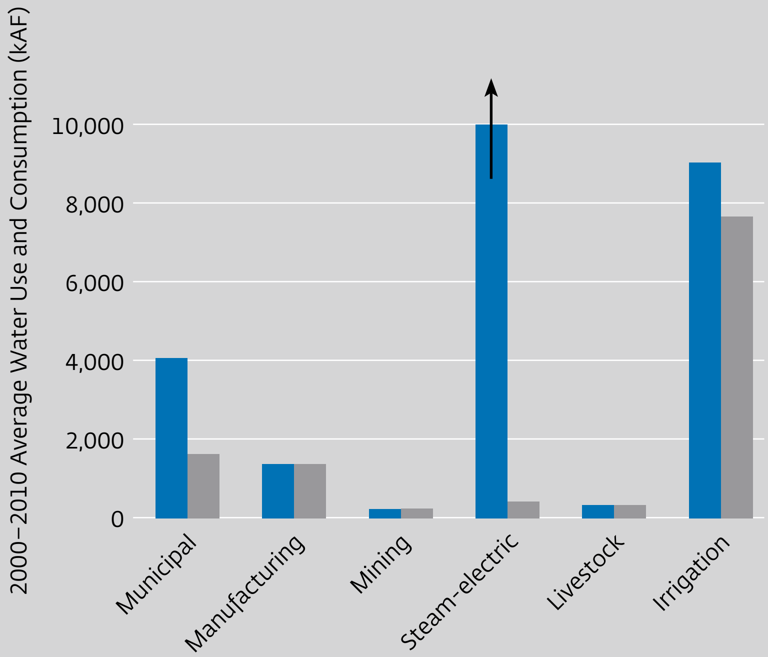
Dr. Carey King performs interdisciplinary research related to energy systems' interactions within the economy and environment.

THE PETROCHEMICAL INDUSTRY

Tim Finley
Global Water Technology Leader
The Dow Chemical Company

Tim Finley leads technical aspects of water rights, water scouring strategy, and water conservation efforts at Dow's Freeport site.

TOTAL ~USE = ~15,000 KAF/YR



Average Annual Water Use vs. Consumption by Sector: 2001–2010

Source: Bureau of Economic Geology, UT Austin

Use
Consumption

2011 Mining consumption

Oil and Gas =~120 kAF water use (HF, drilling, waterflooding)

HF =~81.5 kAF water use

HF =~65 kAF water consumption

All other mining uses =~100 kAF

Total consumption =~190 kAF

UNCONVENTIONALS AND WATER USE IN TEXAS

The shale revolution started in Texas in the 1990s, and the state accounts for a significant portion of the nation's oil and gas production from shales and tight formations using hydraulic fracturing (HF). The amount of water used by the oil and gas industry has continued to increase but has also become more diversified over time, introducing the use of brackish water and recycling in varying amounts across the state.

Water use by the mining sector accounts for about 0.5 percent of the state's total, and oil and gas production accounts for about 60 percent of the water used by the mining sector. Water used (vs. consumed) in HF operations in 2013 has been estimated at approximately 100,000 acre-feet. Although HF operations account for a small fraction of the total water use statewide, the percentages are significantly higher in sparsely populated counties.

Opportunities for reducing the use of freshwater in HF operations include increasing the use of brackish groundwater, the development of less water-intensive technologies and more salt-tolerant additives, and the reuse/recyling of conventional produced water or flowback/produced water.

Brackish aquifers are becoming an important source of water for HF operations, particularly in areas of the state where freshwater is scarce. Access to brackish groundwater supplies can be expensive, as they are usually deeper than freshwater supplies, and in many cases the well yields are not as high. Unlike freshwater, brackish water resources are not

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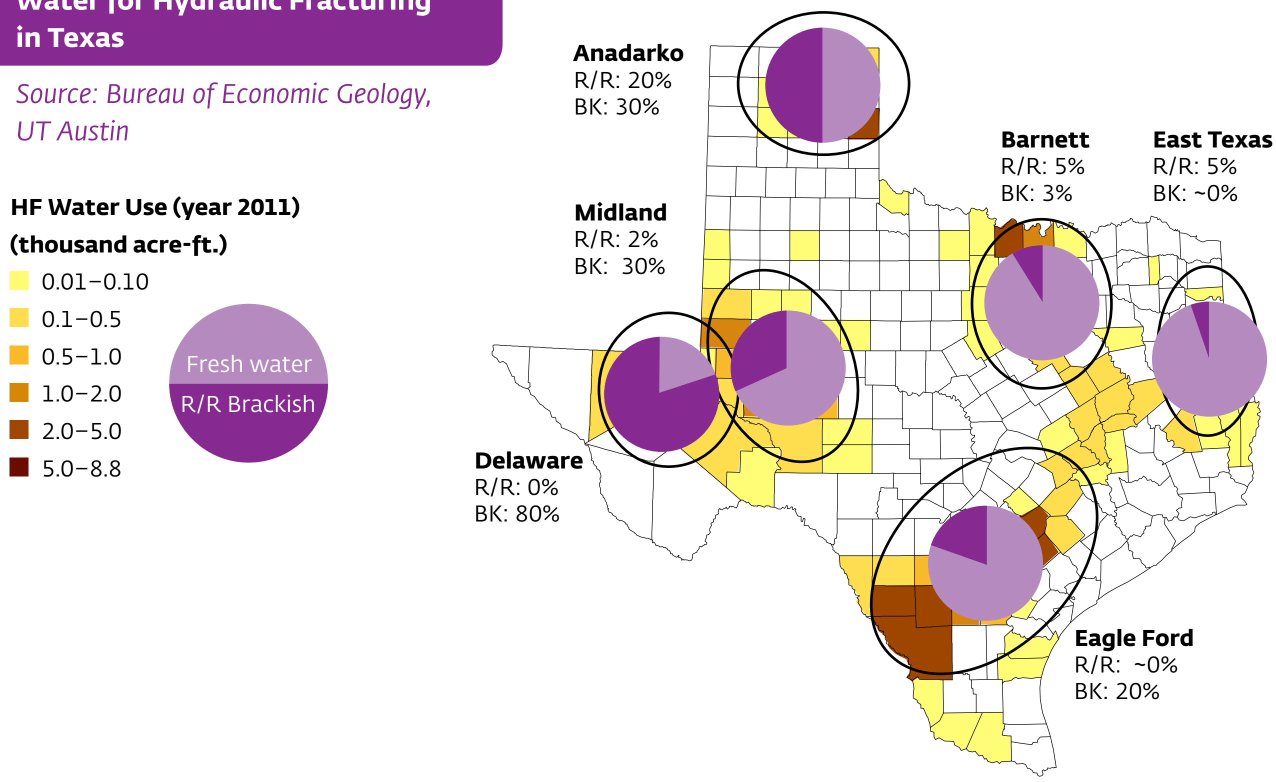
Reuse, Recycling, and Brackish Water for Hydraulic Fracturing in Texas

Source: Bureau of Economic Geology, UT Austin

FRACTION FROM RECYCLING/REUSE (R/R) AND BRACKISH WATER (BK) *Based on ~30% of water use*



"As freshwater supplies decline, the HF industry will be in competition with other sectors, including municipal use, for brackish groundwater resources."

yet well understood, and research is ongoing to determine how much will be available and the long-term impacts of its use. As freshwater supplies decline, the HF industry will be in competition with other sectors, including municipal use, for brackish groundwater resources.

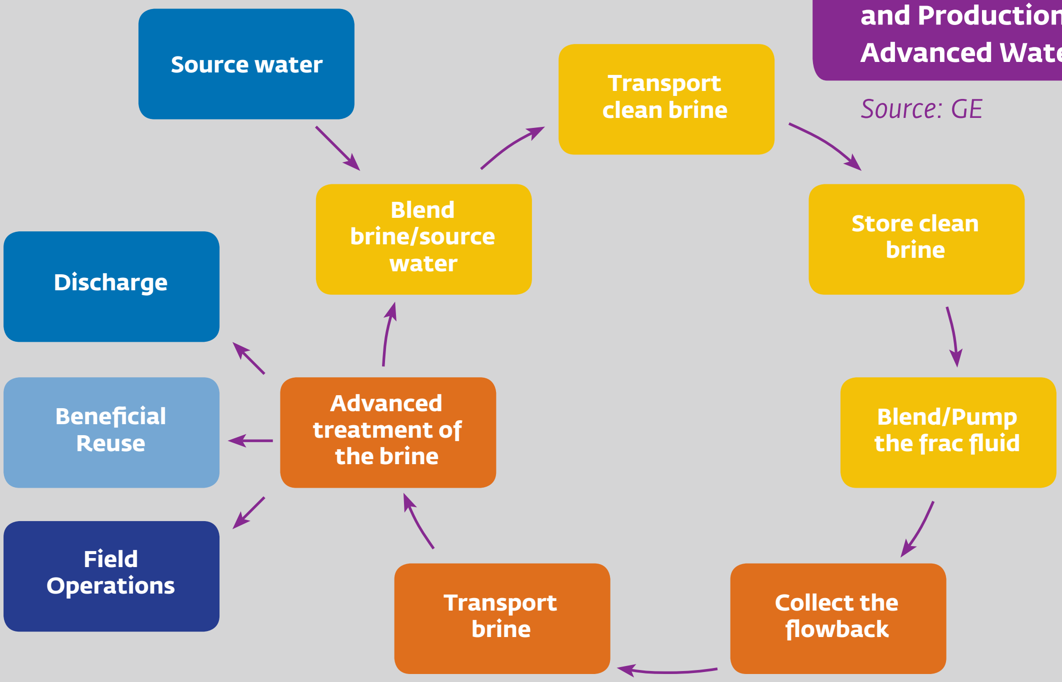
The least expensive way to dispose of flowback and produced water is through injection wells, but the growing scarcity of water will increase incentives for reuse in the future. The overall rate of reuse and recycling across the state was less than 5 percent in 2011, but this varies by area and is based on the volumes, salinity, and contamination levels of flowback and produced water. Flowback for shale formations is usually 20–30 percent of the injected amount with rates approaching or higher than 100 percent in tight formations.

UNCONVENTIONAL OIL AND GAS WATER RECYCLING AND REUSE

On a global scale, unconventional oil and gas development is one of the mega trends impacting localized water scarcity and energy demand/supply discussions. The historical cost of water management for HF includes the costs of source water, transportation and storage at the HF site, blending it to produce HF fluid, using it in the HF process, and the collection, transportation, and ultimate disposal of produced

Hydraulic Fracturing Drilling and Production Life Cycle with Advanced Water Treatment

Source: GE



water. The oil and gas industry's primary needs related to water sustainability are cost-effective reuse technologies, resource recovery, and viable alternative non-potable sources for HF water.

Technology exists to treat flowback and produced water for reuse either directly or by blending it with fresh water, thereby reducing the amount of new source water needed for future HF jobs. Further, advanced treatment options are available to capture byproducts that can be converted to useable forms such as valuable salts, or even to treat produced water to a standard where it can be beneficially reused in other applications.

Water-related risks to the continued growth of unconventional oil and gas production vary by region but could include sourcing the water needed for HF operations, growing concerns about seismic activity possibly associated with salt water disposal wells, and storage and transportation of produced water.

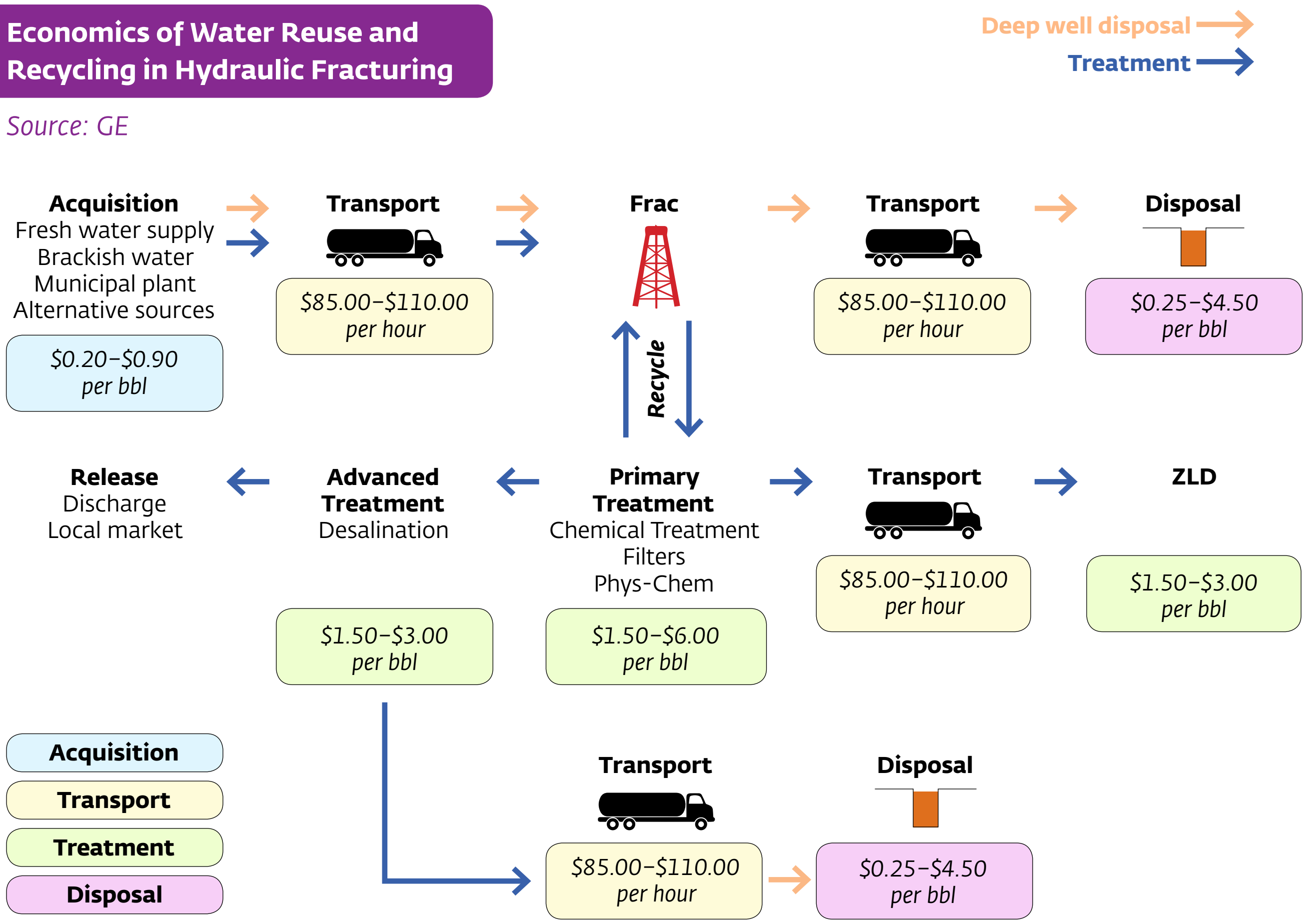
With current technologies, treating water for reuse and recycling in the HF process can raise costs in some areas while reducing costs in others. Sourced water can range from $.20–$.90 per barrel, and on the high end the total cost to bring flowback and produced water to zero liquid discharge can reach up to $9.00 per barrel of water treated.

Disposal wells currently offer the most cost-effective way to manage produced water, but from a sustainability perspective, this water is essentially removed from the

"The oil and gas industry's primary needs related to water sustainability are cost effective reuse technologies, resource recovery, and viable alternative non-potable sources for HF water."

Economics of Water Reuse and Recycling in Hydraulic Fracturing

Source: GE



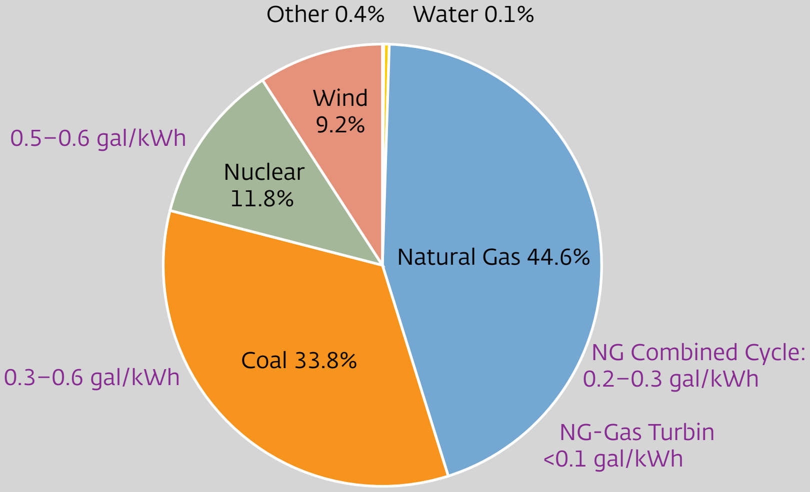
"Disposal wells currently offer the most cost-effective way to manage the produced water, but from a sustainability perspective, this water is essentially removed from the water cycle."

water cycle. Exploration and production companies are now, more than ever, exploring options to minimize their water footprint. Incentives to reuse and recycle should be considered to encourage producers to implement available technologies. In Pennsylvania, around 89 percent of the water produced in the HF process is reused or recycled. This is accomplished primarily because the cost to treat and reuse produced water is economically viable, made possible by technology advancements that allow for use of produced water with higher salinity levels in the HF process.

There is no single silver bullet technology to resolve all the issues surrounding water use, reuse, and recycling in unconventional oil and gas operations. Each project is unique, as the quantity and quality of available and produced water vary by location along with the associated economics. Developing technologies, the rising cost of water, and regulators working with industry will determine the future of reuse and recycling in the unconventional oil and gas sector.

POWER GENERATION

Power generation plants in Texas consume less than 4 percent of the state's water for cooling steam cycles in nuclear, coal,



Water Cooling Use for Texas Power Generation: 2012

Source: Energy Institute, UT Austin

430 terawatt-hours
Cooling Water Consumption:
~0.4–0.5 million acre-ft/yr
(<4% Texas total consumption per TWDB demand)

Chart percentages based on ERCOT generation

and natural gas plants. Combined-cycle technology in natural gas plants results in lower water use because about two-thirds of the power generated comes from gas turbines. Texas also has two dry cooled combined-cycle power plants.

Water consumption by Texas power plants came under scrutiny during the 2011 drought when water rights were being called in the Brazos River Basin. The Texas Commission on Environmental Quality determined that public health and safety concerns justified continuing water access to cities and power plants, effectively overriding the seniority of agricultural water rights.

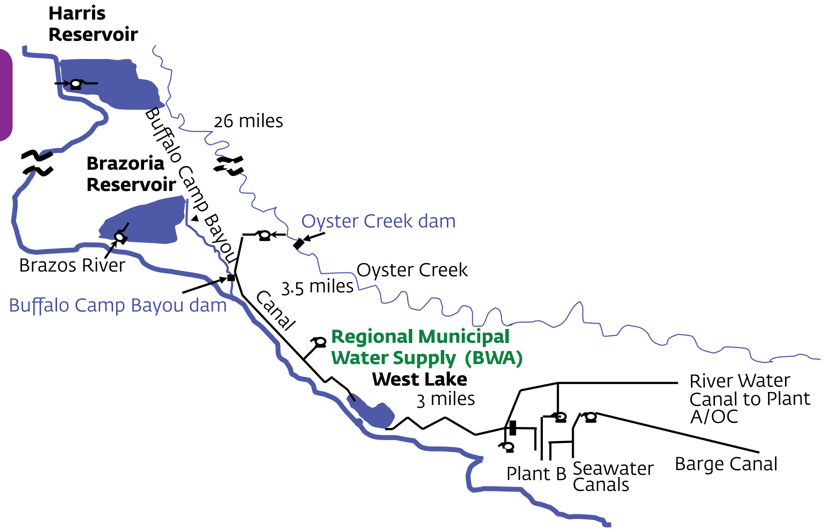
This intervention into the ERCOT market raises questions about the amount of water and electricity needed to ensure public health and safety. The answers to these questions can essentially change some of the dynamics of the ERCOT market:

- Should the electricity needs of commercial and manufacturing operations take priority over agricultural irrigation?
- With the revenue/water ratio for Texas agriculture at $2,000/acre-foot and ERCOT wholesale market sales at $20,000–$40,000/acre-foot, does the decision come down to economics? The industrial sector also generally has a high value of revenue per acre-foot of water consumption compared to agriculture.
- In the future, is Texas going to assure legal access to water for existing power plants in drought conditions?
- Can new thermal power plants assume the same assurance, or do they have to find more expensive water or install dry cooled plant technology?
- Will legacy facilities with water rights have a market advantage in ERCOT?

If Texas has a drought plan but it is not put into effect, it

"If Texas has a drought plan but it is not put into effect, it raises questions about the value and validity of the plan."

Dow Freeport Water Infrastructure



raises questions about the value and validity of the plan. Management of river basins such as the Brazos may need to be less ordered by water rights and consider small water markets that allow the leasing of water rights during drought conditions.

Several competitive new technology applications for power generation, including wind, solar, and dry cooled combined-cycle plants do not consume water. Although it is cost prohibitive to retrofit wet cooled to dry cooled systems, the capital investment required to build dry cooled plants will be justifiable as water gets more expensive and continues to be scarce.

THE PETROCHEMICAL INDUSTRY

Texas has a large number of coastal petrochemical facilities that supply raw materials for downstream product manufacturing nationwide. Dow's Freeport site is the largest petrochemical facility in the Western Hemisphere, with more than 65 production plants on more than 5,000 acres. This site produces in excess of 32 billion pounds of product annually, representing approximately 40 percent of Dow's U.S. production and 20 percent of Dow's global production.

Dow's Freeport site was established in 1940 and is located at the mouth of the Brazos River. Dow holds relatively senior water rights on the Brazos and owns two off-channel reservoirs that store a limited 45-day reserve of water when full. When natural flow is insufficient, in addition to local storage, Dow relies on contracts with the Brazos River Authority (BRA) for releases of interruptible water and long-term contract supplies from BRA's reservoirs.

Water demand in the Lower Brazos River Basin below the flood gage at Hempstead is approximately 400,000 gallons per minute (gpm). The demand at Dow's intake pumps, which supply local communities and industry, is approximately 100,000 gpm or an estimated 8 percent of the water supply coming out of the Brazos. As with other

"Through various strategies, including reuse and recycling, Dow achieved a 5–10 percent reduction in water use in the 4th quarter of 2011 followed by another 5–10 percent reduction in 2012."

Texas river basins over the past decade, available water from the Brazos River has been adversely affected by lack of rainfall, water capture, pumping, and evaporation.

In September of 2011, the majority of Texas was in exceptional drought. Reservoirs across the state were severely depleted, and the only water coming down to Dow's part of the Brazos River was water purchased from BRA reservoirs by Dow, the Gulf Coast Water Authority, and NRG Energy. Due to BRA's prediction that there would be no interruptible/excess water available in 2012 if the drought continued into a second summer, Dow conducted a comprehensive review and assessment of water use on the entire 5,000-acre Freeport site.

Dow's process to develop a long-term strategy was based on the understanding that 1) a secure water supply is essential for business success, and 2) conservation should be viewed as a way to generate new water driven at a price point aligned with the future cost of new water supplies. Through various strategies, including reuse and recycling, Dow achieved a 5–10 percent reduction in water use in the 4th quarter of 2011 followed by another 5–10 percent reduction in 2012. The total estimated permanent demand reduction was 12,000 gpm with additional drought response reductions of 4,200 gpm or 25 million gallons per day. Dow's water conservation efforts were recognized by the Texas Commission on Environmental Quality with a Texas Environmental Excellence Award.

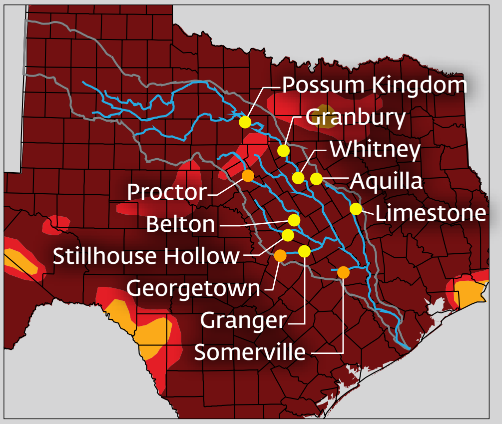
Advanced planning is essential to avoid potential economic consequences of water shortages. It is not uncommon for the lower portion of river basins to experience excess flows at certain times of the year creating a false perception about water stress. Over the past five years, all major Texas river basins have shown evidence of inflow deterioration, and at many locations historically low base flows suggest groundwater depletion may be contributing to the severity of observed effects.

In 2014, water regulators have come close to initiating water rights calls on multiple occasions. Although lower basin flows improve with precipitation, significant rainfall events have primarily occurred nearer to the coast and below major basin reservoirs which are still at or near all-time lows.

In April of 2014, the Texas Commission on Environmental Quality created the office of lower Brazos watermaster to oversee water allocations for the central and lower portions of the Brazos River Basin. Proponents believe this will create transparency and promote a clearer understanding of risk to help drive needed investments in water security. It is also perceived by some as a way to provide the transparency and framework needed to allow market principles to play a more significant role in water allocation.

Brazos River Basin, September 13, 2011

Source: Brazos River Authority



Reservoir Percent Full
- 95–100
- 85–95
- 75–85
- 50–75
- 30–50
- Below 30

Drought Severity
- D0 Abnormally Dry
- D1 Drought – Moderate
- D2 Drought – Severe
- D3 Drought – Extreme
- D4 Drought – Exceptional

Brazos River in June of 2009 Upstream of Dow's Intake

Opportunities for New Industrial Waters:

Industrial Water Reuse

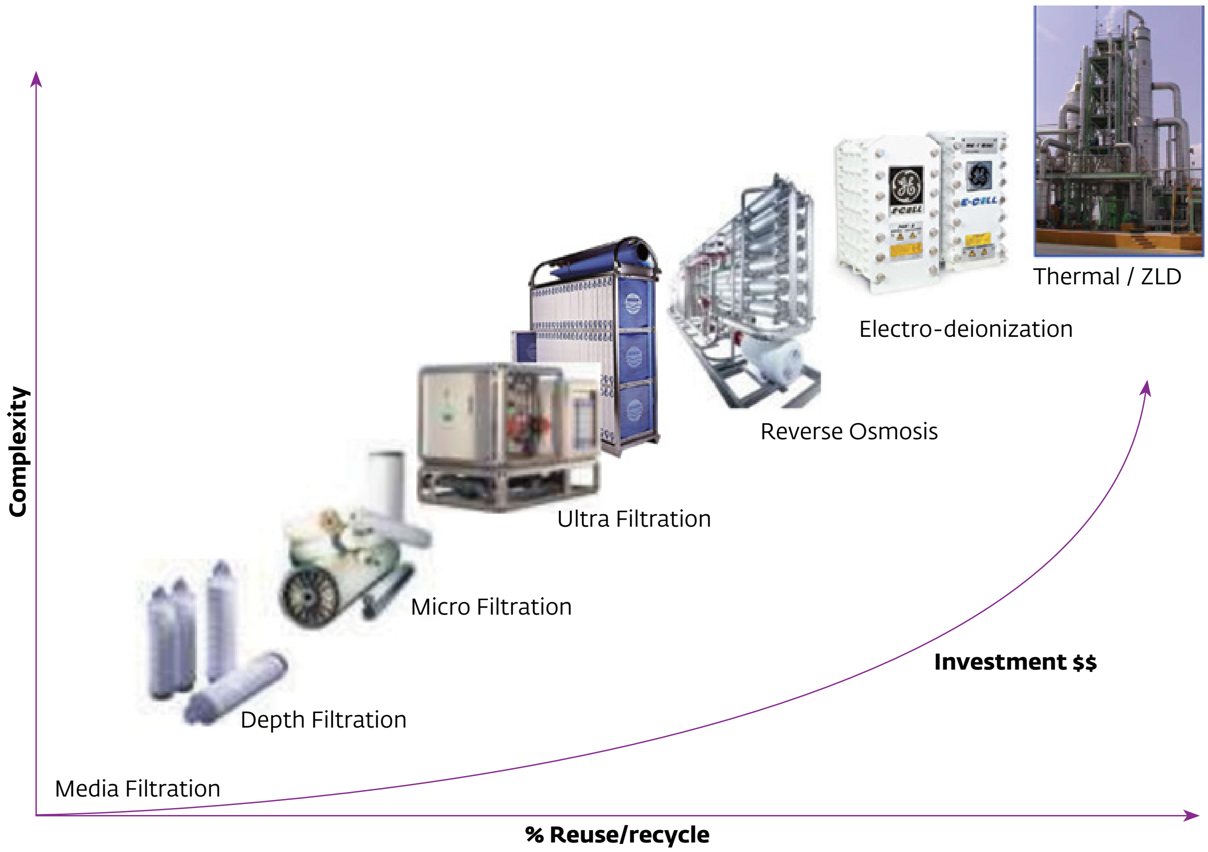
Bob Holt
Corporate Account Executive
GE Power & Water
Water & Process Technologies

Bob Holt has 35 years of experience in developing sustainable integrated water treatment solutions for multiple industries including power, upstream and downstream hydrocarbon processing, chemical processing, biotech, semiconductor, food processing, and mining.

"Key stakeholders in the industrial sector are actively pursuing ways to optimize their water usage and evaluate economically viable and sustainable reuse options."

Water Reuse Technology Spectrum

Source: GE



On a global scale, agriculture accounts for 70 percent of water withdrawals, but in advanced economies, industry leads with 44 percent, and developing countries are moving in this direction. Both municipal and industrial wastewater can be effectively treated for reuse to help augment fresh water supplies and meet demands for irrigation and industrial process water.

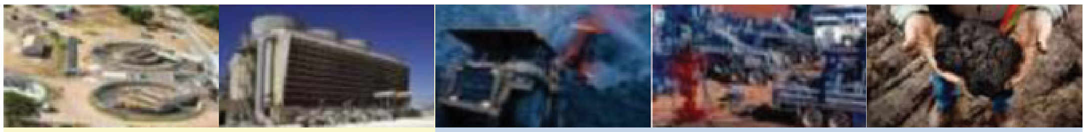
Conventional water treatment technologies are typically used to remove contaminants from industrial and municipal wastewater before discharge into natural water systems. In treating water for reuse or recycling, advanced technology is used to remove particulate, organic, and inorganic constituents prior to beneficial use options including aquifer recharge, direct or indirect potable water production, or process and cooling water. In some applications, the inorganic salts can be converted to useful byproducts and the solid and/or organic content to methane as an alternate energy source.

Water treatment processes can be used as stand-alone technologies or in combination with others, depending on

"Water treatment processes can be used as stand-alone technologies or in combination with others, depending on the end use."

Key Water Reuse Areas

Source: GE



Segment	Muni waste	Cooling Tower	Mines Blowdown	Unconventional Gas	Heavy Oil/ Refineries
Technical challenge	Low	Medium	High	High	High
Customers	Municipal	Utilities	Industrial	Oil & Gas	Oil & Gas
Drivers	Availability	Efficiency	Environmental	Environmental	Environmental

Less challenging ← → **More challenging**

Technologies exist to meet the challenge

"Municipal water reuse is common due to the proximity of the source water to reuse demand, its predictability, availability, and relative ease of treatment."

the end use. The technologies in the reuse spectrum come with distinct capital and operational costs that must be evaluated against alternatives to determine their economic feasibility for each application.

Municipal water reuse is common due to the proximity of the source water to reuse demand, its predictability, availability, and relative ease of treatment. The majority of municipal water reused by industry is for irrigation, cooling water makeup in power generation, and oil refining.

Treating industrial water for reuse is typically more costly than treating municipal water due to higher levels of particulates, organic, and inorganic constituents contained within required removal levels. Key stakeholders in the industrial sector are actively pursuing ways to optimize their water usage and evaluate economically viable and sustainable reuse options.

Food and beverage producers are leaders in water reuse, conducting comprehensive evaluations of their water balance and production processes, and using multiple technologies to maximize water reuse and recovery and minimize the impact on the local watershed and stakeholders.

In the upstream oil and gas sector, there are systems using multiple technologies to treat water for reuse and/or discharge including thermal evaporators treating produced water from the steam assisted gravity drain process. The oil and gas downstream industry operates facilities using multiple technologies including advanced membrane biological, filtration, and desalination processes to treat refinery effluent for water reuse and/or direct discharge.

Other sectors using water reuse/recycling technologies include the automotive, semiconductor, pharmaceutical, and mining industries. The effective application of advanced technologies for industrial water reuse represents an important value creation opportunity and a call for regional integrated resource and infrastructure coordination and development.

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