Keeping Water in Our Rivers

Strategies for Conserving Limited Water Supplies

ENVIRONMENT TEXAS
RESEARCH & POLICY CENTER

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March 2013

Acknowledgments

The authors thank Cyrus Reed with the Lone Star Chapter of the Sierra Club; Dr. Danny Reible, Bettie Margaret Smith Chair of Environmental Health Engineering at the University of Texas and Coordinator of Environmental and Water Resources in the Department of Civil, Architectural and Environmental Engineering; and Roxana Darvari at the Department of Civil, Architectural and Environmental Engineering, University of Texas, for their review and insightful feedback on drafts of this report. The authors would also like to thank Tony Dutzik and Jordan Schneider at Frontier Group for providing editorial support.

Environment Texas Research & Policy Center is grateful to the Cynthia and George Mitchell Foundation for making this report possible.

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Layout & Graphic Design: Harriet Eckstein Graphic Design

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Executive Summary

Water levels in Texas' rivers and streams are dropping. The 2011 drought was the worst in more than a century, and conditions improved little in 2012. Drought has reduced recreational opportunities, harmed wildlife, and threatened drinking water supplies. As Texas' population and economy continue to grow, demand for water will increase, making it more important than ever to use water wisely.

Wasteful water use in Texas remains common. New residential landscaping often requires extensive watering to maintain. Cracked municipal water mains leak billions of gallons a year. Farms withdraw billions of gallons of water annually, much of which is used in ways that do not support crop growth. Oil and gas fracking companies consume freshwater for oil and gas production, recycling little of it. Coal, natural gas and nuclear power plants withdraw and consume vast volumes of water for cooling. In each sector, wasted water means that less is immediately available for other purposes. Moreover, wasted water may evaporate or become contaminated, removing it from the hydrological cycle altogether and permanently reducing the amount of water available to recharge Texas aquifers.

Thankfully, there are many proven technologies and approaches that can improve the efficiency of water use. **Deploying water conservation technologies and implementing conservation programs could reduce water demand by 500 billion gallons by 2020, enough to meet the municipal water needs of 9 million Texans.**

Implementing more efficient irrigation technologies and management practices in agriculture—which withdraws more water than any other consumer, especially in the most arid parts of the state—could reduce water withdrawals by 400 billion gallons per year by 2020, enough to meet the water needs of 7 million Texans.

- Agricultural use is responsible for 56 percent of water demand in Texas, and much of that water is wasted. Evaporation from overhead sprinklers and soil; losses from unlined, open irrigation canals; runoff from oversaturated fields; and water consumption by weeds all use irrigation water without helping crops grow.

- More widespread use of water meters would allow farmers to measure water withdrawals for irrigation and allow better management of limited water supplies. Metering can reduce on-farm water use by 10 to 20 percent.

- Adoption of water-saving practices such as brush clearing and reduced tillage of soils would reduce water consumption by weeds and allow the soil to retain more moisture.

- Installation of more efficient irrigation technologies, such as drip irrigation instead of overhead sprinklers or flood irrigation, can reduce evaporative losses and support greater plant growth.

Increasing the use of drought-tolerant plants in landscaping instead of traditional lawns could reduce withdrawals by 14 billion gallons by 2020, or as much as 260,000 Texans would use in a year.

- Landscapes composed of grass and plants from wetter climates require extensive watering in arid regions of the state. Exacerbating the problem, much of the water that is applied to turf grass is lost through evaporation and permanently removed from the Texas water supply.

- Xeriscaping—landscaping designed to reduce the need for water—can reduce water use by 30 percent.

Detecting and repairing leaking municipal water mains would end the waste of 20 billion gallons of water annually.

- Broken water mains leak at least 35 billion gallons of water per year. Losses may be higher now that drought has accelerated the pace of water line ruptures.

- Electronic leak detection equipment, already in use in cities such as Arlington and Grand Prairie, can find leaks deep underground. Arlington estimates that with its equipment it has identified leaks equal to 5 percent of the water flowing through its system.

Increasing deployment of energy technologies that require little or no water could reduce the amount of water consumed by electricity generation by 43 billion gallons per year in 2020, more than enough for all the residents of Fort Worth.

- Approximately 157 billion gallons of water—equivalent to the residential water needs of 3 million Texans—are consumed every year for cooling the state's coal, natural gas and nuclear power plants and for turning the turbines to produce electricity. Electricity generation is projected to grow to 7 percent of the state's water use by 2060.

- Renewable energy technologies such as wind power and solar power require little to no water, while energy efficiency reduces the demand for power from power plants, thus cutting their water consumption. Strong energy efficiency policies could reduce electricity consumption, while renewables could deliver power without consuming water.

- New natural gas or nuclear power plants should use more efficient cooling technologies such as dry cooling or hybrid cooling systems, and should demonstrate that adequate water supplies will be available for the plant, even during times of drought.

Using brackish water for oil and gas drilling processes would cut the amount of new freshwater withdrawn for those activities. That could mean savings of 23 billion gallons per year in 2020, with benefits concentrated in the counties where fracking is widespread.

- Oil and gas drilling, together with mining activities, are currently responsible for 2 percent of Texas' water demand. Hydraulic fracturing, commonly known as fracking, is a fast-growing, water-intensive production process for oil and gas, and it is concentrated in the Eagle Ford, Haynesville and Barnett shales and the Permian Basin, imposing especially high water demands in those areas.

- Oil and gas drilling using fracking involves drilling a well and then injecting a mixture of water, sand and chemicals to create fissures in the rock to release the oil and gas trapped inside. Each well consumes large amounts of freshwater. In the Eagle Ford shale, each well requires roughly 5 million gallons of water to frack.

- Recycling the water that returns to the surface once fracking is complete would reduce the need for freshwater withdrawals for each new fracking operation. Replacing freshwater with brackish water would largely eliminate the need for freshwater in fracking.

Reducing water waste is a key element of how Texas should address the growing gap between water supply and demand. In the aftermath of two consecutive years of drought that damaged ecosystems and the economy, Texas needs a new plan for addressing the state's water needs. The state has access to a finite amount of water and should ensure that it is used efficiently.

- **Texas should prioritize water conservation above increasing supply.** The state should aim to reduce statewide per capita water use to 140 gallons per day, and should establish efficiency standards for buildings, appliances and irrigation equipment.

- **The state should adjust financial incentives to promote water efficiency.** Municipal users should be billed under a conservation pricing structure, creating financial signals to reduce water consumption. The pricing structure for agricultural users should also be adjusted, and coupled with subsidies for efficiency investments for agricultural users.

- **Texas should adequately fund water conservation programs and efficiency investments.** A one-time use of the Emergency Stabilization Fund or "rainy day fund" would jumpstart investments in efficiency programs. To provide ongoing funding, Texas should collect a small fee on water sales. The small additional charge paid by consumers for each gallon of water delivered would help provide reliable funding for financial and technical assistance to cut water use.

- **Better knowledge about water use and savings opportunities can help guide investments in water efficiency.** The Texas Water Development Board should conduct a statewide feasibility analysis of water efficiency potential, and should improve data collection on water consumption.

- **Funding water education.** Due to a lack of budget allocation, the Texas Water Development Board developed but never implemented a water education and conservation program designed to teach Texans how to conserve their water supply. Previous estimates suggest that a down payment of $16 million could spread the water conservation message throughout the state.

A strong commitment to water efficiency improvements will help ensure access to water for all water users in Texas, including farmers, residents, businesses and the environment.

Introduction

Texans know what a precious resource water is. During the drought that started in 2011, citizens responded to the water shortage by curtailing their water use. They abided by outdoor watering restrictions, watching lawns and landscapes wither and 5.6 million urban trees die due to lack of water.[1] In Midland, outdoor watering use was restricted to just two hours per week by hand.[2] To reduce other water use, the city increased rates five-fold for the biggest water users.

Yet many of the ways in which we consume water are wasteful. Practices, habits and infrastructure that pre-date Texas' drought waste billions of gallons of water each year.

Power companies have continued to use and consume billions of gallons of water for cooling instead of investing in technologies that use less water. Aging municipal water systems leak billions of gallons of water. Most companies that engage in fracking to extract natural gas continue to discard water by injecting water mixed with toxic chemicals underground—never to be used again—after a single use instead of processing it for reuse.

There's no need for continued water waste. In every sector of water use, new technologies and better management practices can enable us to get more out of a gallon of water. Farmers can grow the same crops with the same yields by choosing more efficient irrigation systems and applying water exactly when it provides the greatest benefit. The state can promote technologies—such as wind and solar power and energy efficiency—that consume no water. Any new fossil fuel power plants can be designed with air cooling systems. Recycling and treatment technologies allow fracking companies to recycle some of the water they use, while use of brackish water unsuitable for drinking or irrigation could eliminate freshwater use in drilling altogether.

Adoption of these new technologies and practices will be more widespread and rapid if Texas develops policies and incentives to reduce water use.

As Texas responds to the ongoing drought and plans how to meet the state's water needs in the years to come, it needs to pursue a balanced solution that improves the efficiency of water use and leaves more water in rivers and aquifers to support the ecosystems that depend on water.

We can't control when it rains, but we can control how we use water.

Water Waste Is Harming Texas

The availability of water affects the well-being of Texas communities and wildlife. In the past two years, drought has constrained this valuable resource. Wasteful water use makes the situation worse.

Drought Damage in Texas

During the summer of 2011, Texas was hit by the worst single-year drought in its history, with 97 percent of the state in extreme or exceptional drought.[3] The situation has improved little—nearly 90 percent of Texas continued to experience drought as of early 2013.[4] West Texas, for example, has continued to be in extreme drought with low rainfall.[5]

Texas rivers—from the Guadalupe to the San Marcos to the Colorado—are stressed by this ongoing drought. Low water levels threaten wildlife, strain drinking water supplies, and disrupt outdoor recreational activities.

There are 191,000 miles of rivers and streams in Texas, which provide habitat for fish and support diverse ecosystems.[6] These ecosystems become threatened when rivers dry out, when lake and groundwater levels drop, or when the lack of rainfall increases water salinity or leads to lower levels of dissolved oxygen in waterways. At the height of the drought in 2011, at least seven of Texas' reservoirs were empty.[7] Even in 2012, the ongoing drought continued to leave water levels in lakes and streams far below their capacity. For example, as of early 2013 Lake Travis and Lake Buchanan, two of Texas' major reservoirs, were at 41 percent of capacity.[8]

Ecosystem impacts of water shortages have been widespread:

- The world's last surviving flock of whooping cranes usually spends several months wintering in Texas, and their food supply depends on freshwater flows that support wetlands along the coast.[9] The Fish and Wildlife Service reported a 12 percent drop in flock size in the winter of 2011-2012 compared to a year earlier—one of the most dramatic declines recorded.[10]

- Wetland species like the American alligator have relocated in the face of increasingly stressful conditions as wetlands dry up; during the summer of 2011, alligators were seen much farther north of their usual territory.[11]

- Low water levels in the Brazos River led scientists to collect rare smalleye shiners and sharpnose shiners, important minnows at the bottom of the food chain, to protect the fish from extinction.[12]

- As trees and plants suffer from lack of moisture, mammals such as possums, deer and quail struggle to find sufficient food.[13]

Drought also threatens municipal water systems as reservoirs dry up and infrastructure becomes more prone to failure. Water shortages have forced communities to ration water. As of early 2013, 1,028 public water systems were asking customers to follow water use restrictions.[14] Water lines are more prone to breakage during a drought as soil shrinks and shifts, creating the need for expensive repairs for cities across Texas. In Houston, the city responded to and repaired 17,756 water line breaks in 2011, 40 percent more than in 2010.[15]

Water-based recreation, such as fishing and boating, is also impacted by declining water levels. This is significant in a state that ranks second nationally in angler days and sixth for number of boats registered for use.[16] Low water levels in lakes, rivers and streams impede recreation, as many boat ramps close when water levels decrease and algal blooms disrupt opportunities to fish.[17] The drought has measurably reduced outdoor recreation by Texans: visitor fees paid at Texas state

Low water levels caused the death of these fish in O.C. Fisher Lake near San Angelo. Photo: Travis Dowell/USGS parks declined by $4.2 million in 2011.[18]

Current water supplies are inadequate to meet demand in Texas, and water needs in the state are projected to increase in the future. According to projections from the Texas Water Development Board (TWDB), the state's population will grow 82 percent by 2060, increasing from 25.4 million to 46.3 million.[19] The TWDB predicts that water supply needs will increase by 22 percent by 2060, assuming the state adopts more efficient water use patterns.[20]

Global warming will further exacerbate Texas' water shortage. Climate projections indicate that temperatures will increase, making drought increasingly likely in Texas' future and putting further strain on water supplies.[21] According to the U.S. Global Change Research Program, rising temperatures are likely to cause more frequent extreme drought events in the Great Plains, including the Texas Panhandle, adding more stress to already strained water resources.[22]

Texas Wastes Large Amounts of Water

Efficient water use is critical to ensuring that the water needs of Texas communities are met—especially during times of drought. However, some of the largest

Quantifying Water Use

Texas faces two distinct but related water supply challenges. The first is the challenge of delivering enough water to the people, industries and ecosystems that need it at any particular moment. The second is the challenge of maintaining adequate levels of water in aquifers, rivers and lakes to sustain needs in the medium and long-term.

Practices that waste water can exacerbate both of these challenges. Some practices result in increased water *withdrawal*—that is, they strain the ability of Texas' water infrastructure to deliver enough water from rivers, lakes and aquifers to meet immediate needs. Other practices result in increased water *consumption*—that is, they take water from Texas' rivers, lakes and aquifers that is never returned, exacerbating the state's long-term water challenges. Some practices exacerbate both the withdrawal and consumption challenges.

In the state's long-term water planning document, the TWDB estimates total water use by all sectors of the economy, referring to consumption in the power sector and withdrawals by all other sectors as *demand*.

Some practices that increase withdrawals have only a minimal impact on overall water consumption. For example, power plants withdraw huge volumes of water for cooling, running the water through the plant just once before returning almost all of it to the source. Other practices, however, may result in relatively small increases in water withdrawals, but significant consumption of water. For example, much of the water used in hydraulic fracturing is lost to the water cycle forever.

water users in Texas are wasting billions of gallons of water. Land developers, energy companies and industrial agribusinesses are responsible for the majority of water use in Texas, and yet they often forego conservation measures.

The largest users of water in Texas consume far more water than residential users. Agriculture accounts for 56 percent of water demand, compared to 27 percent for municipal users, which include both residential users and commercial users on municipal systems.[23] Manufacturing activities account for 10 percent and mining is responsible for 2 percent. The electric sector also withdraws large amounts of water.[24]

Water is wasted in a number of sectors. In agriculture, much of the water withdrawn is wasted—not helping to produce crops but evaporating from the ground, being consumed by weeds, or seeping into the ground from unlined ditches or overwatered fields. Power plants withdraw large amounts of water at a time when waterless, renewable energy technologies could be employed to produce a much larger share of the state's electricity. Existing fossil fuel power plants generally fail to employ more modern technologies that reduce the use of water, such as dry or hybrid cooling, combined cycle or combined power and heat technologies. Oil and gas drilling—conducted in part to support water-consuming electricity generation—also uses a significant amount of water. Fracking a single gas well can consume as much as 8 million gallons of water per year (enough water to supply about 150 homes), but very little recycling of fracking water occurs in Texas.[25]

Water-efficient technologies can significantly reduce water waste. Applying these technologies is an essential step towards creating water-secure communities today and into the future.

The Advantages of Water Efficiency

Texas can address the problem of water waste by pursuing water efficiency measures, or it can seek new supplies to cover waste and satisfy rising demand from a growing population and economy. For both environmental and economic reasons, water efficiency should be the first option that Texas pursues as it plans for its future water needs.

Projects to store or transfer more water will have negative environmental consequences. New reservoirs to hold additional water supplies will flood critical wildlife habitat. Transferring water from one region to another will reduce the amount of water available for wildlife in the source basin. Water diversion may decrease freshwater flows into estuaries, which are breeding grounds for birds and fish. Desalination plants produce massive amounts of waste in the form of brine and are energy intensive, which adds to water consumption and produces air pollution.

In addition, water conservation measures are less expensive than building new infrastructure to augment water supplies.[26] For example, the Lower Colorado River Authority, which serves Austin and Central Texas, estimates that conservation measures can cut water use at a cost of $400 per acre-foot, versus importing water for $1,900 per acre-foot, constructing a reservoir for $2,150 per acre-foot, or building a desalination plant for $2,890 per acre-foot.[27] Statewide, if all Texans reduce their water consumption by 1 gallon per day, the state could avoid $407.2 million worth of water supply and infrastructure investment costs.[28] For individual water users who participate in efficiency programs, conservation measures may also help reduce their water bills.

Increasing Water Efficiency and Reducing Consumption

Saving Water in Agriculture

Irrigation accounts for the largest share of Texas' current water use—56 percent of total demand in 2010.[29] Much of that water finds its way back to rivers and aquifers, and is therefore able to be used again in Texas. However, some water evaporates into the air, where it is lost to Texas consumers. The efficiency of water use in agriculture can be improved with: metering of water so farmers better understand how and when water is being used; better management practices such as brush clearing and reduced tillage; infrastructure upgrades to limit water losses from canals; and adoption of more efficient irrigation technologies.

How Current Irrigation Methods Waste Water

Applying water to improve plant growth is a beneficial use, and providing adequate water at the right time is essential to ensuring decent yields and farm profitability. Too often, however, water is wasted when it evaporates or seeps out of unlined canals during transport, when it evaporates from the soil in a field, when so much is applied that it runs off or seeps deep into the soil beyond where plants can reach it, or when the water supports weeds and unwanted vegetation.

Evaporation

Water that evaporates during irrigation is a consumptive use of water, resulting in the permanent loss of that water to the region. Evaporation can make a big difference in the amount of water needed for irrigation, and it becomes faster with warmer and drier air, both of which are common in Texas.

Evaporation happens at every stage of irrigation. The first losses occur from the surface of reservoirs and canals, which may be used to carry water to nearby fields, or for long-distance transfers from regions with water surpluses to water deficit regions. Some water evaporates as it is applied to a crop. For example, sprinkler irrigation systems, such as the common "center pivot" system that is used on circular fields, may spray water high above plants, allowing water to evaporate before it even hits the ground. The amount of evaporation depends in part on the type of sprinkler head used. Sprinklers are the most common form of irrigation in Texas, used on 65 percent of irrigated land.[30]

Irrigation water can evaporate from soil, especially when the irrigation method applies water to an entire field instead of more precisely applying water at each plant. The most common irrigation methods in Texas are:[31]

- Overhead sprinklers, which lose up to 11 percent of their water to evaporation,
- Surface irrigation, in which large amounts of water are periodically released from an irrigation channel at one end of a field, which has evaporation rates of roughly 4 percent, and
- Subsurface irrigation, in which only 1 percent of the water applied is lost to evaporation.

Evaporation from soil also occurs when there is no crop on the field, reducing soil moisture levels for the next crop to be planted. Farm management practices influence how much moisture is lost from a fallow field. Removing all residue from the previous crop and tilling the field, for

Perverse Incentives Inhibit More Efficient Agricultural Water Use

Water use in the agricultural sector is influenced by a number of economic and regulatory incentives that discourage efficiency. These policies create an economic incentive for farmers to use more water, not less.

The relatively low price of water charged to agricultural users encourages overuse. For example, the Lower Colorado River Authority charges farmers $6.50 per acre-foot for water, versus $151 per acre-foot to cities.[32] With water so inexpensive, it does not make sense financially for a farmer to invest in equipment that will improve the efficiency of water use.[33] A more efficient sprinkler system, for example, may produce significant water savings but such small cost savings that the farmer doesn't recoup his or her investment for years.

Crop insurance policies may also spur unnecessary water use. In 2011, during the drought, cotton farmers who wished to receive payments from crop insurance companies had to continue to water their fields even when it was clear that they would not yield a crop.[34] Insurance companies, wary of false claims, ask farmers for evidence that they truly intended to grow a crop and are not claiming a loss on an empty field. That evidence often includes electricity bills that show a farmer operated wells and sprinkler systems.

"Use it or lose it" rules still in place from the earliest establishment of water rights encourage farmers to use all the water to which they are entitled, even if they don't need it in a particular year. A farming operation that fails to withdraw all the water it has permission to withdraw may lose the right to withdraw that much water in a future year. Instead, access to that water will be assigned to somebody else, and the original farming operation will either have to do without the water or find a way to lease water.

example, increases moisture loss and increases carbon loss from the soil, adding to global warming pollution.

Runoff

Overwatering with sprinklers or the use of surface irrigation methods can cause water loss through runoff. Even if water returns to an irrigation canal or soaks into the ground, runoff increases water withdrawal rates. In addition, runoff water typically is more polluted with sediment, fertilizer and pesticides than it was when it was withdrawn. Over time, runoff can carry enough soil away from cropland to hurt its productivity. When the sediment is deposited in rivers and lakes it can damage water quality and aquatic ecosystems, and impede navigability.

Deep Saturation

Water is wasted when it soaks deep into the ground where no plant can use it. Water can seep into the ground as it is being transported from reservoirs or rivers to fields through canals, which historically have been little more than dirt ditches, but more recently have been lined with concrete or plastic to reduce seepage in some places. As water travels along the canal, much seeps into the ground through the dirt or through gaps in the canal liner.

Deep saturation can also occur from overwatering of fields. If too much water is applied to a field at once, it will saturate soil to levels deeper than plant roots can reach—increasing the need for water withdrawals. Unfortunately, water soaking deep into the soil can carry fertilizers, pesticides and other chemicals into aquifers. In other cases, water cannot return to an aquifer because a layer of impermeable rock prevents recharge.

Unwanted Transpiration

Water can also be wasted through transpiration by weeds. Transpiration is the loss of water from the leaves of plants. When it occurs from a planted crop, transpiration does not constitute a waste of water, since transpiration enables a plant to draw water and nutrients from the soil and helps cool the plant in hot weather. It is also a sign of a growing plant that is opening its pores to absorb carbon dioxide.

Transpiration from weeds, however, consumes water without providing any benefit as weeds withdraw moisture from the soil and release it into the atmosphere.

Agricultural Efficiency Opportunities

With changes to water infrastructure, farming practices and irrigation technologies, Texas could use water for agriculture more efficiently, saving billions of gallons each year. Metering devices can help farmers and water system managers better understand how much water is being consumed and identify opportunities for reducing consumption. Changes to farming practices, such as reducing tillage, can reduce water consumption without affecting crop yields. Other tools that can help reduce water waste in agriculture are the lining of irrigation canals and adoption of different irrigation technologies.

Metering Water Use

Most irrigation water use in Texas is unmetered. Farmers may be able to make a rough estimate of water use by monitoring how much energy their pumps consume, but statewide only a small percent of irrigation water is directly measured.[35] A lack of firm knowledge of how much water is being used makes it difficult to identify opportunities for reducing water consumption. More widespread use of water meters would help farmers, water development boards and groundwater conservation districts by providing accurate data on consumption for irrigation and enable better planning for long-term availability of water for all users.

Water meters are installed at the point where water is withdrawn from the ground or diverted from a surface water source, giving producers an accurate portrait of their water use.[36] This alerts agricultural operators of excessive water withdrawals. Farmers who have access to data on their water use reduce water withdrawals by 10 to 20 percent, even without adopting other best management practices.[37]

One obstacle to more widespread use of water meters in Texas is the cost of buying and installing the meters, which can cost $600 to $1,000 per groundwater well.[38] However, this expense can be offset in several ways. By providing data to enable better water management practices and lower water withdrawals, the water meter can help reduce the cost of fuel for operating pumps. Improved data may also raise crop yields and farm incomes.

Metering is being adopted in some Texas water districts. Only six irrigation districts require collection of data on water volumes from wells. Those districts include: the Barton Springs/Edwards Aquifer Conservation District, the Edwards Aquifer Authority, the Harris-Galveston Coastal Subsidence District, the North Plains Groundwater Conservation District, the Hudspeth County Underground Water Conservation District No. 1, and the High Plains Underground Water Conservation District.[39] (Some of those districts rely on calculations based on energy use from pumps.) Irrigation districts in the Lower Rio Grande Valley and El Paso County require water meters for surface water.[40] The Texas Water Development Board has also provided grants to some groundwater conservation districts to install water meters and report on their water use.[41]

Several other states that rely on groundwater for irrigation require all farmers to meter their water use. Georgia requires water meters on permitted wells, with the state paying to install meters on wells permitted before 2003 and farmers responsible for installing meters on newer wells.[42] Colorado and Nebraska meter all groundwater wells, while Kansas annually collects data on all groundwater withdrawals for irrigation. More widespread metering of water use in Texas would help reduce water consumption by providing farmers with better data on consumption patterns and improving the state's planning capacity.

Improving Management Practices

Changes to farm management practices can provide huge savings in water consumption. Decisions about when and how much water to apply to a crop; which irrigation system to use; how to manage a post-harvest field; and how to control weeds and unwanted brush all have an impact on agricultural water use. Selecting the best options can provide benefits, in terms of both water use and farm profitability.

Providing water at the right time can improve crop yield and reduce water withdrawals. A study of pecan farms in New Mexico found that farmers tended to give trees too much water during times of low growth and too little water during critical periods of nut filling.[43] Shifting to a watering schedule more in line with crop needs can improve the quality and quantity of the harvested crop. Irrigation scheduling improvements in Texas could produce water savings of 98,000 to 163,000 gallons of water per acre of cropland.[44]

For field crops, proper management of the field after harvest can allow more water to be retained in the soil. Reduced tillage (also known as conservation tillage) is the practice of leaving crop residue on the surface of a field rather than plowing it under. The crop residue helps protect moisture in the soil from evaporation, reducing irrigation needs for the next year's crop. Other benefits include better soil structure that is able to retain rainfall and nutrients, reduced run-off of pesticides and sediment, and less energy use by farm equipment.[45] Conservation tillage has the potential to result in increased pesticide use, but with the right management practices this does not have to be true.[46] Water savings from conservation tillage in Texas could range from 81,000 to 163,000 gallons per acre.[47]

Removing unwanted brush can reduce water consumption in areas of the state that receive at least 18 inches of rainfall per year.[48] Juniper and mesquite, native to Texas, have expanded far beyond their historic range thanks to overgrazing and wildfire suppression.[49] Saltcedar, not native to Texas, is of particular concern because of its ability to consume 1.3 to 2 million gallons of water annually per acre of mature trees.[50] Clearing brush can cut water consumption, allow a more diverse range of vegetation to thrive, and improve habitat for some species such as the Black-capped Vireo. In the right circumstances, brush clearing activity in Texas can save 108,000 to 179,000 gallons of water per acre cleared.[51] At a ranch near Johnson City, Texas, the water savings of brush clearing became obvious when water flow increased in the creek flowing through the ranch.[52] To maintain any water savings, the cleared areas must be maintained and kept free of brush in subsequent years.

Reducing Water Loss from Canals

Lining canals with an impervious barrier can reduce water lost to ground seepage and protect water quality. Irrigation canals are often little more than dirt trenches that carry water from major reservoirs to agricultural areas, where smaller canals or ditches transport water to each field. Lining canals with concrete overlaid with plastic provides a durable and impermeable lining that limits water loss.

Depending on the type of lining and the size of the canal, lined canals save 70 to 95 percent of the water that would seep back into the ground in unlined irrigation canals.[54] Lower losses during transportation mean that farmers need to withdraw less water from reservoirs or rivers.

Canal lining is uncommon in Texas. According to a survey of Texas irrigation districts published in 2004, canal lining was occurring on only a small scale in one of the 12 irrigation districts responding to the survey.[55]

Agricultural Water Conservation Success from the Lower Colorado River

In 1999, the Texas Legislature approved a law that allows the Lower Colorado River Authority (LCRA) to subsidize the cost of agricultural water conservation efforts and transfer the saved water to Williamson County, on the north side of Austin. LCRA pays up to 20 percent of the cost of water efficiency improvements for rice fields served by the authority. Farmers can receive partial reimbursement for laser-guided leveling of fields irrigated with surface flooding, for adding inlets to flood a field more quickly, and for recovering runoff water.[53] The water conservation funding comes from consumers in Williamson County who pay a surcharge on their bills.

Conservation projects funded through the program cut agricultural water use by 3.3 billion gallons in 2011. With farmers paying for the bulk of the efficiency improvements, the public cost to save this water was $1.6 million from 2006 to 2011, or $158 per acre-foot.

Even lined canals still experience significant evaporative losses. Evaporative losses from canals can be nearly eliminated by replacing open irrigation canals or ditches with pipelines. Limiting factors for making this switch include the time and money needed to construct these pipelines and the need for pipelines that can handle a large quantity of water. Canals with smaller water capacity are more easily replaced with pipeline; efficiency improvements to larger canals may be limited to the addition of a lining.

Adopting More Efficient Irrigation Methods

Depending on the crop and field conditions, changing irrigation systems can help improve efficiency and reduce water use.

The efficiency of overhead sprinkler systems can be improved by installing low-pressure equipment that reduces the amount of time water is airborne and especially vulnerable to evaporation, but for many situations, microirrigation will be more efficient than any overhead sprinkler system. Microirrigation applies water directly to individual plants or root systems using narrow plastic tubing laid throughout the planted area. The tubing systems can either be laid on the surface of the soil or be buried. Water comes out at a much lower pressure than sprinkler systems; microirrigation systems where water comes out drop by drop are called drip irrigation.

Microirrigation has the lowest evaporation rate of any irrigation system and delivers benefits for farmers. Because water is applied directly to the plant in need, crops are better able to absorb water when they need it, reducing risk of water stress and resulting in higher quality produce.[56] Fertilizers can also be added to irrigation water, which allows a more precise application, reduces the cost of fertilizer, and reduces chemical runoff. Finally, microirrigation does not prevent field work during water application, unlike the other methods which leave the fields muddy.

However, microirrigation does not always lead to lower water consumption because plants watered with microirrigation may consume more water. A regular supply of water, applied at key stages of crop growth, may produce larger plants from which greater transpiration occurs and a larger yield—a benefit to the farmer, though not a savings in total water consumption.[57] Obtaining region-wide water savings when using microirrigation may require careful regional planning. More efficient use of water to produce crops may provide broader societal benefits, increasing food production or allowing retirement of the least productive acreage.

Microirrigation can be used on the vast majority of crops grown in Texas. According to Dr. Freddie Lamm at Kansas State University, about 90 percent of all American crops may eventually be appropriate for microirrigation technology, which is being tested and applied to new situations over time.[58] Even rice can be grown with subsurface irrigation instead of traditional surface irrigation in which the field is flooded. One experiment used 80 percent less water to irrigate rice via subsurface equipment, without any negative impact on yield.[59]

A few factors have prevented farmers from taking advantage of microirrigation more broadly. Since the price that farmers pay for water is heavily subsidized, they have little incentive to save water. Additionally, microirrigation has not been in use for as long as surface and sprinkler irrigation, and widespread adoption is slowed by the time and money required to learn and implement the new system. Finally, the advantages of microirrigation are more pronounced with certain crops, while for others it has yet to be tried on a large scale. To obtain the greatest water savings from microirrigation, farmers need appropriate guidance and incentives to make the switch.

Drip irrigation systems allow water to be applied to individual plants, thereby reducing evaporation. Photo: Jeff Vanuga/NRCS

Total Savings from Increased Agricultural Water Efficiency

Texas can obtain large savings from agricultural water use by pursuing changes to irrigation technology and infrastructure, and by helping farmers adopt best practices that balance water conservation and farm output.

Estimates of water savings from changing a single technology or management technique indicate large potential savings. An analysis of upgrading irrigation systems from the existing mix of irrigation systems to very efficient precision application systems and drip irrigation in the Texas Panhandle suggests a savings potential of 18 to 20 percent.[60] A study of agricultural water savings potential in California's main agricultural areas projected savings of 13 percent just from smart irrigation scheduling.[61] Implementing multiple changes at once would yield larger savings than pursuing a single change.

With a concerted effort to help farmers adopt better management practices and with increased funding for water metering and infrastructure upgrades, Texas could obtain significant agricultural water savings. Based on the estimated benefits of better irrigation scheduling alone, we assume Texas could reduce agricultural water withdrawals by 13 percent, or 400 billion gallons by 2020. That volume of water could provide for the residential water needs of more than 7 million people.[62]

Public Policies to Improve Agricultural Water Efficiency

Policy makers have several tools available to them to improve the efficiency of agricultural water use. These policies would enable Texas to prevent further depletion of its water resources. Though many of these strategies require increased public investment, reducing agricultural water consumption could help reduce the need to spend money on expensive new storage capacity and interbasin transfer projects.

Offer Financial Incentives

Buying new equipment and installing water-saving devices can require large financial investments from irrigators and water districts. This initial financial cost can be enough to deter improvements in agricultural water use. Texas could offer grants, loans or tax credits to help address this problem.

The Texas Water Development Board currently offers an Agricultural Water Loan Program and an Agricultural Water Conservation Grants Program to help defray the cost of water efficiency investments. However, current funding can achieve only a fraction of potential efficiency improvements. Greater funding to help defray the cost of water efficiency investments would reduce water use in the agricultural sector.

Provide Technical Assistance

Farmers trying to improve irrigation scheduling, transition to conservation tillage practices, identify brush clearing opportunities, or adopt other best management practices to save water can benefit from technical assistance programs. Expert advice tailored to the conditions on each farm can help ensure farmers make the changes that provide the greatest water savings. Texas should expand its efforts to provide guidance to farmers.

Increase Water Metering

When irrigators monitor how much water they withdraw, they have the knowledge to better manage their irrigation practices and thus consume less water. Texas should encourage more widespread use of water metering.

The state could mandate the use of water meters on wells or pumping systems that withdraw more than a threshold level of water. Because the cost of purchasing and installing meters can add up for farmers who have multiple wells, a cost-sharing program could help alleviate financial concerns. For example, irrigation water districts in the Lower Rio Grande Valley have paid for half of the cost of water meters.[63]

End Artificially Low Rates Charged for Agricultural Water Use

Restructuring the price of water to better reflect the true cost of providing and consuming it would encourage more efficient use of water through better technologies and practices. More sensible water pricing would make investing in water efficiency upgrades more financially attractive to farmers weighing the cost of water against investing in more efficient equipment.

Allow the Leasing of Saved Water

Allowing or encouraging the leasing of surplus agricultural water to other users can create appropriate incentives for water-saving techniques on farmland while also helping farmers overcome upfront investment costs in water-saving technologies like microirrigation. Water saved through efficiency measures could be leased to municipalities or for environmental uses such as instream flow. This will incentivize farmers to take steps to monitor water use, increase water application efficiency, and save water where possible. Farmers should not be forced to give up their water rights if they choose to conserve water and lease saved water to eager users.

Saving Water in Residential Areas through Water-Efficient Landscaping

Landscape watering accounts for nearly one third of residential water use.[64] Texas home developers can facilitate large reductions in water use by xeriscaping the landscapes of new homes instead of installing water-thirsty lawns.

Xeriscaping Can Reduce Water Use

Xeriscaping is the art of creating and maintaining a landscape that reflects the natural vegetation and climate of the region. Use of succulent plants, for example, which have evolved to survive in arid climates by storing moisture within the plant organism, reduces the watering requirement in gardens. On the other hand, Kentucky Bluegrass and St. Augustine grass, some of the most common types of lawn grasses, cannot survive in arid regions of Texas without copious amounts of water. Besides choosing appropriate plants for gardens, xeriscaping techniques include landscape design and the use of microirrigation, mulches and landscape maintenance to further reduce watering needs.

The first step in xeriscaping is planning out a yard in a way that reduces water consumption. Home developers and homeowners' associations have significant influence in this process. Where xeriscaping is not allowed by homeowners' associations, or where developers install turf-grass instead of plants adapted to arid conditions, homeowners are forced to waste water on plants ill-suited for the climate. Planning developments in a water-conscious way includes planning landscapes that will use water efficiently.

The Southern Nevada Water Authority (SNWA) completed a five-year study in which it looked at the water savings of lawns and gardens converted to xeriscapes. The authority found that homeowners cut total domestic water usage by 30 percent, and saved one-third of the labor and financial cost of irrigating a lawn.[65] Additional incentives for water savings could enable Texas developers to take advantage of these potential water savings in their planning processes.

Assuming that Texas homes in the drier areas of the state can achieve savings similar to the households studied in the SNWA study, Texas could save 14 billion gallons of water annually in 2020 by applying xeriscaping techniques to all new yards.[66] That's enough water to meet the annual needs of 260,000 Texans.[67]

Public Policies to Encourage Xeriscaping

Policy makers have several tools available to them to increase the use of xeriscaping in new developments. These policies would enable Texas to prevent further depletion of its water resources.

Establish New Development Efficiency Standards

In order to help stop the growth in water consumption, Texas could adopt water efficiency requirements that new developments would have to meet. Developers would have to design homes and yards with water efficiency in mind.

One advantage of focusing on new homes is that many efficiency improvements, both for landscaping and indoor water use, are cheaper and easier to make during original planning and construction. The clear weakness in this policy is that it doesn't address existing homes, which, in the aggregate, will continue to be the biggest residential water users for many years. Combining this policy with xeriscaping in existing homes would make it significantly stronger.

A number of communities in other states have already adopted residential landscape efficiency requirements. Tampa, Florida, limits turf grass in new development. When the standard was first adopted, grass watered with a permanent irrigation system could cover only 50 percent of a yard. Over time, the standard has tightened so that by 2013 just 25 percent of the landscaping in new development can be grass with a permanent irrigation system.[68]

California has adopted a Model Water Efficient Landscape Ordinance establishing water efficiency standards for residential landscaping.[69] All communities in the state have to adopt a residential landscape water efficiency standard at least as stringent as the state's model. A number of cities have opted for tighter standards, limiting turf to 25 percent of the landscaped area or requiring that 80 percent of plants selected require little or no water.[70] Salinas, California, requires that all new homes use xeriscaping principles, and limits turf grass to 20 percent of the landscaped area.[71] In Texas, Austin's water utility has discussed limiting grass and plants requiring irrigation to 2.5 times the footprint of a new home.[72]

Saving Water in Cities by Repairing Water Mains

Municipal water utilities must maintain hundreds of miles of pipes and tens of thousands of connections. Each joint and length of pipe has the potential to leak.

Encouraging Xeriscaping in Existing Developments

Replacing lawns and water-thirsty landscaping in existing developments will require changes in policy and financial incentives.

Local homeowners' associations may need to change their policies. Existing guidelines may prevent the use of xeriscaping and require that homeowners install grass or other water-intensive flora. These restrictions mandate water consumption and make water shortages in the region more intense. Forcing homeowners to grow grass when they prefer a xeriscape or want to conserve water goes against the long-term interests of the state and puts a ceiling on the potential to save water at home. When water use restrictions are imposed during droughts, the grass dies and lawns become an eyesore. Texas should prevent homeowners' associations from enforcing anti-xeriscaping measures to allow individuals and communities to protect their water resources.

Financial support for renovating existing landscapes could come from developers of new housing. With existing water sources already failing to sustainably meet demand, new developments could be required to make up for their new water demand by using efficiency to decrease demand elsewhere. For example, a developer could pay for enough xeriscape conversions in a nearby neighborhood to free up the water needed for a new development.

Traditional lawn-based landscapes require extensive watering. Photo: NRCS

Small leaks may go undetected for years, leaking thousands of gallons of water into the soil. Larger leaks, though short-lived, can result in large volumes of water waste. After each leak is repaired, potentially contaminated water must be flushed out of the system, wasting more water. Detecting and repairing leaks in municipal water infrastructure to cut water losses by half would save 20 billion gallons in 2020.[73]

Water Loss from Leaking Water Mains

Since 2006, municipal utilities have been required to audit their systems and report water losses once every five years.[74] Data reported for 2005 by utilities serving the majority of the state's population indicate broken or leaking water mains result in the loss of 27 billion gallons per year.[75] That's equal to 2.2 percent of all water provided by those utilities. If that same leakage rate holds true statewide, 35 billion gallons currently are lost each year to broken mains, enough to meet the needs of 600,000 Texans.[76]

Actual losses from leaking mains may be larger. Utilities expressed a large degree of uncertainty in their audits regarding all the ways in which they lose water, including faulty meters that undercount consumption by customers, unmetered consumption such as for firefighting, and unauthorized consumption. Adding to the uncertainty, broken water mains may waste more water than Texas utilities estimated: Texas water utilities report an average leakage rate less than one-quarter of that reported by other water systems across North America.[77] Mark Mathis with the TWDB and Brian McDonald, a professional engineer with expertise in water management who reviewed the data submitted by utilities, concluded that most utilities were underestimating their losses.[78] The results of more recent audits support this conclusion. Audit data from 2010 suggest total system losses of 16.7 percent, versus 5.6 percent from the 2005 audit.[79]

The ongoing drought may also cause losses to be even larger than when utilities reported the results of their 2005 audits. Drought can cause pipes to fail as dry soil shrinks and shifts. At the peak of the drought, Houston suffered from 1,200 water main breaks per day, up from 200 per day during normal conditions.[80] A single drought-related water main break in San Angelo, in West Texas, caused the loss of 250,000 gallons of water.[81] Arlington estimates that the city loses 10,000 gallons of water flushing out water mains after each repair to rid them of contamination.[82]

Public Policies to Reduce Waste from Leaking Water Mains

Reducing leaks from water mains requires utilities to identify leaks and to fund repairs.

Use Leak-Detection Equipment

Small water leaks can go undetected for years if utilities don't employ monitoring devices. Computerized monitors can "listen" for leaks and accurately identify their location. All water utilities in the state should use leak monitoring equipment to examine all their water mains each year.

Leak-detection equipment has enabled Grand Prairie to identify 1,000 water leaks over four years. The water utility operations manager told the *Star Telegram*, "We've found lots of leaks that we didn't know about."[83] Arlington recently purchased $75,000 worth of leak-detection equipment to identify small leaks in its 1,300 miles of water mains, water losses that add up to 5 percent of water flowing through the system.[84] The TWDB owns leak detection equipment that it lends to utilities, enabling smaller utilities to examine the condition of their water mains.[85]

Ensure Adequate Funding for Water Main Repair

The cost of repairing and maintaining water mains could reach into the millions of dollars statewide.

The U.S. Environmental Protection Agency estimates that Texas faces $15.95 billion in repairs and replacements to its water transmission and distribution network in the next 20 years.[86] One-third of this expense is in cities with populations of less than 10,000. This expense includes installation, replacement and repair of pipes that carry water from a drinking water source to a treatment plant and from the treatment plant to customers. Leaking water mains will be a large part of the total anticipated repair costs. For example, Houston spent at least $8.5 million repairing water mains that broke during the drought.[87] Finding and repairing all leaking mains will cost the city far more.

Typically, utilities are responsible for paying for their infrastructure costs using revenues from customers, though in some instances federal grants may be available. Larger cities may be able to spread the cost of detecting and repairing water mains over their extensive customer base, but the cost may be too high for small cities to fund through user fees. Additional funding in the form of grants or low-cost loans may be needed.

Saving Water in Electricity Production

Electricity generation in Texas was responsible for 4 percent of water consumption in 2010.[88] This share could rise if future electricity needs are met with similarly water-intensive cooling systems. Future demand for electricity is expected to increase 38 percent by 2020 and 58 percent by 2030. Increasing deployment of energy technologies that require little or no water would reduce the need for water for cooling by 43 billion gallons of water per year in 2020, more than enough for the population of Fort Worth. Further savings could be obtained by upgrading cooling technologies to use less water.

Water Consumption in Power Plants

Power plants that use steam-driven turbines, such as nuclear and coal-fired power plants, use water as a cooling mechanism to increase their efficiency. After steam passes through the turbine, it is exposed to cool water—flowing through a separate loop—and condenses. The change from gas to liquid shrinks the volume of the steam and pulls more steam from the turbine behind it, thereby driving the turbine faster.

Depending on the power plant's design, the water used for cooling may then be discharged to a surface water body or be cooled and recirculated through the plant. These systems have very different water withdrawal and consumption patterns. The two most common cooling systems are:

- **Once-through or open loop cooling systems,** which withdraw water from a lake, river or ocean, pass it through the plant one time to condense steam, and then discharge the water back into the original source. The discharge water is warmer than when it was withdrawn, increasing evaporation from the water source. This evaporation is considered consumption by the plant.

- **Recirculating systems**, which may withdraw water from and return it to a reservoir, or use a cooling tower in which most of the water is recaptured. After cooling steam in the plant, water returned to a reservoir cools through evaporation. In a cooling tower, water is cooled by air. Some water will escape as steam but most falls to the bottom of the cooling tower to be used again. Recirculating systems withdraw far less water than once-through systems but consume more water per unit of power produced, removing it from the hydrologic system and making it permanently unavailable to other users.

Neither of the predominant cooling systems used in Texas is ideal for protecting water supplies. Once-through systems impose a huge water withdrawal burden—accounting for 40 percent of freshwater withdrawals nationwide—while recirculating systems consume significant amounts of water.[89] In Texas, the majority of coal and natural gas plants rely on recirculating cooling technology, which increases consumption and removes water from the state's water cycle.[90] Some nuclear power plants in Texas use once-through cooling systems; others use recirculating systems.

Meeting Electricity Needs with Less Water

By far the most effective option for reducing water withdrawal and consumption for electricity production is to reduce demand for steam-generated power from coal, natural gas and nuclear power plants. That can be accomplished by using energy efficiency to reduce the total demand for electricity and by replacing electricity from steam-generated power plants with electricity from wind and solar power. The second, less attractive option for reducing water demand in electricity generation is to adopt cooling technologies that use less water, such as air cooling.

Energy efficiency—getting more useful work out of a unit of electricity—requires no water. By reducing electricity consumption, energy efficiency cuts the need to generate electricity from power plants that use water. Texas has abundant energy efficiency potential that it could tap.

Another option for reducing water consumption in electricity generation is to use more renewable energy, which consumes little water. Wind turbines and solar photovoltaics do not require cooling and thus they do not consume a significant amount of water.[91]

A third option is to make coal, natural gas and nuclear power plants more water-efficient with dry cooling. Instead of cooling steam using cold water, air-cooled systems use cool air to turn steam back into liquid form, much as a car's radiator uses air to cool the engine.[92] Air cooling delivers water withdrawal and consumption benefits. A natural gas plant cooled with air withdraws less than 1 percent of the water that an open-loop cooling system would require, and water consumption is 40 percent less than an open-loop system.[93]

The disadvantage of air cooling is that it is less energy efficient. Air is less efficient at cooling than water, which makes the power plant operate less efficiently. In addition, air cooling may consume some electricity to power fans that move large volumes of air. When ambient air temperature rises in the summer months, efficiency losses can add up. For this reason, hybrid cooling systems that combine air cooling with a water-based cooling tower are used at some power plants. This requires less water than a closed-loop cooling tower while enabling the plant to continue operating efficiently on the hottest summer days. The other disadvantage of air cooling and hybrid systems is that they are several times more expensive to build than water-based cooling systems.

Figures 1 and 2 compare the water withdrawal and consumption rates for various technologies and fuels.

Public Policies to Reduce Water in Electricity Production

Texas can meet the state's electricity needs while consuming far less water by adopting policies to boost energy efficiency, increase the use of renewable energy technologies, and reduce water use in power plants.

Improve Energy Efficiency

Texas currently requires major utilities to meet part of the projected growth in electricity demand with energy efficiency.

Figure 1. Comparison of Water Withdrawals by Various Cooling Technologies and Fuels[94]

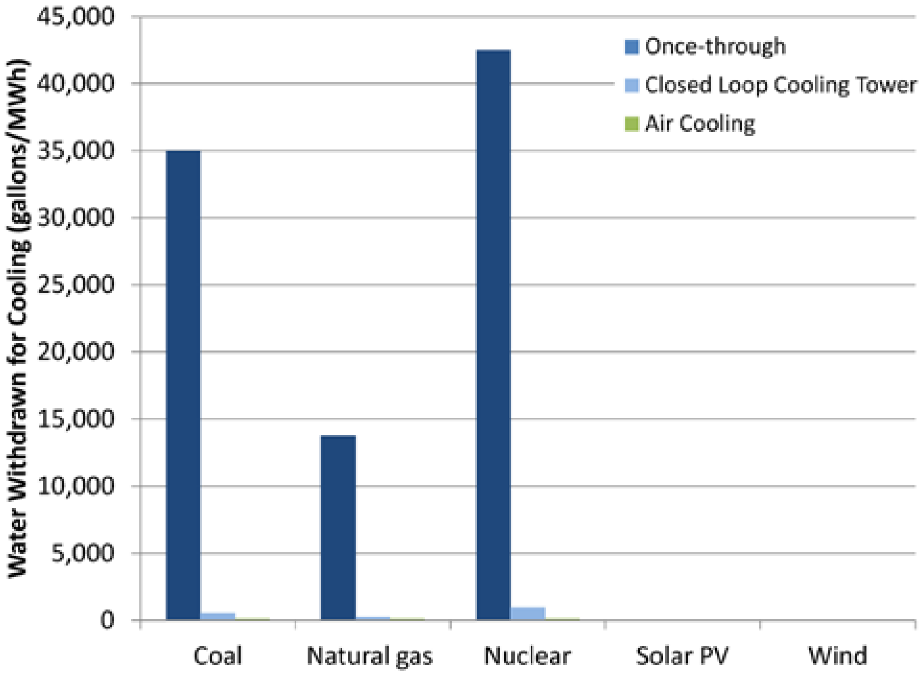
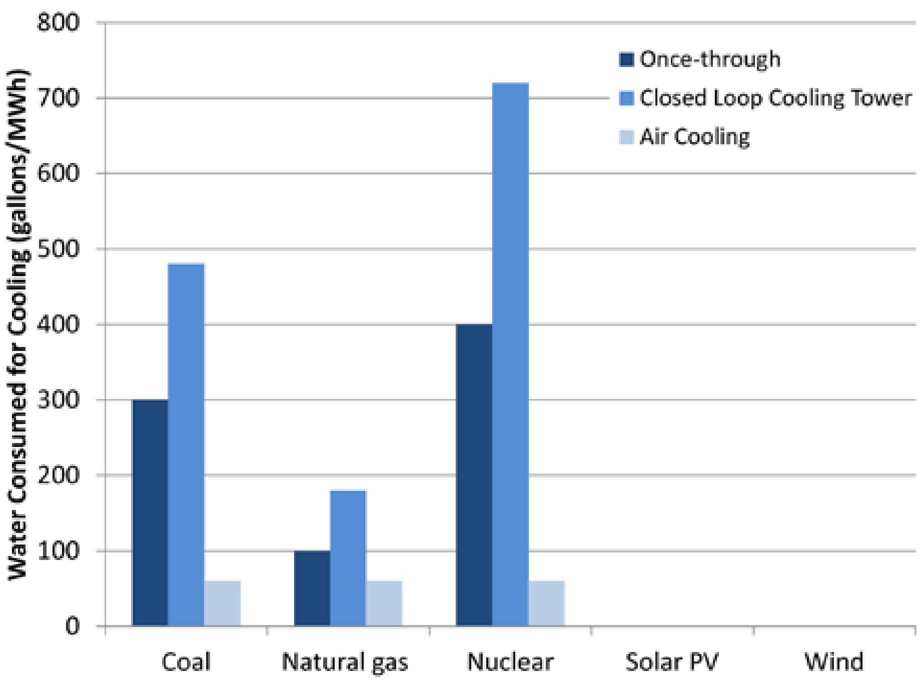


Figure 2. Comparison of Water Consumption by Various Cooling Technologies and Fuels[95]



However, the required savings are just a fraction of the energy efficiency savings available in Texas. Increasing the state's energy efficiency requirements would reduce water consumption and create a net economic benefit for the state.

The state's existing energy efficiency resource standard requires that utilities meet either 30 percent of the annual growth in electricity demand, or 0.4 percent of peak demand through energy efficiency, beginning in 2013.[96] That's less than one-half of one percent of total demand each year.[97] By 2030, this is expected to reduce electricity demand by just 3.5 percent, relative to demand if there were no efficiency requirement. The American Council for an Energy-Efficient Economy estimates that Texas could increase its energy efficiency savings to hold residential and commercial electricity consumption steady and decrease industrial consumption.[98] That would reduce electricity consumption by 18 percent from projected levels in 2030, while providing net savings for households and creating 45,200 jobs in 2030.

Achieving this level of energy efficiency savings is feasible. It would require energy efficiency savings equal to a 1.1 percent annual reduction in projected demand each year, less than the savings rate required in a number of other states. Arizona, for example, requires utilities to achieve energy efficiency savings equal to 2 percent of projected demand each year starting in 2013, and 2.5 percent per year in 2016.[99] To obtain a 1.1 percent annual reduction from projected demand, utilities would need to help their consumers reduce energy use and the state would need to adopt strong building codes.

Austin Energy has already used energy efficiency to reduce water consumption. From 2001 to 2006, Austin Energy saved an estimated 62 million gallons of water by reducing electricity consumption through energy efficiency investments such as installing more efficient lights in traffic signals.[100]

Increase Use of Renewable Energy

Texas should increase its requirement for how much electricity should be generated from renewable sources. The state's existing renewable generation requirement calls for installation of 5,880 MW of wind, solar and other renewable generating capacity by 2015.[101] Texas has already exceeded these requirements, reaching more than 10,900 MW of wind generating capacity.[102] The state should set new, stronger goals.

The state should aim to get 20 percent of its electricity from wind power and to install 4,000 MW of solar photovoltaic capacity by 2020. Existing projections for wind power assume that Texas will obtain nearly 15 percent of its electricity from wind turbines by 2020, provided that transmission lines are constructed to connect the state's competitive renewable energy zones to consumers.[103] Reaching the 20 percent by 2020 goal would require accelerated construction of wind capacity that is already anticipated for later years.[104]

To encourage construction of solar energy capacity, Texas should establish a goal for solar energy generation and create financial and policy supports to facilitate rapid expansion of solar technology. Financial incentives for solar power installations will help consumers defray the cost of purchasing solar panels, a cost that has been declining dramatically and consistently. The average residential and commercial installed cost of a watt of solar energy fell by almost half from 1998 to 2011.[105] Consumers should be allowed to sell any excess power generated by their solar panels and to receive a fair market value for that power.

Improve the Water Efficiency of Coal, Natural Gas and Nuclear Power Plants

New natural gas or coal-fired power plants should meet efficiency standards for water use. Texas could set a technology requirement, such as that all new plants must use air cooling technology (already in use in more than 60 power plants in the United States), or, if the energy penalty of air cooling is found to be too great in Texas, hybrid-cooling technology.[106] Alternatively, the state could establish a performance standard for the amount of cooling water withdrawn per megawatt-hour of electricity generated. The performance of water-based cooling systems varies tremendously: the withdrawal rate for water-cooled natural gas plants can vary more than 50-fold and the consumption rate can vary by 80 percent.[107] In addition, proposed new power plants should demonstrate that cooling water supplies will be adequate over the lifetime of the plant, even during severe drought. Ideally, to the extent that new power plants require water, they should seek to use brackish water so as to not compete with other users for freshwater.

Saving Water in Oil and Gas Drilling

Oil and gas drilling, together with mining activities, is currently responsible for 2 percent of water demand statewide.[108] That low statewide percentage belies the impact of oil and gas extraction on water supplies in the few areas of the state where oil and gas production is most prevalent.

Water use for mining is a much bigger share of water use in regions where drilling is most common. In the Coastal Bend region overlying the Eagle Ford shale formation, for instance, mining accounts for 6.5 percent of water demand.[109] Water demand for mining is predicted to increase by 26 percent from 2010 to 2060 for the region.[110]

Most importantly, almost all the water used in fracking—by which we mean all of the activities needed to bring a well into production using hydraulic fracturing and to operate that well—is permanently consumed. Unlike most water withdrawn for irrigation, manufacturing or domestic use, water withdrawn for fracking is mixed with toxic chemicals and injected deep underground. The volume that returns to the surface is heavily contaminated.

Fracking is fundamentally bad for water availability and quality, and even the best measures to reduce water consumption can mitigate just a small part of fracking's impact on water. Nonetheless, there are multiple actions that drillers can pursue to reduce water consumption: recycling and reusing of fracking water, using brackish water, and investigating water-free alternatives all have the potential to cut water use.

Water Consumption in Oil and Gas Drilling

Large amounts of water are used for drilling and hydraulic fracturing of each well. After a borehole is established, a mixture of water, sand and chemicals is injected into a well at high pressure in order to create fissures in the rock to release trapped oil or gas deposits.

Water use varies by the size and conditions of the shale formation, with wells in the Haynesville Shale formation requiring the most water per well—close to 8 million gallons per well—followed by Eagle Ford at 5 million and then the Barnett Shale at more than 4 million gallons.[111]

As a well is drilled and fractured and as it starts to produce gas or oil, water comes to the surface. "Flowback" water is water that was injected during hydraulic fracturing that returns to the surface, while "produced" water is water that was already underground. Flowback and produced water are both considered wastewater: flowback water is contaminated with chemicals and produced water is often saline. The amount of wastewater varies by formation.

Well operators have several options for

how to deal with this wastewater. Treated or untreated water can be disposed of via underground injection wells; in the Barnett Shale region, some disposal wells inject 6.3 million gallons of water per month.[112] Wastewater can be returned to surface waters if it has been treated. Another option is to reuse a bit of the water in fracking.

Industrial water recycling technology gives oil and gas drilling companies the capability to recycle and reuse flowback water instead of withdrawing additional water for each new fracking operation.[113] However, very little flowback water is recycled in Texas, in part because of the high cost of treating it. Currently, an estimated 5 percent of flowback in the Barnett Shale is recycled and reused.[114] Little to no recycling occurs in the Eagle Ford Shale and in the Texas portion of the Haynesville Shale.[115] (See Table 1.) Even less recycling of produced water occurs because its poor quality makes it more expensive to treat.

Water Conservation Opportunities in Fracking

Fracking operations can reduce water consumption through several approaches.

Conserving Water by Reusing and Recycling Flowback Water

Recycling or reusing the water used in fracking would reduce the need to draw on freshwater resources for additional fracking operations.

Some flowback water can be *reused* by mixing it with fresh water, in a ratio of 5 to 10 percent flowback water to 90 to 95 percent clean water.[117] *Recycling* is a more involved process that requires treating the flowback water before reusing it.

From a practical standpoint, only water that returns to the surface within the first 10 days after a well is fracked can be reused or recycled.[118] After 10 days, the infrastructure for dealing with large volumes of

Table 1. Most Water Used in Fracking Is Freshwater[116]

Region	Source of Water			Total Water Used (acre-feet/year)
	Brackish Water	Recycled or Reused Water	Freshwater	
Permian Basin - Far West	80%	0%	20%	14,440
Permian Basin - Midland	30%	2%	68%	
Anadarko Basin	30%	20%	50%	6,520
Barnett Shale	3%	5%	92%	25,750
Eagle Ford Shale	20%	0%	80%	23,760
East Texas Shale	0%	5%	95%	7,540
Statewide	NA	NA	79%	81,500

water typically is removed. Approximately 5 percent of the fluid injected in Haynesville Shale wells during fracking returns to the surface in the first 10 days; in the Barnett Shale, 16 percent of injected water returns in that time, limiting recycling potential.[119]

In selected areas, recycling is greater. Currently, the highest rate of recycling in the state is 20 percent, in the Anadarko Basin. (See Table 1.) Projections for the TWDB suggest that recycling rates in the Permian Basin could climb to 50 percent by 2020, in part because freshwater supplies are so limited and there is competition for brackish water.[120]

Recycling or reusing flowback water reduces the volume of water that requires disposal. In most cases, water has to be trucked away from the fracking well for disposal, a cost that adds up quickly.

Alternatives to Freshwater

Fracking operations can reduce their freshwater use by seeking alternatives, such as brackish water or water-free methods.

Brackish water is unsuitable for drinking or irrigation because of its salt content, but it can be used for fracking. Some of the salt must be removed before the water can be used for fracking, an expensive process.[121] In regions where freshwater is scarce, such as in West Texas, brackish water provides up to 80 percent of the total water used in fracking.[122] Aquifers containing brackish water exist throughout Texas, and TWDB is in the process of mapping and assessing those supplies.[123]

Some companies have been experimenting with using propane gel instead of water to frack wells. The well still must be drilled using water, but instead of injecting water laced with chemicals and sand to hydraulically fracture the well, the companies use propane gel to transport chemicals and sand.[124] In the Eagle Ford Shale, the use of gel fracking has halved the water intensity of the fracking process.[125] The technique has been used in more than 1,000 wells in North America, but data on the safety of the method are not available.[126]

Public Policies to Reduce Water Consumption in Fracking

Require Recycling and Reuse of Flowback Water

Though several drilling companies have invested in water recycling infrastructure and other businesses focused solely on water recycling technology have sprung up, only a fraction of the flowback water from fracking that could be recycled is actually recycled. Texas could boost the recycling rate for flowback water by mandating recycling and limiting the amount of freshwater that drillers can withdraw from aquifers and surface water sources.

Even if fracking operations achieve the maximum potential recycling rate for flowback water, unconventional oil and natural gas extraction will continue to consume large amounts of freshwater in Texas, permanently removing much of it from the state's hydrologic cycle. In the interest of protecting long-term access to clean water, Texas should establish limits on how much water can be contaminated by fracking and disposed of in deep injection wells. Better tracking is also needed to give the public and water planners individual and aggregate information on the source of water used in fracking, rates of recycling and waste disposal.

Investigate Alternatives

Texas should require companies to use brackish water instead of freshwater, thereby cutting freshwater demand from fracking by 23 billion gallons in 2020, enough for 400,000 Texans. Companies would need to invest in new equipment to treat brackish water before they could use it and would still need to collect and dispose of flowback water.

If fracking companies in Texas want to use propane gel for fracking instead of water, the full implications of the technique must be better understood. An environmental impact analysis should evaluate the risks—in addition to the water-saving benefits—of the approach.

Conclusion

In the aftermath of two consecutive years of drought that damaged ecosystems and the economy, Texas needs a new plan for addressing the state's water needs. The state has access to a finite amount of water, and trying to capture and use more of this water is an expensive and environmentally harmful proposition. The state should develop strategies to do more with the water that it has.

The water conservation technologies and efficiency measures discussed in this report could reduce water demand by 500 billion gallons by 2020, equal to 31 percent of the shortfall identified in the state water plan in 2020 and enough to meet the water needs of 9 million Texans. Achieving this level of water savings will leave more water in Texas' streams, rivers and aquifers, making it available to other users and to ecosystems. Water conservation measures require strong and consistent state policies and investments.

Texas should prioritize water conservation above increasing supply.

- The State of Texas should adopt a policy that efficiency improvements should precede development of supply side resources. This clarity will motivate regional water authorities to evaluate and invest in water efficiency opportunities.

- The Texas Water Development Board's recommended statewide goal of limiting municipal water use to 140 gallons per capita per day should be formalized. Average statewide municipal water use currently is 154 gallons per person per day.[127]

- Setting statewide efficiency standards for water-using products would help ensure that investments in new buildings, appliances and landscape irrigation equipment—all long-lived products that will influence water use for years to come—do not undermine efforts to improve water efficiency. Strong water efficiency standards will promote market transformation and new innovations.

- Energy planning decisions should be strongly influenced by water impacts. Texas should set higher goals for meeting the state's electricity needs with energy efficiency and renewable energy, helping to cut water demand.

Texas should adjust financial incentives to promote water efficiency.

- Municipal water users should be subject to a conservation pricing structure, in which the price of water increases as the volume consumed increases. This means that consumers who use an above-average amount of water would pay substantially more, while those who use average or below-average amounts would continue to pay lower prices. Such a pricing structure encourages more efficient water use.

- Water agencies should work to decouple sales from revenue so that high water sales are not essential for an agency's fiscal stability. Even if water sales fall, the agency should be able to recover adequate money from customers. With income separated from the volume of water sold, water agencies will be able to promote efficiency more aggressively.

- Pricing structures for agricultural users should promote efficiency. Higher water prices coupled with access to technical assistance and financial support to identify and implement water efficiency improvements would encourage conservation. In addition, farmers should be allowed to sell or lease saved water to others.

Provide adequate funding for water conservation programs.

- A one-time use of the Emergency Stabilization Fund or "rainy day fund" would jumpstart investments in efficiency programs.

- To provide ongoing funding, Texas should collect a small fee on water sales. The small additional charge paid by consumers for each gallon of water delivered would help provide reliable funding for financial and technical assistance to cut water use.

- Funding could also be provided by imposing a one-time fee on each new home construction permit issued.

- Energy utilities and water agencies should coordinate energy efficiency and water efficiency programs. Water and energy use often are closely related. Services such as audits to identify efficiency opportunities and programs to replace inefficient equipment may be more cost-effective if water and energy use are evaluated jointly. Any state funding to promote local agency work on energy or water efficiency could prioritize funding for such partnerships.

- Texas should amend and strengthen its property-assessed clean energy (PACE) program to include water conservation measures. PACE allows the owner of a building to obtain a loan for clean energy investments that deliver cost savings, and to repay that loan through a special property tax assessment. If the owner sells the building before the debt is repaid, the debt remains with the property and is assumed by the next owner. This allows owners to make cost-effective upgrades even if the building might be sold soon. Though residential PACE financing is faltering due to opposition from federal mortage lenders, Texas should press forward to allow commercial PACE financing for water conservation.

Improve knowledge of water use and savings opportunities.

- Better data are needed on how water is used and what opportunities exist to reduce consumption. Water authorities should collect uniform data on water use for compilation into a database on statewide water use to provide easier comparison between regions and to identify opportunities and best practices. All municipal water utilities should submit an annual water loss audit.

- The Railroad Commission of Texas should require oil and gas companies to report water use and the water source for each fracking well.

- The TWDB should conduct a statewide feasibility analysis of water efficiency potential. The state water plan includes regional estimates of water conservation possibilities, but conducting a statewide feasibility analysis would provide a comprehensive tally of water-saving opportunities—and a clear vision for what the state might achieve if it prioritized conservation.

- Adequate funding of the Water Conservation Education Program would improve public knowledge of water savings opportunities. The Water Development Board developed a comprehensive water conservation education program in 2007. However, lack of funding has meant the program has been used by just one utility in northern Texas. A statewide basic education program about the benefits and the strategies of water conservation could help reduce water use.

Methodology and Assumptions

We started with data for a business-as-usual scenario, using baseline consumption data from the Texas Water Development Board, *Water for Texas: 2012 State Water Plan*, January 2012. We then estimated potential efficiency savings for each sector, as explained below, and tallied those total savings. We assume savings are additive because the TWDB's sector totals do not overlap.

Savings from Agriculture

The baseline data for agricultural water use shows an 8 percent decline in consumption from 2010 to 2030, due to a reduction in the number of acres under cultivation and assumed improvements in efficiency. We assume greater savings are possible.

Our estimate of potential water savings from improved efficiency in the agricultural sector is based on data from Heather Cooley, et al., Pacific Institute, *More with Less: Agricultural Water Conservation and Efficiency in California*, September 2008. That study estimates that smart irrigation scheduling alone could reduce water use in California's main agricultural areas by 13 percent. Our estimate is conservative: savings would be even greater with the addition of other policies to reduce water use.

Savings from Xeriscaping

In order to estimate the potential water savings from xeriscaped landscapes, we compared water use in xeriscaped yards to traditional turf landscapes. We estimated new outdoor domestic water use in 2020 and then calculated how much of that new consumption could be avoided by requiring xeriscaping in new residential developments.

We assumed that 67 percent of municipal water use is for residential purposes, per Joan Kenny, et al., U.S. Geological Survey, U.S. Department of the Interior, *Estimates of Water Use in the United States in 2005*, 2009, and that this percentage remains steady over time. Of residential water use, we assumed that 31 percent is used outdoors and that approximately 85 percent of outdoor water use is for watering lawns, plants and gardens, per Sam Marie Hermitte and Robert Mace, Texas Water Development Board, *Technical Note 12-01: The Grass Is Always Greener…Outdoor Residential Water Use in Texas*, November 2012. These data points allowed us to calculate the percent of new municipal water use that will occur on lawns in a residential setting.

To calculate how much of this could be saved through xeriscaping, we used data from Kent Sovocol, Southern Nevada Water Authority, *Xeriscape Conversion Study*, *Final Report*, 2005, to calculate that xeriscaped landscapes use 76 percent less water on the same area of land as turf landscapes do. Texas is not as uniformly dry as Nevada, meaning that the water savings potential from xeriscaping is not as great. To account for this, we assume Texas would, on average, save water at half the rate of Nevada. We assume that 10 percent of new landscapes would be xeriscaped even without a change in policy.

Savings from Repairing Water Mains

We based our estimate of potential savings from repairing leaking water mains on the 2.2 percent loss rate reported in Mark Mathis, Texas Water Development Board, and Brian McDonald, Alan Plummer Associates, Inc., *An Analysis of Water Loss as Reported by Public Water Supplies in Texas*, downloaded from www.tawwa.org/TW07, 4 February, 2013. If that loss rate were cut in half, we estimated that 1.1 percent of municipal water use would be saved.

Savings from Electricity Production

Our calculation of potential savings in the electricity sector from increased energy efficiency and renewable energy required that we create two different scenarios for how Texas would generate electricity: a baseline scenario assuming no changes in policy, and a scenario with both improvements energy efficiency and increases in renewable energy. Once we knew the generation sources that would provide Texas' electricity, we estimated the water consumption in each scenario.

The business-as-usual electricity generation scenario is from Appendix A, BAU Case, Scenario 3 in Carey King, et al., University of Texas at Austin, Bureau of Economic Geology, *Water Demand Projections for Power Generation in Texas*, prepared for the Texas Water Development Board, 31 August 2008. This generation mix is based on assumption of low natural gas prices and no federal regulation of carbon prices, and includes the assumptions that 20 percent of Texas' electricity will be generated by wind in 2060 and that there will be no efficiency improvements.

From this business-as-usual scenario, we created a policy scenario. We first assumed that Texas would build 4 gigawatts of solar photovoltaic capacity by 2020, and that the state would accelerate development of its wind energy resources to generate 20 percent of its electricity from wind by 2020. One quarter of this increased renewable electricity generation would offset coal-fired generation and three quarters would offset natural gas.

We then added increased energy efficiency to our policy scenario, assuming that Texas reduces its electricity consumption from the business-as-usual consumption levels by 8 percent by 2020. This is based on a scenario presented in John "Skip" Laitner, American Council for an Energy-Efficient Economy, *Energy*

Efficiency Investments as an Economic Productivity Strategy for Texas, March 2011, in which Texas holds residential and commercial consumption steady in the future and reduces industrial consumption.

We translated the business-as-usual scenario and policy scenario into water consumption volumes. First, we determined how coal and natural gas power plants in Texas are cooled, using data from Union of Concerned Scientists, *UCS EW3 Energy-Water Database V.1.3*, 2012, available from www.ucsusa.org/ew3database. This database places cooling systems into one of three categories: once-through, recirculating using a tower or a reservoir, and cooling pond, which can be either once-through or recirculating. The database doesn't specify which cooling ponds use which method. We assumed that half the power plants with cooling ponds use once-through cooling and half use recirculating. For nuclear power plants, we obtained information from Nuclear Regulatory Commission, *Texas*, downloaded from www.nrc.gov/info-finder/region-state/texas.html, 26 September 2012. All concentrated solar power facilities were assumed to be cooled with closed-loop cooling towers, per Ashlynn Stillwell, et al., University of Texas at Austin and Environmental Defense Fund, *Energy-Water Nexus in Texas*, April 2009.

Data on water withdrawal and consumption rates in different cooling systems came from Ashlynn Stillwell, et al., University of Texas at Austin and Environmental Defense Fund, *Energy-Water Nexus in Texas*, April 2009. For water use in recirculating systems, we used an average of water consumption in closed-loop reservoirs and closed-loop cooling towers.

By combining data on the electricity generation mix with water consumption rates by different cooling systems, we estimated water consumption under a business-as-usual scenario versus in our policy scenario. We applied the percent reduction from the policy scenario to the baseline water consumption rate from electricity generation in Texas Water Development Board's estimates of municipal water use in *Water for Texas: 2012 State Water Plan*, January 2012.

Savings from Replacing Freshwater in Fracking

To calculate savings from recycling fracking flowback water, we first had to obtain an estimate of statewide water consumption from fracking. We obtained data on current and projected water use from fracking from Jean-Philippe Nicot, et al., for the Texas Oil & Gas Association, *Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report*, September 2012. Currently, 21 percent of water used in fracking comes from recycled or reused sources or is brackish water. Nicot et al. predict that will increase to 44 percent by 2020.

We assume that Texas eliminates freshwater use in fracking by using brackish water or water recycled from conventional oil and gas drilling operations.

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