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Viability and Impacts of Implementing Various Power Plant Cooling Technologies in Texas

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and
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Abstract

Pressures to reduce water withdrawal and consumption are no longer limited to arid regions of the world, and water use and conservation at electric power plants are becoming increasingly prominent issues worldwide. At most plants, the requirement for condensing exhaust steam from the steam turbine, generically known as power plant cooling, is the major use of water. Different types of cooling systems exist, and some offer significant opportunity for water conservation. However, water savings normally come at a price in the form of more costly cooling equipment, higher power requirements, reduced plant efficiency, and limited plant capacity.

This report from the Electric Power Research Institute (EPRI) presents a focused evaluation of the viability and impacts of implementing various power plant cooling technologies. The geographical scope is limited to one particular area—the state of Texas, where an ongoing drought has underscored issues regarding water consumption—although the concepts and principles have broader applicability because the same issues are faced by the entire industry. Within this context, the report presents summary descriptions of existing cooling technologies; defines essential terminology and concepts related to power plant water consumption and conservation; and looks at the applicability, costs, and benefits of various options.

One of the purposes of this study was to collect and analyze the most current and accurate data available to clarify the relationship between energy and water for Texas to support decisions related to power generation and water conservation efforts. The report therefore evaluates water consumption by the power generation industry in comparison to consumption by other industry sectors, and notes the larger picture of power plant water use including public benefits of reservoirs. Economic and societal aspects of cooling system retrofitting, and potential consequences of a dry cooling mandate, are also examined.

Keywords
Power plant cooling
Once-through cooling
Cooling towers
Dry cooling
Economic impacts
Retrofitting

Executive Summary

The ongoing Texas drought, particularly the extreme conditions of summer 2011, has underscored issues regarding water consumption in the state. Stakeholders have expressed concern regarding the water consumption of various industries in the state, including water used and/or consumed through power generation.

In the recent analysis and discussion, there has been apparent confusion over terminology when describing the complex relationship between water and energy – otherwise known as the energy/water nexus. There is particularly confusion between the meanings of "water use" and "water consumption." Water ***use*** is a general term that can refer to either consumptive or non-consumptive use. Water **consumption** refers to a water use that makes it no longer available for other uses. Consumption is a truer, "big picture" measure of *impact on water resources*. Making a distinction between these two terms is important to measuring the actual impact that the power generation industry has on Texas' water resources

There is not one method or technology to generate electricity. Thermal power plants generate electricity using either the steam (Rankine cycle), combustion turbines (Brayton cycle), or both (combined cycle). Plants that use steam typically use water to cool or condense the steam for re-use. Cooling water is the largest *user* of water at many thermal power plants.

There are also multiple methods of cooling steam. The cooling technologies currently in use at Texas thermal power plants are once-through cooling, wet cooling tower systems, and dry cooling systems. Once-through cooling and wet cooling systems utilize water to condense steam (i.e. they provide "wet cooling"). Dry cooling systems use air to condense steam. There are currently no power plants in Texas with hybrid cooling systems. Hybrid cooling systems are combined cooling systems that have both a wet cooling component and a dry cooling component.

Each cooling technology has advantages and disadvantages and there is no cooling technology that is optimal for all thermal power plants. Water availability, plant efficiency, cost impacts to electricity, infrastructure, and meteorological conditions are all factors in a power generator's determination of the appropriate technology to employ.

For instance, once-through cooling plants withdraw more, but consume less water than wet cooling towers. Dry cooling uses and consumes less water than once-through systems, but are less efficient and may not perform in arid, windy climates and they require more real estate than wet cooling towers.

Typically, Texas power producers that use once-through cooling consume less than 1 acre-foot of water per 1000 megawatt-hours of electricity produced. This means that Texas power plants consume just over 1.5% of the water they use. This is below the national average of 3.3%. In comparison, wet cooling towers only *use* approximately 5% of the water that once-through systems use, but they *consume* approximately 50% more water than a once-through system. Dry cooling systems use less water and consume less water than either of the wet cooling systems but are less effective in certain environments, particularly hot climates, or may not be the technology of choice for a variety of other reasons.

Retro-fitting existing plants to wet cooling towers or to a dry cooling system or mandating a single cooling option is also typically not a viable option. In addition to likely prohibitive costs, it could:

- Limit investor's ability to make a return on investment, discouraging future investment;
- Cause premature retirement of multiple plants;
- Hinder power producers' ability to meet the electric demands of the citizens of Texas;
- Negatively impact the treatment and distribution of water throughout the state; and
- Cause a negative ripple effect on both the Texas economy and the national economy.

All of the water used in power generation is a large cost that companies carefully manage. This can include the purchase of water rights, water contracts, a purchase of land for a well field, or of recycled water, or processing and equipment for lower quality water use. For many generation companies this expense is measured in multi-millions of dollars annually. This large investment for a power plant ensures that the water is managed as a valuable commodity and the stewardship of that investment means that water is used responsibly. Mandating a single cooling technology be used on new builds or retro-fits could have a negative ripple effect on the Texas economy and could impact other sectors throughout the nation.

Texas has also benefitted indirectly and directly from the use of once-through cooling in other ways. There are 209 reservoirs in the state of Texas, a subset were either constructed by electric utilities, or other entities, as a power plant reservoir (Martin Creek) , or a multipurpose reservoir that supports electric generation (i.e., Bob Sandlin, Limestone, etc.). Many of these "lakes" are also open for public recreation. Recreational lakes bring value to the state and its citizens through tourism and tax revenue. Utility-funded lakes bring in additional revenue when other industrial users withdraw water from the same reservoir.

The once-through cooling consumption rate of one acre-foot of water for every 1000 MWh produced equates to approximately 1/3 of a gallon per kWh. Stated another way, if once-through cooling provided the average American with all of the electricity needed to meet its needs, this would result in daily household water consumption due to electricity of 9 ½ gallons.

In comparison, the typical American household consumes 300 gallons of water each day. More specifically, in the average American household, 92 gallons of water are consumed for bathing, assuming one 10-min shower per person. If only one load of clothes is washed each day, an additional 25 gallons will be consumed, assuming the home has a newer washing machine. Each household also consumes 25 gallons for washing dishes and 2½ gallons of drinking water on average. Americans flush a minimum of 44 gallons of water, but the national average is 87 gallons; the average Texas household flushes 76 gallons of water down the toilet each day. A super-efficient green home would flush a minimum of 23.4 and an average of 46.92 gallons of water per day. In comparison, the 9 ½ gallons of water that would be dedicated to once-through cooled electricity would comprise approximately 3% of the total water consumed by the typical household to generate the electricity needed by that household each day.

Once-through cooling has aided in keeping power generation water use low. For instance, as the population has increased over the last several decades, so has the demand for water. Thermoelectric, agricultural, municipal and industrial sectors have all had increases in water use and consumption. However, in Texas and throughout the country, within the thermoelectric sector, the number of gallons consumed per MWh produced has declined significantly during the same time period. For instance, the country's population increased by 90,700,000 people between 1980 and 2005, but thermoelectric power generators were able to meet corresponding increased electricity demands using approximately the same amount of water.

Texas has allowed electricity producers to choose their cooling technology of choice, particularly once-through cooling. As a result, Texas has been able to effectively manage its electricity demand growth, thereby, also limiting increase demand for water. For instance, Texas has one of the largest industrial sectors in the nation. Industrial users account for 50% of all energy used in the state. A great deal of Texas' energy consumption drives industries that are manufacturing and processing products used to produce electricity across America and around the world . By comparison, only 32% of the total U.S. energy consumption is attributable to industry. All the while, Texas per capita industrial consumption has dropped to the lowest level since 1960.

Discussions about the energy-water nexus have provided a critical opportunity to discover the facts and better understand the role water plays in the cost effective generation of electricity. In Texas, the facts are particularly clear. Electric generators apply technologies and processes appropriate for their specific local conditions to ensure the effective and efficient use of water. As a result, statewide energy demands are met by consuming less than 4% of the total water required to meet all needs for water in the state.

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Section 1: Introduction and Background

1.1 Water Terminology

The production of electric power using steam turbines requires water. Water is treated and used to generate steam to power the turbine and then condensed and re-circulated to produce additional steam. Water is also traditionally used as the cooling medium to condense the steam. It is very important in this context to clarify the distinction between the terms *use* and *consume* as well as several other terms in order to understand the true relationship between water and power generation.

Water ***use*** is a general term that can refer to either consumptive or non-consumptive use. Water ***use*** includes drinking, flushing toilets, irrigation, cooling, boating, fishing, and many other applications.

Water **consumption** refers to a water use that makes it no longer available for other uses. Examples are drinking water, evaporated water, or water incorporated into a product like corn or concrete. When water is consumed, it is no longer available in the system. Consumption is a truer, "big picture" measure of ***impact on water resources***.[1]

Consider the example of two car fluids. A car uses anti-freeze or cooling water during its operation, but it does not consume it. On the other hand, the car consumes gasoline as it performs. In generating power with steam, water is used to produce steam, but little or none of it is consumed, as the steam is condensed and returned to the boiler. Water is also used to cool the steam. Nationally, a small percentage (estimated at approximately 3.3% of the circulating flow) of the water used to cool the steam is consumed for once-through cooling.[2] The percentage is even lower, estimated to average just over 1.5%, in Texas.[3]

Water **withdrawal** or **diversion** is defined as the removal of water from a water source. In Texas, water may be diverted or withdrawn from (1) a stream or river for direct use or to maintain the water level in a reservoir, (2) a reservoir, or (3) a groundwater well. The general terms *use withdrawal and diversion*, can be defined in many different ways which can lead to confusion when discussing the issues. For the purpose of this study we will use the definitions listed above.

1.2 Problem Statement

Affordable electric power and water are two highly interdependent, essential resources that must be sustained if Texas is to preserve its economic health and prosperity, and position the state for future growth. Producing energy and electric power require access to sufficient water supplies. Conversely, water pumping, treatment, and distribution are dependent on sufficient energy at a reasonable cost. This energy-water nexus presents challenges when the availability of either resource is limited. One of the purposes of this study was to collect and analyze the most current and accurate data available to clarify the relationship between energy and water for Texas to support decisions related to power generation and water conservation efforts. This study results provide a clear understanding of the water conservation and consumption in Texas electric generation as well as the viability and impacts of implementing various power plant cooling technologies in Texas.

1.3 Background

Thermal power plants generate electricity using either the steam (Rankine cycle), combustion turbines (Brayton cycle), or both (combined cycle).[4] Approximately 76% of Texas power plants use the steam cycle as their primary generation process.[5] These plants generate heat from fuel (be it fossil, nuclear, biomass, geothermal, or solar) to generate steam. The steam expands through a turbine to drive a generator, to produce electricity.[6] About 6% of Texas power plants rely on combustion turbines as their primary generation process.[5] These plants burn natural gas or synthetic gas (from coal or biomass gasification) within the gas turbine to drive an electric generator.[6] Many of the newer Texas power plants use a combination of combustion turbines and steam cycles in sequence and are called "combined cycle" plants.[4] These combined cycle plants use the waste heat from the combustion turbine in a Heat Recovery Steam Generator to produce steam for the steam turbine(s). The resulting combined cycle provides the most efficient power production currently available.[7] Approximately 17% of the current Texas fleet are combined-cycle plants.[5]

Most of the water used in the thermal electric generation process is used to condense exhaust steam to be returned to the boiler.[6] The steam condensation process warms the cooling water, and this added heat subsequently needs to be dissipated by some mechanism so that the cooling water can be re-circulated to condense the steam.[4] This need for cooling water applies only to the steam cycle of combined cycle plants, while the combustion turbines do not require cooling water. Combined cycle plants therefore consume approximately 1/3 as much cooling water as steam plants.[8] There is a misconception, however, that the cooling system is only affecting the steam portion of the power production process. If the cooling system is unable to provide sufficient heat removal, then the steam flow from the heat recovery steam generator (HRSG) to the steam turbine will have to be reduced. If steam flow is reduced, it may also be necessary to reduce the flow of exhaust gases by curtailing the production of the combustion turbines.[6]

Water is also employed in power plant processes such as flue gas desulfurization (SO_2 removal), ash handling, dust suppression, equipment washing and cooling, domestic use (restrooms, drinking fountains, etc.), and makeup water for the steam cycle itself [6, 7] All of these uses of "process water" typically account for less than 15% of power plant water consumption.[11]

1.4 Section Summary

There is confusion over terminology when describing the energy/water nexus, particularly between water use and water consumption. Water ***use*** is a general term that can refer to either consumptive or non-consumptive use. Water **consumption** refers to a water use that makes it no longer available for other uses. Making a distinction between these two terms is important in understanding the relationship because affordable electric power and water are two highly interdependent, essential resources that must be sustained if Texas is to preserve its economic health and prosperity, and position the state for future growth. Thermal power plants generate electricity using either the steam (Rankine cycle), combustion turbines (Brayton cycle), or both (combined cycle). Plants that use steam also require water to cool or condense the steam for re-use. Cooling water is the largest *user* of water at many thermal power plants.

References for Chapter 1

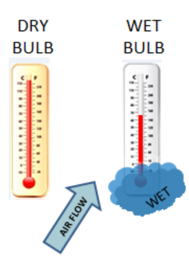
1. World Economic Forum in partnership with Cambridge Energy Research Associates. 2008. "ENERGY VISION UPDATE 2009. Thirsty Energy: Water and Energy in the 21st Century."
2. Sandia National Laboratories. March 2007. "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources." SAND 2007-1349C. R. Pate, M. Hightower, C. Cameron, and W. Einfeld.
3. Calculation using 2010 data provided by Texas power generators participating in this study. July 2012.
4. Lloyd, Gosselink, Blevins, Rochelle, Baldwin & Townsend, P.C., American Electric Power, TXU Energy, Reliant Energy. January 2003. "Power Generation Water Use In Texas For The Years 2000 Through 2060." Prepared for the Texas Water Development Board (TWDB). B.L. Sledge, W.G. Carter, C.A. Bissett, J. Simecek, P. Zweiacker, K.M. Whelan, J. Fluharty.
5. United States (U.S.) Department of Energy (DOE), Energy Information Administration (EIA). November 30, 2011. Form EIA-860 Annual Electric Generator Report. Form EIA-860 datafiles available for download from: http://205.254.135.7/cneaf/electricity/page/eia860.html. Accessed June 2012.
6. U.S. DOE, National Energy Technology Laboratory (NETL). 2008. "Department of Energy, National Energy Technology Laboratory, Power Plant-Water R&D Program." B. Carney, T. Feeley, and A. McNemar.

Proceedings of 2008 United Nations Educational, Scientific, and Cultural Organization Conference.

7. Universities Council on Water Resources. December 2009. “An Electric Power Industry Perspective on Water Use Efficiency.” J. Wolfe, R. Goldstein, J. Maulbetsch, and C. McGowin. *Journal of Contemporary Water Research & Education*, Issue 143.
8. Electric Power Research Institute (EPRI). March 2008. “Program on Technology Innovation: Technology Research Opportunities for Efficient Water Treatment and Use.” Report 1016460.
9. Calpine, CPS Energy, LCRA, Luminant, NRG Energy. February 2012. “Water Conservation Practices for Texas Generators.” Prepared for the Electric Reliability Council of Texas (ERCOT).
10. U.S. DOE. December 2006. “Energy Demands on Water Resources.” Report to Congress on the Interdependency of Energy and Water.
11. Wayne C. Micheletti, Inc., and Burns Engineering Services, Inc. “Emerging Issues and Needs in Power Plant Cooling Systems.” W. Micheletti and John M. Burns, P.E. July 2002. Proceedings of a workshop entitled "Electric Utilities and Water: Emerging Issues and R&D Needs."

Section 2: Power Plant Cooling Technologies

There are multiple methods and technologies used to condense steam. The cooling technologies currently in use at Texas thermal power plants are once-through and wet cooling tower systems, which utilize water to condense steam (i.e. they provide "wet cooling"), and dry cooling systems that use air to condense steam.[1] Following are descriptions and diagrams for these three cooling technologies. It is important to note that each cooling technology has advantages and disadvantages and there is no cooling technology that is optimal for all thermal power plants. Some use more water, but consume less, while others use less water, but consume more. A technology is appropriate in some environments, but is far less effective in others. One technology may consume less water, but have a lower plant efficiency (more fuel is required to provide the same amount of power). Others may have a minimal impact on water, but a significant detrimental impact on the cost to provide power. Furthermore, there are many site-specific factors and conditions – such as existing infrastructure, local meteorological conditions, water allocation rights, etc. – that impact the determination of the optimal cooling system for the particular location's resources and conditions.[2, 3] It is critical to understand all the pertinent relationships prior to making decisions that impact both water and power production.



WET BULB AND DRY BULB TEMPERATURES

Wet bulb temperature is the lowest temperature that can be obtained by evaporating water into the air at a constant pressure. Expressed differently, the wet bulb temperature is the temperature at which the rate of heat transferred (convection) to the wet bulb (think of a wet bulb at the bottom of a thermometer) from the surrounding area is equal to the rate of heat transferred resulting from evaporation at the dampened surface. Dry bulb temperature can be thought of as the ambient air temperature. It is called "dry bulb" because the air temperature is being determined by a device (thermometer) that is not affected by moisture. This means that the wet bulb temperature is always lower than the dry bulb temperature, but will be identical with 100% relative humidity (air is at the saturation point). What's the bottom line? Evaporation cools more effectively than convection. [16, 17]

Figure 2-1
Wet Bulb and Dry Bulb Temperatures

2.1 Once-Through Cooling Systems

The vast majority of once-through cooled power plants in Texas withdraw water cooling reservoirs that were constructed by a utility to support the power plant.[4] Cooling water is pumped through a condenser to condense the steam which is then pumped back to the boiler to complete the cycle. Virtually all the cooling water is returned to the cooling reservoir where it re-circulates, cools naturally, and can be pumped back to the condenser or used for other purposes (e.g. within the power plant, for recreation, or by other industrial users).[5] The heat transferred to the cooling water in the condenser increases the reservoir water temperature slightly, then dissipates through evaporation, radiation, and convection (conduction at the boundary layer enhanced by air movement) from the cooling reservoir.[6] Water lost to evaporation can be replaced by rain and storm water runoff and supplemented by water from a surface water source.[7] It should be noted that the term "once-through" is appropriate where water is withdrawn and returned to a river, but can be misleading for cooling ponds where the same cooling water can be re-circulated through the system repeatedly.[3] Refer to Figure 2-2 for a diagram of once-through cooling.

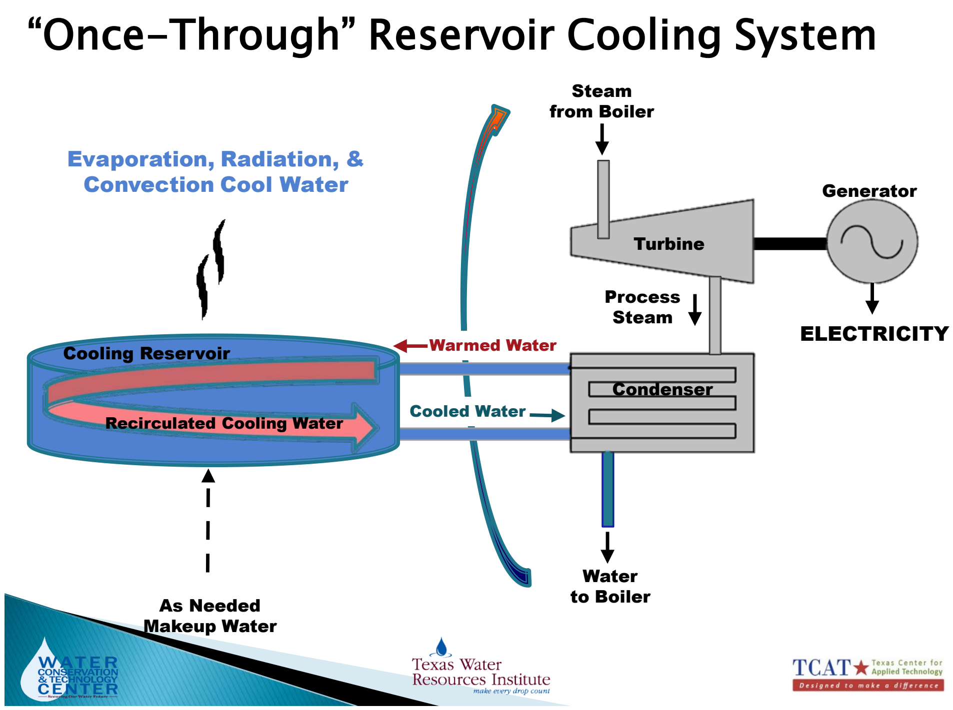


Figure 2-2
Typical Texas "once-through" cooling system

Once-through cooling systems are the simplest, least expensive, and most effective technology for condensing steam, providing the best power plant efficiency (i.e. the most electricity is produced for the amount of fuel burned).[8] There are a few once-through cooled thermal power plants in Texas using cooling water from Galveston Bay or other saline or brackish waterbodies.[4] The process is the same aside from conserving freshwater.

2.2 Wet Cooling Tower Systems

Thermal power plants with wet cooling tower systems pump water from a water source (which can be municipal wastewater treatment plant effluent, captured rain and storm water runoff, groundwater, and/or surface water) through a condenser and then to a cooling tower. Large fans (forced draft) or hyperbolic designs (natural draft) provide air flow to dissipate the transferred heat from the cooling water to the air, primarily by means of evaporation.[9] The cooled water is then re-circulated back to the condenser. As water evaporates from the cooling tower, dissolved salts and suspended solids are left behind. A small portion of the cooling water must be discharged from the system – known as “blow-down” – to prevent excess build-up of these salts and solids to prevent scaling and fouling that could impede equipment performance.[10] Makeup water is continuously pumped from a water source to replace water lost through evaporation and blowdown.[5] Wet cooling tower systems are also called evaporative or re-circulating cooling systems or wet cooling towers, and are often simply referred to as cooling towers. Refer to Figure 2-3 for a diagram of a cooling tower system.

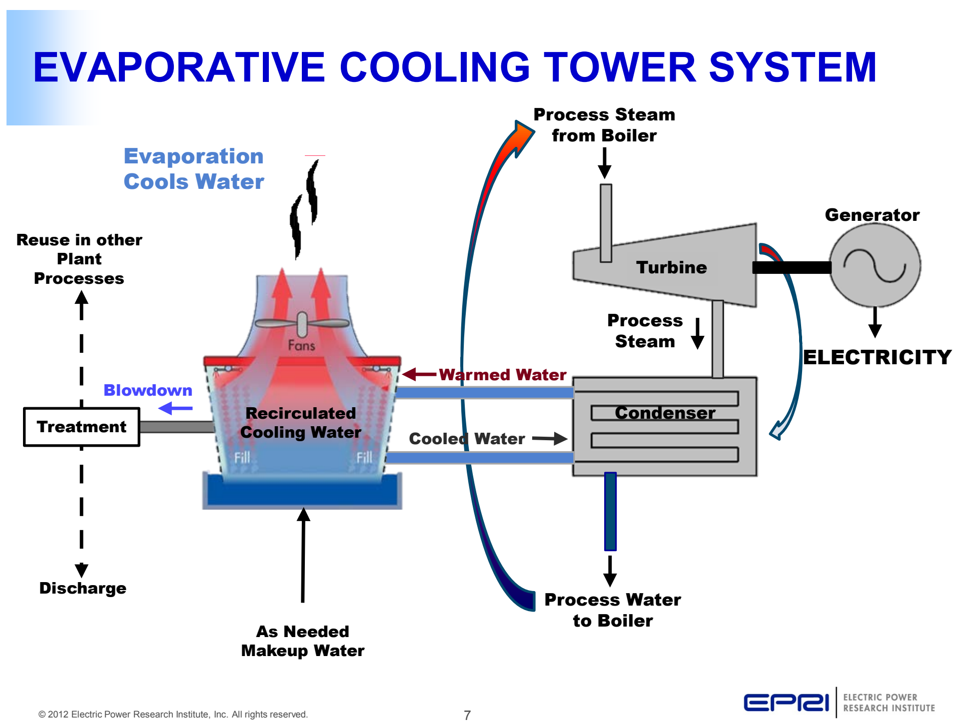


Figure 2-3
Typical evaporative cooling tower system

After once-through cooling systems that rely on multiple thermal processes to dissipate heat, cooling tower systems typically provide the second best power plant efficiency[8] due to the effectiveness of the evaporation process at transferring heat.[7] Cooling tower systems are more expensive to construct than once-through systems, and less expensive to construct than dry or hybrid cooling systems. Additionally, the power plant's net energy production is reduced by the amount of power needed to run the cooling tower fans and additional water pumps, known as the "parasitic load." [10] Once-through cooling uses more water, but consumes less, while cooling towers use less water, but consume ***more** water*.[11]

2.3 Dry Cooling Systems

There are only two power plants with dry cooling systems currently operating in Texas. Both of these plants employ air-cooled condensers (ACCs) to condense steam;[3] this is known as direct dry cooling. With dry cooling, large fans (forced-draft) or hyperbolic towers (natural draft) generate air flow to condense the steam as it flows through finned tubes in the condensers. Cooling water is not needed because the steam is condensed as the heat is transferred directly to the air[10] by means of convection.[3] Refer to Figure 2-4 for a diagram of dry cooling using air cooled condensers .

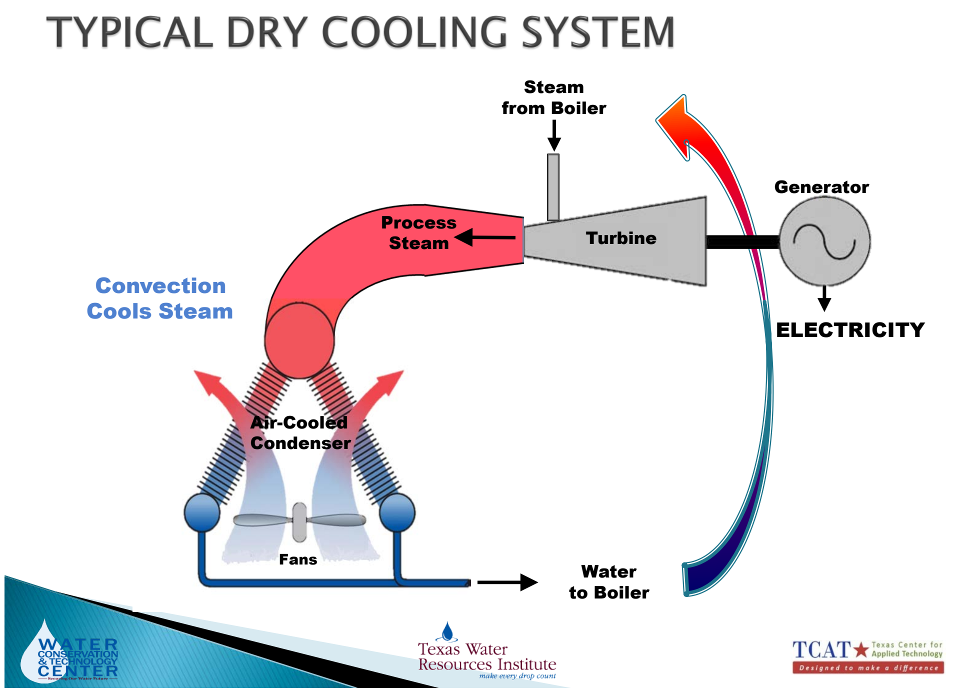


Figure 2-4
Typical Texas dry cooling system – air-cooled condenser (direct dry cooling)

The heat transfer to air via convection is less efficient than the previously described heat transfer mechanisms and the heat capacity of air is lower than water,[7] so a significantly larger condenser, greater number and size of fans, and higher air flow are required than for traditional wet cooling towers. This large number of fans can increase the parasitic load by 2-3%. In addition the efficiency penalty can be as high as 10-15% in hot weather.[3]

Even with the large number and size of the fans in air cooled condensers units, the steam condensing temperature achieved by air cooled condensers is higher than that for wet cooling, particularly during hot weather. This higher condensing temperature translates to higher backpressures in the turbines. For plants with air cooled condensers, the associated steam turbine would have to be modified to withstand the higher backpressures; and these modifications would significantly reduce power plant efficiency and generating capacity on a year-round basis. Power production may also have to be curtailed at peak ambient temperatures because of these high backpressures, in order to protect the turbines from damage caused by condensation. High, gusty winds can also have a negative impact on the reliability of air cooled condensers plants, as these winds can reduce airflow through leading edge cells, further reducing the cooling capability of the air cooled condensers or, in extreme conditions, causing unit trips. This means that power plants with air cooled condensers may not be able to produce as much power during hot Texas summer conditions, precisely when it is most needed (peak load demand). These factors can be particularly challenging in parts of Texas that experience high winds and higher temperatures. [9]

The fans also generate more noise than wet cooling systems, which can create conflict with neighboring landowners.[10] The Texas state legislature has specified 85 decibels (db) as the maximum allowable daytime noise level.[12] Many cities and towns have stricter standards, some in the low and mid-50s db, depending on the time of day, location of the noise source, and other variables.[13] When noise reduction is required for air cooled condensers, the cost can be significant, ranging from 1.25 to 3 times the cost of standard fans in use.[14]

Because more electricity must be used to operate the cooling equipment, less net electricity is produced from the fuel burned. This translates to increased fuel consumption. Because more fuel is burned, there is a corresponding potential increase in emissions nitrogen oxides, particulate matter, sulfur dioxide, carbon dioxide, etc.[3] The consumption of more fuel also means that it costs more to provide the same amount of power. Dry cooling systems often have higher operating costs as well.[15]

It should also be noted that the typical additional efficiency of combined cycle plants is offset to some degree by the inefficiency of the air cooled condensers cooling the steam cycle during hot months. And finally, dry cooling systems cost approximately four to five times more than comparable wet cooling systems, which must be taken into consideration in the financial viability analysis for the plant.[14]

2.4 Hybrid Cooling Systems

There are currently no power plants in Texas with hybrid cooling systems, although they are seeing increasing popularity in other parts of the U. S.[3] Hybrid cooling systems are dual cooling systems that have both a wet cooling component and a dry cooling component. The two primary types of hybrid cooling systems are plume abatement systems and water conservation systems. Plume abatement systems are basically wet cooling towers with small air cooled condensers sections to minimize visible water vapor plumes. Water conservation systems come in any number of configurations of wet cooling towers and dry cooling (typically air cooled condensers), either in series or parallel arrangements. In some situations, such as for nuclear plants, standard condensers can be used to condense the steam, and warm cooling water routed to an air-cooled heat exchanger (ACHE), rather than air cooled condensers, in combination with wet cooling towers. Use of condensers and air-cooled heat exchangers is known as indirect dry cooling and the air-cooled heat exchanger are sometimes called dry cooling towers or simply dry towers. Hybrid cooling systems are typically designed to be operated as dry cooling systems during the cooler seasons, supplemented with wet cooling during the hot seasons, whenever dry cooling cannot achieve the low turbine backpressures desired for power plant efficiency and reliability.[14]

It is important to reiterate that there are many site-specific factors and conditions – such as existing infrastructure, local meteorological conditions, water allocation rights, etc. – that impact the determination of the optimal cooling system for the particular location's resources and conditions.[2, 3]

2.5 Section Summary

There are multiple methods of cooling steam. The cooling technologies currently in use at Texas thermal power plants are once-through and wet cooling tower systems, which utilize water to condense steam (i.e. they provide "wet cooling"), and dry cooling systems that use air to condense steam. There are currently no power plants in Texas with hybrid cooling systems. Hybrid cooling systems are combined cooling systems that have both a wet cooling component and a dry cooling component. It is important to note that each cooling technology has advantages and disadvantages and there is no cooling technology that is optimal for all thermal power plants. Some use more water, but consume less, while others use less water, but consume more. A technology is appropriate in some environments, but is far less effective in others. One technology may consume less water, but have a lower plant efficiency (more fuel is required to provide the same amount of power). Others may have a minimal impact on water, but a significant detrimental impact on the cost to provide power. Furthermore, there are many site-specific factors and conditions – such as existing infrastructure, local meteorological conditions, water allocation rights, etc. – that impact the determination of the optimal cooling system for the particular location's resources and conditions. It is critical to understand all the pertinent relationships prior to making decisions that impact both water and electric power production.

Once-through cooling plants use more, but consume less water than wet cooling towers. Wet cooling towers consume more water, but do not require a reservoir for cooling. Dry cooling uses and consumes less water than once-through systems, but are less efficient and may not perform in arid, windy climates and they require more real estate than wet cooling towers. It is imperative that power producers have choices so that the most appropriate cooling system may be selected for a given location.

References for Chapter 2

1. 2010 data provided by Texas power generators participating in this study.
2. World Economic Forum in partnership with Cambridge Energy Research Associates. 2008. "ENERGY VISION UPDATE 2009. Thirsty Energy: Water and Energy in the 21st Century."
3. Interviews with study participants and other power generators during plant tours. April and May 2012.
4. U.S. DOE, EIA. November 30, 2011. Form EIA-860 Annual Electric Generator Report. Form EIA-860 datafiles available for download from: http://205.254.135.7/cneaf/electricity/page/eia860.html. Accessed June 2012.
5. Lloyd, Gosselink, Blevins, Rochelle, Baldwin & Townsend, P.C., American Electric Power, TXU Energy, Reliant Energy. January 2003. "Power Generation Water Use In Texas For The Years 2000 Through 2060." Prepared for the TWDB. B.L. Sledge, W.G. Carter, C.A. Bissett, J. Simecek, P. Zweiacker, K.M. Whelan, J. Fluharty.
6. U.S. Department of the Interior (DOI), U.S. Geological Survey (USGS). 1959. "The Effect of the Addition of Heat From A Power Plant On The Thermal Structure and Evaporation of Lake Colorado City, Texas." Professional Paper 272-B. G. Harbeck, G. Koberg, and G. Hughes.
7. World Nuclear Association. November 2011. "Cooling Power Plants." http://www.world-nuclear.org/info/cooling_power_plants_inf121.htm. Accessed March 2012.
8. U.S. DOE. December 2006. "Energy Demands on Water Resources." Report to Congress on the Interdependency of Energy and Water.
9. Electric Power Research Institute (EPRI). March 2008. "Program on Technology Innovation: Technology Research Opportunities for Efficient Water Treatment and Use." Report 1016460.
10. U.S. DOE, National Energy Technology Laboratory. 2008. "Department of Energy, National Energy Technology Laboratory, Power Plant-Water R&D Program." B. Carney, T. Feeley, and A. McNemar. Proceedings of 2008 United Nations Educational, Scientific, and Cultural Organization Conference.
11. Sandia National Laboratories. March 2007. "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources." SAND 2007-1349C. R. Pate, M. Hightower, C. Cameron, and W. Einfeld.
12. Texas Penal Code, Title 9, Section 42.01 (Disorderly Conduct), Amendment C, Part 2. 2011.
13. Code of Ordinances, City of Houston, Texas. Codified Through Ord. No. 97-1394. Adopted November 5, 1997. Supplement No. 38, Update 5, Chapter 30 Noise and Sound Level Regulation.

14. EPRI. December 2011. "Economic Evaluation of Alternative Cooling Technologies." Report 1024805.
15. SPX Cooling Technologies, Inc. March 31, 2011. "Improved Performance of an Air Cooled Condenser (ACC) Using SPX Wind Guide Technology at Coal-Based Thermoelectric Power Plants." Report DEFC2606NT06549. K. Mortensen.
16. The Engineering ToolBox. Dry Bulb, Wet Bulb and Dew Point Temperature. http://www.engineeringtoolbox.com/dry-wet-bulb-dew-point-air-d_682.html. Accessed August16, 2012.
17. Nellis, Gregory, Klein, Sanford. Heat Transfer, Example 9.5-1: Wet-bulb and Adiabatic Saturation Temperatures. Cambridge Engineering. December 2008.

Section 3: Power Plant Water Consumption and Conservation

3.1 Power Plant Water Consumption

As part of this study, data was collected from multiple Texas power generators that use once-through cooling.[1] This sample of 24 Texas power plants with once-through cooling systems consume between 0.6 and 1.75 acre-feet of water per 1000 megawatt hours (MWh), depending on fuel type and other variables. The low value of 0.6 acre-foot per 1000 MWh was reported by a combined-cycle plant using once-through cooling. Half of the plants reported one acre-foot of water per 1000 MWh produced, while the remaining plants reported less than one acre-foot per 1000 MWh of electricity produced.[2] While this is not an exhaustive list, it is fairly representative of Texas plants using once-through cooling. The data is recorded in Table 3-1 below.

Several power plants in Texas use wet cooling towers. In general, wet cooling towers are estimated to consume approximately 50% more water than once-through systems.[2, 3]

The water savings are significant when air cooled condensers (dry cooling) are employed, but there are trade-offs. As noted previously, using air cooled condensers results in less efficient power generation. More electricity must be used to operate the cooling equipment. These efficiency penalties come from the higher condensing temperature (approaching ambient dry-bulb temperature) and higher fan horsepower, resulting in less net electricity produced from the fuel burned. This translates to increased fuel consumption and air emissions, and higher production costs. It should also be noted that air cooled condensers performance penalties peak during hot weather and windy conditions, precisely when demand and power prices are at their highest.

While there are currently no power plants in Texas with hybrid cooling systems, there are a few hybrid systems in the U.S.[3] It should be noted that there may be increased costs involved in constructing and maintaining two cooling systems, although together the two systems may be less expensive than a stand-alone dry cooling system. There is a dual cooling system (not a hybrid system) in Texas that uses wet cooling towers and air cooled condensers. During an interview with one of the plant operators stated that under hot and windy conditions the wet component of the system is used most often so that the plant can operate most efficiently. [4] When water conservation is the priority, this would not necessarily be the case. It is important to understand that any cooling technology will be optimized for the given local conditions.

Table 3-1
2010 water consumption of Texas once-through cooled power plants

	FACILITY	WATER CONSUMED (ACFT/PLANT UNIT)	WATER CONSUMED PER ELECTRIC GENERATION (ACFT/1000 MWH)	WATER CONSUMED PER ELECTRIC GENERATION (GALLONS/KWH)
TOTAL WATER CONSUMED 2010 BY TEXAS ONCE-THROUGH PLANTS		11,914.4		
	PLANT 1	4,718.0	1.05	0.49
		250.0		
	PLANT 2	23,522.0	1.24	0.40
	PLANT 3	9,774.3	1.04	0.34
	PLANT 4	2,602.0	1.40	0.46
	PLANT 5	206.0	1.20	0.41
	PLANT 6	3,707.6	0.62	0.20
	PLANT 7	1,797.0	1.20	0.40
	PLANT 8	3,509.0	0.78	0.25
	PLANT 9	379.9	0.54	0.18
	PLANT 10	13,896.4	1.04	0.34
	PLANT 11	426.3	1.25	0.41
	PLANT 12 (2 UNITS COMBINED)	37,893.0	1.79	0.58
	PLANT 13	21,066.3	0.99	0.33
	PLANT 14	505.8	1.00	0.33
	PLANT 15	405.9	1.20	0.40
	PLANT 16	5,176.0	0.99	0.32
		13,262.2		
	PLANT 17	9,688.6	1.75	0.57
	PLANT 18	9,366.1	1.18	0.39
	PLANT 19	219.9	1.00	0.33
	PLANT 20	680.2	1.30	0.42
	PLANT 21	2,779.6	1.71	0.56
	PLANT 22	35.1	1.00	0.33
	PLANT 23	636.1	0.92	0.30
	PLANT 24	285.7	1.06	0.35
		AVERAGE	**1.14**	**0.38**

3.2 Power Plant Water Conservation

Texas power generators have made water conservation an integral part of their operations for many years now. While no power plant employs all of the examples provided below, all of these practices are in use in Texas. Examples of water conservation techniques include the following.

- Use of saline or brackish water to reduce the amount of freshwater consumed
- Capture and re-use of stormwater and gray water
- Effluent or clean municipal water use
- Addition of pumping capability or adjustment of pumping schedule to take full advantage of alternative water sources with variable availability (example: storage of excess water for use in drought conditions)
- Operation of only the most efficient parts of the plant whenever possible, supplementing with less efficient elements of the plant as needed
- Use of cooling towers with specialized computer-controlled systems to maximize water conservation
- Evaluation of pump placement, arrangement, and size to maximize reservoir capacity
- Timely equipment maintenance and repair to minimize water loss
- Pipeline monitoring (i.e., leak detection) and repair
- Turbine modification to increase power generation efficiency
  - More electricity produced per unit fuel (i.e., lower power penalty)
  - More electricity produced for the same amount of water consumed
- Re-use of water within the plant for multiple purposes
  - Fly ash handling
  - Bottom ash handling
  - Flue gas desulfurization water
  - Dust suppression
- Use of chemicals in specific situations to minimize the amount of water required to accomplish a task (e.g., dust suppression)
- Use of once-through cooling systems to reduce the amount of water consumed in power generation
- Management of the cooling reservoir water level to balance cooling efficiency and natural evaporation rate reduction
- Water dispatching – changing generation sources to conserve water
- Fostering a culture of water conservation for domestic water uses
  - Low flow toilets and faucets
  - Water efficient and energy efficient heating, ventilation, and air conditioning systems

- Use of xerophytic plants and modified irrigation practices to conserve water.[2, 4, 5]

Water consumption by the power industry began to decrease in 1980 and has since remained fairly constant. This is significant in that population and electric demand have increased over the same time period.[3]

Thermoelectric-power water use in the U.S. from 1955-2005
(Data are in billion gallons per day (Bgal/d))

	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Population	150.7	164.0	179.3	193.8	205.9	216.4	229.6	242.4	252.3	267.1	285.3	300.7
Water withdrawals	40	72	100	130	170	200	210	187	194	190	195	201

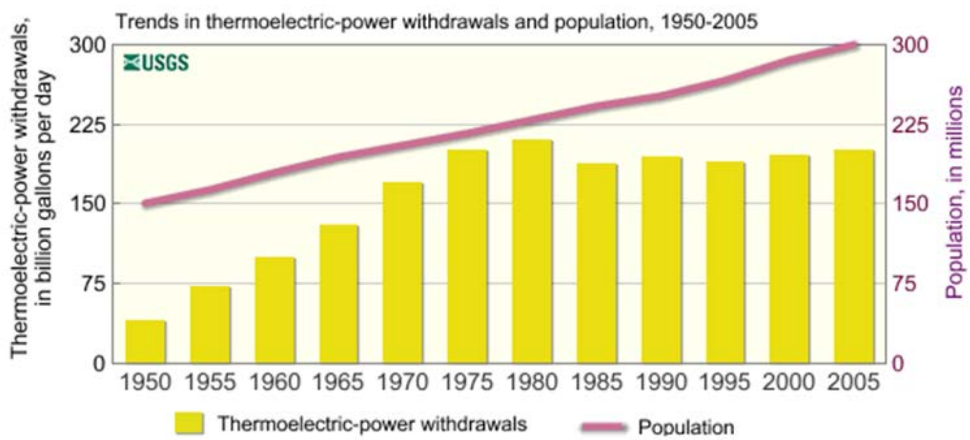


Figure 3-1
Thermoelectric plant water withdrawals and population trends, 1950-2005

In other words, thermoelectric power generators were able to meet the increasing electric demands of an additional 90,700,000 people in 2005, using approximately the same amount of water needed to produce power in 1980.[6] Refer to Figures 3-1 and 3-2 for a tables and graphic representation of these numbers.[7,8]

Nationally, the energy sector is doing well in demonstrating water stewardship, and Texas power plants have even lower per capita water consumption rates than the national average. As previously stated, the national average water consumption for once-through power plants is estimated to be approximately 3.3%, while the Texas power plant average is estimated to be just over 1.5%.

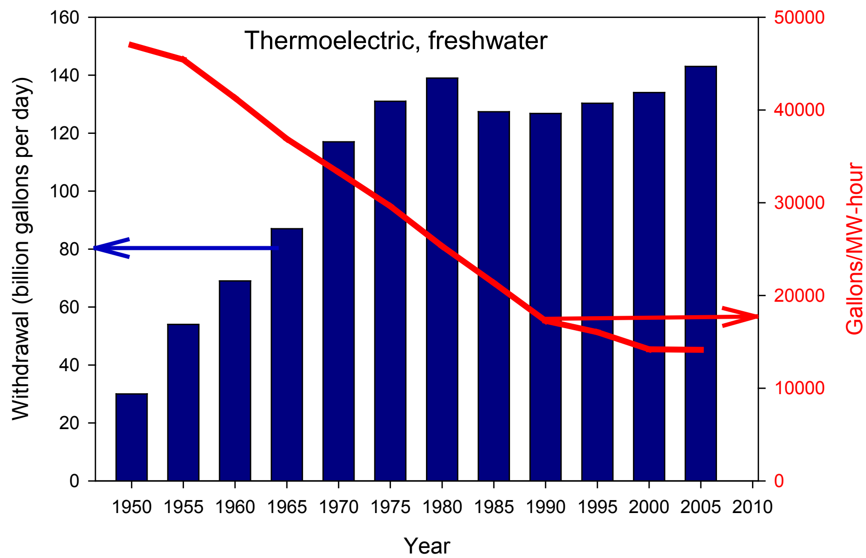


Figure 3-2
US Trend in Water Withdrawals and Consumption for Electricity Generation

Building power plants requires substantial planning. Power plants are built to meet the needs at peak demand levels. In addition, water requirements, fuels sources, cooling technologies, climate and other variables are part of the planning process. Electric power generation companies have to plan ahead and procure a supply of cooling water, often decades in advance. That quantity of water includes extra capacity to ensure cooling water is available during times of drought in order to have reliable electric power. This means that the water has already been allocated to the plant for various purposes and that it is not being withdrawn from a reservoir at the expense of another user.

3.3 Section Summary

Typically, Texas power producers that use once- through cooling consume less than 1 acre-foot of water per 1000 Mega Watt hours of electricity produced. This is lower than the national average for once-through systems. Wet cooling towers only *use* approximately 5% of the water that once-through systems use, but they *consume* approximately 50% more water than a once-through system. Dry cooling systems use less water and consume less water than either of the wet cooling systems. However, they may not be as effective in certain environments, or may not be the technology of choice for a variety of reasons. It is important that balances between supply, demand, investment opportunities, affordability, climate and other site specific variables are considered when selecting the most appropriate cooling technology for a power plant. Conservation is part of the culture of Texas power producers and various forms of water conservation are practiced at every public power producer's plants in Texas.

References for Chapter 3

1. Wayne C. Micheletti, Inc., and Burns Engineering Services, Inc. July 2002. "Emerging Issues and Needs in Power Plant Cooling Systems." W. Micheletti and John M. Burns, P.E. Proceedings of a workshop entitled "Electric Utilities and Water: Emerging Issues and R&D Needs."

2. 2010 data provided by Texas power generators participating in this study.

3. TWDB. "Water Demand Projections for Power Generation in Texas." S. Norvell.

4. Interviews with study participants and other power generators during plant tours. April and May 2012.

5. Calpine, CPS Energy, LCRA, Luminant, NRG Energy. February 2012. "Water Conservation Practices for Texas Generators." Prepared for the Electric Reliability Council of Texas (ERCOT).

6. U.S. DOI, USGS. March 2012. "Science for a Changing World. Thermoelectric Power Water Use." http://ga.water.usgs.gov/edu/wupt.html. Accessed June 2012.

7. U.S. DOI, USGS. 2009. "Estimated Use of Water in the United States in 2005." Circular 1344. J. Kenny, N. Barber, S. Hutson, K. Linsey, J. Lovelace, and M. Maupin.

Section 4: Cooling Technology Applicability, Costs, and Benefits

4.1 Retrofit to Cooling Towers

There has been discussion at both the national and state levels about requiring existing power plants using once-through cooling to retrofit to cooling towers. There are, however, inherent challenges, costs, and positive and negative outcomes associated with such retrofits.

The cooling system is one of the largest, most basic systems in a power plant, and usually is designed without consideration for future major modifications.[1] Consequently, provisions are not typically made in the design to allow for major modifications or of cooling system components, so retrofitting power plant cooling systems can be very complex. Another complicating factor is that the condenser is generally centrally located underneath the steam turbine, surrounded by circulating water piping, the turbine foundations, and other equipment that impede the access required for retrofit. Additionally, the multiple units that many plants have are typically located side-by-side, using common intake bays and discharge canals, but are able to operate independently. By comparison, most of the cooling tower equipment and components need space and clear separations between units to allow for independent cooling systems and dedicated towers for each unit, and this space may not be available.

In addition, cooling towers require a great deal of land area, and some plants may not have available, suitable space within their property lines. Cooling towers would need to be sited away from neighboring properties (noise, nuisance and viewshed issues). The towers would also need to be located far away from energized equipment to avoid deposition and arching. Issues with critical habitat, and topography and elevation changes would need to be addressed. Finding suitable sites for location of the cooling towers is not always possible, depending on given site conditions.

Another retrofit design option is to modify the original cooling system within existing plant structures and extend the cooling loop to include the new cooling tower(s) located outside of existing structures. This retrofit design would be employed at plants with significant elevation variability, lack of space for a separate external cooling tower loop, or other unusual site features or plant layout. In this case, the existing pumps, pipes, valves, and condenser would all be replaced or modified to accommodate higher hydraulic pressures. This retrofit work would significantly impact plant operation and likely require an extended plant outage. At many power plants, the added cooling tower(s) would need to be installed on a separate loop external to existing plant structures. This retrofit design option maintains the existing low hydraulic pressures on the pumps, pipes, valves, and condenser of the once-through system, rather than taking advantage of the much higher hydraulic pressures that would be utilized for a new cooling tower system. In this case, construction of an intermediate cooling tower sump or pump basin would be required after the condenser, where new higher pressure pumps for the cooling tower would be installed, in addition to continued use of the existing pumps. As a positive, however, part of the retrofit work could be done without interrupting plant operation, so the associated plant outage time is minimized.

A third design option is to re-optimize the entire plant for operation with cooling towers. This option is usually employed when the long-term efficiency gains outweigh the initial costs or there is another driver for making a significant change to the cooling system flow, design, or both parameters. Some examples of situations warranting such re-optimized retrofits are when there is not enough space to site the number or size of cooling towers needed, when a condenser otherwise needs replacement, and when retrofit coincides with other station improvements. When there is a significant change in the cooling water flow rate, major changes to the condenser and cooling water pumps would also be required. All of this additional work will typically extend the duration of plant outage.

The design option employed dictates the extent to which the following retrofit work can be done without disrupting plant operation, and therefore likewise dictates the scheduling and duration of plant outage. The cooling tower(s) must be constructed, along with associated equipment such as lightning and fire protection, access roads, lighting, basin screens, fans and plume abatement equipment, if needed. The blow-down facility with a pump station, if needed, must be built and water monitoring and treatment equipment, controls, and instrumentation installed. Extensive large diameter buried piping or open channel canals and an abundance of electrical cables, controls, and other components sufficient to power and operate all the cooling tower pumps and fans would also have to be installed.

During plant outage, much of the once-through intake would be removed and the pump suction bay modified to create a tower makeup water intake structure and pump house and accommodate the cooling water return line from the tower. Depending on the design option, either the existing circulating water pumps are used in conjunction with an intermediate cooling tower pump basin and new pumps, or the existing circulating water pumps are replaced or modified to accommodate higher hydraulic pressures. To support these larger pumps, structural analysis and potentially replacement or modification of pipes, valves, the condenser and related components, and the electrical system would also be required. And finally, demolition of any remaining obsolete once-through equipment, components, and materials would also have to be done primarily during plant outage.[1]

The Electric Power Research Institute (EPRI) conducted a thorough analysis to estimate the cost to retrofit all U.S. once-through cooling systems to cooling towers. Based on that study, the facility-specific cost to retrofit 39 nuclear and 389 fossil power plants would be approximately $95 billion. The referenced 428 U.S. power plants have at least one unit with once-through cooling using in excess of 50 million gallons per day (MGD) of cooling water. This large, nationwide retrofit cost includes capital costs, additional operating power costs, heat rate penalty costs, and costs of lost revenue during retrofit-induced downtime.[2] EPRI also analyzed the retrofit capital costs on a regional basis and determined that there was no discernible correlation between retrofit cost and plant location. There was, however, a correlation between retrofit cost and source water type, so the national retrofit costs are divided by nuclear or fossil fuel and categorized by source water type.[3] Based on the study findings, it would cost approximately $12.5 billion to retrofit the 39 Texas once-through cooling systems included in the EPRI study to cooling towers. This cost includes an approximate $1.6 billion to retrofit one nuclear plant using a reservoir water source, another approximate $1.6 billion to retrofit five fossil plants using "oceans/estuaries/tidal rivers," and approximately $9.3 billion to retrofit 33 fossil plants using reservoirs.[2] ERCOT used a straight cost estimate of $200/kW for cooling tower retrofits in their study, resulting in a total statewide cost of approximately $7 billion.[4]

The magnitude of these retrofit costs would clearly alter the economics of existing generation facilities. As stated in the EPRI study results summary, "some units would prematurely retire rather than retrofit while others would retrofit and continue to operate but incur an energy penalty as a result of the cooling towers."[2] The outcomes of these compliance and operational decisions could affect the state's electric system reliability. As part of their study, EPRI simulated impacts to power adequacy for the ERCOT region using electrical system simulation models. These reliability impact simulations are planning tools, not predictions.[2] ERCOT would ultimately approve or delay electric generation retirement requests in the effort to maintain system reliability.[5]

Since ERCOT provides 85% of the Texas electric power load,[6] the EPRI results for ERCOT provide a reasonable indicator of overall Texas electric system reliability. ERCOT set a minimum reliability margin that EPRI used as the 2016 target capacity margin. EPRI estimated a drop in ERCOT's 2016 capacity margin with a cooling tower retrofit requirement to be in excess of 8%, based on a projected capacity reduction of 5,683 MW. The fixed cost to replace this projected lost generation due to premature plant shutdown with combustion turbine plants is $4.6 billion.[2] ERCOT System Planning performed a simulation study with a different financial model that identified the retirement of almost 10,000 MW of electric generation, reducing the reserve margin below 0% in 2016. (This projection is based on only the imposition of a closed-loop cooling tower requirement; i.e. the "Base Scenario" in the "With Closed-Loop Cooling

Tower Requirement" table. The study also looks at the imposition of carbon emission requirements in their 3rd and 4th scenarios.)[4]

As detailed above, retrofitting from once-through cooling to wet cooling towers is both complicated and expensive. However, an equally significant issue is that after retrofitting to cooling towers, power plants will actually *consume more water*. As noted in Chapter 3.1, cooling towers consume approximately 50% more water than once-through systems.

Once-through cooling systems are the most effective means of cooling and provide the best power plant efficiency. Higher efficiency means lower electricity costs. And, once-through cooling systems, when appropriate, *conserve water* compared with wet cooling towers.

4.2 Retrofit to Air-Cooled Condensers

There has also been discussion at the state level about requiring existing power plants using once-through cooling to retrofit to dry cooling. While there are certainly water conservation benefits of such retrofits, there are also technical and logistical challenges, high costs, and other negative outcomes associated with mandating dry cooling statewide.

Retrofitting from once-through cooling to cooling towers is expensive and complicated, but retrofitting from once-through cooling to dry cooling is considerably more expensive and complicated.[3] Power plants would require much more extensive modifications to retrofit dry cooling to address the higher turbine back pressures and accommodate the steam lines and air cooled condensers into the existing plant.[1, 7] One engineering study identified the need for twenty dry-cooled cells as opposed to six wet-cooled cells, at three times both the land area and height.[8] At most plants, there is simply not enough space in the location where the air cooled condensers would need to be placed (close to the turbine to minimize length of steam ducts). There are technical and cost challenges associated with transferring the steam from the turbines over any distance to a location where there is room for the massive air cooled condensers.[7] Additionally, at many plants, the turbines themselves would have to be replaced with turbines that can operate at the higher backpressures resulting from dry cooling.[3] To complete this extensive type of retrofit, power companies would incur extraordinarily high costs that would be very difficult to recover during the remaining life of existing plants. For traditional simple-cycle steam plants, the efficiency penalties associated with dry cooling would impact the entire plant output, and would not be offset by the higher efficiencies gained by combined cycle plants. In addition, the higher production costs from these plants retrofit with dry cooling may make it harder to bid power to the grid, and eliminate economic viability of the plants. As power generator costs go up, electricity rates would also increase.

As noted in Chapter 1.3 of this report, more than 85% of the water consumed at a power plant is used to condense steam. When dry cooling is implemented, water is no longer consumed for condensing steam, so the plant's water consumption is greatly reduced. Because good cost estimates for dry cooling retrofits are not available, a cost per gallon of water saved was not calculated but it is clear that such water savings would come at an extremely high cost.

It is noteworthy that, in the EPRI nationwide closed-cycle retrofit study, dry cooling retrofits were excluded because of the considerably higher capital and operating costs, significantly higher efficiency/capacity penalties, and much greater physical site constraints as compared to cooling tower retrofits, as well as the energy output limitation on hot days when power demand is typically highest.[3] Other studies also make this same exclusion.[9, 10]

4.3 New Plant Construction

There has also been discussion at the state level about shutting down existing power plants and replacing them with combined cycle plants using air cooled condensers. Power plants will be retired as they come to the end of their useful life and replaced with new plants using more efficient technologies, which will produce water conservation benefits. The early retirement of power plants due a statewide dry cooling mandate, however, could present electric reliability challenges and result in higher electric rates.

The competitive market in the ERCOT region of the state means that power generators or other investors must project sufficient profitability for them to be willing to finance the high cost of building new electric generation facilities. Even though growing state population and faster growing power demand, coupled with routine plant retirements, are causing the generation reserve margin to decline, "investment appears to have stalled" according to a study The Brattle Group completed for ERCOT in June 2012.[11] The study goes on to state that no major new generation projects are starting construction and many planned projects have been cancelled or postponed. ERCOT is therefore projecting the reserve margin to drop to 9.8% by 2014, and the margin will continue to fall unless new generation is added. The Public Utility Commission of Texas (PUC) continues to take action in their efforts to strengthen the ability of market prices to spur sufficient generation investment.[11]

If and when the decision is made to build a new power plant, a multitude of design decisions must be made. Initial capital costs and plant efficiency are the primary factors in selecting the type of cooling system to be used, and other such design choices. Factors such as operating costs, maintenance requirements, existing infrastructure, local meteorological data, water supply, water allocation rights, and permitting requirements are also important considerations. As stated in Chapter 2, there is not one cooling technology that is best for all thermal power plants. All cooling technologies have advantages and disadvantages as well as other local factors that should be considered when selecting the most appropriate cooling technology for the specific plant site's resources and conditions. Limiting the cooling technologies that can be employed would reduce power generators' ability to remain viable in the competitive Texas market, and could therefore be a disincentive to build new power plants in Texas.[7]

The cost of a dry cooling system for a new power plant is approximately four to five times as much as the cost of a cooling tower system. The average annualized cost of a cooling tower system is approximately $1.7 million at a new 525-MW natural gas combined cycle plant and approximately $3.6 million at a new 500-MW coal-fired steam plant. In comparison, the average annualized cost of a dry cooling system is approximately $8.6 million at a new natural gas combined cycle plant and approximately $15.5 million at a new a coal-fired steam plant (Table 4-1). These costs include annualized capital costs, annual operating power costs, maintenance costs (O&M), costs of heat rate penalty, and costs of output shortfall.[12] Three U.S. locations – sites 1, 2, and 5 of the referenced EPRI study of five U.S. locations – were used to derive these average costs, based on a range of ambient temperatures and humidity representative of Texas meteorological conditions. Power generators incurring these high costs would have to increase their bid-in rates to remain viable.

Table 4-1
Estimated average annualized capital and O&M costs above once-through cooling power plants

New Plant Being Constructed	Cooling Tower System	Dry Cooling System
525-MW Natural Gas Combined Cycle Plant	$1.7 Million	$8.6 Million
100-MW Coal Fired Steam Plant	$3.6 Million	$15.5 Million

Power generators typically build new power plants or add new units at existing or former plant locations because of the capital previously invested at those sites. The addition of new generating units at existing plants is the most economical way to increase generation capacity, particularly when existing infrastructure can be shared. Similarly, as existing power plants come to the end of their useful lives, the plants are demolished and the land and any usable improvements, such as transmission and fuel access, roads, and cooling reservoirs, are retained for future use. The existence of a cooling reservoir on or adjacent to a plant site is due to prior substantial investment by a power generator to develop the reservoir and generally means that the generator owns sufficient water rights for a once-through cooling system.[7] These factors may well result in once-through cooling being identified as the most appropriate cooling technology at such a location.

At existing or former plant locations without cooling reservoirs where once-through cooling is or was being utilized, the water rights needed for a once-through system are already in place through existing groundwater wells, brackish or saline water sources, or via contract to purchase water from a water rights owner or wastewater from a municipal treatment plant.[7] The economic benefit that dry cooling offers in not needing to establish sufficient water source(s) and rights is negated in this case.

While it is beyond the scope of this study to identify the time required for permitting and construction of a new plant, this time factor should be taken into account in the context of forced plant shutdowns. One benefit of dry cooling is that it can often accelerate the time needed to review and receive a permit for construction for a new plant, and this is often the driver for adopting this technology where dry cooling is otherwise not mandated.

Use of dry cooling does mean that water is no longer consumed for condensing steam, so power plant water consumption is greatly reduced. It is beyond the scope of this study to identify the total cost of new power plant construction, with the myriad costs that would be entailed; therefore a cost per gallon of water saved was not calculated.

4.4 Section Summary

Power plants are built to meet the needs at peak demand levels. In addition, water requirements, fuels sources, cooling technologies, climate and other variables are part of the planning process. Power producers pay for water rights years in advance. This means that the water has already been allocated to the plant for various purposes and that it is not being withdrawn from a reservoir at the expense of another user.

Retro-fitting existing plants to wet cooling towers or to a dry cooling system would be expensive and have severe consequences. It would:

- Cause the premature retirement of multiple plants
- Hinder the power producer's ability to meet the electric demands for the state resulting in brown outs and blacks outs.
- Negatively impact the treatment and distribution of water throughout the state

Mandating a single cooling technology be used would have similar results. It would:

- Limits investor's ability to make a return on investment thereby discouraging future investment
- Cause premature retirement of multiple plants
- Hinder power producers' ability to meet the electric demands of the citizens of Texas
- Cause a negative ripple effect on both the Texas economy and the national economy

References for Chapter 4

1. EPRI. March 2011. "Report on Plant Outages Required to Retrofit Closed-Cycle Cooling Systems." Report EP-P38757/C17239. Published as Attachment B to EPRI Report 1023453.
2. EPRI. August 2011. "Clean Water Act Section 316(b) Closed-Cycle Cooling Retrofit Research Program Results Summary." Report 1023453.
3. EPRI. January 2011. "Closed-Cycle Cooling System Retrofit Study: Capital and Performance Cost Estimates." Report 1022491.
4. ERCOT. 2011. "Review of the Potential Impacts of Proposed Environmental Regulations on the ERCOT System, Revision 1, June 21, 2011." http://www.ercot.com/news/presentations/2011/ERCOT_Review_EPA_Planning_Final.pdf. Accessed May 2012.
5. ERCOT. July 1, 2012. "ERCOT Nodal Protocols – July 1, 2012." Section 3.14.1. http://www.ercot.com/mktrules/nprotocols/lib.html. Accessed July 2012.
6. ERCOT. 2012. "ERCOT Quick Facts-Jan 2012." http://www.ercot.com/content/news/presentations/2012/ERCOT%20Quick%20Facts%20-%20Jan%202012.pdf. Accessed May 2012.
7. Interviews with study participants and other power generators during plant tours. April and May 2012.
8. Sargent & Lundy. August 17, 2005. "Huntington Beach Cooling Study." Report 11831-013.
9. U.S. Environmental Protection Agency (EPA). February 12, 2004. "EPA Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule." EPA-821-R-04-007.
10. TetraTech, Inc. February 2008. "California's Coastal Power Plants: Alternative Cooling System Analysis."
11. The Brattle Group. June 1, 2012. "ERCOT Investment Incentives and Resource Adequacy." S. Newell, K. Spees, J. Pfeifenberger, R. Mudge, M. DeLucia, and R. Carlton. Prepared for ERCOT.
12. EPRI. December 2011. "Economic Evaluation of Alternative Cooling Technologies." Report 1024805.

Section 5: Public Benefits of Water Use and Power Generation

5.1 Benefits of Power Plant Reservoirs

Texans benefit not only directly, but also indirectly from reservoirs constructed for once-through cooling. One such indirect benefit is electric price stability. Capitalizing on multiple fuel sources and different cooling techniques has had a stabilizing effect on the price of electricity for Texas citizens. When prices increase dramatically on one fuel source; a proportional increase is not normally reflected in electric rates.[1] In addition, having flexibility in pairing fuels and cooling technologies allows communities and investors to make decisions based on what is most appropriate and beneficial as determined by local conditions.[2] Another indirect benefit of once-through cooling is the positive impact on breeding of many fish species due to extended breeding seasons.[3, 5] Increased fish populations, in turn, have positive impacts to recreation and tourism in the state.

There are many direct benefits as well. There are 209 reservoirs in the state of Texas. Of those, approximately 32% were built for the purpose of cooling steam or as a source of water for hydro-electric plants. Some of them were built by industrial users for the sole purpose of cooling steam at a power plant. These are commonly referred to as Co-Gen plants. Power plant cooling reservoirs in Texas were constructed (often by the electric utilities or the Corps of Engineers) to support those public utilities or power plants that provide power to the general public. Beyond that use, however, some are also used for drinking water supplies. Many of these "lakes" are also open for public recreation. Recreational lakes bring value to the state and its citizens through tourism and tax revenue. The utility-funded lakes bring in additional revenue when other industrial users withdraw water from the same reservoir.[4]

5.2 Water Consumption and Electric Generation

Texans also benefit from the water consumed for power generation in multiple ways. Reliable generation of electricity is necessary for pumping water to cities and farms, and for water and sewage treatment. Electricity powers nearly everything we do and is particularly important in providing heating or cooling and providing power to business and medical equipment.[1] In short, electricity drives the state's economy and resulting quality of life.

5.3 Putting Water Consumption and Electric Generation in Perspective

Based on 2010 data collected from the study sample of 24 Texas power plants with once-through systems, half of these plants consumed one acre-foot of water for every 1000 MWh produced. That equates to approximately 1/3 of a gallon per kWh, as follows.

1 acre-feet / 1000 MWh = 325,851.429 gallons / 1000 MWh = **0.326 gallons / kWh**

More efficient plants consume less water to produce the same amount of power. One of the plants in the study is a natural gas plant using once-through cooling. It consumes 0.6 acre-feet per 1000 MWh. Only two of the 24 once-through systems consumed more than one acre-feet; those two plants consumed 1.03 and 1.07 acre-feet per 1000 MWh electricity produced. The remaining plants in the sample consumed less than one acre-foot of water for every 1000 MWh generated.

Table 5-1
Water consumption of Texas power plants with once-through cooling

Plant Efficiency	Water Consumer per 1000 MWh	Water Consumed per kWh
Typical	1.1 acre-foot	0.36 gallon
More Efficient	0.96 acre-foot	0.31 gallon
Very Efficient	0.84 acre-foot	0.27 gallon
Nat Gas Plt with Once-Through	0.54 acre-foot	0.18 gallon

For comparison:

- The typical American household is 4.6 people in a 2,500 square foot house and uses 29 kWh of electricity each day.[7, 8] The typical Texas once-through plant consumes less than 10 gallons of water to produce that 29 kWh of power.
  - 5.7 to 9.45 gallons / day to power a home by the typical once-through system
- In comparison to the 9½ gallons of water to produce the electricity consumed in one day, the typical American household consumes 300 gallons of water each day.[7, 8] That means it takes approximately 3% of the total water consumed by the typical household to generate the electricity needed by that household each day.

In the average American household, 92 gallons of water are consumed for bathing, assuming one 10-min shower per person. If only one load of clothes is washed each day, an additional 25 gallons will be consumed, assuming the home has a newer washing machine. Each household consumes 25 gallons for washing dishes, and 2½ gallons of drinking water. One source states that Americans flush a minimum of 44 gallons of water, but the national average is 87 gallons. The average Texas household flushes 76 gallons of water down the toilet each day. A super-efficient green home would flush a minimum of 23.4 and an average of 46.92 gallons of water per day. Other household uses include brushing teeth, watering plants, bathing pets, cooking, cleaning and other miscellaneous activities.[7, 8]

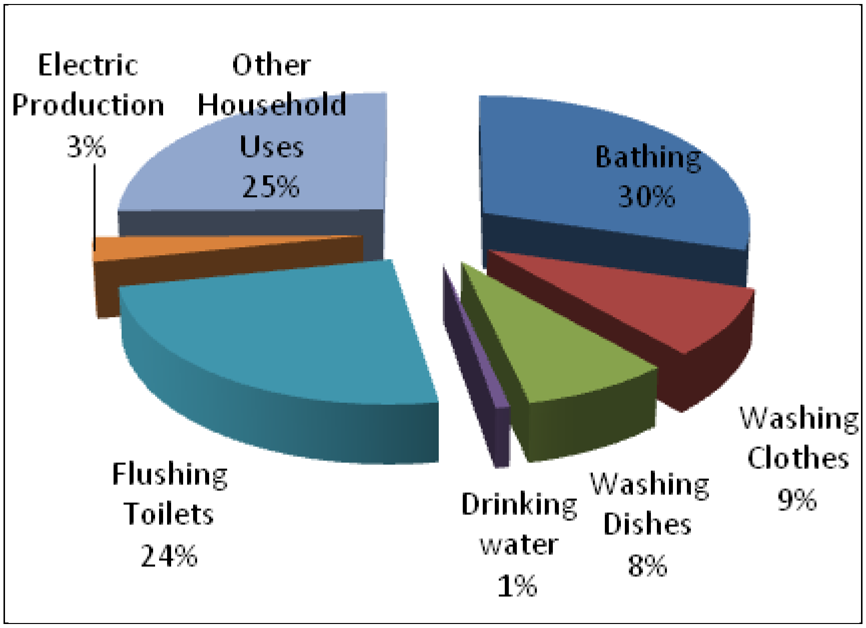


Figure 5-1
Water use in the average household

5.4 Section Summary

Based on 2010 data collected from the study sample plants consumed one acre-foot of water for every 1000 MWh produced. That equates to approximately 1/3 of a gallon per kWh. More efficient plants consume less water (approximately .85 acre-feet or 1/4 gallon of water per kWh) to produce the same amount of power.

In comparison to the 9½ gallons of water to produce the electricity consumed in one day, the typical American household consumes 300 gallons of water each day.[7, 8] That means it takes approximately 3% of the total water consumed by the typical household to generate the electricity needed by that household each day.

In the average American household, 92 gallons of water are consumed for bathing, assuming one 10-min shower per person. If only one load of clothes is washed each day, an additional 25 gallons will be consumed, assuming the home has a newer washing machine. Each household consumes 25 gallons for washing dishes, and 2½ gallons of drinking water. One source states that Americans flush a minimum of 44 gallons of water, but the national average is 87 gallons. The average Texas household flushes 76 gallons of water down the toilet each day. A super-efficient green home would flush a minimum of 23.4 and an average of 46.92 gallons of water per day.

References for Chapter 5

1. Texas Comptroller of Public Accounts. May, 2008. “The Energy Report.” S. Combs et al.
2. World Economic Forum in partnership with Cambridge Energy Research Associates. 2008. "ENERGY VISION UPDATE 2009. Thirsty Energy: Water and Energy in the 21st Century.”
3. Texas A&M University System, Agrilife. “Aquiculture in Power Plant Effluent.” November 1995. L. Pilgrim.
4. Texas A&M University, Department of Wildlife and Fisheries Sciences, Human Dimensions of Fisheries Research Laboratory. October 15, 1996. “A Social and Economic Study of the Lake Fork Reservoir Recreational Fishery.” K. Hunt and R. Ditton.
5. H. Brielmann, C. Griebler, S. Schmidt, R. Michel, T. Lueders. June 2009. “Effects of Thermal Energy Discharge on Shallow Groundwater Ecosystems.”
6. 2010 data provided by Texas power generators participating in this study.
7. U.S. EPA. June 2008. “Indoor Water Use in the United States.” EPA WATERSENSE publications. PEA-832-F-06-004.
8. U.S. DOI, USGS. March 2012. “Water Questions & Answers: Water at Home.” http://ga.water.usgs.gov/edu/qa-home-percapita.html. Accessed April 2012.
9. Texas Comptroller of Public Accounts. “Finances & Economy: Texas Energy Quick Facts.” http://www.window.state.tx.us/finances/captrade/tx_energy_quickfacts.html. Accessed June 2012

Section 6: Water Consumption of Various Sectors

As the U.S. population has increased through the years, demand for water has likewise increased. As this water demand increases, so too will competition for water increase between the agricultural, municipal, industrial, and energy sectors.[1]

The population of Texas grew more than any other state between 2000 and 2010, and this robust growth rate is expected to continue, according to the *Water for Texas: 2012 State Water Plan*. The Texas population is projected to increase approximately 82% between 2010 and 2060. The purpose of the State Water Plan is to ensure water users (cities, rural communities, farms, ranches, businesses, and industries) have enough water during a repeat of the 1950's "drought of record."[2]

6.1 Thermoelectric Sector

According to the USGS, in 2005 the statewide total fresh water withdrawal was approximately 72,425 acre-feet per day. Of this amount, thermoelectric plants diverted 29,707 acre-feet of fresh water each day, or 41% of the total daily withdrawals, to generate electricity.[4] The thermoelectric generators, however, only consumed a small fraction of that water. Based on the 2009 data collected by the TWDB, thermoelectric plants consumed 3% of the water consumed in Texas. Refer to Figure 6-1 for a graphic representation of 2009 water consumption in Texas by sector.[9] In 2010, the sample of Texas once-through thermoelectric plants used in this study consumed 1.6% of the total water withdrawn. This equates to a range of 0.19 to 0.38 gallons per kWh of electricity.[5] As stated in Section 3, thermoelectric power generators were able to meet the increasing electric demands of an additional 90,700,000 people in 2005, using approximately the same amount of water needed to produce power in 1980.

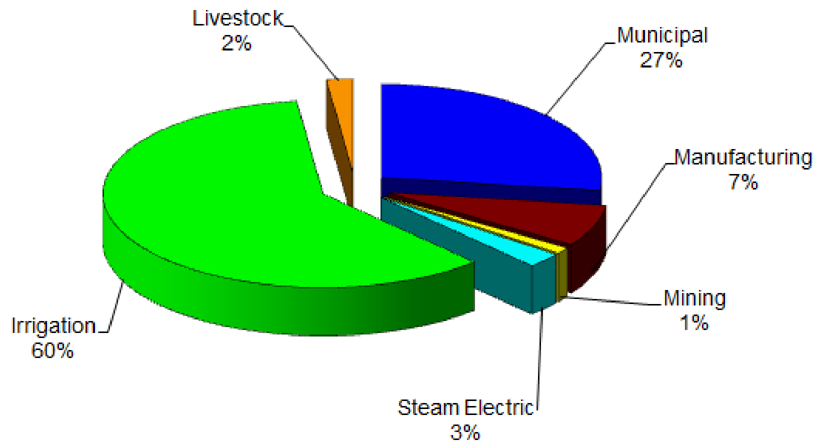


Figure 6-1
2009 Water consumption in Texas by sector

6.2 Agriculture Sector

According to the TWDB data, Texas farmers withdrew and consumed 9,256,426 acre-feet of water to irrigate crops in 2009. This equates to 60% of total state water consumption. Texas ranchers withdrew and consumed 297,047 acre-feet of water for livestock production that same year, for 2% of total state water consumption. Combined, agriculture withdrew and consumed 9,553,473 acre-feet in 2009, representing approximately 62% of the total water consumed in the state.[9]

6.3 Municipal Sector

The municipal sector provides water for residential (homes, apartments, etc.), commercial (businesses and industry that do not use water in production processes), and institutional (libraries, hospitals, and other public buildings) users.[2] Texas municipalities consumed 4,181,318 acre-feet of water in 2009, which is 27% of the total water consumed in the state.[9] Water consumed for human consumption in Texas municipalities, regardless of the source (surface water or underground sources), is pumped to water treatment plants. These plants filter and chemically treat the water so that high quality drinking water standards are met. The treatment plants then pump water through delivery pipes to the end users. The treatment and distribution processes are very energy-intensive. As much as 80% of treatment costs are due to electricity consumption.[7]

6.4 Industrial Sector

According to 2009 TWDB data, industrial customers consumed 1,278,784 acre-feet of fresh water in 2009. The Texas industrial sector's water use comprised 8% of the total water use for the year.[9]

6.5 Section Summary

As the population in Texas has increased over the last several decades so has the demand for water. Thermoelectric, agricultural, municipal and industrial sectors have all had increases in water use and consumption. However, in Texas, within the thermoelectric sector, the number of gallons consumed per MWh produced has declined significantly during the same time period. Thermoelectric power generators were able to meet the increasing electric demands of an additional 90,700,000 people in 2005, using approximately the same amount of water needed to produce power in 1980.

References for Chapter 6

1. Sandia National Laboratories. March 2007. "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources." SAND 2007-1349C. R. Pate, M. Hightower, C. Cameron, and W. Einfeld.
2. Texas Water Development Board. January 2012. "Water for Texas: 2012 State Water Plan."
3. Texas Water Resources Institute, Environmental Defense. September 2002. "Efficient Water Use for Texas: Policies, Tools, and Management Strategies." J. Gerston, M. MacLeod, C. Jones.
4. U.S. DOI, USGS. 2009. "Estimated Use of Water in the United States in 2005." Circular 1344. J. Kenny, N. Barber, S. Hutson, K. Linsey, J. Lovelace, and M. Maupin.
5. Calculation using 2010 data provided by Texas power generators participating in this study. July 2012.
6. Texas Comptroller of Public Accounts. "Texas in Focus: A Statewide View of Opportunities. Infrastructure. Water." http://www.window.state.tx.us/specialrpt/tif/water.html. Accessed June 2012.
7. Sandia National Laboratories. "Energy-Water Nexus Overview." http://www.sandia.gov/energy-water/nexus_overview.htm. Accessed June 2012.
8. U.S. DOE, EIA. April 28, 2008. "State Energy Profiles-Texas." http://www.eia.gov/state/state-energy-profiles.cfm?sid=TX. Accessed June 2012.
9. TWDB. "Water Resources Planning & Information. 2009 Texas Water Use Summary Estimates. Water Use Summary Estimates by Geographic Location. 2009 Water Use Survey Summary Estimates – Regional & State Totals. WATER USE SURVEY HISTORICAL SUMMARY ESTIMATES BY REGION IN ACRE-FEET." http://www.twdb.state.tx.us/wrpi/wus/2009est/2009wus.asp. Accessed July 2012.

Section 7: Economic and Societal Impacts of a Texas Dry Cooling Mandate

Energy costs are reflected in all products that require energy to manufacture, transport, store, and distribute them to consumers.[7] Municipal, agricultural, and other industrial users of energy are all impacted when electricity costs increase and when there are interruptions in the electric supply.

7.1 Electric Costs

Municipalities are one of the largest consumers of electricity and energy as a whole. In fact, during fiscal year 2007, the Texas state government spent $205,447,358 on electricity.[3] The Texas per capita residential and commercial consumption of electricity are slightly lower than the national average, however, and are at the lowest levels since 1965.[2] Treating and providing water to citizens is a major energy consumer. Worldwide 7% of the total energy consumed is used to treat and deliver water. In the U.S., 3% of the total *electricity* consumption is used to treat and deliver water. This is more electricity than is consumed by the pulp and paper and petroleum industries combined.[8]

There are severe economic impacts when electric capacity cannot meet demand, as could be the case if existing power plants were to be prematurely retired. Outages are very costly to high-tech companies, such as semiconductor producers, data centers, and chip makers, in particular. In August 2009, *The Austin American-Statesman* published an article on the costs of power outages on the local economy. One high-tech company in Austin lost between $15 and $20 million over a four-year period, having only suffered from four power outages during that time.[9]

7.2 Food Prices

The agricultural industry relies heavily on multiple forms of energy.

> Energy is used throughout the U.S. food supply chain, from the manufacture and application of agricultural inputs, such as fertilizers and irrigation, through crop and livestock production, processing, and packaging; distribution services, such as shipping and cold storage; the

> running of refrigeration, preparation, and disposal equipment in food retailing and foodservice establishments; and in home kitchens. Dependence on energy throughout the food chain raises concerns about the impact of high or volatile energy prices on the price of food, as well as about domestic food security and the Nation's reliance on imported energy.[7]

Since the 1970s energy use by the agricultural industry has decreased by 28% due to improved equipment, sound conservation, and production practices. In spite of these improvements, the industry paid nearly $29 billion for energy in 2003. Changes in energy prices or in energy availability can have a significant impact on revenues, particularly in rural communities. There are four areas where increased energy prices impact food prices. The first is production of food. Examples include the transporting or pumping of water for irrigation, producing nitrogen-based fertilizers, and providing feed to livestock. A second area is food manufactured with high-energy technologies. The transportation of food products is a third. The final area is the storage and distribution of food items in climate-controlled facilities and carriers. An increase in energy costs would result in higher food prices for consumers.[6]

7.3 Manufactured Products

Texas consumes more power than other states, due in part to its large population and hot climates, as well as the sizeable industrial sector.[3] Texas has one of the largest industrial sectors in the nation.[1] Industrial users account for 50% of all energy used in the state. By comparison, only 32% of the total U.S. energy consumption is attributable to industry. Examples of Texas industrial users are aluminum and glass manufacturing, forest products, petroleum refining, and petrochemical production.[1] This means that a great deal of Texas' energy consumption drives industries that are manufacturing and processing products used to produce electricity across America and around the world.

> Texas per capita industrial consumption has dropped steadily in recent years to its lowest level since 1960, the first year for which data are available. Per capita transportation use also has declined in recent years.[2]

7.4 Job Losses and Other Unintended Consequences

In 2005, based on the most recent data available, Texans spent more per capita on energy than the national average.[4] Increasing the costs to generate electricity would have a ripple effect on the Texas economy. Well intentioned government action often has unintended results.

A good example is recent government policy intended to encourage corn-based ethanol production. As a result, ethanol production increased dramatically, so the government policy achieved its goal. Unfortunately, in promoting ethanol production, this same policy also had significantly negative impacts throughout the economy. The demand for corn drove corn and corn-product prices up.

Farmers subsequently switched from growing other crops to growing higher-priced corn. As the supply of other crops and agricultural products decreased, the cost of those goods increased. The higher demand and price of corn also raised feed costs for cattle ranchers and poultry and pork producers, resulting in higher meat prices.[2] But the negative impacts on consumers and Texas businesses went even further. Texas-based livestock producers laid off thousands of employees in 2008 in Texas and in other states. The layoffs were attributed to the record high prices for corn and other feed ingredients. In addition, other crop based markets such as soybeans, wheat and cotton, were negatively impacted. Increases costs associated with these and other crops also had a negative impact on the costs to produce dairy products, cattle, swine, and poultry. Since the level of ethanol production is mandated by government regardless of demand, market corrections will have less impact on allowing costs to decrease. [5] The current wide spread drought of 2012 has exacerbated the situation by placing increased demand on a very limited corn supply. Because a government mandated number of gallons of ethanol must be produced regardless of supply or demand; the price of corn is increasing. This is forcing many ranchers to dramatically reduce herd size or to leave the livestock industry altogether resulting in substantial job losses across the country.[10] This has also resulted in an increased demand on water in the San Antonio area. Because corn prices are high, and the drought has killed off corn crops in other parts of the country, local farmers have planted a rare fall rotation of corn instead of the winter wheat that is normally planted this time of year. Corn crops consume more water than winter wheat.[11]

7.5 Section Summary

Mandating one cooling technology may result in job losses and have unintended consequences. Job losses, food shortages, and escalating feed prices are all well documented results of the ethanol mandate. Another unintended consequence is a significant increase in water demand by the agricultural sector in the San Antonio region. Because corn prices are high, and the drought has killed off corn crops in other parts of the country, local farmers have planted a rare fall rotation of corn instead of the winter wheat that is normally planted this time of year. Corn crops consume more water than winter wheat.

References for Chapter 7

1. U.S. DOE, EIA. April 28, 2008. “State Energy Profiles: Texas.” http://www.eia.gov/state/state-energy-profiles.cfm?sid=TX. Accessed April 2012.

2. Texas Comptroller of Public Accounts. May, 2008. “The Energy Report.” S. Combs et al.

3. Texas Comptroller of Public Accounts. “Finances & Economy: Texas Energy Quick Facts.” http://www.window.state.tx.us/finances/captrade/tx_energy_quickfacts.html. Accessed June 2012.

4. U.S. DOE, EIA. April 28, 2008. “State Energy Consumption, Price and Expenditure Estimates.”

http://www.eia.doe.gov/emeu/states/sep_prices/total/pr_tot_tx.html. Accessed April 2012.

5. Texas A&M System, AgriLIFE Research and Extension. Agricultural and Food Policy Center. "The Effects of Ethanol on Texas Food and Feed." Anderson, David P., Outlaw, Joe L., Bryant, Henry L., Richardson, James W., Ernstes, David P., Raulston, J. Marc, Welch, J. Mark, Knapek, George M., Herbst, Brian K., and Allison, Marc S. April 10, 2008.
6. The Library of Congress, Congressional Research Service. November 19, 2004. "Energy Use in Agriculture: Background and Issues." R. Schnepf.
7. U.S. Department of Agriculture (USDA), Economic Research Service. March 2010. "Energy Use in the U.S. Food System." USDA Economic Research Report Number 94. P. Canning, A. Charles, S. Huang, K. Polenske, A. Waters.
8. U.S. Agency for International Development (USAID), Bureau of Economic Growth, Agriculture, and Trade, Office of Energy, Environment, and Technology and The Alliance to Save Energy. October 2004. "Watergy: Taking Advantage of Untapped Energy and Water Efficiency Opportunities in Municipal Water Systems."
9. K. Ladendorf. August 29, 2006. "Power Loss Also Stings at Samsung." *The Austin American-Statesman*, p. A-1.
10. Daniel James Devine. August 3, 2012. "Renewable Fuel Relief: Expensive Corn Pits Livestock Producers Against Ethanol Makers and Farmers in a Clash Over Boifuel". WORLD Magazine. http://www.worldmag.com/webextra/19794.
11. Jim Forsyth, News Director. WOAI News. "SAWS Issues Stage 3 Water Restrictions for Large Water Consumers". Reported on 1200 WOAI Radio, August 17, 2012.

Section 8: Conclusions

There is confusion over terms water *use* and water *consumption*. Water use is a general term that can refer to either consumptive or non-consumptive use. Water use includes drinking, flushing toilets, irrigation, cooling, boating, fishing, and many other applications.

Water consumption refers to a water use that makes it no longer available for other uses. Examples are drinking water, evaporated water, or water incorporated into a product like corn or concrete. When water is consumed, it is no longer available in the system. Consumption is a truer, "big picture" measure of impact on water resources.

Water conservation is an integral part of current operations of the Texas power industry. Texas power plants have lower per capita water consumption rates than the national average, and that downward trend is expected to continue. The Texas once-through cooled power plants consume less than ten gallons of water to produce the electricity that a household consumes each day.

Texas power generators must be able to offer cost competitive pricing to remain viable in the deregulated ERCOT electric market. Legislative action limiting the cooling technology options could reduce the economic viability of many current power plants or provide a disincentive to build needed new power plants in the state.

Mandating one cooling technology statewide would result in very expensive retrofits or plant replacements, potentially leading to electric rate increases. Every household, farm, business, and industry across the state would be impacted by higher electricity rates, in addition to higher water rates, as the cost of treating and distributing water goes up. The increased expense in getting water to crops would result in higher food prices. The cost of many other goods and products would increase as well, as industries have to pay more for power and water used in manufacturing. The cost of treating wastewater would also increase, as the impacts ripple through the economy.

Any premature shutdown of existing power plants, at a time when ERCOT is already projecting a decline in the margin of available electricity, would strain the Texas power industry's ability to meet the power demand. The consequence would be a strong probability that citizens and businesses would face power outages. In order to meet electric demand for the short term, the use of older, mothballed plants that are less efficient, consume more water, and have more emissions may be required.

Thermoelectric power producers have invested considerable effort in making water conservation a part of their standard operating procedures. Power plants are built to meet the needs at peak demand levels. In addition, water requirements, fuels sources, cooling technologies, climate and other variables are part of the planning process. Power producers pay for water rights years in advance. This means that the water has already been allocated to the plant for various purposes and that it is not being withdrawn from a reservoir at the expense of another user. Mandating a single cooling technology be used on new builds or retro-fits could have a negative ripple effect on the Texas economy many detrimental effects that would impact other sectors of the state and national economies.

Appendix A: List of Texas Electric Generators

ELECTRIC GENERATORS IN THE STATE OF TEXAS

PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Abbott TP 3	McQueeney	Guadalupe	Guadalupe River
Abilene	Abilene	Taylor	Municipality
Aeolus Wind Facility	Spearman	Hansford	
AES Deepwater	Pasadena	Harris	River and Municipality
Air Products Port Arthur	Port Arthur	Tarrant	Valer Port Arthur Refinery
Amelia Energy Center		Jefferson	LNVRA
Amistad Dam & Power	Del Rio	Val Verde	Rio Grande
Arthur Von Rosenberg	Elmendorf	Bexar	San Antonio River
Aspen Biomass Power Plant	Lufkin	Angelina	Well
Atascosita	Houston	Harris	Municipality
Austin	Austin	Travis	Lake Austin
Austin Gas Recovery	Austin	Travis	
Barney M Davis	Corpus Christi	Nueces	Laguna Madre
Barton Chapel Wind Farm	Jacksboro	Jack	
Bastrop Energy Center	Cedar Creek	Bastrop	Colorado River
Baytown	Baytown	Chambers	Municipality
Baytown Energy Center LLC	Baytown	Chambers	Coastal Water Authority/Muncpl
Bell Energy Facility		Bell	Belton Lake
Big Brown Power Company LLC	Fairfield	Freestone	Fairfield Lake
Big Spring Wind Power Facility	Big Spring	Howard	
Black Hawk Station	Borger	Hutchinson	Wells
Blue Wing Solar Energy Generation	San Antonio	Bexar	
Bluebonnet	Houston	Harris	Municipality
Bosque County Peaking	Laquna Park	Bosque	Brazos River
Brandon Station	Lubbock	Lubbock	Municipality
Brazos Valley Generating Facility	Thompsons	Fort Bend	Brazos River
Brazos Wind Farm	Fluvanna	Scurry	none
Brownfield	Brownfield	Terry	Municipality
Bryan	Bryan	Brazos	Municipality
Buchanan	Buchanan Dam	Llano	Lake Buchanan
Buffalo Gap 2 Wind Farm	Merkel	Nolan	
Buffalo Gap 3 Wind Farm	Nolan	Nolan	
Buffalo Gap Wind Farm	Merkel	Taylor	
Bull Creek Wind	O'Donnell	Borden	
C E Newman	Garland	Dallas	Municipality
C R Wing Cogen Plant	Big Spring	Howard	Colo.River Municipal Water Dis
Callahan Divide Wind Energy Center	Tusocola	Taylor	
Canyon	Canyon Lake	Comal	Canyon Lake

ELECTRIC GENERATORS IN THE STATE OF TEXAS

PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Capricorn Ridge Wind LLC	Sterling City	Sterling	
Cedar Bayou	Baytown	Chambers	Upper Galveston Bay
Cedar Bayou 4	Eldon	Chambers	Cedar Bayou
Cedar Power Project	Dayton	Liberty	Lake Houston
Cedro Hill Wind LLC	Bruni	Webb	
Celanese	Pampa	Gray	Wells
Champion Wind Farm LLC	Roscoe	Nolan	NA
Channel Energy Center LLC	Pasadena	Harris	Coastal Water Authority
Channelview Cogeneration Plant	Channelview	Harris	Lyondell Bassel Chemicals
Clear Lake Cogeneration Ltd	Pasadena	Harris	Municipality
Coastal Plains	Alvin	Galveston	Municipality
Coleman	Coleman	Coleman	Lake Coleman
Coleto Creek	Fannin	Goliad	Coleto Creek Reservoir
Collin Power Company LLC	Frisco	COLLIN	Wells
Colorado Bend Energy Center	Wharton	Wharton	WELLS
Comanche Peak	Glen Rose	Somervell	Squaw Creek Reservoir
Conroe	Conroe	Montgomery	Municipality
Copper	El Paso	El Paso	Municipality
Corpus Christi Cogeneration LLC	Corpus Christi	Nueces	Corpus Christi Ship Channel
Center	Sweetwater	Nolan	
Cottonwood Energy Project	Deweyville	Newton	Sabine River
Covel Gardens Gas Recovery	San Antonio	BEXAR	N/A
Dansby	Bryan	Brazos	Lake
Decker Creek	Austin	Travis	Lake Walter E. Long
DeCordova Power Company LLC	Granbury	Hood	Lake Granbury
Deepwater	Pasadena	Harris	Houston Ship Channel
Deer Park Energy Center	Deer Park	Harris	Municipal-CIWA
Delaware Mountain Windfarm	Salt Flat	Culberson	
Denison	Denison	Grayson	Red River
Denton Power LLC	Denton	Denton	
Desert Sky	Iraan	Pecos	n/a
DeWind Frisco	Gruver	Hansford	
DFW Gas Recovery	Lewsiville	Denton	
Domain Integrated Energy System	Austin	TRAVIS	City of Austin
Dunlap TP 1	New Brannfels	Guadalupe	Guadalupe River
E S Joslin	Point Comfort	CALHOUN	Lavaca Bay
Eagle Mountain	Fort Worth	Tarrant	Eagle Mountain Reservoir
Eagle Pass	Eagle Pass	Maverick	Maverick County Irrigation Dis
Eastman Cogeneration Facility	Longview	Harrison	Ferguson Lake

PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
EC&R Panther Creek Wind Farm I	Big Spring	Howard	
EC&R Panther Creek Wind Farm II	Big Spring	Howard	
EC&R Panther Creek Wind Farm III	Big Spring	Sterling	
EC&R Papalote Creek I LLC	Taft	San Patricio	
EC&R Papalote Creek II LLC	Taft	San Patricio	
Edinburg Energy Project		Hidalgo	City Of Edinburg
Elbow Creek Wind Project LLC	Forsan	Howard	
Electra		Wichita	
Ennis Power Company LLC	Ennis	Ellis	Municipality
EXC Wind 1 LLC	Gruver	Hansford	
EXC Wind 10 LLC	Dumas	Moore	
EXC Wind 11 LLC	Dumas	Moore	
EXC Wind 2 LLC	Gruver	Hansford	
EXC Wind 3 LLC	Gruver	Hansford	
EXC Wind 4 LLC	Spearman	Hansford	
EXC Wind 5 LLC	Texhoma	Sherman	
EXC Wind 6 LLC	Texhoma	Sherman	
EXC Wind 7 LLC	Sunray	Moore	
EXC Wind 8 LLC	Sunray	Moore	
Exelon LaPorte Generating Station	LaPorte	Harris	Municipality
Falcon Dam & Power	Falcon Heights	Starr	Rio Grande
Facility	Lewisville	DENTON	
Fayette Power Project	La Grange	Fayette	Fayette County Lake
Floydada		Floyd	N/A
Forest Creek Wind Farm LLC	Big Springs	Glasscock	NA
Forney Energy Center	Forney	Kaufman	Duck Creek Water Treatment
Fort Davis	Ft. Davis	Jeff Davis	
Fort Phantom	Abilene	Jones	Lake
Fort Stockton	None	Pecos	Wells
Freestone Power Generation LLC	Fairfield	Freestone	Richland Chambers Resovoir
Frontera Energy Center	Mission	Hidalgo	Rio Grande
Gateway Power Project		Upshur	Municipality
Gibbons Creek	Anderson	Grimes	Gibbons Creek
Goat Wind LP	Sterling City	Sterling	
Gonzales Hydro Plant	Gonzales	Gonzales	Municipality
Graham	Graham	Young	Lake Graham
Granite Shoals	Marble Falls	Burnet	Lake Lyndon B. Johnson
Greens Bayou	Houston	Harris	Lake Houston
Gregory Power Facility	Gregory	San Patricio	San Patricio Municipality

ELECTRIC GENERATORS IN THE STATE OF TEXAS

ELECTRIC GENERATORS IN THE STATE OF TEXAS

PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Guadalupe Generating Station	Marion	Guadalupe	Lake Dunlap
LLC	Big Spring	Howard	
H 4	Cost	Gonzales	Guadalupe River
H 5	Gonzales	Gonzales	Guadalupe River
Hackberry Wind Farm	Albany	Shackelford	NA
Handley	Fort Worth	Tarrant	Lake Arlington
Hardin County Peaking Facility	Kountze	Hardin	NA
Harrington	Amarillo	Potter	Municipality
Harris Energy Facility		Harris	City Of Houston
Harrison County Power Project	Marshall	Harrison	City Of Longview
Hartburg		Newton	
Hays Energy Project	San Marcos	Hays	GBRA/City of San Marcos
Hidalgo Energy Center	Edinburg	Hidalgo	City Of McAllen
Hidalgo Wind Farm LLC	McCook	Hidalgo & Starr	
High Plains Wind Power LLC	Panhandle	Carson	
Hiram Clarke	Houston	Harris	Water Wells
Holly Street	Austin	Travis	Colorado River
Horse Hollow Wind Energy Center	Wingate	Taylor	
Hueco Mountain Wind Ranch	Horizon City	Hudspeth	N/A
Inadale Wind Farm LLC	Roscoe	Nolan	
Inks	Buchanan Dam	Burnet	Inks Lake
IPA Texas Solar LLC	San Marcos	HAYS	
J K Spruce	San Antonio	Bexar	San Antonio River
J L Bates	Palmview	Hidalgo	Hidalgo Co. Dist. #6 and wells
J Robert Massengale	Lubock	Lubbock	Municipality
J T Deely	San Antonio	Bexar	San Antonio River
Jack County	Bridgeport	Wise	Lake Bridgeport
Johnson County	Cleburne	Johnson	Municipal
Jones	Lubbock	Lubbock	Municipality
Kaufman	Mesquite	Kaufman	River
King Mountain Wind Ranch 1	McCamey	Upton	
Knox Lee	Longview	Gregg	Lake Cherokee
La Palma	San Benito	Cameron	Resaca De Los Fresnos
Lake Creek	Waco	McLennan	Lake Creek Lake
Lake Hubbard	Sunnyvale	Dallas	Lake Ray Hubbard
Lake Pauline	Quanah	Hardeman	Lake
Lamar Power Project	Paris	Lamar	Lake Pat Mayse
Langford Wind Power	Christoval	Tom Green	
Laredo	Laredo	Webb	Rio Grande River

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PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Leon Creek	San Antonio	Bexar	Wells
Lewis Creek	Willis	Montgomery	Lewis Creek Reservoir
Lewisville	Lewisville	DENTON	Lewisville Lake
Limestone	Jewett	Limestone	Lake Limestone
Little Pringle I Wind Farm	Morse	HANSFORD	
Little Pringle II Wind Farm	Morse	HANSFORD	
Llano Estacado Wind Ranch	White Deer	Carson	
Lon C Hill	Corpus Christi	Nueces	Municipality
Lone Star	Lone Star	Morris	Ellison Creek Reserv
Loraine Windpower Park LLC	Loraine	Mitchell	
Lost Pines 1 Power Project	Bastrop	Bastrop	Lake Bastrop
Lubbock Wind Ranch	Lubbock	Lubbock	
Magic Valley Generating Station	Edinburg	Hidalgo	Municipality
Majestic 1 Wind Farm	Panhandle	Carson	n/a
Majestic 2 Wind Farm	Panhandle	CARSON	na
Marble Falls	Marble Falls	Burnet	Lake Marble Falls
Markham Energy Storage Center		Matagorda	N/A
Marshall Ford	Austin	Travis	Lake Travis
Martin Lake	Tatum	Rusk	Martin Lake
MC Energy Project	Dobbin	Montgomery	Lake Conroe
McAdoo Wind Energy LLC	McAdoo	Dickens	
McAllen Energy Facility		Hidalgo	
McKinney LFG	McKinney	Collin	
Mesquite Creek LFGTE Project	New Braunfels	COMAL	
Mesquite Wind Power LLC	Abilene	Shackelford	
Midlothian Energy Facility	Midlothian	Ellis	None (Air Cooled)
Mirant Texas Weatherford	Weatherford	Parker	Brazos River
Mission Road	San Antonio	Bexar	Wells
Monticello	Mount Pleasant	Titus	Monticello Reservoir
Moore County	Sunray	Moore	Wells
Morgan Creek	Colorado City	Mitchell	Lake Colorado City
Morris Sheppard	Graford	Palo Pinto	Brazos River
Mountain Creek	Dallas	Dallas	Mountain Creek Lake
Mustang Station	Denver City	Yoakum	Wells
Mustang Station Unit 4	Denver City	Yoakum	Wells
Nacogdoches Power	Cushing	Nacogdoches	Angelina River
Neches	Beaumont	Jefferson	Neches River
Newgulf Cogen	NewGulf	Wharton	San Bernard River
Newman	El Paso	El Paso	Wells/Treated Municipal Waste

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PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Nichols	Amarillo	Potter	Municipality
Noble Great Plains Windpark LLC	Spearman	Hansford	
Nolte	Seguin	Guadalupe	Guadalupe River
North Dayton Gas Storage Facility		Liberty	
North Lake	Coppell	Dallas	North Lake
North Main	Fort Worth	Tarrant	Trinity River
North Texas	Weatherford	Parker	Lake Weatherford
Notrees Windpower	Goldsmith	Ector	
Nueces Bay	Corpus Christi	Nueces	Corpus Christi Ship Channel
Nueces Energy Project		Nueces	
NWP Indian Mesa Wind Farm	Iraan	Pecos	
O W Sommers	San Antonio	Bexar	San Antonio River
Oak Creek	Blackwell	Coke	Lake
Oak Grove	Franklin	Robertson	Twin Oak Reservoir
Oak Grove	Franklin	Robertson	Twin Oak Reservoir
Oak Ridge North Power	North	Montgomery	Municipal
Ocotillo Windpower	Forsan	Howard	
Odessa Ector Generating Station	Odessa	Ector	Wells
Oklaunion	Oklaunion	Wilbarger	Municipality
Optim Energy Altura Cogen LLC	Channelview	Harris	San Jacinto River Basin
Oyster Creek Unit VIII	Freeport	Brazoria	Brazos River (Dow Chemical)
P H Robinson	Bacliff	Galveston	Dickinson Bay
Paint Creek	Haskell	Haskell	Lake
Paris Energy Center	Paris	Lamar	Pat Mayse , Lamar County
Parkdale	Dallas	Dallas	Surface And Wells
Pasadena Cogeneration	Pasadena	Harris	Coastal Ind. Water Authority
Pattern Gulf Wind	Armstrong	Kenedy	na
Pearsall	Pearsall	Frio	Wells
Penascal II Wind Project LLC	Sarita	Kenedy	
Penascal Wind Power LLC	Sarita	Kenedy	
Permian Basin	Monahans	Ward	Wells
Pflugerville Solar Farm	Manor	Travis	
Pirkey	Hallsville	Harrison	Brandy Branch Reserv
Plant X	Earth	Lamb	Wells
Post Oak Wind LLC	Abilene	Shackelford	
Post Wind Farm LP	Fluvanna	Borden	
Powerlane Plant	Greenville	HUNT	No 4 Resevoir
Presidio	Presidio	Presidio	Municipality
Pyron Wind Farm LLC	Hermleigh	Fisher	

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PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
Quail Run Energy Center	Odessa	Ector	Texland Great Plants Water Sup
R W Miller	Palo Pinto	Palo Pinto	Lake Palo Pinto
Ralls Wind Farm	Ralls	Crosby	
Ray Olinger	Navada	Collin	Lake Lavon
Ray Roberts	Aubrey	Denton	Ray Roberts Resevoir
Rio Nogales Power Project	Seguin	Guadalupe	Municipality
Rio Pecos	Girvin	Crockett	Wells
River Crest	Bogota	Red River	River Crest Lake
Riverview	Borger	Hutchinson	N/A
Robert D Willis	Jasper	Jasper	Angelina River
Robert Mueller Energy Center	Austin	Travis	Municipality
Robstown	Robstown	Nueces	Nueces Water District
Roscoe Wind Farm LLC	Roscoe	Nolan	NA
Sabine	Bridge City	Orange	Sabine Lake
Sabine Cogen	Orange	Orange	Sabine River
Sam Bertron	Laporte	Harris	Houston Ship Channel
Sam Rayburn	Nursery	Victoria	Guadalupe River
Sam Rayburn	Jasper	Jasper	Angelina River
San Angelo	San Angelo	Tom Green	Lake
San Jacinto County Peaking Facility	Shepherd	San Jacinto	NA
San Jacinto Steam Electric Station	La Porte	Harris	Dupont
San Miguel	Christine	Atascosa	Wells
Sand Bluff Wind Farm	Big Spring	Glasscock	N/A
Sand Hill	Austin	Travis	Colorado River/ SA Reg WWTP
Sandow No 4	Rockdale	Milam	Lake Alcoa
Sandy Creek Energy Station	Riesel	McLennan	WMARSS
Scurry County Wind II	Snyder	Scurry	
Scurry County Wind LP	Snyder	Scurry	
Security	Cleveland	Liberty	Municipality
Sherbino I Wind Farm	Fort Stockton	Pecos	N/A
Sherbino II	Fort Stockton	Pecos	
Signal Hill Wichita Falls Power LP	Wichita Falls	Wichita	Municipality
Silas Ray	Brownsville	Cameron	Rio Grande River
Silver Star I Wind Power Project	Dublin	Erath	N/A
Sim Gideon	Bastrop	Bastrop	Lake Bastrop
Skyline Gas Recovery	Ferris	Dallas	
Small Hydro of Texas	Cuero	De Witt	Guadalupe River
Snyder Wind Farm	Synder	Lincoln	N/A
South Texas Project	Wadsworth	Matagorda	Colorado River

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PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
South Trent Wind Farm	Sweetwater	Nolan	N/A
Spencer	Denton	Denton	Municipality
SRW Cogen LP	Orange	Orange	Sabine River Authority Canal
Stanton Wind Energy LLC	Lenorah	Martin	
Stryker Creek	Jacksonville	Cherokee	Stryker Creek Reservoir
Sunray Wind I	Sunray	Moore	
Sunset Farms	Austin	Travis	N/A
Sweeny Cogen Facility	Old Ocean	Brazoria	San Bernard River
Sweeny IGCC Plant	Old Ocean	Brazoria	Refinery Effluent Water
Sweetwater Wind 1 LLC	Sweetwater	Nolan	NA
Sweetwater Wind 2 LLC	Sweetwater	Nolan	NA
Sweetwater Wind 3 LLC	Sweetwater	Nolan	NA
Sweetwater Wind 4 LLC	Roscoe	Nolan	n/a
Sweetwater Wind 5	Roscoe	Nolan	n/a
T H Wharton	Houston	Harris	Water Wells
Tenaska Frontier Generation Station	Shiro	Grimes	Municipallity
Station	Mt. Enterprise	Rusk	Sabine River
Tessman Road	San Antonio	Bexar	N/A
Texas City Cogeneration LLC	Texas City	Galveston	Brazos River
Texas Gulf Wind 2	Armstrong	Kenedy	na
Thomas C Ferguson	Marble Falls	Llano	Lake Lyndon B. Johnson
Toledo Bend	Burkville	Newton	Toledo Bend Reservoir
Tolk	Muleshoe	Lamb	Wells
TP 4	Seguin	Guadalupe	Guadalupe River
Tradinghouse Power Company LLC	Waco	McLennan	Tradinghouse Creek Reservoir
Trent Wind Farm LP	Trent	Nolan	
Trinidad	Trinidad	Henderson	Trinidad Lake
Trinity Hills	Olney	Young	
Tulia	Tulia	Swisher	Municipality
Turbine	El Paso	El Paso	
Turkey Track Wind Energy LLC	Nolan	Nolan	
Twin Oaks Power One	Bremond	Robertson	Wells
TXU Sweetwater Generating Plant	Sweetwater	Nolan	Municipality
Ty Cooke	Lubbock	Lubbock	Municipality
V H Braunig	Elmendorf	Bexar	San Antonio River
Valley NG Power Company LLC	Savoy	Fannin	Valley Lake
Vernon	Vernon	Wilbarger	Municipality
Victoria	Victoria	Victoria	Wells and Guadalupe River
W A Parish	Thompsons	Fort Bend	Smithers Lake

PLANT NAME	CITY	COUNTY	WATER SOURCE NAME
W B Tuttle	San Antonio	Bexar	Wells
Watermill Electric Generating		Ellis	
Weatherford	Weatherford	Parker	Municipality
Webberville Solar Project	Manor	Travis	
Webster	Webster	Harris	Clear Lake
Welsh	Pittsburg	Titus	Swauano Creek Reserv
West Texas Energy Facility		El Paso	
West Texas Wind Energy LLC	McCamey	Upton	
West Texas Windplant	Van Horn	Culberson	
Westex Windpower Facility	Big Spring	HOWARD	N/A
Westside Landfill Gas Recovery	Aledo	PARKER	NA
Whirlwind Energy Center	Floydada	Floyd	N/A
Whitesboro	Whitesboro	Grayson	Municipality
Whitney	Clifton	Bosque	Brazos River
Wildorado Wind Ranch	Amarillo	Potter	
Wilkes	Avinger	Marion	Johnson Creek Reserv
Winchester Power Park	Winchester	Fayette	
Wise County Power LLC	Poolville	Wise	Municipal
Wolf Hollow I LP	Granbury	Hood	Lake Granbury
Woodlands Area Power Project	Conroe	Montgomery	Water Well
Woodward Mountain I	Girvin	Pecos	
Woodward Mountain II	Girvin	Pecos	

ELECTRIC GENERATORS IN THE STATE OF TEXAS

Reference for Appendix

1. U.S. DOE, EIA. November 30, 2011. Form EIA-860 Annual Electric Generator Report. Form EIA-860 datafiles available for download from: http://205.254.135.7/cneaf/electricity/page/eia860.html. Accessed June 2012.

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