United States Government Accountability Office

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Report to the Chairman, Committee on Science and Technology, House of Representatives

October 2009

ENERGY-WATER NEXUS

Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use

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Highlights

Highlights of GAO-10-23, a report to the Chairman, Committee on Science and Technology, House of Representatives

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ENERGY-WATER NEXUS

Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use

Why GAO Did This Study

In 2000, thermoelectric power plants accounted for 39 percent of total U.S. freshwater withdrawals. Traditionally, power plants have withdrawn water from rivers and other water sources to cool the steam used to produce electricity, so that it may be reused to produce more electricity. Some of this water is consumed, and some is discharged back to a water source.

In the context of growing demands for both water and electricity, this report discusses (1) approaches to reduce freshwater use by power plants and their drawbacks, (2) states' consideration of water use when reviewing proposals to build power plants, and (3) the usefulness of federal water data to experts and state regulators. GAO reviewed federal water data and studies on cooling technologies. GAO interviewed federal officials, as well as officials from seven selected states.

What GAO Recommends

To improve federal data collection efforts, GAO is making several recommendations, including that EIA consider collecting and reporting data on power plants' use of advanced cooling technologies and alternative water sources, and that USGS consider reinstating collection of data on power plant water consumption and distributing data on the use of alternative water sources. USGS agreed with our recommendations. DOE provided technical comments that we incorporated, as appropriate.

View GAO-10-23 or key components.
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What GAO Found

Advanced cooling technologies that rely on air to cool part or all of the steam used in generating electricity and alternative water sources such as treated effluent can reduce freshwater use by thermoelectric power plants. Use of such approaches may lead to environmental benefits from reduced freshwater use, as well as increase developer flexibility in locating a plant. However, these approaches also present certain drawbacks. For example, the use of advanced cooling technologies may result in energy production penalties and higher costs. Similarly, the use of alternative water sources may result in adverse effects on cooling equipment or regulatory compliance issues. Power plant developers must weigh these drawbacks with the benefits of reduced freshwater use when determining which approaches to pursue.

Consideration of water use by proposed power plants varies in the states GAO contacted, but the extent of state oversight is influenced by state water laws, related state regulatory policies, and additional layers of state regulatory review. For example, California and Arizona—states that historically faced constrained water supplies, have taken formal steps aimed at minimizing freshwater use at power plants. In contrast, officials in five other states GAO contacted said that their states had not developed official policies regarding water use by power plants and, in some cases, did not require a state permit for water use by new power plants.

Federal agencies collect national data on water availability and water use; however, of these data, state water agencies rely on federal water availability data when evaluating power plants' proposals to use freshwater more than federal water use data. Water availability data are collected by the U.S. Geological Survey (USGS) through stream flow gauges, groundwater studies, and monitoring stations. In contrast, federal data on water use are primarily used by experts, federal agencies, and others to identify industry trends. However, these data users identified limitations with the federal water use data that make them less useful for conducting trend analyses and tracking industry changes. For example, the Department of Energy's (DOE) Energy Information Administration (EIA) does not systematically collect information on the use of advanced cooling technologies and other data it collects are incomplete. Similarly, USGS discontinued distribution of data on water consumption by power plants and now only provides information on water withdrawals. Finally, neither EIA nor USGS collect data on power plant developers' use of alternative water sources, which some experts believe is a growing trend in the industry. Because federal data sources are a primary source of national data on water use by various sectors, data users told GAO that without improvements to these data, it becomes more difficult for them to conduct comprehensive analyses of industry trends and limits understanding of changes in the industry.

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Abbreviations

CEC	California Energy Commission
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
USGS	U.S. Geological Survey

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United States Government Accountability Office
Washington, DC 20548

October 16, 2009

The Honorable Bart Gordon
Chairman
Committee on Science and Technology
House of Representatives

Water and electricity are inexorably linked and mutually dependent, with each affecting the other's availability. Electricity is required to supply, purify, distribute, and treat water and wastewater; water is needed to generate electricity and to extract and process fuels used to generate electricity. Freshwater and electricity are important to our health, quality of life, and economic growth, and demand for both of these resources is rising. Freshwater is increasingly in demand to meet the needs of the public in growing cities and suburbs, farms, industries, and for recreation and wildlife. At the same time, electricity demand is projected to continue to grow in the United States, with the Department of Energy (DOE) estimating that U.S. electricity consumption will increase by an average of about 1 percent each year from 2007 through 2030. Limited availability of freshwater may make it more difficult to build new power plants, particularly in communities concerned about the adequacy of their water supply and maintaining the quality of aquatic environments. Periodic water shortages may also make it difficult for existing plants to satisfy demand for electricity. In recent years, water shortages and high water temperatures have caused reductions in electricity production at power plants in the United States and abroad, according to news reports.

In 2007, around three-fourths of the United States' electricity generating capacity consisted of thermoelectric power plants, which rely heavily on water for cooling. Thermoelectric power plants use a fuel source—for example, coal, natural gas, nuclear material such as uranium, or the sun—to boil water (boiler water) to produce steam. The steam turns a turbine connected to a generator that produces electricity. The steam is then cooled back into boiler water, a process which traditionally involves transferring heat from the steam to a separate water source (cooling water) and reusing it. Because the cooling water takes on the heat of the boiler water, some of it may evaporate, and the amount that evaporates varies, depending on the type of cooling technology that is used. In recent years, the majority of new thermoelectric power generating units have been combined cycle units, which use two processes to produce electricity, one of which is thermoelectric. In this type of plant, electricity is first generated by a simple cycle turbine that turns a generator directly as a result of burning fuel in the turbine—similar to jet engines used in aircraft. The heat produced by the simple cycle turbine that would otherwise be released to the atmosphere is used to produce steam which turns a steam turbine connected to a generator to produce electricity. Because some of the electricity is generated via the simple cycle turbine—a non-thermoelectric process—combined cycle plants use less water for cooling than similarly sized plants using only steam to produce electricity. Non-thermoelectric power plants, which accounted for the other one-quarter of 2007 U.S. electricity generating capacity, do not use water for cooling but still require water for other plant purposes, such as water for improving turbine performance on non-thermoelectric natural gas plants, as well as water for housekeeping activities.

Water use by thermoelectric power plants can be generally characterized as withdrawal, consumption, and discharge. Water withdrawals refer to water removed from the ground or diverted from a surface water source—for example, an ocean, river, or lake—for use by the plant. In 2000, the most recent USGS data available, thermoelectric power plants accounted for 39 percent of total U.S. freshwater withdrawals. Water consumption refers to the portion of the water withdrawn that is no longer available to be returned to a water source, such as when it has evaporated. In 1995, the most recent USGS data available, thermoelectric power plants accounted for 3 percent of freshwater consumption in the United States. Discharge refers to the return of water to its original source or a new source and represents the difference between withdrawals and consumption. For many thermoelectric power plants, much of the water they withdraw is later discharged, although often at higher temperatures. The amount of water discharged from a thermoelectric power plant depends on a number of factors, including the type of cooling technology used, plant economics, and environmental regulations.

Decisions to build a new power plant may be made independently by the power plant developer or with the consent of a state public utility commission. In either case, power plant developers must obtain approval from a number of state and local officials, generally by obtaining preconstruction and operating permits, before they can proceed with building their plant in a particular location. This process is meant to balance any adverse impacts a power plant may have on nearby communities and environments with the benefits it provides, such as energy supply and jobs. This regulation of the electricity industry's water use is complex and involves both state and federal laws. States are primarily responsible for managing the allocation and use of freshwater supplies. However, federal laws provide for control over the use of water in specific cases, such as on federal lands or in interstate commerce. In addition to the water power plants may withdraw, for which developers have to seek permits or purchase a water right, power plants may have to obtain permits to discharge water, since water discharged from a plant is regulated by the federal government and the states to ensure that it meets certain quality standards and does not harm protected species.[1] In some cases, plants may design their operations so they discharge no water into sources outside the plant boundaries, known as zero-liquid discharge.

Two federal agencies—the Department of the Interior's U.S. Geological Survey (USGS) and the Energy Information Administration (EIA), the independent statistical and analytical agency within DOE—collect key data that address how power plants use water. In addition, Congress recently passed the Omnibus Public Land Management Act of 2009, which included provisions known as the Secure Water Act.[2] The law authorizes, among other things, additional funding for the Department of the Interior to report water data to Congress, including thermoelectric power plant withdrawal data. Congress is also considering pending legislation related to energy and water. The Energy and Water Integration Act of 2009, among other things, calls for the National Academy of Sciences to conduct an analysis of the impact of energy development and production on U.S. water resources, including an assessment of water used in electricity production.[3] Similarly, the Energy and Water Research Integration Act directs DOE to take such steps as advancing energy and energy efficiency technologies that minimize freshwater use, increase water use efficiency, and utilize alternative water sources.[4] It also provides for the creation of a council to enhance energy and water resource data collection, including improving data on trends in power plant water use, among other things.

Because of the importance of freshwater to the public and society at large, the environment, and many industries, information about the country's current and expected use of freshwater and electricity is critical to making appropriate decisions about how these resources are managed. In this context, you asked us to provide information about the relationship

[1]The Environmental Protection Agency announced in a September 15, 2009, press release its plans to revise existing standards for water discharges from coal-fired power plants.

[2]Pub. L. No. 111-11, § 9508 (2009).

[3]S. 531, 111th Cong. § 2 (2009).

[4]H.R. 3598, 111th Cong. (2009).

between water and energy, which we will be addressing in several reports.[5] This report discusses water use in electricity production. More specifically, this report (1) describes technologies and other approaches to help reduce freshwater use by power plants and what, if any, drawbacks there are to using them, (2) describes the extent to which selected states consider water impacts of power plants when reviewing power plant development proposals, and (3) evaluates the usefulness of federal water data to experts and state regulators who evaluate power plant development proposals. We focused our evaluation on thermoelectric power plants, such as nuclear, coal, and certain natural gas plants. We did not consider the water supply issues associated with hydroelectric power, since the process through which hydroelectric plants use water is substantially different from that of thermoelectric plants and water is used to generate hydroelectric power without being directly consumed. We also limited our review to water used during the production of electricity at power plants and did not include water issues associated with extracting fuels used to produce electricity.

To understand technologies or other approaches to help reduce freshwater use by power plants and what, if any, drawbacks there are to using them, we reviewed industry, federal, and academic studies on alternative water sources and advanced cooling technologies that discussed these alternatives' benefits, as well as their drawbacks. We discussed the trade-offs associated with the use of these alternatives with power plant and cooling system manufacturers, U.S. national laboratory staff, academics, and other industry experts. To determine the extent to which selected states consider water impacts of power plants when reviewing power plant development proposals, we conducted case study reviews of three states: Arizona, California, and Georgia. We selected these states because of their differences in water availability and water law, high energy production, and large population centers. For each of these states, we met with state water regulators and siting authorities, power plant developers, water research institutions, and other subject matter experts. We also reviewed state water laws and policies for power plant water use. To supplement our case studies, we spoke with water regulators from four additional states: Nevada and Alabama, which shared watersheds with the

[5]We provided preliminary information from our work on two of these reports—biofuels and water use and thermoelectric power plants and water use—in a testimony before the Subcommittee on Energy and Environment in July 2009. GAO, *Energy and Water: Preliminary Observations on the Links between Water and Biofuels and Electricity Production.* (Washington, D.C.: July 9, 2009). GAO-09-862T.

case study states, and Illinois and Texas, which are large electricity producing states with sizable population centers. We did not attempt to determine whether states' efforts were reasonable or effective, rather, we only describe what states do to consider water impacts when making power plant siting decisions. To understand the usefulness of federal water data to experts and state regulators who evaluate power plant development proposals, we reviewed data and analysis from USGS and DOE's EIA and National Energy Technology Laboratory. We also conducted interviews about the usefulness of federal data with data users, including federal agencies; regulators from state departments of water resources and public utility commissions; and experts from environmental and water organizations, industry, and academia. A more detailed description of our scope and methodology is presented in appendix I.

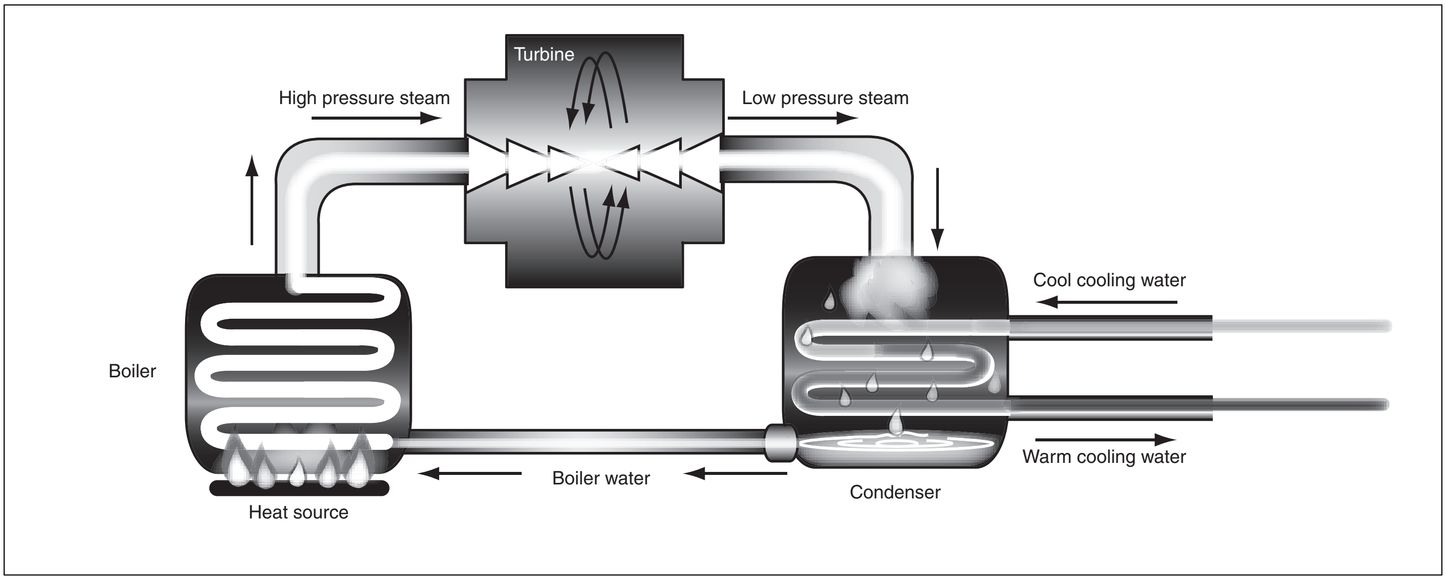
We conducted this performance audit from October 2008 to October 2009, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Power plant developers consider many factors when determining where to locate a power plant, including the availability of fuel, water, and land; access to electrical transmission lines; electricity demand; and potential environmental issues. Often, developers will consider several sites that meet their minimum requirements, but narrow their selection based on economic considerations such as the cost of accessing fuel, water, or transmission lines, or the costs of addressing environmental factors at each specific site.

One key requirement for thermoelectric power plants is access to water. Thermoelectric power plants use a heat source to make steam, which is used to turn a turbine connected to a generator that makes electricity. As shown in figure 1, the water used to make steam (boiler water) circulates in a closed loop. This means the same water used to make steam is also converted back to liquid water —referred to as condensing—in a device called a condenser and, finally, moved back to the heat source to again make steam. In typical thermoelectric plants, water from a separate source, known as cooling water, flows through the condenser to cool and condense the steam in the closed loop after it has turned the turbine.

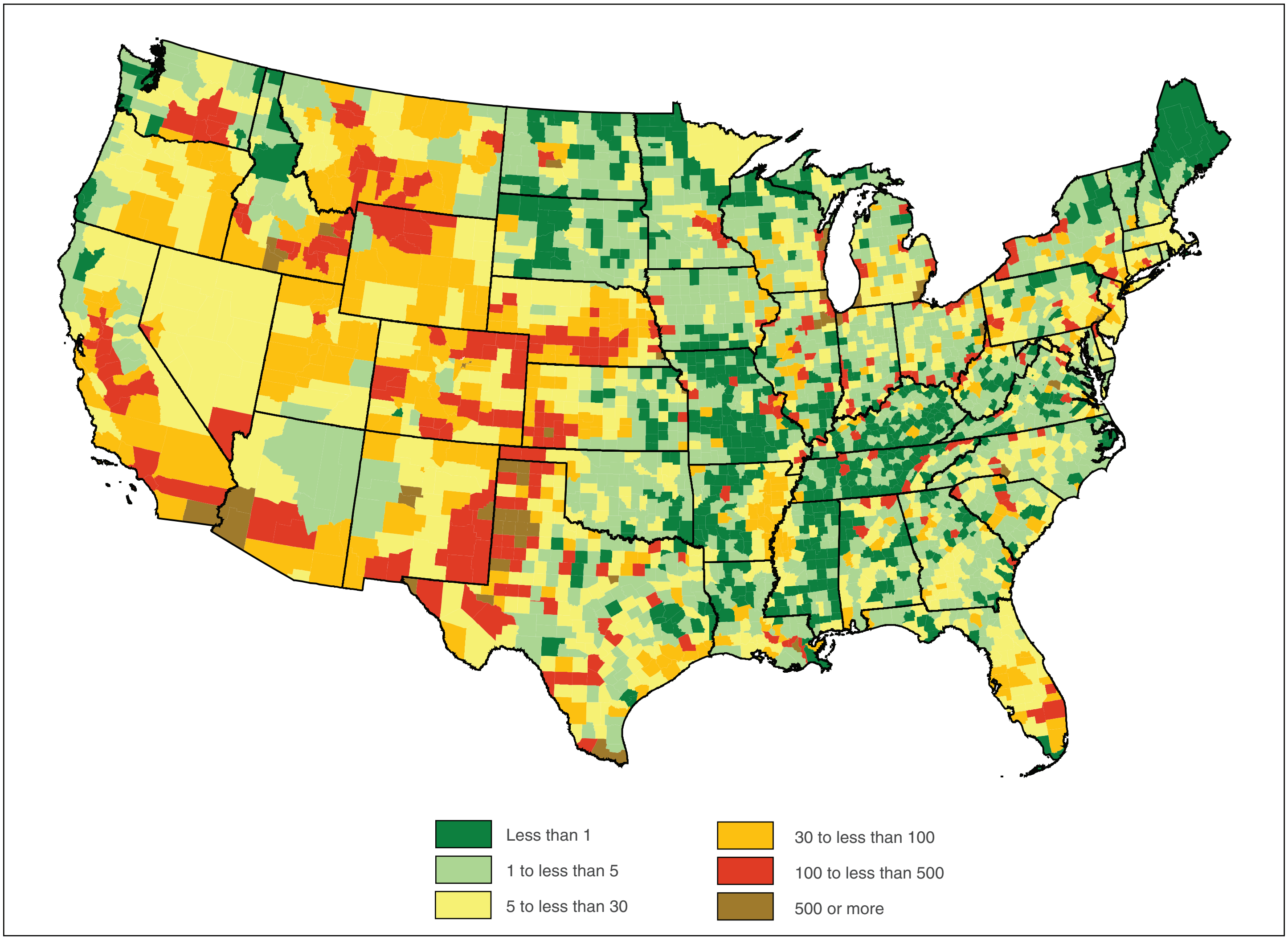
Figure 1: Diagram of a Boiler Water Loop in a Power Plant



Source: GAO analysis of various national laboratory and industry sources.

Consideration of water availability during the power plant siting process can pose different challenges in different parts of the country because precipitation and, relatedly, water availability varies substantially across the United States. Figure 2 shows the total amount of freshwater withdrawn in the United States as a percentage of available precipitation. Areas where the percentage is greater than 100—where more water is withdrawn than locally renewed through precipitation—are indicative of basins using other water sources transported by natural rivers and manmade flow structures, or may indicate unsustainable groundwater use.

Figure 2: Total Freshwater Withdrawal in 1995 as a Percentage of Available Precipitation



Source: Electric Power Research Institute. *A Survey of Water Use and Sustainability in the United States With a Focus on Power Generation.* (Palo Alto, CA. 2003.) 1005474; Map (Mapinfo).

Note: According to an Electric Power Research Institute official, the organization plans to update this analysis once USGS publishes 2005 freshwater withdrawal data.

Power plants can use various types of water for cooling—such as freshwater or saline water—and different water sources, including surface water, groundwater, and alternative water sources. An example of alternative water sources is reclaimed water such as treated effluent from sewage treatment plants. To make siting decisions, power plant developers typically consider the water sources that are available and least costly to use. Fresh surface water is the most common water source for power plants nationally, as shown in table 1.

Table 1: Estimated Water Withdrawals by Thermoelectric Power Plants in the United States in 2000

Millions of gallons per day

	Surface Water	Groundwater
Saline water	59,500	0
Freshwater	135,000	409

Source: U.S. Geological Survey, *Estimated Use of Water in the United States in 2000*, (Reston, Virginia, 2004).

Cooling Technologies

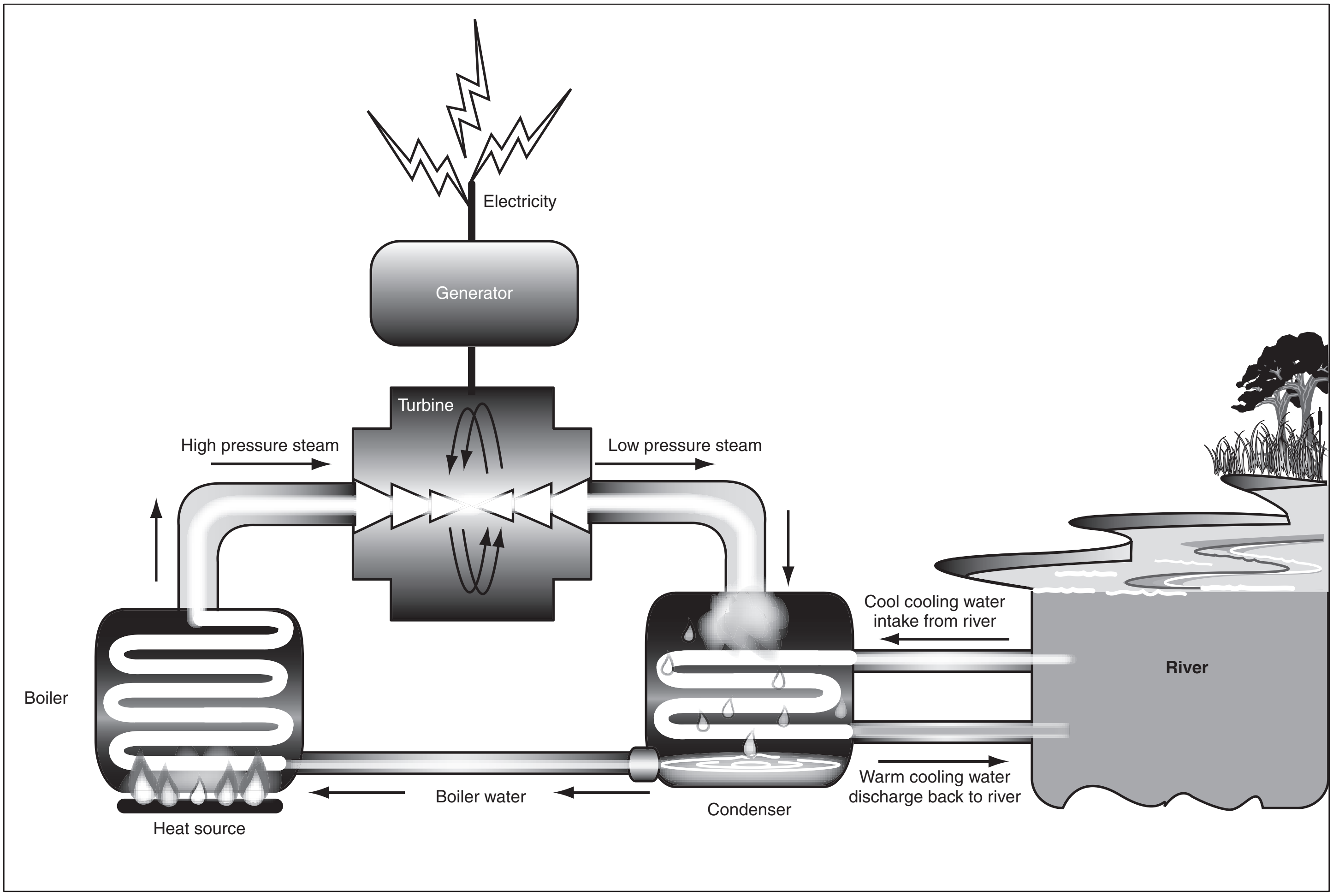
Power plant developers must also consider what cooling technologies they plan to use in the plant. There are four general types of cooling technologies. Traditional cooling technologies that have been used for decades include once-through and wet recirculating cooling systems. Advanced cooling technologies that have focused on reducing the amount of cooling water used are relatively newer in the United States and include dry cooling and hybrid cooling. Specifically:

Once-through cooling systems. In once-through cooling systems, large amounts of cooling water are withdrawn from a water body such as a lake, river, or ocean, and used in the cooling loop. As shown in figure 3, the cooling water passes through the tubes of a condenser. As steam in the boiler water loop exits the turbine, it passes over the condenser tubes. This contact with the condenser tubes cools and condenses the steam back into boiler water for reuse. After the cooling water passes through the condenser tubes, it is discharged back into the water body warmer than it was when it was withdrawn.[6] Once-through cooling systems withdraw a significant amount of water but directly consume almost no water. However, because the water discharged back into the water body is warmer, experts believe that once-through systems may increase evaporation from the receiving water body. Furthermore, because of

[6]Studies we reviewed indicated a range of temperature increases for water discharged from once-through cooling systems. EPA officials we spoke with told us that once-through cooling plants often discharge cooling water between 10 and 20 degrees Fahrenheit warmer than it was when it was withdrawn, but they explained that there are examples of plants above and below this range, as well.

concerns about the harm withdrawal for once-through systems can have on aquatic life—when aquatic organisms are pulled into cooling systems, trapped against water intake screens, or their habitat is adversely affected by warm water discharges—these systems are rarely installed at new plants.

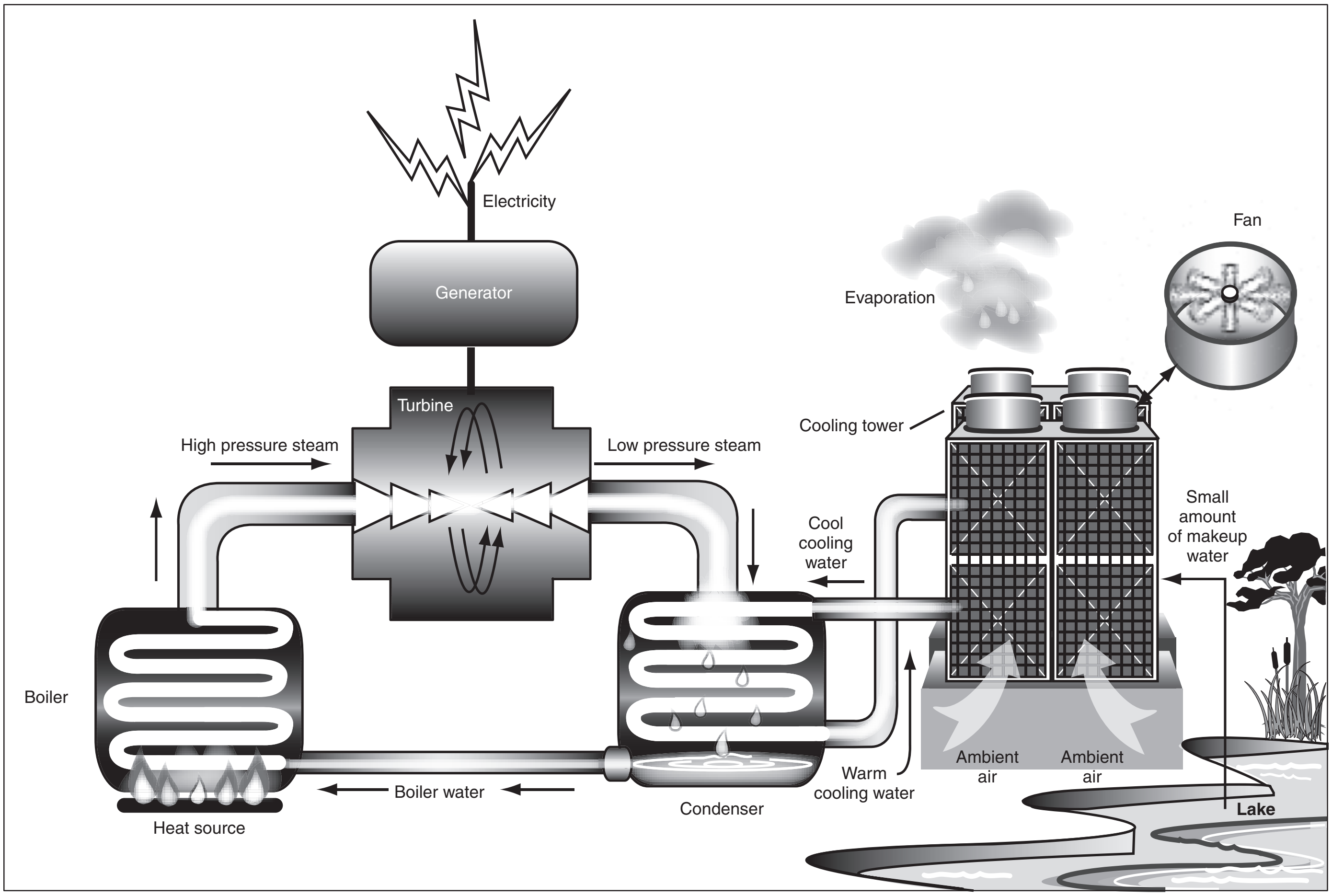
Figure 3: Diagram of a Once-through Cooling System



Source: GAO analysis of various national laboratory and industry sources.

Wet recirculating systems. Wet recirculating systems differ from once-through cooling systems in that they reuse cooling water multiple times. The most common type of recirculating system, shown in figure 4, uses cooling towers to dissipate the heat from the cooling water to the atmosphere. Similar to the once-through system, steam exiting the turbine is brought in contact with the tubes of a condenser that contain cooling water. The cooling water condenses the steam back into water for reuse in the boiler. The cooling water, warmed from the condenser, is then pumped to a cooling tower where it is exposed to the air. The heat from the warm cooling water is transferred to air flowing through the cooling tower, primarily through evaporation. In this process, some of the warm cooling water is consumed as it evaporates from the cooling tower, but most of it is returned to the condenser and used again. Over time, the quality of the cooling water is diminished as minerals and other dissolved and suspended solids present in the water are concentrated because of the water lost to evaporation. A portion of the cooling water containing the minerals and other dissolved solids must be discharged (known as blowdown) to prevent accumulation of those minerals and dissolved solids in the condenser, which could have adverse effects on condenser and cooling tower performance. For example, the National Energy Technology Laboratory estimated that a 520 megawatt wet recirculating system with a cooling tower circulates approximately 188,000 gallons of cooling water per minute. It withdraws around 5,000 gallons of water per minute to make up for the nearly 4,000 gallons per minute consumed through evaporation and approximately 1,000 gallons per minute discharged in the blowdown process. Some wet recirculating plants do not use a cooling tower but, instead, discharge cooling water to a pond, allowing it to cool before it is returned to the plant for reuse. For a wet recirculating system, water is only withdrawn from a water body to replace cooling water lost through evaporation and blowdown; thus, considerably less water is withdrawn than in a once-through cooling system. As a result, plants equipped with wet recirculating systems have relatively low water withdrawal but higher direct water consumption compared to once-through systems.

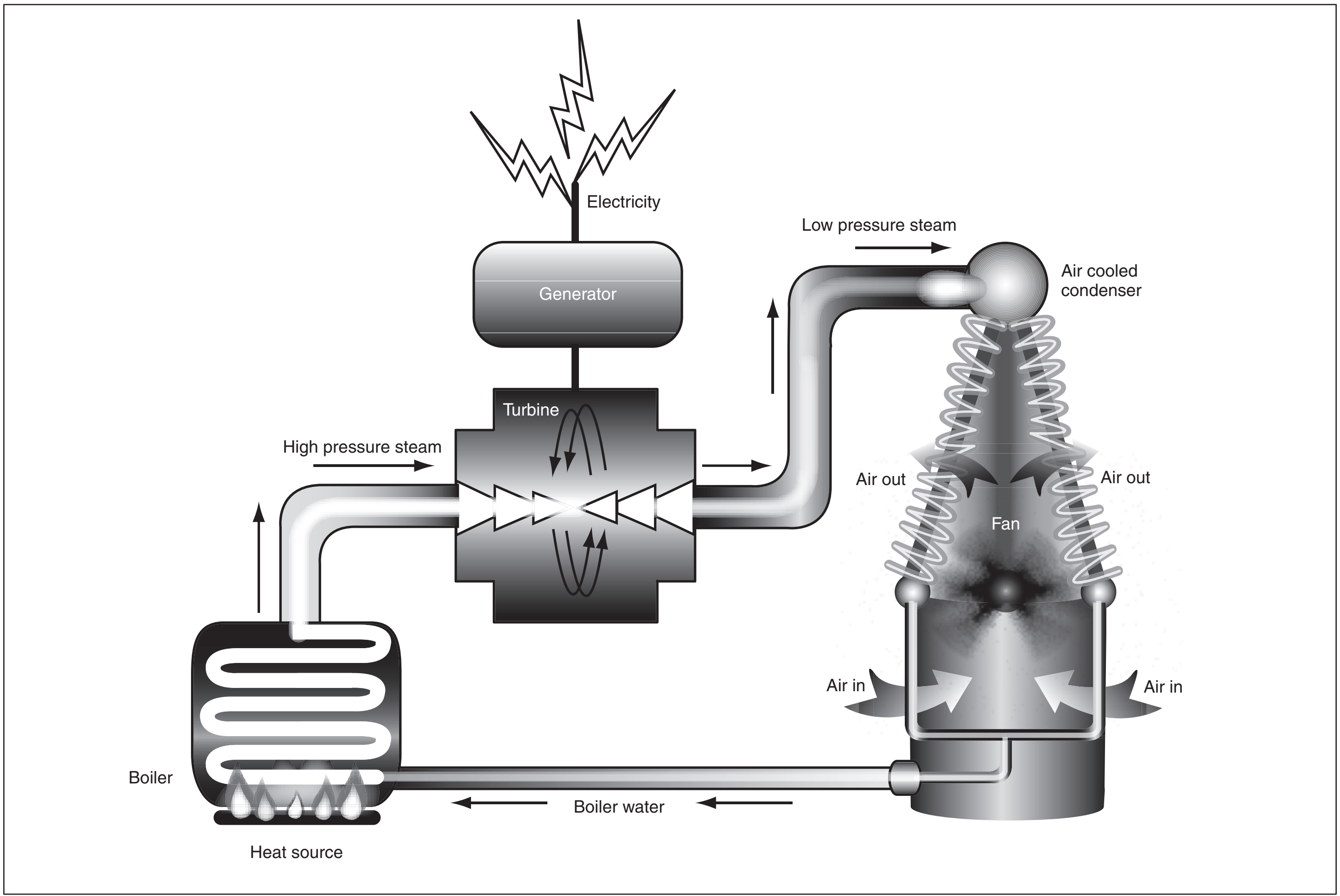
Figure 4: Diagram of a Wet Recirculating System with a Cooling Tower



Source: GAO analysis of various national laboratory and industry sources.

Dry cooling systems. Dry cooling systems rely primarily on air, rather than water, for cooling. In dry cooling systems, steam exiting the turbine flows through condenser tubes and is cooled directly by fans blowing air across the outside of these tubes to condense the steam back into liquid water. The cooled boiler water can then be reheated into steam to turn the turbine. In this approach, water is not used for cooling, although water still may be used for other plant purposes, such as pollution control equipment. As with the other systems, the steam, once cooled back into liquid water, is returned to the turbine for reuse.[7] See figure 5 for an illustration of dry cooling.

Figure 5: Diagram of a Dry Cooling System



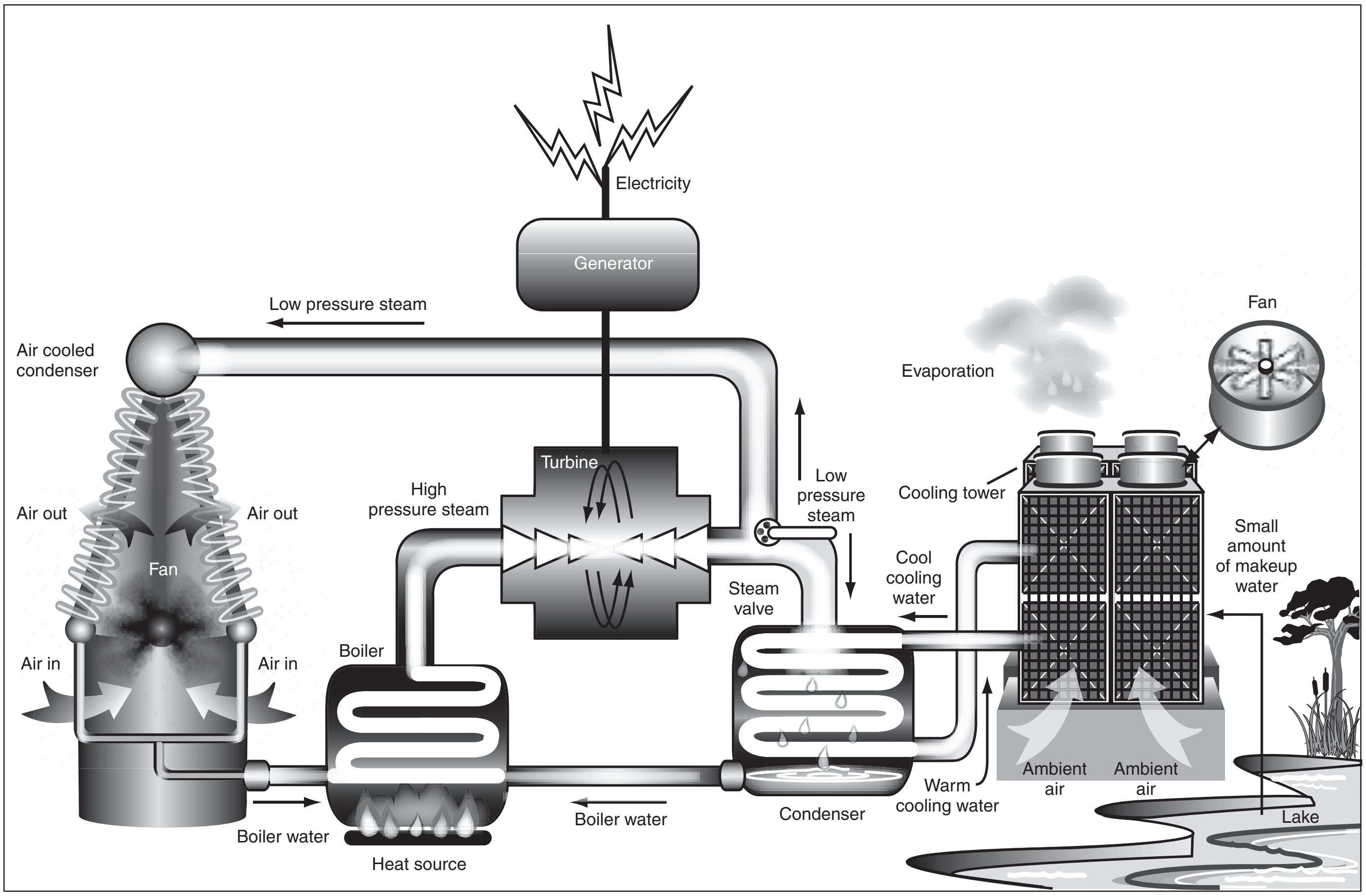
Source: GAO analysis of various national laboratory and industry sources.

[7]Another method of dry cooling, referred to as indirect dry cooling, uses a closed-loop of cooling water to condense the steam exiting the turbine—similar to recirculating systems. However, instead of dissipating the cooling water's heat through evaporation, a dry cooling tower is used to transfer the heat from the cooling water to the ambient air.

Hybrid cooling systems. Hybrid cooling technology offers a middle-ground option between wet and dry cooling systems, where wet and dry cooling components can be used either separately or simultaneously, as shown in figure 6. The system can operate both the wet and dry components in unison to increase cooling efficiency or may rely only on dry cooling to conserve water as needed.[8]

[8]Some experts we spoke with and documents we reviewed described two other types of hybrid cooling technology designs. One version is designed to minimize plumes released from wet recirculating systems with cooling towers; although, according to one expert, this version has very little effect on the plant's water consumption. The other consists of various system configurations designed to improve the efficiency of dry cooling by either spraying water on the air-cooled condenser directly or using water to lower the temperature of inlet air entering the air-cooled condenser.

Figure 6: Diagram of a Hybrid Cooling System

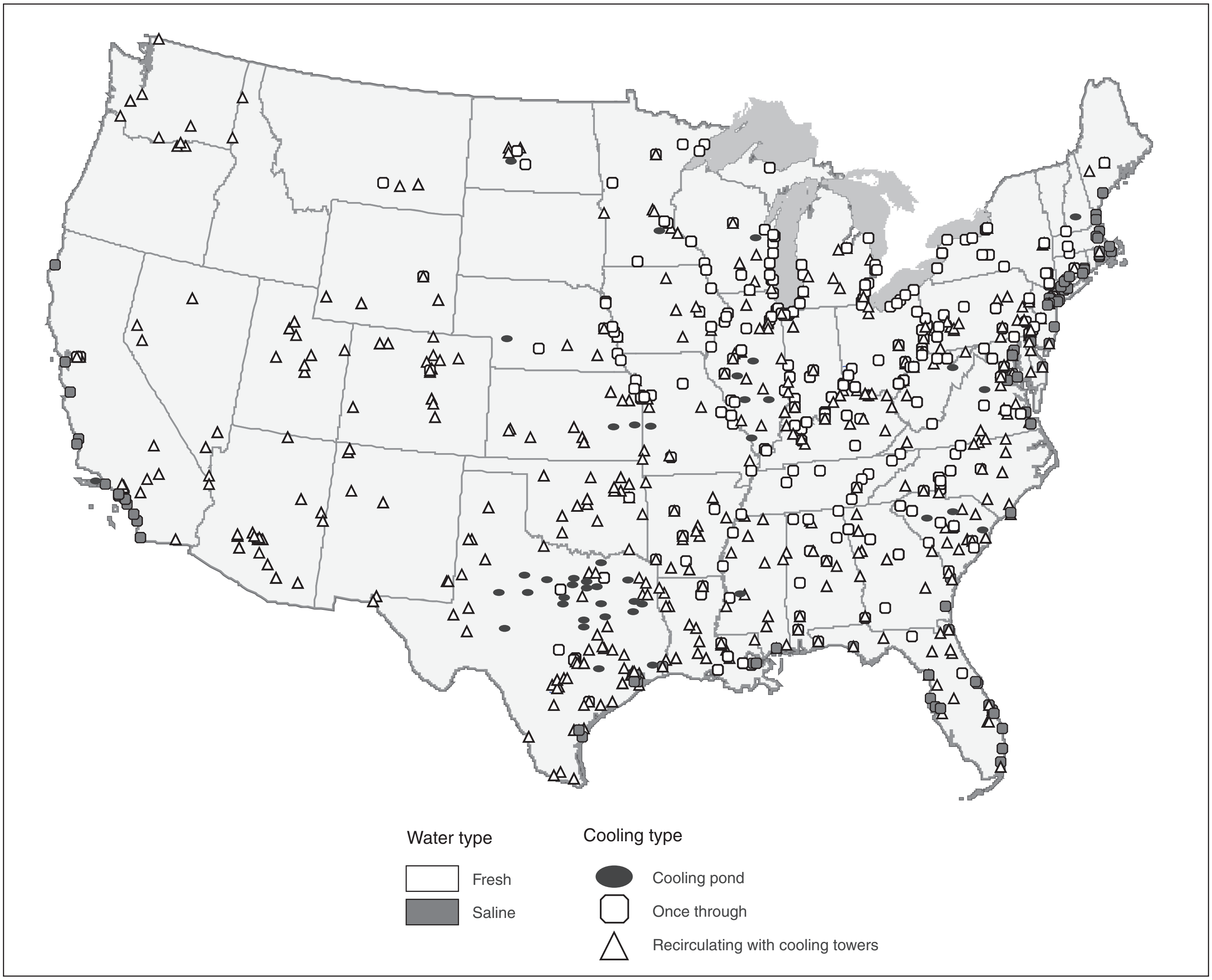


Source: GAO analysis of various national laboratory and industry sources.

In 2008, the National Energy Technology Laboratory—a U.S. DOE laboratory that conducts and implements science and technology research and development programs in energy—estimated that 42.7 percent of U.S. thermoelectric generating capacity uses once-through cooling, 41.9 percent uses cooling towers, 14.5 percent uses cooling ponds, and 0.9 percent uses dry cooling.[9] Figure 7 illustrates the prevalence of different cooling technologies across the United States.

[9]Department of Energy, National Energy Technology Laboratory, *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements.* 2008. This report did not include statistics regarding the use of hybrid systems.

Figure 7: Water Based Cooling Systems by Technology and Water Source



Source: National Energy Technology Laboratory, based on EIA-collected data; Map (Mapinfo).

Note: The National Energy Technology Laboratory developed this graphic based on 2000 and 2005 data collected by EIA and, as a result, power plants with a capacity less than 100 megawatts are not shown. According to an official from the National Energy Technology Laboratory, it was not possible using EIA data to determine the water type of cooling ponds. Additionally, as discussed later in the report, it is not possible to use EIA data to comprehensively identify the universe of plants with dry or hybrid cooling systems.

Federal Data Collection

Although a number of federal agencies collect data on water, two collect key data that are used to analyze the impacts of thermoelectric power plants and water availability: USGS and EIA.

- USGS's mission is to provide reliable scientific information to manage water, energy and other resources, among other things. USGS collects surface water and groundwater availability data through a national network of stream gauges and groundwater monitoring stations. USGS currently monitors surface and groundwater availability with approximately 7,500 streamflow gauges and 22,000 groundwater monitoring stations located throughout the United States.

- USGS compiles data and distributes a report every 5 years on national water use that describes how various sectors, such as irrigation, mining, and thermoelectric power plants, use water. USGS data related to thermoelectric power plants include (1) water withdrawal data at the state and county level organized by cooling technology—once-through and wet recirculating; (2) water source—surface or groundwater; and (3) whether water used was fresh or saline. USGS compiles water use data from multiple sources, including state water regulatory officials, power plant operators, and EIA. If data are not available for a particular state or use, USGS makes estimates.

- EIA's mission is to provide policy-neutral data, forecasts, and analyses to promote sound policy making, efficient markets, and public understanding regarding energy and its interaction with the economy and the environment. In carrying out this mission, EIA collects a variety of energy and electricity data nationwide, about topics such as energy supply and demand. For certain plants producing 100 megawatts or more of electricity, EIA collects data on water withdrawals, consumption, discharge, as well as some information on water source and cooling technology type. EIA annually collects water use data directly from power plants by using a survey.

State Water Laws

The variety of state water laws relating to the allocation and use of surface water can generally be traced to two basic doctrinesthe riparian doctrine, often used in the eastern United States, and the prior appropriation doctrine, often used in the western United States.

- Under the riparian doctrine, water rights are linked to land ownership—owners of land bordering a waterway have a right to use the water that flows past the land for any reasonable purpose. In general, water rights in riparian states may not be bought or sold. Landowners may, at any time, use water flowing past the land, even if they have never done so before. All landowners have an equal right to use the water, and no one gains a greater right through prior use. In some riparian states, water use is closely tracked by requiring users to apply for permits to withdraw water. In other states, where water has traditionally not been scarce, water use is not closely tracked. When there is a water shortage, water users share the shortage in proportion to their rights, or the amount they are permitted to withdraw, to the extent that it is possible to determine.

- Under the prior appropriation doctrine, water rights are not linked with land ownership. Instead, water rights are property rights that can be owned independent of land and are linked to priority and beneficial water use. A water right establishes a property right claim to a specific amount of water—called an allotment. Because water rights are not tied to land, water rights can be bought and sold without any ownership of land, although the rights to water may have specific geographic limitations. For example, a water right generally provides the ability to use water in a specific river basin taken from a specific area of the river. Water rights are also prioritized—water rights established first generally have seniority for the use of water over water rights established later—commonly described as "first in time, first in right." As a result, once established, water rights retain their priority for as long as they remain valid. For example, a water right to 100 acre feet of Colorado River water established in 1885 would retain that 1885 priority and allotment, even if the right was sold by the original party who established it. Water rights also must be exercised in order to remain valid, meaning rights holders must put the water to beneficial use or their right can be deemed abandoned and terminated—commonly referred to as "use it or lose it." When there is a water shortage in prior appropriation states, shortages fall on those who last obtained a legal right to use the water. As a result, a shortage can result in junior water rights holders losing all access to water, while senior rights holders have access to their entire allotment.

For some states, the legal framework for groundwater is similar to that of surface water as they use variants of either the riparian or prior appropriation doctrine to allocate water rights. However, in other states, the allocation of groundwater rights follows other legal doctrines, including the rule of capture doctrine and the doctrine of reasonable use. Under the rule of capture doctrine, landowners have the right to all the water they can capture under their land for any use, regardless of the effect on other water users. The doctrine of reasonable use similarly affords landowners the right to water underneath their land, provided the use is restricted to an amount necessary for reasonable use. In some cases, permits may be required prior to use and additional regulation may occur if a groundwater source is interconnected with surface water.

Power Plant Applications

A number of state agencies may be involved in considering or approving applications to build power plants or to use water in power plants. In some states, a centralized agency considers applications to build new power plants. In other states, applications may be filed with multiple state agencies. State water regulators issue water permits for power plants and other sectors to regulate water use and ensure compliance with relevant state laws and regulations. Public Utility Commissions, or the equivalent, may also have a role in authorizing the development of a power plant. In many states where retail electricity rates are regulated, these commissions are primarily responsible for approving the rates (or prices) electric utilities charge their customers and ensuring they are reasonable. As part of approving rates, these commissions approve utility investments into such things as new power plants and, as a result, may consider whether specific power plant design and cooling technologies are reasonable.

Thermoelectric Power Plants and Water Availability

Based on figures from EIA's 2009 Annual Energy Outlook, thermoelectric power plant generating capacity will increase by about 15 percent between 2006 and 2030. Depending on which cooling approaches are used, such an increase could further strain water resources. A variety of additional factors may also affect the availability of water for electricity generation and other uses, as well as the amount of water used to produce electricity. Some studies indicate that climate change will result in changes in local temperatures and more seasonal variations, both of which could cause increased levels of water consumption from thermoelectric power plant generation. Climate change may also result in changes in local precipitation and water availability, as well as more and longer droughts in some areas of the country. To the extent that this occurs, power plant operators may need to reduce the use of water for power plant cooling. In addition, some technologies aimed at reducing greenhouse gas emissions, such as carbon capture technologies, may require additional water. The combination of environmental laws, climate change, and the inclusion of new water intensive air emission technologies may impact water availability and require power plants operators to reduce water use in the future. In addition, since the water inlet structures used at once-through cooling plants can either trap or draw in fish and other aquatic life—referred to as impingement and entrainment—there is increased pressure to reduce the use of once-through cooling at existing plants.

Advanced Cooling Technologies and Alternative Water Sources Can Reduce the Use of Freshwater at Power Plants, but Their Adoption Poses Certain Drawbacks

Advanced cooling technologies and alternative water sources can reduce freshwater use by thermoelectric power plants, leading to a number of benefits for plant developers; however, incorporating each of these options for reducing freshwater use into thermoelectric power plants also poses certain drawbacks. Benefits of reducing freshwater use may include social and environmental benefits, minimizing water-related costs, as well as increasing a developer's flexibility in determining where to locate a new plant. On the other hand, drawbacks to using advanced cooling technologies may include potentially lower net electricity output, higher costs, and other trade-offs. Similarly, the use of alternative water sources, such as treated effluent or groundwater unsuitable for drinking or irrigation, may have adverse effects on cooling equipment, pose regulatory challenges, or be located too far from a proposed plant location to be a viable option. Power plant developers must weigh the trade-offs of these drawbacks with the benefits of reduced freshwater use when determining what approaches to pursue, and must consider both the economic costs over a plant's lifetime and the regulatory climate. For example, in a water-scarce region of the country where water costs are high and there is significant regulatory scrutiny of water use, a power plant developer may opt for a water-saving technology despite its drawbacks.

Advanced Cooling Technologies and Alternative Water Sources Can Reduce Freshwater Use, Leading to a Number of Benefits

Advanced cooling technologies under development and in limited commercial use and alternative water sources can reduce the amount of freshwater needed by plants, resulting in a number of benefits to both the environment and plant developers. As shown in table 2, dry cooling can eliminate nearly all the water withdrawn and consumed for power plant cooling.

Table 2: Selected Estimates of Water Withdrawn and Consumed for Power Plant Cooling by Cooling Technology and Plant Type[a]

Gallons per megawatt hour by type of plant	Once-through		Wet recirculating with cooling tower		Dry cooling	
	Withdrawal	Consumption[b]	Withdrawal	Consumption	Withdrawal	Consumption
Coal	20,000 – 50,000	300	500-600	480	0	0
Combined cycle	7,500-20,000	100	230	180	0	0
Nuclear	25,000 – 60,000	400	800-1,100	720	[c]	[c]
Solar thermal (trough)	—	—	600-850[d]	[d]	0	0

Sources: Coal, natural gas and nuclear estimates: Electric Power Research Institute, *Water and Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century.* (Palo Alto, CA, 2002). 1006786. Dry cooling and solar thermal: Electric Power Research Institute, *Water Use for Electric Power Generation*, (Palo Alto, CA, 2008). 1014026.

Note: We did not include water use estimates for hybrid cooling in this table, because these systems' water use is very dependent on their design and operation, including the proportion of wet versus dry cooling. Additionally, for wet recirculating systems, we provided water use estimates only for those systems with cooling towers, since according to work conducted by the National Energy Technology Laboratory, they are more common than wet recirculating systems with cooling ponds.

[a]In addition to cooling water, water may be used for other plant purposes, such as environmental controls; make-up boiler water; and water for cleaning, drinking, and sanitation. As a result, while dry and hybrid systems may eliminate or minimize water needs for cooling, total plant water use will not be eliminated entirely. Furthermore, some plants, such as natural gas simple cycle, solar photovoltaic, and wind, are not considered thermoelectric and do not use water for cooling but may use water for other plant purposes.

[b]Once-through cooling systems discharge water at a warm temperature; therefore, water consumption in these systems occurs via evaporation downstream of the plant.

[c]Representatives from one engineering firm and some power plant developers we spoke to explained that the large size of dry cooling systems needed for plants that derive all of their electricity production from the steam cycle, for example, nuclear and coal plants, may introduce challenges. Furthermore, according to another expert, one type of dry cooled technology may not be approved for use with certain nuclear reactors because of safety concerns.

[d]This estimate for solar thermal (trough) water withdrawals is from the Electric Power Research Institute's 2008 report. This report did not identify a comparable range for water consumption. Other sources we reviewed estimated water consumption rates for solar trough plants ranging from 740 gallons to 920 gallons per megawatt hour.

Hybrid cooling systems, depending on design, can reduce water use—generally to a level between that of a wet recirculating system with cooling towers and a dry cooling system. According to the Electric Power Research Institute, hybrid systems are typically designed to use 20-80 percent of the water used for a wet recirculating system with cooling towers.[10]

[10]Electric Power Research Institute, *Water Use for Electric Power Generation*, (Palo Alto, CA, 2008). 1014026.

In addition to using advanced cooling technologies, power plant operators can reduce freshwater use by utilizing water sources other than freshwater. Alternative water sources include treated effluent from sewage treatment plants; groundwater that is unsuitable for drinking or irrigation because it is high in salts or other impurities; sea water; industrial water and water generated when extracting minerals like oil, gas, and coal. For example, the oil and gas production process can generate wastewater, which is the subject of research as a possible source of cooling water for power plants.

Use of alternative water sources by power plants is increasing in some areas, and two power plant developers we spoke with said they routinely consider alternative water sources when planning new power plants, particularly in areas where water has become scarce, tightly regulated, or both. A 2007 report by the DOE's Argonne National Laboratory identified at least 50 power plants in the United States that use reclaimed water for cooling and other purposes, with Florida and California having the largest number of plants using reclaimed water.[11] According to the report, the use of reclaimed water at power plants has become more common, with 38 percent of the plants using reclaimed water doing so after 2000. One example of a power plant using an alternative to freshwater is Palo Verde, located near Phoenix, Arizona—the largest U.S. nuclear power plant, with a capacity of around 4,000 megawatts. Palo Verde uses approximately 20 billion gallons of treated effluent annually from treatment plants that serve several area municipalities, comprising over 1.5 million people.

Reducing the amount of freshwater needed for cooling leads to a number of social and environmental benefits and may benefit developers by lowering water-related costs and providing more flexibility in choosing a location for a new plant, among other things.

Social and Environmental Benefits

Reducing the amount of freshwater used by power plants through the use of advanced cooling technologies and alternative water sources has the potential to produce a number of social and environmental benefits. For example, limiting freshwater use may reduce the impact to the environment associated with withdrawals, consumption, and discharge. Freshwater is in high demand across the United States. Reducing freshwater withdrawals and consumption by the electricity sector makes

[11]Argonne National Laboratory, *Use of Reclaimed Water for Power Plant Cooling*, (Argonne, IL., 2007).

this limited resource more available for additional electricity production or competing uses, such as public water supplies or wildlife habitat. Furthermore, eliminating water use for cooling entirely, such as by using dry cooling, could minimize or eliminate the water discharges from power plants, a possible source of heat and pollutants to receiving water bodies, although regulations limit the amount of heat and certain pollutants that may be discharged into water bodies.

Water-Related Cost Savings

By eliminating or minimizing the use of freshwater for cooling, power plant developers may reduce some water-related costs, including the costs associated with acquiring, transporting, treating, and disposing of water. Depending on state water laws, a number of costs may be associated with acquiring water—purchasing a right to use water, buying land with a water source on or underneath it, or buying a quantity of freshwater from a municipal or other source. Eliminating the need to purchase water for cooling by using dry cooling could reduce these water-related expenses. Using an alternative water source, if less expensive than freshwater, could reduce the costs of acquiring water, although treatment costs may be higher. Power plant developers and an expert from a national laboratory told us the costs of acquiring an alternative water source are sometimes less than freshwater, but vary widely depending on its quality and location. In addition to lowering the costs associated with acquiring water, if water use for cooling is eliminated entirely, plant developers may eliminate the need for a pipeline to transport the water, as well as minimize costs associated with treating the water. Water-related costs are one of several costs that power plant developers will consider when evaluating alternatives to freshwater. Since the cost of freshwater may rise as demand for freshwater increases, a developer's ability to minimize power plant freshwater use could become increasingly valuable over time.

Siting Flexibility and Other Benefits

Minimizing or eliminating the use of freshwater may offer a plant developer increased flexibility in determining where to locate a power plant. According to power plant developers we spoke with, siting a power plant involves balancing factors such as access to fuel, including natural gas pipelines, and access to large transmission lines that carry the electricity produced to areas of customer demand. Some explained that finding a site that meets these factors and also has access to freshwater can be challenging. Power plant developers we spoke with said options such as dry cooling and alternative water sources have offered their companies the flexibility to choose sites without freshwater, but with good access to fuel and transmission.

According to power plant developers and an expert from a national laboratory we spoke with, eliminating or lowering freshwater use can lead to other benefits, such as minimizing regulatory hurdles like the need to acquire certain water permits. Furthermore, using a nonfreshwater source may be advantageous in areas with more regulatory scrutiny of or public opposition to freshwater use.

Adoption of Advanced Cooling Technologies May Reduce Electricity Production, Increase Costs, and Pose Other Drawbacks

Despite the benefits associated with the lower freshwater requirements of advanced cooling technologies, these technologies have a number of drawbacks related to electricity production and costs that power plant developers will have to consider during their decisionmaking process.

Energy Production Penalties

Despite the many benefits advanced cooling technologies offer, both dry cooling and hybrid cooling technologies may reduce a plant's net energy production to a greater extent than traditional cooling systems—referred to as an "energy penalty." Energy penalties result in less electricity available outside the plant, which can affect plant revenues, and making up for the loss of this electricity by generating it elsewhere can result in increases in water use, fuel consumption, and air emissions. Energy penalties result from (1) energy consumed to run cooling system equipment, such as fans and pumps, and (2) lower plant operating efficiency—measured as electricity production per unit of fuel—in hot weather due to lower cooling system performance. Specifically, energy penalties include:

- *Energy needed for cooling system equipment.* Cooling systems, like many systems in a power plant, use electricity produced at the plant to operate, which results in less electricity available for sale. According to experts we spoke with, because dry cooling systems and hybrid cooling systems rely on air flowing through a condenser, energy is needed to run fans that provide air flow, and the amount of energy needed to run cooling equipment will depend on such factors as system design, season, and region.[12] A 2001 EPA study estimated that for a combined cycle plant, energy requirements to operate a once-through system (pumps) are 0.15 percent of plant output, 0.39 percent of plant output for a wet recirculating system with cooling towers (pumps and fans), and 0.81 percent of plant output for a dry cooled system (fans).[13]

- *Plant operating efficiency and cooling system performance*. Plants using a dry cooling component, whether entirely dry cooled or in a hybrid cooled configuration, may face reduced operating efficiency under certain conditions. A power plant's operating efficiency is affected by the performance of the cooling system, among other things, and power plants with systems that cool more effectively produce electricity more efficiently. A cooling system's effectiveness is influenced both by the design of the cooling system and ambient conditions that determine the temperature of that system's cooling medium—water in once-through and wet recirculating systems and air in dry cooling systems. In general, the effectiveness of a cooling system decreases as the temperature of the cooling medium increases, since a warmer medium can absorb less heat from the steam. Once-through systems cool steam using water being withdrawn from the river, lake, or ocean. Wet recirculating systems with cooling towers, on the other hand, use the process of evaporation to cool the steam to a temperature that approaches the "wet-bulb temperature"—an alternate measure of temperature that incorporates both the ambient air temperature and relative humidity. In contrast, dry cooled systems transfer heat only to the ambient air, without evaporation. As a result, dry cooled systems can cool steam only to a temperature that approaches the "dry-bulb temperature"—the measure of ambient air temperature measured by a standard thermometer and with which most people are familiar. In general, once-through systems tend to cool most effectively

[12]Energy is also needed in wet recirculating systems with fan-forced cooling towers, as well as to operate water pumps in both once-through and wet recirculating systems with cooling towers. Wet recirculating systems with cooling towers can also be constructed with a type of cooling tower that relies on a chimney effect, rather than fans, to naturally produce airflow. These natural draft cooling towers are large concrete structures that are significantly more expensive to build than cooling towers with fans, although they would eliminate the energy costs associated with fan operation.

[13]Environmental Protection Agency, *Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities*, (Washington, D.C., Nov. 2001). These figures were higher for a full steam fossil fueled plant, such as a coal plant. Representatives from EPA explained that energy penalty and cost comparisons between dry cooled systems and wet recirculating systems with cooling towers may have changed since EPA's 2001 report was issued. The agency is in the process of updating its estimates of energy penalties and cooling system costs.

because the temperature of the body of water from which cooling water is drawn is, on average, lower than the wet- or dry-bulb temperature. Moreover, wet-bulb temperatures are generally lower than dry-bulb temperatures, often making recirculating systems more effective at cooling than dry cooled systems. Further, according to one report that we reviewed, greater fluctuations in dry-bulb temperatures seasonally and throughout the day can make dry cooled systems harder to design.[14] Dry bulb temperatures can be especially high in hot, dry parts of the country, such as the Southwest, leading to significant plant efficiency losses during periods of high temperatures, particularly during the summer. According to experts and power plant developers we spoke with, plant efficiencies may witness smaller reductions during other parts of the year when temperatures are lower or in cooler climates.[15] Nevertheless, in practice, lower cooling system performance can result in reduced plant net electricity output or greater fuel use if more fuel is burned to produce electricity to offset efficiency losses. Plant developers can take steps to reduce efficiency losses such as by installing a larger dry cooling system with additional cooling capability, but such a system will result in higher capital costs.

A plant's total energy penalty will be a combination of both effects described—energy needed for cooling system equipment and the impact of cooling system performance on plant operating efficiency. Energy penalties may result in lost revenue for the plant due to the net loss in electricity produced for a given unit of fuel, especially during the summer when electricity demand and prices are often the highest. Energy penalties may also affect the price consumers pay for electricity in a regulated market, if the cost of the additional fuel needed to produce lost electricity is passed on to consumers by regulators. Finally, energy penalties may affect emissions of pollutants and carbon dioxide if lost output is made up for by an emissions producing power plant, such as a coal- or natural gas-fueled power plant. This is because additional fuel is burned to produce

[14]Burns, John M. and Wayne Micheletti, *Emerging Issues and Needs in Power Plant Cooling Systems*. (Presented at DOE's Workshop on Electric Utilities and Water: Emerging Issues and Needs, Pittsburgh, PA, July 23-24, 2002).

[15]Plants with once-through systems and wet recirculating systems with cooling towers also face efficiency losses as water and wet-bulb temperatures rise. As noted, dry cooled plants tend to be less efficient than plants with both of these wet cooling systems, but the efficiency of dry cooled plants will approach that of wet cooled plants at certain times of the year and in certain climatic conditions. For example, according to experts we spoke with, there will be a smaller difference in efficiency between a plant with a wet recirculating system with cooling towers and a dry cooled plant in cool, humid climates.

electricity that offsets what was lost as a result of the energy penalty, and, thus, additional carbon dioxide and other pollutants are released.

Recent studies comparing total energy penalties between cooling systems have used differing methodologies to estimate energy penalties and have reached varying conclusions.[16] For example, a 2001 EPA study estimates the national average, mean annual energy penalties—lower electricity output—for plants operating at two-thirds capacity with dry cooling to be larger than those with wet recirculating systems with cooling towers. In this study, EPA estimated penalties of 1.7 percent lower output for a combined cycle plant with a dry system compared to a wet recirculating system with a cooling tower, and 6.9 percent lower output for a fossil fueled plant run fully on steam, such as a coal plant.[17] Similarly, a separate study conducted by two DOE national labs in 2002 estimated larger annual energy penalties for hypothetical 400 megawatt coal plants in multiple regions of the country retrofitted to dry cooling—these penalties ranged between 3 to 7 percent lower output on average for a plant retrofitted with a dry cooled system compared to a plant retrofitted with a wet recirculating system with a cooling tower. On the hottest 1 percent of temperature conditions during the year, this energy penalty rose to between 6 and 10 percent lower output for plants retrofitted to dry cooling compared with those retrofitted to a wet recirculating system with cooling

[16]We include examples from these studies to provide context about the magnitude of estimated energy penalties. We have not validated the methodology or results of these studies. Estimates are subject to study assumptions and methodology, and actual energy penalties depend highly on plant design, location, and decisions made by plant developers about how to optimize total plant costs.

[17]Environmental Protection Agency, *Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities*, (Washington, D.C., Nov. 2001). EPA estimated energy penalties at peak summer conditions when plants operate at 100 percent capacity to be higher. For example, the study estimates national average energy penalties at peak summer conditions (100 percent capacity) to result in 2.4 percent lower output for combined cycle plants with dry cooling systems compared to those with wet recirculated systems with a cooling tower. EPA estimated national average energy penalties at peak summer conditions (100 percent capacity) to result in 8.4 percent lower output for full steam fossil fueled plants, such as coal plants, with dry cooling systems, compared to those with wet recirculated systems with a cooling tower. Representatives from EPA explained that energy penalty and cost comparisons between dry cooled systems and wet recirculating systems with cooling towers may have changed since EPA’s 2001 report was issued. The agency is in the process of updating its estimates of energy penalties and cooling system costs.

towers.[18] However, some experts we spoke with told us energy penalties are higher in retrofitted plants than when a dry cooled system is designed according to the unique specifications of a newly built plant.

A 2006 study conducted for the California Energy Commission estimated electricity output and other characteristics for new, theoretical combined cycle natural gas plants in four climatic zones of California using different cooling systems. The study found that dry cooling systems result in significant water savings, but that plants using wet cooling systems generally experience higher annual net electricity output, as shown in table 3, and lower fuel consumption. Furthermore, while the study estimates that plant capacity to produce electricity is limited on hot days for both types of cooling systems, the hot day capacity of the dry cooled plant to produce electricity is up to 6 percent lower than the wet recirculating plant with cooling tower.[19]

[18]Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory and Argonne National Laboratory, *Energy Penalty Analysis of Possible Cooling Water Intake Structure Requirements on Existing Coal-Fired Power Plants.* (2002). These estimates refer to a dry cooling tower with a 20 degree Fahrenheit approach, the difference between the air temperature and the temperature of cold water discharged from the condenser. Energy penalty estimates for a dry tower with a 40 degree Fahrenheit approach were higher. The 1 percent hottest day estimate is for plants with a range of 15 degrees Fahrenheit, where the range refers to the difference between the temperature of the water entering and leaving the condenser. This study focused on existing plants retrofitted with indirect dry cooled systems, which are considered less efficient than direct dry systems. Experts we spoke with told us energy penalties are higher in retrofitted plants than when a dry cooled system is designed according to the unique specifications of a newly built plant because indirect dry cooling systems are more likely to be used; plant components, like the turbine, have not been designed to work most effectively with a dry cooled system; and because of size constraints placed on the dry cooled system.

[19]Hot day performance is estimated to be the 1 percent highest dry bulb temperature and the corresponding wet bulb temperature for that condition.

Table 3: Percentage Difference in Annual Net Plant Electricity Output for Theoretical Combined Cycle Plants with Different Cooling Systems at Four Geographic Locations in California

Geographic locations	Percentage difference in annual net plant electricity output for a wet recirculating system with cooling towers compared to a dry cooled system
Desert (hot, arid)	1.07
Valley (hot, humid)	1.46
Coast (cool, humid)	0.37
Mountain (variable, elevated)	1.87

Source: Maulbetsch, J. S. and M.N. DiFilippo, *Cost and Value of Water Use at Combined-Cycle Power Plants*, California Energy Commission, PIER Energy-Related Environmental Research, CEC-500-2006-034. April 2006.

Power plant developers can take steps to address the energy penalties associated with dry cooling technology by designing their plants with larger dry cooled systems capable of performing better during periods of high ambient temperatures. Alternatively, they can use a hybrid technology that supplements the dry system with a wet recirculating system with a cooling tower during the hottest times of the year. However, in making this decision, developers must weigh the trade-offs between the costs associated with building and operating a larger dry cooled system or a hybrid system and the benefits of lowering their energy penalties.

Higher Costs

According to some power plant developers and experts we spoke with, another drawback to using dry and hybrid cooling technologies is that these technologies typically have higher capital costs. Experts, power plant developers, and studies indicated that while capital costs for each system can vary significantly, as a general rule, capital costs are lowest for once-through systems, higher for wet recirculating systems, and highest for dry cooling. Some told us the capital costs of hybrid systems—as a combination of wet recirculating and dry cooling systems—generally fall in between these two systems. Furthermore, according to some of the experts we spoke with and studies we reviewed, the capital costs of a plant's cooling system vary based on the specific characteristics of a given plant, such as the costs of the cooling towers, the circulating water lines to transport water to and around the plant, pumps, fans, as well as the extent to which a dry cooled system is sized larger to offset energy penalties. As with energy penalties, studies estimating capital costs for dry and hybrid systems have used differing methodologies and provide varying estimates of capital costs.[20] One study by the Electric Power Research Institute estimated dry cooling system capital costs for theoretical 500 megawatt combined cycle plants in 5 climatic locations to be 3.6 to 4.0 times that of wet recirculating systems with cooling towers.[21] Experts from an engineering firm we spoke with also explained that capital costs for dry and hybrid cooled systems can be many times that of a wet recirculating system with cooling towers. They estimated that, in general, installing a dry system on a 500 megawatt combined cycle plant instead of a wet recirculating system with a cooling tower could increase baseline capital costs by $9 to $24 million, depending on location—an increase in baseline capital costs that is 2.0 to 5.1 times higher than if a wet recirculating system with a cooling tower were used. They estimated dry cooling to be more costly on a 500 megawatt coal plant, with dry cooling resulting in an increase in baseline capital costs that was 2.6 to 7.0 times higher than if a wet recirculating system with a cooling tower were used.

With respect to annual costs, according to experts we spoke with and studies we reviewed, annual cost differences between alternative cooling technologies and traditional cooling technologies are variable and may depend on such factors as the costliness of obtaining and treating water, the extent to which cooling water is reused within the system, the need for maintenance, the extent to which energy penalties result in lost revenue, and the extent to which a cooling system is sized larger to offset energy penalties. Estimates from four reports we reviewed calculated varying cooling system annual costs for a range of plant types and locations using different methodologies, and found annual costs of dry systems to generally range from one and a half to four times those of wet recirculating systems with cooling towers. One of these studies, however, in examining the potential for higher water costs, found that dry cooling

[20]We include examples of cost estimates from selected studies and expert interviews in this section to provide context about the magnitude of estimated capital and operating costs of dry cooling systems compared to wet cooling systems. We have not validated the methodology or results of these estimates. Estimates are subject to each study's assumptions and methodology, and actual costs depend highly on plant design, locational factors such as water costs, and decisions made by plant developers about how to optimize total costs. Furthermore, it should be noted that cooling system costs are but one component of total plant costs.

[21]Electric Power Research Institute, *Comparison of Alternate Cooling Technologies for U.S. Power Plants. Economic, Environmental, and Other Trade-offs*, (Palo Alto, CA., 2004). 1005358. Similarly, capital costs for a dry cooled system on theoretical 350 megawatt coal plants ranged between $43 and $47 million for 5 climatic locations—3.2 to 3.6 times that of a wet recirculating system with cooling tower.

could be more economical on an annual basis in some areas of the country with expensive water or become more economical in the future if water costs were to rise.[22] Furthermore, an expert from an engineering firm we spoke with explained that cooling system costs are only one component of total plant costs, and that while one cooling system may be expensive relative to another, its impact on total plant costs may not be as significant in a relative sense if the plant's total costs are high.

Space, Noise, and Suitability Issues

There may be other drawbacks to dry cooled technology, including space and noise considerations. Towers, pumps, and piping for both dry cooled and wet cooled systems with cooling towers require substantial space, but according to experts we spoke with, dry cooled systems tend to be larger. For example, according to one expert we spoke with, a dry cooled system for a natural gas combined cycle plant that derives one-third of its electricity from the steam cycle could be almost as large as two football fields. Moreover, according to others, the large size of dry cooling systems needed for plants that derive all of their electricity production from the steam cycle—for example, nuclear and coal plants—may make the use of dry cooling systems less suitable for these kinds of power plants. Experts we spoke with explained that because full steam plants produce all of their electricity by heating water to make steam, they require larger cooling systems to condense the steam back into usable liquid water. As a result, the size of a dry cooling system for a full steam plant could be three times that of a dry cooling system for a similarly-sized combined cycle plant that only produces one-third of its electricity from the steam cycle.

Furthermore, according to one expert we spoke with, the most efficient type of dry cooled technology may not be approved for use with certain nuclear reactors, because of safety concerns. Finally, the motors, fans, and water of both dry cooled and wet recirculating systems with cooling towers may create noise that disturbs plant employees, nearby residents, and wildlife. Noise-reduction systems may be used to address this concern, although they introduce another cost trade-off that plant developers must consider.

[22] Electric Power Research Institute, *Comparison of Alternate Cooling Technologies for U.S. Power Plants. Economic, Environmental, and Other Trade-offs*, (Palo Alto, CA., 2004). 1005358.

Use of Alternative Water Sources May Also Pose Certain Drawbacks

Despite the growth in plants using alternative water sources, there are a number of drawbacks to using this water source instead of freshwater. While some of these drawbacks are similar to those faced by power plants that use freshwater, they may be exacerbated by the lower quality of alternative water sources. These drawbacks include adverse effects to cooling equipment, regulatory compliance issues, and access to alternative water sources, as follows.

Adverse Effects to Cooling Equipment

Water used in power plants must meet certain quality standards in order to avoid adverse effects to cooling equipment, such as corrosion, scaling, and the accumulation of micro or macrobiological organisms. While freshwater can also cause adverse effects, the generally lower quality of alternative water sources make them more likely to result in these effects. For example, effluent from a sewage treatment plant may be higher in ammonia than freshwater, which can cause damage to copper alloys and other metals. High levels of ammonia and phosphates can also lead to excessive biological growth on certain cooling tower structures. Chemical treatment is used to mitigate such adverse effects of alternative water sources when they occur, but this treatment results in additional costs. According to one power plant operator we spoke with, alternative water sources often require more extensive and expensive treatment than freshwater sources, and it can be a challenging process to determine the precise makeup of chemicals needed to minimize the adverse effects.

Regulatory Compliance Issues

Power plant developers using alternative water sources may face additional regulatory challenges. Depending on their design, power plants may discharge water directly to a water source, such as a surface water body, or release water into the air through cooling towers. As a result, power plants must comply with a number of water quality and air regulations, and the presence of certain pollutants in alternative water sources can make compliance more challenging. For example, reclaimed water from sewage treatment plants is treated to eliminate bacteria and other contaminants that can be harmful to humans. Similarly, water associated with minerals extraction may contain higher total dissolved and suspended solids and other constituents, which could adversely affect the environment if discharged. Addressing these issues through the following actions entail additional costs to the power plant operators: (1) chemical treatment prior to discharging water to another water source, (2) discharging water to a holding pond unconnected to another water source for evaporation, or (3) eliminating all liquid discharges by, for example, evaporating all the water used at the plant and disposing of the resulting solid waste into a facility such as a landfill.

Access to Alternative Water Sources

As with freshwater sources, the proximity of an alternative water source may be a drawback that power plant developers have to consider when pursuing this option. Power plant developers wishing to use an alternative water source must either build the plant near that source—which can be challenging if that water source is not also near fuel and transmission lines—or pay the costs of transporting the water to the power plant's location, such as through a pipeline. Furthermore, two power plant developers we spoke with told us that certain alternative water sources, like treated effluent, are in increasing demand in some parts of the country, making it more challenging or costly to obtain than in the past.

Power Plant Developers Must Weigh Trade-offs When Evaluating Options to Reduce Freshwater Use

A power plant developer may want to reduce the use of freshwater for a number of reasons, such as when freshwater is unavailable or costly to obtain, to comply with regulatory requirements, or to address public concern. However, power plant developers we spoke with told us that when considering the viability of an advanced cooling technology or alternative water source, they must weigh the trade-offs between the water savings and other benefits these alternatives offer with the drawbacks to their use. For example, in a water-scarce region of the country where water costs are high and there is much regulatory scrutiny of water use, a power plant developer may determine that, despite the drawbacks associated with the use of advanced cooling technologies or alternative water sources, these alternatives still offer the best option for getting a potentially profitable plant built in a specific area. Furthermore, according to power plant developers we spoke with, these decisions have to be made on a project by project basis because the magnitude of benefits and drawbacks will vary depending on a plant's type, location, and the related climate. For example, dry cooling has been installed in regions of the country where water is relatively plentiful, such as the Northeast, to help shorten regulatory approval times and avoid concerns about the adverse impacts that other cooling technologies might have on aquatic life. In making a determination about what cooling technology to use, power plant developers evaluate the net economic costs of alternatives like dry cooling or an alternative water source—its savings compared to its costs—over the life of a proposed plant, as well as the regulatory climate. Experts we spoke with told us this involves consideration of both capital and annual costs, including how expected water savings compare to costs related to energy penalties and other factors. Anticipated future increases in water-related costs could prompt a developer to use a water-saving alternative. For example, a recent report by the Electric Power Research Institute estimates that a power plant's economic trade-offs vary considerably depending on its location and that high water costs could make dry cooling less expensive annually than wet cooling.[23]

The National Energy Technology Laboratory is funding research and development projects aimed at minimizing the drawbacks of advanced cooling technologies and alternative water sources. In 2008, the laboratory awarded close to $9 million to support research and development of projects that, among other things, could improve the performance of dry cooled technologies, recover water used to reduce emissions at coal plants for reuse, and facilitate the use of alternative water sources in cooling towers. Such research endeavors, if successful and deemed economical, could alter the trade-off analysis power plant developers conduct in favor of nontraditional alternatives to cooling.

States We Contacted Vary in the Extent to Which They Consider Water Impacts When Reviewing Power Plant Development Proposals

The seven states that we contacted—Alabama, Arizona, California, Georgia, Illinois, Nevada, and Texas—vary in the extent to which they consider the impacts that power plants will have on water when they review power plant water use proposals. Specifically, these states have differences in water laws that may influence their oversight of power plant water use. Some also have other regulatory policies and requirements specific to power plants and water use. Still other states require additional levels of review that may affect their states' oversight of how power plants use water.

States We Contacted Have Differences in Water Laws that Influence Their Oversight of Water Use by Proposed Power Plants

Differences in water laws in the seven states we contacted—Alabama, Arizona, California, Georgia, Illinois, Nevada, and Texas—influence the steps that power plant developers need to take to obtain approval to use surface or groundwater, and provide for varying levels of regulatory oversight of power plant water use. Table 4 shows the differences in water laws and water permitting for the seven states we contacted.

[23] Electric Power Research Institute, *Water Use for Electric Power Generation.*

Table 4: State Water Laws and Permit Requirements for Water Supply in Seven Selected States

	Type of state water laws		State water permit required	
State	**Surface water**	**Groundwater**	**Surface water**	**Groundwater**
Alabama	Riparian	Reasonable use	No[a]	No[a]
Arizona	Prior appropriation	Reasonable use[b]	Yes	Yes[b]
California	Riparian and prior appropriation	Reasonable use and prior appropriation	Yes	No
Georgia	Riparian	Reasonable use	Yes[c]	Yes[c]
Illinois	Other doctrine[d]	Reasonable use	Yes[e]	No
Nevada	Prior appropriation[f]	Prior appropriation[f]	Yes	Yes
Texas	Prior appropriation	Rule of capture	Yes	No[g]

Source: GAO analysis of state laws, documents, and discussions with state officials.

[a]Alabama issues a certificate of use upon registration to users with a capacity to withdraw 100,000 gallons of water per day or more.

[b]Arizona issues state permits for groundwater in areas of severe water overdraft where water shortages could occur, known as Active Management Areas, established under Arizona law. Reasonable use would not apply in these areas.

[c]Georgia issues water permits for users withdrawing more than 100,000 gallons a day.

[d]Illinois surface water law is based on various state statutes.

[e]Illinois issues surface permits only for public water bodies, which excludes some surface water.

[f]In Nevada, water appropriated from either surface or underground sources is limited to that which is reasonably required for beneficial use.

[g]Water use permits can be required locally in Texas through Groundwater Conservation Districts.

With regard to surface water—the source of water most often used for power plant cooling nationally—of the seven states we contacted, all but Alabama required power plant developers to obtain water permits through the state agency that regulates the water supply. However, the states requiring permits varied in how the permits were obtained and under what circumstances. For example, in general, under Illinois law, water supply permits are only necessary if the surface water is defined as a public water body, which covers most major navigable lakes, rivers, streams, and waterways as defined by the Illinois Office of Water Resources. However, for any other surface water body, such as smaller rivers and streams, no such permit is required. To obtain a permit to use water in a power plant in Illinois, developers must file an application with the Illinois Office of Water Resources. In determining whether to issue a permit, the Office of Water Resources requires the applicant to address public comments and evaluates USGS streamflow data to determine whether restrictions on water use are needed. In some instances, such as to support fish and other wildlife, the state may designate a minimum level of flow required for a river or stream and restrict the amount of water that can be used by a power plant or other water user when that minimum level is reached. The Director of the Office of Water Resources told us that the office has sometimes encouraged power plant operators to establish backup water sources, such as onsite reservoirs, for use when minimum streamflow levels are reached and water use is restricted. In contrast, under Georgia and Alabama riparian law, landowners have the right to the water on and adjacent to their land, and both states require users who have the capacity to withdraw (Alabama) or actually withdraw (Georgia) an average of more than 100,000 gallons per day to provide information to the state concerning their usage and legal rights to the water. However, this requirement is applied differently in the two states. Alabama requires that water users register their planned water use for informational purposes with the Alabama Office of Water Resources but does not require users to obtain a permit for the water withdrawal or conduct analysis of the impact of the proposed water use.[24] In contrast, Georgia requires water users to apply for and receive a water permit from the Georgia Environmental Protection Division. In determining whether to issue a permit for water use, this Georgia agency analyzes the potential effect of the water use on downstream users and others in the watershed. State water regulators in Georgia told us they have never denied an application for water use in a power plant due to water supply issues since there has historically been adequate available water in the state. For more details on Georgia's process for approving water use in power plants, see appendix IV.

Groundwater laws in the selected states we reviewed also varied and affected the extent to which state regulators provided oversight over power plant water use. In four of the seven states—Alabama, California, Illinois, and Texas—groundwater is largely unregulated at the state level, and landowners may generally freely drill new wells and use groundwater as they wish unless restricted by local entities, such as groundwater conservation districts. However, in three of the seven states we contacted—Arizona, Georgia, and Nevada—state-issued water permits are required for water withdrawals for some or all regions of the state. For example, in Nevada, which has 256 separate groundwater basins, and in which most of the in-state power generation uses groundwater for cooling, state water law follows the doctrine of prior appropriation. A power plant developer or other entity wanting to acquire a new water right for

[24]These users are issued a Certificate of Use, indicating the use has been registered with the State of Alabama. All Certificate of Use holders are required to annually report their water usage to the Alabama Office of Water Resources.

groundwater must apply for a water permit with the Nevada Division of Water Resources. In evaluating the application for a water permit, the Division determines if water is available—referred to as unappropriated; whether the proposed use will conflict with existing water rights or domestic wells; and whether the use of the water is in the public interest. In determining whether groundwater is available, if the Division of Water Resources determines that the amount of water that replenishes the groundwater basin annually is greater than the existing committed ground water rights in a given basin, unappropriated water may be available for appropriation.[25] In two cases where groundwater was being considered for possible power plants, the State Engineer, the official in the Division of Water Resources who approves permits, either denied the application or expressed reservations over the use of groundwater for cooling.[26] For example, in one case, the State Engineer noted that large amounts of water should not be used in a dry state like Nevada when an alternative, like dry cooling, that is less water intensive was available.

In contrast, in Texas, where 8 percent of in state electricity capacity uses groundwater for cooling, state regulators do not issue groundwater use permits or routinely review a power plant or other users' proposed use of the groundwater. Texas groundwater law is based on the "rule of capture," meaning landowners, including developers of power plants that own land, have the right to the water beneath their property. Landowners can pump any amount of water from their land, subject to certain restrictions, regardless of the effect on other wells located on adjacent or other property.[27] Although Texas state water regulators do not issue water permits for the use of groundwater, in more than half the counties in Texas, groundwater is managed locally through groundwater conservation districts which are generally authorized by the Texas Legislature and ratified at the local level to protect groundwater. These districts can impose their own requirements on landowners to protect water resources. This includes requiring a water use permit and, in some districts, placing

[25]If a prospective water user is unable to acquire a new water right, he or she may choose to purchase or lease an existing water right.

[26]In the two cases we identified, an official from the Public Utilities Commission of Nevada told us the power plants in question were never built. He also noted that as many as six power plants have been sited in Nevada with dry cooling due to lack of available water.

[27]Examples of restrictions include 1) to not maliciously injure a neighbor, 2) to not willfully waste water, 3) to not drill a well slanting under a neighbor's property or 4) to assume liability for damages for negligent pumping that causes subsidence of a neighboring land.

restrictions on the amount of water used or location of groundwater wells for landowners.[28]

States We Contacted Have Other Regulatory Policies That Influence the Extent of Water Use Oversight for Proposed Power Plants

Oversight of water use by proposed power plants in the selected states may be influenced by regulatory policies and requirements that formally emphasize minimizing freshwater use by power plants and other new industrial users. With respect to regulatory policies, of the 7 states, California and Arizona have established formal policies or requirements to encourage power plant developers to consider alternative cooling methods and reduce the amount of freshwater used in a proposed power plant. Specifically:

- California, a state that has faced constrained water supplies for many years, established a formal policy in 1975 that requires applicants seeking to use water in power plants to consider alternative water sources before proposing the use of freshwater.[29] More recently, the California Energy Commission, the state agency that is to review and approve power plant developer applications, reiterated in its 2003 Integrated Energy Policy Report, the 1975 policy that the commission would only approve power plants using freshwater for cooling in limited circumstances.[30] Furthermore, state regulators at the Commission told us that in discussing potential new power plant developer applications, commission staff encourage power plant developers to consider using advanced cooling technologies, such as dry cooling or alternative water sources, such as effluent from sewage treatment plants. Between January 2004 and April 2009, California regulators approved 10 thermoelectric power plants—3 that will use dry cooling; 6 that will use an alternative water source, such

[28]California also has local districts, known as Adjudicated Groundwater Basins, that may impose similar requirements.

[29]In 1975, the State Water Resources Control Board established a policy that inland freshwater should be considered the water type of last resort for power plants and encouraged utilities to study the feasibility of effluent from sewage treatment plants for power plant cooling. The policy states the use of fresh inland waters for power plant cooling will only be approved when it is demonstrated that the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound.

[30]The California Energy Commission reiterated the 1975 policy in the December 2003 Integrated Energy Policy Report that, consistent with that 1975 State Water Resources Control Board policy, it would only approve the use of freshwater where alternative cooling technologies were shown to be “environmentally undesirable” or “economically unsound.”

as reclaimed water; and 2 that will use freshwater purchased from a water supplier, such as a municipal water district, for power plant cooling.[31] Of 20 additional thermoelectric power plant applications pending California Energy Commission approval, developers have proposed 11 plants that plan to use dry cooling, 8 plants that plan to use an alternative water source, and 1 that plans to use freshwater for cooling.[32] For more details on California's process for approving water use in power plants, see appendix III.

- In Arizona, where there is limited available surface water and where groundwater is commonly used for power plant cooling, the state has requirements to minimize how much water may be used by power plants. Specifically, in Active Management Areas—areas the state has determined require regulatory oversight over the use of groundwater—the state requires that developers of new power plants 25 megawatts or larger using groundwater in a wet recirculating system with a cooling tower, design the plants to reuse the cooling water to a greater extent than what is common in the industry. Plants must cycle water through the cooling loop at least 15 times before discharging it, whereas, according to an Arizona public utility official, outside of Active Management Areas plants would generally cycle water 3 to 7 times.[33] These additional cycles result in water savings, since less water must be withdrawn from ground or surface water sources to replace discharges, but can require plant operators to undertake more costly and extensive treatment of the cooling water and to more carefully manage the plant cooling equipment to avoid mineral buildup.[34] Arizona officials also told us they encourage the use of alternative water sources for cooling and have informally encouraged developers to consider dry cooling. According to Arizona state officials, no plants with dry cooling have been approved to date in the state and, due mostly to climatic conditions, dry cooling is probably too inefficient and costly to currently

[31]One of these power plants uses a hybrid cooling system and is counted as having a water source and as using dry cooling.

[32]Simple cycle natural gas plants are excluded from these statistics since they do not have a steam cycle and, therefore, do not need water for cooling.

[33]There are variations for different plants in the number of cycles required and exemptions for the first full year of operation.

[34]The most significant loss of water in a wet recirculating system with cooling towers is through evaporation from cooling towers. However, studies conducted by the Electric Power Research Institute indicate that increasing the cycles of concentration can result in water savings, though with diminishing returns after a certain number of cycles.

be a viable option. For details on Arizona's process for approving water use in power plants, see appendix II.

In contrast to California and Arizona, water supply and public utility commission officials in the other 5 selected states told us their states had not developed official state policies regarding water use by power plants. For example, Alabama, a state where water has traditionally been plentiful, has not developed a specific policy related to power plant water use or required the use of advanced cooling technologies or alternative water sources. Additionally, the state does not require that power plant developers and other proposed water users seek a water use permit; rather power plant operators are only required to register their maximum and average expected water use with the state and report annual usage. State officials told us that they require this information so that they can know how much water is being used but that their review of power plant water use is limited. Officials from the state's Public Service Commission, responsible for certifying the development of power plants, said their office does not have authority to regulate a utility's water use and, therefore, generally does not analyze how a proposed power plant will affect the water supply. Rather, their office focuses on the reasonableness of power plant costs.[35]

Similarly, Illinois, where most power plants use surface water for cooling and water is relatively plentiful, has not developed a policy on water use by thermoelectric power plants or required the use of advanced cooling technologies or alternative water sources, according to an official at the Office of Water Resources. However, the Illinois Office of Water Resources does require power plant operators, like other proposed water users, to apply for water permits for use of surface water from the major public water bodies.

[35]Commission officials noted that their review may indirectly affect a power plant's water use since consideration of cooling systems can be one component in their consideration of a power plant's feasibility, reliability and cost. In general, the Commission will favor the least-cost cooling option that ensures electric reliability and defers to state water agencies to address issues related to a plant's potential impact on water quality and quantity. However, officials also explained there may be circumstances where cooling or water issues are raised in a public hearing that may need to be considered by the Commission.

States We Contacted May Require Additional Levels of Review That Affect Oversight

Three of the states we selected—Arizona, Nevada, and California—conduct regulatory proceedings that consider water availability, in addition to determining whether to issue a water permit, while the other states do not. In Arizona, water use for power plants is subject to three reviews: (1) the process for a prospective water user to obtain a water permit, if required; (2) review by a committee of the Arizona Corporation Commission, known as the Arizona Power Plant and Transmission Line Siting Committee; and (3) review by the Commission as part of an overall evaluation of the plant's feasibility and its potential environmental and economic impacts. Both the Committee and Commission evaluate water supply concerns, along with other environmental issues, and determine whether to recommend (Committee) or issue (Commission) a Certificate of Environmental Compatibility, which is necessary for the plant to be approved.[36] Water supply concerns have been a factor in denying such a certificate for a proposed power plant. For example, in 2001, the Commission denied an application to build a new plant over concerns that groundwater withdrawals for cooling water would not be naturally replenished and, thereby, would reduce surface water availability which could adversely affect the habitat for an endangered species. For more details on Arizona's processes for approving water use in power plants see appendix II.

Similarly, in Nevada and California, several state agencies may play a role in the approval of water use and the type of cooling technology used by power plants. In Nevada, although water permits for groundwater and surface water are issued by the State Engineer, the Public Utilities Commission oversees final power plant approval under the Utility Environmental Protection Act. Even if the power plant developer has obtained a water permit, water use could play a role in the review process if the plant's use of the cooling water or technologies has environmental effects that need to be mitigated. Additionally, as in a number of states where electricity rates are regulated, the Public Utilities Commission could consider the effect of dry cooling on electricity rates. In California, the California Energy Commission reviews all aspects of power plant certifications, including issuing any water permits and approvals for

[36]The Line Siting Committee makes a recommendation to the Arizona Corporation Commission about whether to issue a Certificate of Environmental Compatibility. The Arizona Corporation Commission is responsible for the final approval, modification, or denial of the certificate.

cooling technologies.[37] According to a California Energy Commission official, during this process the Commission works with other state and local agencies to ensure their requirements are met.

The other four states we contacted do not conduct reviews of how power plants will affect water availability beyond issuing a water use permit or certificate of registration. Public utility regulators in Illinois, Texas, Alabama, and Georgia told us they had no direct role in regulating water use or cooling technologies in power plants. Officials from the Public Utility Commission of Texas noted that since they do not regulate electricity rates in most of the state, the Commission plays no role in the approval of power plants in most areas. In other areas, they told us water use and cooling technologies were not reviewed by the Commission. Similarly, in Illinois—a state that does not regulate electricity rates—an official from the Illinois Commerce Commission stated that the agency had no role in reviewing water use or cooling technologies for power plants. While Georgia and Alabama are states that regulate electricity rates, officials from their Public Service Commissions—the state agencies regulating electricity rates—noted that they focus on economic considerations of power generation and not the impact that a power plant might have on the state's water supply.

[37]Power plants planning to use surface water must have surface water rights approved by the State Water Resources Control Board. Board officials told us that recent power plant applications for surface water rights were rare. According to an official at the California Energy Commission, power plants planning to use surface water often obtain their supply through a retail water agency, rather than obtaining surface water rights directly.

Some Federal Water Data Are Useful for Evaluating Power Plant Applications, but Limitations in Other Federal Data Make the Identification of Certain Water Use Trends More Difficult

State water regulators rely on data on water availability collected by USGS's streamflow gauges and groundwater studies and monitoring stations when they are evaluating developers' proposals for new power plants. In contrast, state water regulators do not routinely rely on federal data on water use when evaluating power plant applications, although these data are used by water and industry experts, federal agencies, and others to analyze trends in the industry. However, these users of federal data on water use identified a number of limitations with the data that they believe limits its usefulness.

State Water Regulators and Others Rely on Federal Data on Water Availability to Evaluate Power Plant Proposals

State water regulators, federal agency officials, and water experts we spoke with agreed that federal data on water availability are important for multiple purposes, including for deciding whether to approve power plant developer proposals for water permits and water rights. Most state water regulators we contacted explained that they rely upon federal data on water availability, particularly streamflow and groundwater data collected by USGS, for permitting decisions and said these data helped promote more informed water planning. For example, water regulatory officials from the Texas Commission on Environmental Quality—the agency that evaluates surface water rights applications from prospective water users in Texas—told us that streamflow data collected by USGS are a primary data source for their water model that predicts how water use by power plants and others applying for water rights will impact state water supplies and existing rights holders.

USGS's network of streamflow gauges and groundwater monitoring stations provide the only national data of their kind on water availability over long periods. As a result, state officials told us that these data are instrumental in predicting how much water is likely to be available in a river under a variety of weather conditions, such as droughts. For example, state regulators in Georgia and Illinois told us that they rely on USGS streamflow data to determine whether or not to establish special conditions on water withdrawal permits, such as minimum river flow requirements that affect the amount of cooling water a power plant can withdraw during periods when water levels in the river are low. State water regulators in Nevada also told us they rely on a number of data sources, including USGS groundwater studies, to determine the amount of time necessary for water to naturally refill a groundwater basin. This information helps them ensure that water withdrawals for power plants and others are sustainable and do not risk depleting a groundwater basin.

State regulators told us that while federal water availability data is a key input into their decisionmaking process for power plant permits, they also rely on a number of other sources of data, as shown in table 5. These include data that they themselves collect and data collected by universities; private industry, such as power plant developers; and various other water experts.

Table 5: Water Data Considered in Support of State Water Regulators' Permitting Decisions

	USGS data on water availability		State, industry, academic, or other data
	Groundwater	Streamflow	
Alabama	[a]	[a]	[a]
Arizona	[b]	[b]	[b]
California	[c]	Yes	Yes
Georgia	Yes	Yes	Yes
Illinois	[c]	Yes	Yes
Nevada	Yes	Yes	Yes
Texas	[c]	Yes	Yes

Source: GAO analysis of information provided by state regulators.

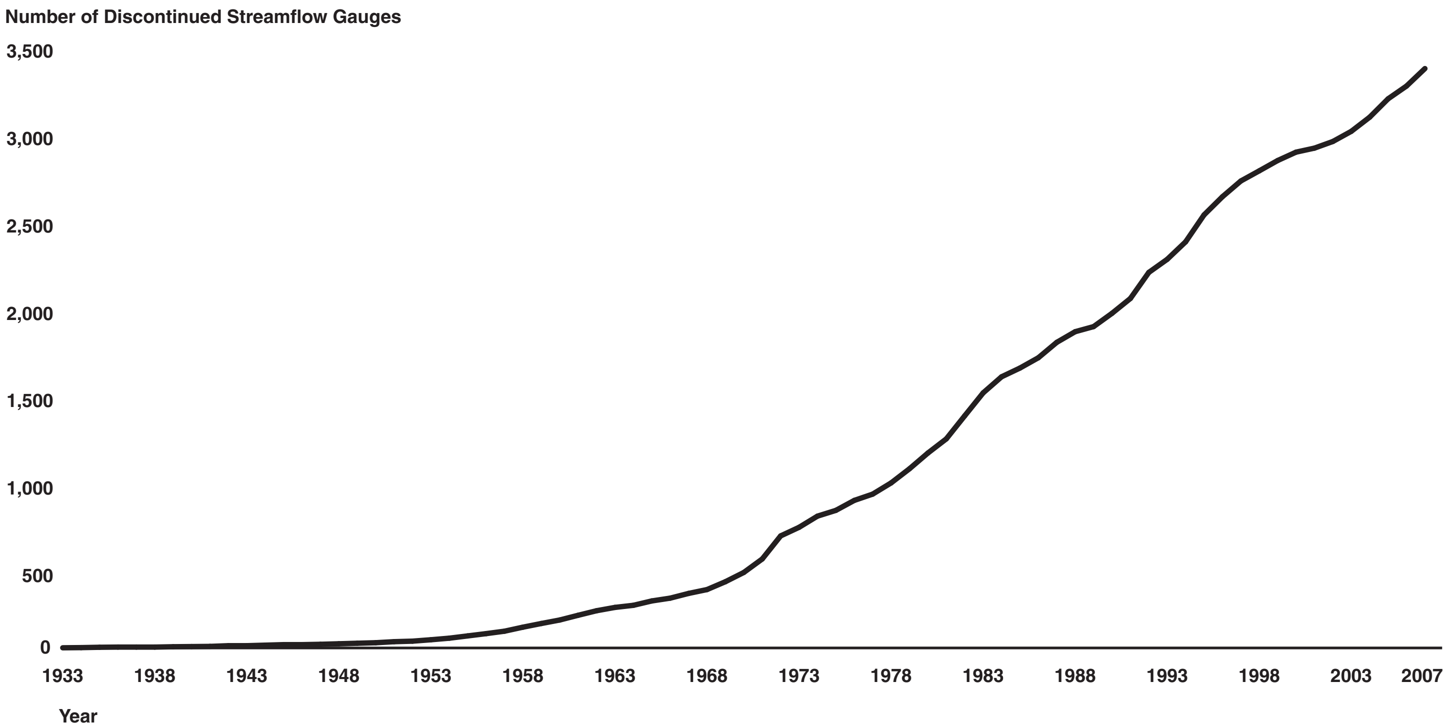
[a]Alabama officials told us they are not authorized to issue water withdrawal permits and, thus, do not rely on USGS water availability data for this purpose. However they rely on these data for a variety of other purposes.

[b]Arizona officials told us that, in practice, they do not often rely on USGS streamflow data for permitting because surface water is fully allocated throughout the state. Similarly, groundwater availability data is not routinely relied upon for permits for groundwater rights in Active Management Areas, since most power plant developers purchase existing rights, rather than apply for a new right. Outside of Active Management Areas, water users only seek drilling permits, which requires limited review. However, surface and groundwater availability data may be relied on to support the Line Siting Committee and the Arizona Corporation Commission's decision to issue a Certificate of Environmental Compatibility.

[c]These states do not issue permits for groundwater at the state level. However, in California, any groundwater use for a power plant would be permitted, if necessary, through the California Energy Commission, which regulates the licensing of power plants.

Some state regulators and water experts we spoke with expressed concern about streamflow gauges being discontinued, which they said may make evaluating trends in water availability and water planning more difficult in the future. Without accurate data on water availability, decisions about water planning and allocation of water resources—including power plant permitting decisions—may be less informed, according to regulators and experts. For example, an official from Arizona told us that a reduction in streamflow gauges would adversely impact the quality of the states' water programs and that state budget constraints have made it increasingly difficult to allocate the necessary state funds to ensure cooperatively-funded streamflow gauges remain operational. Similarly, an official from the Texas Commission on Environmental Quality told us that if particular streamflow gauges were discontinued, water availability records would be unavailable to update existing data for their water availability models—which are relied upon for water planning and permitting decisions—and alternative data would be needed to replace these missing data. USGS officials told us that the cumulative number of streamflow gauges with 30 or more years of record that have been discontinued has increased, as seen in figure 8, due to budget constraints.

Figure 8: Cumulative Number of Discontinued U.S. Geological Survey Streamflow Gauges with 30 or More Years of Record, 1933-2007



Source: U.S. Geological Survey.

Water Experts, Federal Agencies, and Others Value Federal Data on Water Use for Analyzing Industry Trends but Identified Limitations In These Data

Unlike federal data on water availability, federal data on water use is not routinely relied upon by state officials we spoke with to make regulatory decisions; but, instead is used by a variety of data users to identify trends in the industry. Specifically, data users we spoke with, including water experts, representatives of an environmental group, and federal agency officials, identified the following benefits of the water use data collected by USGS and EIA:

- *USGS Data on Water Use.* A number of users of federal water data we spoke with told us that USGS's 5-year data on thermoelectric power plant water use are the only centralized source of long-term, national data for comparing water use trends across sectors, including for thermoelectric power plants. As a result, they are valuable data for informing policymakers and the public about the state of water resources, including changes to water use among power plants and other sectors. For example, one utility representative we spoke with said that USGS data are important for educating the public about how power plants use water and the fact that while thermoelectric power plants withdraw large amounts of water overall—39 percent of U.S. freshwater withdrawals in 2000—their water consumption as an industry has been low—3 percent of U.S. freshwater consumption in 1995. Furthermore, some state water regulators told us that USGS's water use data allow them to compare their state's water use to that of other states and better evaluate and plan around their state's water conditions.[38] An Arizona Department of Water Resources official, for example, told us that USGS's water use data are essential for understanding how water is used in certain parts of the state where the Department has no ability to collect such data.[39]

- *EIA Data on Water Use.* EIA's annual data are the only federally-collected, national data available on water use and cooling technologies at individual power plants; and data users noted that EIA's national data were useful for

[38]Unlike federal data on water availability, federal data on water use developed by USGS and EIA is not routinely relied upon by representatives from most of the state water regulators we spoke with, who evaluate applications for water use permits and water rights for new power plants. Some said they, instead, used data their offices had developed internally, including water use data reported to them by water permit and rights holders.

[39]The Arizona Department of Water Resources collects water use data from water users in Active Management Areas, which are statutorily designated areas of constrained water supply. However, according to one official, the Department does not generally have the ability to collect these data outside of Active Management Areas and Irrigation Non-expansion Areas. Instead, the Department has entered into a cooperative agreement with USGS to collect these data.

analyzing the water use characteristics of individual plants, as well as for comparing water use across different cooling technologies. For example, officials at USGS and the National Energy Technology Laboratory told us that they use EIA data to research trends in current and future thermoelectric power plant and other categories of water use. Specifically, USGS utilizes EIA's data on individual plant water use, in addition to data from state water regulators and individual power plants, to develop county and national estimates of thermoelectric power plant water use. USGS officials explained that in some of their state offices, such as California and Texas, agency staff primarily use EIA and other federal data to develop USGS's 5-year thermoelectric power plant water use estimates. Officials from USGS also explained that other USGS state offices use EIA data on water use to corroborate their estimates of thermoelectric power plant water withdrawals and to identify the cooling technology utilized by power plants. Similarly, officials at the National Energy Technology Laboratory have extensively used EIA's data on individual power plant water withdrawals and consumption to develop estimates of how freshwater use by thermoelectric power plants will change from 2005 to 2030.

However, data users we spoke with also identified a number of shortcomings in the federal data on water use, collected by USGS and EIA, that limits their ability to conduct certain types of industry analyses and understanding of industry trends. Specifically, they identified the following issues, along with others that are detailed in appendix V.

- *Lack of comprehensive data on the use of advanced cooling technologies.* Currently, EIA does not systematically collect information on power plants' use of advanced cooling technologies. In the EIA database, for example, data on power plants' use of advanced cooling technologies is incomplete and inconsistent—not all power plants report information on their use of advanced cooling technologies or do so in a consistent way. Lacking these national data, it is not possible without significant additional work to comprehensively identify how many power plants are using advanced cooling technologies, where they are located, and to what extent the use of these technologies has reduced the use of freshwater. According to a study by the Electric Power Research Institute, although the total number of dry cooled plants is still small relative to plants using traditional cooling systems, the use of advanced cooling technologies is becoming increasingly common.[40] As these technologies become more prevalent, we believe that information about their adoption would help policymakers better understand the extent to which advanced cooling technologies have been successful in reducing freshwater use by power plants and identify those areas of the country where further adoption of these technologies could be encouraged. EIA officials told us they formally coordinate with a group of selected stakeholders every 3 years to determine what changes are needed to EIA data collection forms. They told us they have not previously collected data on advanced cooling technologies because EIA's stakeholder consultation process had not identified these as needed data. However, these officials acknowledged that EIA has not included USGS as a stakeholder during this consultation process and were unaware of USGS' extensive use of their data. In discussing these concerns, EIA officials also said that they did not expect that collecting this information would be too difficult and agreed that such data could benefit various environmental and efficiency analyses conducted by other federal agencies and water and industry experts. Furthermore, in discussing our preliminary findings, EIA officials also said they believed that EIA could collect these data during its triennial review process by, for example, adding a reporting code for these types of cooling systems. However, they noted that they would have to begin the process soon to incorporate it into their ongoing review.

- *Lack of comprehensive data on the use of alternative water sources.* Our review of federal data sources indicates that they cannot be used to comprehensively identify plants using alternative water sources. EIA routinely reports data on individual plant water sources, but we found that these data do not always identify whether the source of water is an alternative source or not. Similarly, while the USGS data identify thermoelectric power plants using ground, surface, fresh, and saline water, they do not identify those using alternative water sources, such as reclaimed water. While a goal of USGS's water use program is to document trends in U.S. water use and provide information needed to understand the nation's water resources, USGS officials said budget constraints have limited the water use data the agency can provide, and has led to USGS discontinuing distribution of data on one alternative water source—reclaimed water. According to two studies we reviewed, use of some alternative water sources is becoming more common and, based on our discussions with regulators and power plant developers,

[40]Electric Power Research Institute, *Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental and Other Tradeoffs*, (Palo Alto, CA., 2002).

there is much interest in this nonfreshwater option, particularly in areas where freshwater is constrained. As use of these alternative water sources becomes more prevalent, we believe that information about how many plants are using these resources and in what locations, could help policymakers better understand how the use of alternative water sources by power plants can replace freshwater use and help identify those areas of the country where such substitution could be further encouraged.

- *Incomplete water and cooling system data.* Though part of EIA's mission is to provide data that promote public understanding of energy's interaction with the environment, EIA does not collect data on the water use and cooling systems of two significant components of the thermoelectric power plant sector. First, in 2002, EIA discontinued its reporting of water use and cooling technology information for nuclear plants. According to data users we spoke with, this is a significant limitation in the federal data on water use and makes it more difficult for them to monitor trends in the industry. For example, USGS officials said that the lack of these data make developing their estimates for thermoelectric power plant water use more difficult because they either have to use older data or call plants directly for this information, which is resource intensive. EIA officials told us they discontinued collection of data from nuclear plants due to priorities stemming from budget limitations.[41] Second, EIA does not collect water use and cooling system data from operators of some combined cycle thermoelectric power plants. Combined cycle plants represented about 25 percent of thermoelectric capacity in 2007, and constituted the majority of thermoelectric generating units built from 2000 to 2007. According to EIA officials, water use and cooling technology data are not collected from operators of combined cycle plants that are not equipped with duct burning technology—a technology that injects fuel into the exhaust stream from the combustion turbine to provide supplemental heat to the steam component of the plant. However, these plants use a cooling system and water, as do other combined cycle and thermoelectric power plants whose operators are required to report to the agency. As a result, data EIA currently collects on water use and cooling systems for thermoelectric power plants is incomplete. EIA officials acknowledged that not collecting these data results in an incomplete understanding of water use by these

[41]EIA officials noted that the agency collects environmental information from all U.S. plants with an existing or planned organic-fueled or combustible renewable stream-electric unit with a generator nameplate rating of 10 megawatts or larger. Form 767 instructions require cooling system and water information to be reported by plants with a nameplate capacity of 100 megawatts or greater.

thermoelectric power plants; however, budget limitations have thus far precluded collection of such data. According to a senior EIA staff in the Electric Power Division, since speaking with GAO, the agency has begun exploring options for collecting these data as part of its current data review process.

- *Discontinued distribution of thermoelectric power plant water consumption data.* One of the stated goals of USGS's water use program is to document trends in U.S. water use, but officials told us that a lack of funding has prompted the agency to discontinue distribution of data on water consumption for thermoelectric power plants and other water users.[42] These USGS officials told us they would like to restart distribution of the data on water consumption by thermoelectric power plants and other water users if additional funding were made available, because such data can be used to determine the amount of water available for reuse by others. Similarly, some users of federal water data told us that not having USGS data on consumption limits their and the public's understanding of how power plant water consumption is changing over time, in comparison to other sectors. They said that the increased use of wet recirculating technologies, which directly consume more water but withdraw significantly less than once-through cooling systems, has changed thermoelectric power plant water use patterns.[43]

In a 2002 report, the National Research Council recommended that USGS's water use program be elevated from one of water use accounting to water science—research and analysis to improve understanding of how human behavior affects patterns of water use.[44] Furthermore, the council's report concluded that statistical analysis of explanatory variables, like cooling system type or water law, is a promising technique for helping determine patterns in thermoelectric power plant water use. The report suggested

[42]EIA reports water consumption data for plants 100 megawatts in size or larger, but has not published aggregated data in such a way that allows them to be readily used to identify overall trends in thermoelectric power plant water consumption compared to withdrawal. However, these and other environmental data collected by EIA from 1996 to 2005 for individual plants are available on EIA's Web site and can be assessed by all users at http://www.eia.doe.gov/cneaf/electricity/page/eia767.html.

[43]Warm water discharged back into a water body from a once-through system may increase evaporation—water consumption—from the receiving water body. One expert we spoke with suggested that including this indirect form of water consumption in plant estimates would improve the federal data.

[44]National Research Council, *Estimating Water Use in the United States* (Washington, D.C., 2002).

these and other approaches could help USGS improve the quality of its water use estimates and the value of the water data it reports. USGS has proposed a national water assessment with the goal of, among other things, addressing some of the recommendations made by the National Research Council report. USGS officials also told us such an initiative would make addressing some of the limitations in USGS water use data identified by water experts and others possible, such as reporting data on water consumption and by hydrologic code.

Conclusions

While much of the authority for regulating water use resides at the state level, the federal government plays an important role in collecting and distributing information about water availability and water use across the country that can help promote more effective management of water resources. However, the lack of collection and reporting of some key data related to power plant water use limits the ability of federal agencies and industry analysts to assess important trends in water use by power plants, compare them to other sectors, and identify the adoption of new technologies that can reduce freshwater use. Without this comprehensive information, policymakers have an incomplete picture of the impact that thermoelectric power plants will have on water resources in different regions of the country and will be less able to determine what additional activities they should encourage for water conservation in these areas. Moreover, although both EIA and USGS seek to provide timely and accurate information about the electricity sector's water use, they have not routinely coordinated their efforts in a consistent and formal way. As a result, key water data collected by EIA and used by USGS have been discontinued or omitted and important trends in the electricity sector have been overlooked. EIA's ongoing triennial review of the data it collects about power plants and the recent passage of the Secure Water Act, that authorizes funding for USGS to report data on water use to Congress, provide a timely opportunity to address gaps in federal data collection and reporting and improve coordination between USGS and EIA in a cost-effective way.

Recommendations for Executive Action

We are making seven recommendations. Specifically, to improve the usefulness of the data collected by EIA and better inform the nation's understanding of power plant water use and how it affects water availability, we recommend that the Administrator of EIA consider taking the following four actions as part of its ongoing review of the data it collects about power plants:

- add cooling technology reporting codes for alternative cooling technologies, such as dry and hybrid cooling, or take equivalent steps to ensure these cooling technologies can be identified in EIA's database;

- expand reporting of water use and cooling technology data to include all significant types of thermoelectric power plants, particularly by reinstating data collection for nuclear plants and initiating collection of data for all combined cycle natural gas plants;

- collect and report data on the use of alternative water sources, such as treated effluent and groundwater that is not suitable for drinking or irrigation, by individual power plants; and

- include USGS and other key users of power plant water use and cooling system data as part of EIA's triennial review process.

To improve the usefulness of the data collected by USGS and better inform the nation's understanding of power plant water use and how it affects water availability, we recommend that the Secretary of the Interior consider:

- expanding efforts to disseminate available data on the use of alternative water sources, such as treated effluent and groundwater that is not suitable for drinking or irrigation, by thermoelectric power plants, to the extent that this information becomes available from EIA; and

- reinstating collection and distribution of water consumption data at thermoelectric power plants.

To improve the overall quality of data collected on water use from power plants, we recommend that EIA and USGS establish a process for regularly coordinating with each other, water and electricity industry experts, environmental groups, academics, and other federal agencies, to identify and implement steps to improve data collection and dissemination.

Agency Comments and Our Evaluation

We provided a draft of this report to the Secretary of the Interior and to the Secretary of Energy for review and comment.

The Department of the Interior, in a letter dated September 29, 2009, provided written comments from the Assistant Secretary for Water and

Science. These comments are reprinted in appendix VI. In her letter, the Assistant Secretary agreed with GAO's recommendations and noted the importance of improving water use data, including data on water consumption at thermoelectric power plants. The letter noted that USGS plans to reinstate data collection on water consumption as future resources allow and will expand efforts to disseminate data on alternative water use as information becomes available from EIA. In addition, USGS plans to coordinate with EIA to establish a process to identify and implement steps to improve and expand water use data collection and dissemination by the two agencies.

In response to our request for comments from the Department of Energy, we received emails from the audit liaisons at the National Energy Technology Laboratory and the EIA. The laboratory's comments note that the report accurately described the energy-water nexus as it relates to power plants and accurately documented the current state of power plant cooling technologies. These comments expressed the importance of completing a full assessment of the energy-water relationship in the future, especially in light of climate change regulations. The laboratory also provided technical comments, which we incorporated as appropriate. EIA provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to interested congressional committees; the Administrator of the Energy Information Administration; the Secretaries of Energy and the Interior; and other interested parties. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact us at (202) 512-3841 or mittala@gao.gov or gaffiganm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix VII.

Sincerely yours,

Anu Mittal
Director, Natural Resources and
Environment

Mark Gaffigan
Director, Natural Resources and
Environment

Appendix I: Objectives, Scope and Methodology

At the request of the Chairman of the House Committee on Science and Technology, we reviewed (1) technologies and other approaches that can help reduce freshwater use by power plants and what, if any, drawbacks there are to implementation; (2) the extent to which selected states consider water impacts of power plants when reviewing power plant development proposals; and (3) the usefulness of federal water data to experts and state regulators who evaluate power plant development proposals. We focused our evaluation on thermoelectric power plants, such as nuclear, coal, and natural gas plants using a steam cycle. We did not consider the water supply issues associated with hydroelectric power, since the process through which these plants use water is substantially different from that of thermoelectric plants (e.g., water is used as it passes through a dam but is not directly consumed in the process). We also focused the review on water used during the production of electricity at power plants, and did not include water issues associated with extracting fuels used to produce electricity.

To understand technologies and other approaches that can help reduce freshwater use by power plants and their drawbacks, we reviewed industry, federal, and academic studies on advanced cooling technologies and alternative water sources that discussed their benefits, such as reduced freshwater use, and what, if any, drawbacks their implementation entails. These included studies with information on power plants' use of water and the drawbacks of nonfreshwater alternatives conducted by the Electric Power Research Institute, the Department of Energy's National Energy Technology Laboratory, and others. We discussed these trade-offs with various experts, including power plant and cooling system manufacturers, such as GEA Power Cooling Inc., General Electric, Siemens, and SPX Cooling Technologies; other industry groups and consultants, such as the Electric Power Research Institute, Maulbetsch Consulting, Nalco, and Tetra Tech; an engineering firm, Black & Veatch; and federal, national laboratory, and academic sources. To get a user perspective on these different technologies and alternative water sources, we met with power plant operators, including Arizona Public Service Company, Calpine, Georgia Power Company, and Sempra Generation. We also spoke with representatives from and reviewed reports prepared by other National Laboratories, such as the Department of Energy's Argonne National Laboratory, to understand related research activities concerning water and electricity. To better understand how the differences in cooling technologies and heat sources used by power plants affect power plant configuration and design, we toured three power plant facilities in Texas—Comanche Peak (nuclear, once-through cooling), Limestone (coal, wet recirculating with cooling towers), and Midlothian (natural gas combined cycle, dry cooling).

To determine the extent to which selected states consider water impacts of power plants when reviewing power plant development proposals, we conducted case study reviews of three statesArizona, California, and Georgia. These states were selected because of their historic differences in water availability, differences in water law, high energy production, and large population centers. We did not attempt to determine whether states' efforts were reasonable or effective, rather we only described what states do to consider water impacts when making power plant siting decisions. For each of these case study states, we met with state water regulators and power plant developers to understand how water planning and permitting decisions are approached from both a regulatory and private industry perspective. We also met with water research institutions and other subject matter experts to understand current and future research related to water impacts of power plants and the extent to which these research endeavors help inform power plant development proposals and regulatory water permitting decisions. Specifically, in California we met with the California Department of Water Resources; the California Energy Commission; the California State Water Resources Control Board; the San Francisco Bay Regional Water Quality Control Board; and the U.S. Geological Survey's (USGS) California Water Science Center. In Georgia we met with the Georgia Environmental Protection Division; the Georgia Public Service Commission; the Georgia Water Resources Institute; the Metropolitan North Georgia Water Planning District; the U.S. Army Corps of Engineers, South Atlantic Division; and the USGS Georgia Water Science Center. In Arizona we met with the Arizona Corporation Commission; the Arizona Department of Environmental Quality; the Arizona Department of Water Resources; the Arizona Power Plant and Transmission Line Siting Committee; the Arizona Office of Energy, Department of Commerce; the Arizona Water Institute, and the USGS Arizona Water Science Center. In addition, we reviewed state water laws and policies for thermoelectric power plant water use, selected power plant operator proposals to use water, and state water regulators' water permitting decisions. We also reviewed selected public utility commission dockets and testimonies describing various power plant siting decisions to understand what, if any, water issues were addressed. To broaden our understanding of how states consider the water impacts of power plants when reviewing power plant development proposals, we supplemented our case studies by conducting interviews and reviewing documents from four additional states Nevada and Alabama—which shared watersheds with the case study states—and Illinois and Texas, which are large electricity producing states with sizable population centers. For each of these four states, we spoke with the primary state water regulatory agencies—the Alabama Office of Water Resources, the Illinois Office of Water Resources, the Nevada Division of Water Resources, and the Texas Commission on Environmental Quality—to understand how state water regulators consider the impacts of power plant operators' proposals to use water. In Texas, additional discussions were held with the Public Utility Commission of Texas; the Texas Water Development Board; the University of Texas; and the USGS Texas Water Science Center to further understand how water supply issues and energy demand are managed in Texas. In Alabama, we held additional discussions with officials from the Alabama Public Service Commission and the Alabama Department of Environmental Management to learn more about how Alabama's state water regulators and power plant operators manage water supply and energy demand. In Nevada, we held a discussion with an official from the Public Utilities Commission of Nevada to determine how they evaluate cooling technologies and water issues in plant siting certification proceedings. We also contacted the Illinois Commerce Commission.

Finally, to determine how useful federal water data are to experts and state regulators who evaluate power plant development proposals, we reviewed data and analysis from the Energy Information Administration (EIA), USGS, and the Department of Energy's National Energy Technology Laboratory and analyzed how the data were being used. We also conducted interviews with federal agencies, including the Bureau of Reclamation; EIA; Environmental Protection Agency; Tennessee Valley Authority; U.S. Army Corps of Engineers; and USGS to understand whether each organization also collected water data and their opinions about the strengths and limitations of EIA and USGS data. We spoke with several regional offices for the Bureau of Reclamation, including the Lower Colorado and Mid-Pacific offices to understand federal water issues in California, Arizona, and Nevada. In addition, to understand how valuable federal water data are to experts and state regulators who evaluate power plant development proposals to use water, we conducted interviews and reviewed documents from state water regulators and public utility commissions, as well as water and electricity experts at environmental and water organizations, such as the Pacific Institute and Environmental Defense Fund; at universities such as the Georgia Institute of Technology; Southern Illinois University, Carbondale; and the University of Maryland, Baltimore County; and experts from industry, national laboratories, and other organizations and universities previously mentioned. We also contacted other electricity groups, including the North American Electric Reliability Corporation and the National Association of

Regulatory Utility Commissioners, to get a broader understanding of how the electricity industry addresses water supply issues.

We conducted this performance audit from October 2008 through October 2009, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Review of Proposals to Use Water in New Power Plants in Arizona

Background

Arizona, with a population of 6.5 million, was the 16th most populous state in the country in 2008 and was one of the fastest growing states, growing at a rate of 2.3 percent from 2007 to 2008. Most of the land in Arizona is relatively dry, therefore, water for electricity production is limited. For 2007, Arizona accounted for 2.7 percent of U.S. net electricity generation, ranking it 13th, with most generation coming from coal (36 percent); natural gas (34 percent); nuclear (24 percent); and renewable sources, such as hydroelectric (6 percent), although the state has a strong interest in developing solar and other renewable sources.

Arizona Water Law and Policy

Arizona relies on three water sources for electricity production: (1) surface water, including the Colorado River; (2) groundwater; and (3) effluent. Arizona water law varies depending on the source and the user's location, specifically:

- *Surface water.* The use of surface water in Arizona is determined by the doctrine of prior appropriation. The Arizona Department of Water Resources issues permits to use surface water statewide, with the exception of water from the Colorado River.[1] The federal government developed water storage and distribution via a series of canals to divert water from the Colorado River to southern Arizona, and the Bureau of Reclamation issues contracts for any new water entitlements related to Colorado River water, in consultation with the Arizona Department of Water Resources.

- *Groundwater.* The use of groundwater depends on its location. Because some areas receive seasonal rain and snow, average annual precipitation can vary by location, from 3 to over 36 inches of moisture. The state established five regions where groundwater is most limited known as Active Management Areas. Permits to use groundwater in these five areas are coordinated through the Arizona Department of Water Resources,

[1]According to an Arizona Department of Water Resources official, it issues a Certificate of Water Right once the water is put to beneficial use. Several areas of decreed rights exist, for example, Globe Equity Decree on the Upper Gila River.

which provides several permitting options for power plants.[2] Outside Active Management Areas, the state subjects groundwater to little regulation or monitoring and generally only requires users to submit a well application to the Department of Water Resources.

- *Effluent.* Effluent is owned by the entity that generates it until it is discharged into a surface water channel. The owner has the right to put effluent to beneficial use or convey it to another entity, such as a power plant, that will put it to beneficial use. However, once it is discharged from the pipe, generally into a surface water body, such as a river, it is considered abandoned and subject to laws governing surface water.

Arizona has no overall statewide policy on the use of water in thermoelectric power plants. However, in Active Management Areas, the state requires developers of newer power plants with a generating capacity of 25 megawatts or larger to use groundwater in a wet recirculating system with a cooling tower and to cycle water through the cooling loop at least 15 times before discharging it.[3] An official of an Arizona public utility noted that it was more common to cycle water 3 to 7 times outside of Active Management Areas.

Certification and Water Permitting for New Power Plants

Before a power plant developer can begin constructing a power plant with a generating capacity of 100 megawatts or larger, it must go through a two-step certification process and a permitting process, as follows:[4]

[2]According to Arizona Department of Water Resources officials, options for obtaining groundwater rights include the following: (1) an existing Irrigation Grandfathered Groundwater Right that can be legally retired to a Type 1 Non-Irrigation Grandfathered Groundwater Right (A.R.S. § 45-469); (2) an existing Type 1 Non-Irrigation Grandfathered Groundwater Right (A.R.S. §§ 45-470, 45-472, 45-473, 45-542)); (3) a Type 2 Non-Irrigation Grandfathered Groundwater Right, which can be purchased or leased from another owner within the same Active Management Area (A.R.S. § 45-471); or (4) a General Industrial Use Permit, a permit to pump groundwater from a point outside of the exterior boundaries of the service area of a city, town, or private water company for non-irrigation purposes (A.R.S. § 45-515). Inside the Harquahala Irrigation Non-Expansion Area, there are some limitations to pumping groundwater for industrial uses, pursuant to A.R.S. § 45-440.

[3]There are variations for different plants in the number of cycles required and exemptions for the first full year of operation.

[4]Plants smaller that 100 megawatts do not need state siting approval. However, they must still comply with any and all local ordinances or state ordinances such as zoning, water quality, air quality, etc.

- The first step of the certification process involves public hearings before the Arizona Power Plant and Transmission Line Siting Committee, made up of representatives from five state agencies and six additional members appointed by the Arizona Corporation Commission.[5] Although the Line Siting Committee is not required to evaluate water use unless the plant will be located within an Active Management Area, it typically considers water rights, water availability for the life of the power plant, and the environmental effects of groundwater pumping around the plant. Committee members told us they often ask about the planned water sources and whether alternative water sources and cooling technologies are available. If the plant will be located within an Active Management Area, a representative of the Department of Water Resources serving on the Committee takes the lead in evaluating the plant's potential adverse impacts on the water source, including reviewing state data or U.S. Geological Survey (USGS) studies that document the status and health of the proposed water source. A representative from the Arizona Department of Environmental Quality serving on the Committee considers the plant's potential adverse effects on water quality. Based on this information, as well as the proposed plant's feasibility and its potential environmental and economic impacts, the Committee issues a recommended Certificate of Environmental Compatibility, if appropriate.

- In the second step of the certification process, the Arizona Corporation Commission reviews the power plant developer's application to ensure there is a balance between the state's need for energy and the plant's cost and potential environmental impacts, including water quality, water supply, ecological, and wetlands impacts. The Commission can accept, deny, or modify the Certificate of Environmental Compatibility that was recommended by the Line Siting Committee and has denied some certificates. The Commission places the burden on the applicant to demonstrate that the proposed water supply is sustainable and how any water quality impacts will be mitigated. The Commission does not collect or review additional water data or conduct quality checks on the data provided by the power plant developers.

- The permitting process applies to both water supply and water quality. With respect to water supply, when required, power plant developers who plan to use surface water in most areas of the state or groundwater in an Active Management Area must obtain a water use permit from the

[5]The Committee is chaired by a representative from the Office of the Arizona Attorney General. Other agencies represented include the Department of Environmental Quality, Department of Water Resources, the Office of Energy in the Department of Commerce, and the Arizona Corporation Commission.

Department of Water Resources. When applying for a permit, power plant developers are required to provide information on the amount of water they will use, the source, points of diversion and release, and how the power they generate will be used. For groundwater in an Active Management Area, users are strictly limited to a total volume of water permitted for withdrawal and are subject to annual reporting and an analysis of the impact on other wells. According to an official at the Department of Water Resources, the Department has extensive data on available groundwater for each Active Management Area to assist in determining the effects of groundwater use. With respect to water quality, power plant developers must obtain permits which regulate water quality through the Department of Environmental Quality. Further, power plants discharging into federally-regulated waters also need a National Pollutant Discharge Elimination System permit that covers effluent limitations and sets discharge requirements. This program is intended to ensure that discharges to surface waters do not adversely affect the quality and beneficial uses of such water.

Recent State Decisions about Power Plant Water Use

Between January 2004 and July 2009, Arizona has approved three new power plants, two of which are simple cycle natural gas plants that do not need water for cooling. The third plant is a concentrating solar thermal plant using a wet recirculating system with cooling towers. According to an official from the Arizona Department or Water Resources, once the plant begins operating, it will use 3,000 acre feet of water annually from groundwater and surface water, under contract from an Irrigation District.

Between 1999 and 2002, a large number of applications for power plants in Arizona were filed, most of which were approved.[6] However, at least one plant was denied a Certificate of Environmental Compatibility due to a water supply concern—the potential loss of habitat for an endangered species from possible groundwater depletion. Approved plants used a variety of water sources for cooling, including recycled wastewater, surface water through arrangements with the Central Arizona Project, and groundwater—both directly used or from conversion of agricultural land. No dry cooled power plants have been approved in Arizona, according to state officials. State officials told us dry cooling is too inefficient and costly, but that it may be considered in the future if water shortages become more acute.

[6]Due to declining electricity prices, some of the approved plants were never constructed and others were sold to new owners.

Appendix III: Review of Proposals to Use Water in New Power Plants in California

Background

As of January 2009, California had the nation's largest population—an estimated 38.3 million people—and grew at a rate of 1.1 percent annually from 2008 to 2009. California has significant variations in water availability, with a long coastline; several large rivers, particularly in the north; mountainous areas that receive substantial snowfall; and arid regions, particularly the Mojave Desert in southeastern California. Statewide, California averages 21.4 inches of rain annually, but has suffered significant droughts for the past three years. For 2007, California accounted for 5.1 percent of U.S. net electricity generation, ranking it 4th nationally. California generates electricity primarily from natural gas (55 percent); nuclear (17 percent); and renewable energy sources—primarily hydroelectric, wind, solar, and geothermal (25 percent). California imports 27 percent of its electricity from other states.

California Water Law and Policy

California water law depends on whether the water is surface water or groundwater, specifically:

- *Surface water.* The use of surface water is subject to both the riparian and appropriative rights doctrines. No permit is needed to act upon riparian surface water rights, which result from ownership of land bordering a water source, and are senior to most appropriative rights. Appropriative rights, on the other hand, must be acquired through the State Water Resources Control Board. Applicants for appropriative rights must show, among other things, that the water will be put to beneficial use.

- *Groundwater.* The majority of California's groundwater is unregulated.[1] Additionally, California does not have a comprehensive groundwater permit process in place, except for groundwater that flows through subterranean streams, which is permitted by the State Water Resources Control Board.

California has several policies that directly and indirectly address how thermoelectric power plants can use water. Specifically:

- California's State Water Resources Control Board, as the designated state water pollution control agency and issuer of surface water rights, established a policy in 1975 that states that the use of fresh inland waters for power plant cooling will only be approved when it is demonstrated that

[1] In some areas of California, groundwater is managed locally through Adjudicated Groundwater Basins that can regulate the amount of groundwater extracted.

the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound. Freshwater should be considered the last resort for power plant cooling in California. Since that time, according to officials we spoke with, the Board has encouraged the use of alternative sources of cooling water and alternative cooling technologies.

- The California Energy Commission (CEC), the state's principal energy policy and planning organization, in 2003, reiterated the 1975 policy and further required developers to consider whether zero-liquid discharge technologies should be used to reduce water use unless it can be shown that the use of these technologies would be environmentally undesirable or economically unsound. Under these policies, dry cooling and use of alternative water for cooling would be the preferred alternatives.

- The State Water Resources Control Board discourages the use of once-through cooling in power plants due to potential harm to aquatic organisms. The agency is considering a state policy to require power plants using this technology to begin using other cooling technologies or retire from service.

Certification and Water Permitting for New Power Plants

California has a centralized permitting process for new large power plants, including thermoelectric power plants. Developers constructing new power plants with a generating capacity of 50 megawatts or larger must apply for certification with the CEC, the lead state agency for ensuring proposed plants meet requirements of the California Environmental Quality Act and generally overseeing the siting of new power plants.[2] The CEC coordinates review of other state environmental agencies, such as the State Water Resources Control Board and issues all required state permits (air permits, water permits, etc.). Prior to issuing the permits needed to construct a new power plant, the CEC conducts an independent assessment, with public participation, of each proposed plant's environmental impacts; public health and safety impacts; and compliance with federal, state, and local laws, ordinances, and regulations. As part of its review, CEC staff analyze the effect on other water users of power plant developers' proposed use of water for cooling and other purposes, access to needed water supplies throughout the life of the plant, and the

[2]California's local air pollution control and air quality management districts have the authority to issue construction permits for the operation of power plants with less than 50 megawatts of generating capacity.

plant's impact on the proposed water source and the state's water supply overall.[3] The CEC also ensures power plant developers have obtained the required water supply agreements; analyzed the feasibility of alternative water sources and cooling technologies; and addressed water supply, water quality, and wastewater disposal impacts. The CEC may require implementation of various measures to mitigate the impacts of water use, if it identifies problems. The CEC's goal is to complete the entire certification process in 12 months, but public objections, incomplete application submittals, staff shortages, and limited budgets sometimes delay the process.

The CEC evaluates several sources of water data before certifying plant applicants' water use. These include:

- the developer's proposals;
- data from the Department of Water Resources' groundwater database on water availability and water quality;
- U.S. Geological Survey data on water availability through its streamflow and groundwater monitoring programs and any specific basin studies;
- the State Water Resources Control Board's information on surface and groundwater quality; and
- computer groundwater models that analyze the long-term yield of the basin.

With respect to water quality, the CEC coordinates the issuance of permits relating to water quality for new power plants, but the State Water Resources Control Board sets overall state policy. The Board operates under authority delegated to it by the U.S. Environmental Protection Agency to implement certain federal laws, including the Clean Water Act, as well as authority provided under state laws designed to protect water quality and ensure that the state's water is put to beneficial uses. Nine Regional Water Boards are delegated responsibility for implementing the

[3]Though not common, if a power plant developer plans to make use of surface water in California, it may be required to apply for a water right from the State Water Resources Control Board. In evaluating the permit application, the State Water Resources Control Board would conduct its own analysis using a combination of state and federal data sources.

statewide water quality control plans and policies, including setting discharge requirements for permits for the National Pollutant Discharge Elimination System Program and issuing the permits.

Recent State Decisions and Current Proposals about Power Plant Water Use

Since 2004, most power plants the CEC has approved or is currently reviewing plan to use dry cooling or a wet recirculating system that uses an alternative water source, as shown in table 6. According to a state official we spoke with, no plants approved to be built in the last 25 years have used once-through cooling technology. Over the last 7 years, the CEC has also commissioned, or been involved in, substantial research into the use and possible effects of using alternative cooling technologies.

Table 6: Power Plants Implemented, Approved or Planned Since January 1, 2004, by Cooling Type

			Wet recirculating cooling system		
Category[a]	Number of plants	Dry cooled	Freshwater	Reclaimed water	Impaired groundwater
Operational Plant[b,c,d,g]	7	0	3	4	1
Approved by the CEC but not yet operational[c,e,g]	10	3	2	4	2
Currently under CEC review[f]	20	11	1	7	1
Total[d,e,g]	**37**	**14**	**6**	**15**	**4**

Source: GAO analysis of data from the California Energy Commission for plants sited, approved, or currently under review between January 1, 2004, and April 30, 2009.

[a]Excludes simple cycle gas plants with no steam cycle.

[b]Plants that started operating after 1/1/2004. These plants may have been approved by the CEC earlier.

[c]Includes one geothermal plant.

[d]One plant uses both recycled and impaired groundwater.

[e]Includes one hybrid plant that combines dry and wet cooling.

[f]Includes 7 solar thermal plants.

[g]Totals do not equal due to several plants using multiple water or cooling sources. See notes d and e.

Appendix IV: Review of Proposals to Use Water in New Power Plants in Georgia

Background

In 2008, Georgia ranked 9th in population among states, with 9.7 million people, and had the 4th fastest growing population in the U.S. between the years 2000 and 2007. Georgia is historically water rich, receiving approximately 51 inches of precipitation annually, but recent droughts and growing population have prompted additional focus on water supply and management strategies. Georgia ranked 8th in total net electricity generation in 2007, accounting for approximately 3.5 percent of net electricity generation in the United States. Coal and nuclear power are the primary fuel sources for electricity in Georgia, with coal-fired power plants providing more than 60 percent of electricity output.

Georgia Water Law and Policy

Georgia is a regulated riparian state, meaning that the owners of land adjacent to a water body can choose when, where, and how to use the water. The use must be considered reasonable relative to a competing user, with the courts responsible for resolving disputes about reasonable use. Since the late 1970s, Georgia law has required any water user who withdraws more than an average of 100,000 gallons per day to obtain a withdrawal permit from the Georgia Environmental Protection Division.[1]

Georgia does not have a policy or guidance specifically addressing thermoelectric power plants' water use. However, in response to recent droughts and population growth, the state adopted its first statewide water management plan in 2008. State water regulators we spoke with said they expect the new state water plan to consider how future power generation siting decisions align with state water supplies.

Certification and Water Permitting for New Power Plants

Before power plant developers can begin construction, they may be required to obtain certification from the Georgia Public Service Commission and relevant permits from offices such as the Georgia Environmental Protection Division, as follows:

- *Georgia Public Service Commission.* Georgia Power Company, the state's investor-owned utility, is fully regulated by the Public Service Commission and must obtain a certificate of public convenience and necessity prior to constructing new power plants. Other power plant developers, including municipality- and cooperatively-owned power plants and others, are not

[1]Any entity that withdraws more than 100,000 gallons a day (monthly average) of surface water or 100,000 gallons a day (daily average) of groundwater requires a water permit from the Division.

subject to certification. Public Service Commission officials explained that during the certification process, they balance the need for the new plant and its costs, but they do not consider the impact a plant will have on Georgia's water supply. However, these officials explained that, in their capacity to ensure utilities charge just and reasonable rates, they could consider the economic impact of using an alternative water source or advanced cooling technology, should a plant propose to use one.

- *Georgia Environmental Protection Division.* Any entity seeking to use more than 100,000 gallons of water per day, including power plant developers, must obtain a permit from the Georgia Environmental Protection Division. The Division analyzes the proposed quantity of withdrawals and the water source and determines whether the withdrawal amounts and potential effects for downstream water users are acceptable. In some instances, the Division may place special conditions on power plants to ensure adequate water availability, such as requiring on-site reservoirs or groundwater withdrawals for water use during droughts. In making their decisions, the Georgia Environmental Protection Division reviews the plant's application and hydrologic data from a number of sources. Water withdrawal applications include many factors, in addition to withdrawal amounts and sources, such as water conservation and drought contingency plans; documentation of growth in water demand, location, and purpose of water withdrawn or diverted; and annual consumption estimates. Other data sources include their own and U.S. Geological Survey (USGS) groundwater data, USGS streamflow data, and existing water use permits. In some instances, the Environmental Protection Division may also use water withdrawal and water quality data collected by the U.S. Army Corps of Engineers if an applicant is downstream of federally-regulated waters. In addition to permitting water use, the Division is also responsible for issuing and enforcing all state permits involving water quality impacts. It is authorized by the Environmental Protection Agency to issue National Pollutant Discharge Elimination System permits that address discharge limits and reporting requirements.

Recent State Decisions about Power Plant Water Use

According to Division officials, the Division has never denied a water withdrawal permit to a power plant developer on the basis of insufficient water, which they attributed partly to the fact that the staff meets with applicants numerous times before they submit the application to identify and mitigate concerns about water availability. Moreover, they told us that thermoelectric power plant developers have submitted few applications for water withdrawal permits. For example, as shown in table 7, between January 1, 2004, and December 31, 2008, the Division received only 6 water withdrawal applications from thermoelectric power plant developers; of these, it approved 5. An official from the Public Service Commission was unaware of any regulated power plant developers proposing the use of advanced cooling technologies, such as dry cooling or hybrid cooling, over this time period.

Table 7: Thermoelectric Power Plant Applications for Water Withdrawal Permits in Georgia Between January 2004 and December 2008

			Recirculating		
Category	Number of Plants	Once-through	Groundwater (Freshwater)	Surface water (Freshwater)	Reclaimed water
Applied	6	0	4	2	1
Permitted[a]	5	0	3	1	1

Source: GAO analysis of data provided by the Georgia Environmental Protection Division.

Note: Totals do not equal due to one power plant developer submitting both a groundwater and surface water withdrawal application.

[a]As of August 12, 2009, one plant's application is still pending a decision by the Georgia Environmental Protection Division.

Georgia Environmental Protection Division officials told us they do not advocate or refuse the use of particular cooling technologies. However, officials said they do not expect to receive applications for once-through cooling plants because federal environmental regulations make the permitting process difficult.

Appendix V: Limitations to Federal Water Use Data Identified by Those GAO Contacted

Data source	Limitation	Cause	Effect
EIA	*Advanced cooling technologies:* Data users cannot comprehensively identify plants making use of advanced cooling technologies, such as dry and hybrid cooling.	EIA forms are not designed to collect information on advanced cooling technologies.	Understanding of trends in the adoption of advanced cooling technologies cannot be systematically determined using only EIA data.
EIA	*Cooling system codes:* Codes used to classify plant cooling systems may be incomplete, lack explanation, overlap, or contain errors.	Cooling system codes are not defined in detail and plants may be uncertain about what cooling system code to use.	Inconsistent use of cooling tower codes could potentially make EIA data less valuable and lead to inaccurate or inconsistent data and analysis.
EIA	*Nuclear water data:* Water use data (withdrawal, consumption and discharge) and cooling information were discontinued for nuclear plants in 2002.	EIA discontinued reporting nuclear water use data and cooling system information due to priorities stemming from budget limitations.	Data users must use noncurrent data or seek out an alternate source. If this limitation persists, water data will not be available for any new nuclear plants constructed.
EIA and USGS	*Alternative water sources:* It is not possible to comprehensively identify power plants using alternative water sources.	EIA forms are not designed to collect information on alternative water sources. According to USGS, budget constraints have limited the amount of water use information the agency can provide.	Understanding trends in power plant adoption of alternative water sources is limited.
EIA and USGS	*Frequency:* EIA reports data on annual water use, rather than data on water use over shorter time periods, such as monthly. USGS reports 5-year data.	EIA's form 767, used to collect cooling system and water data, was developed and revised in the 1980s, and EIA officials we spoke with were not aware of why an annual time period was originally chosen. According to USGS, budget constraints have limited the amount of water use information the agency can provide.	Seasonal trends in water use by power plants are not evident from annual EIA or 5-year USGS data.
EIA and USGS	*Quality:* Reporting of some EIA data elements may be inaccurate or inconsistent. USGS data are compiled from many different data sources, and the accuracy and methodology of these sources may vary. Furthermore, USGS state offices have different methods for developing water use estimates, potentially contributing to data inconsistency.	Respondents may use different methods to measure or estimate data and instructions may be limited or unclear. Respondents may make mistakes or have nontechnical staff fill out surveys, since EIA's form for collecting this data does not require technical staff to complete the survey. According to USGS, budget constraints in its water use program kept the agency from implementing improvements it would like to make to its quality control of water use data.	Inaccurate and inconsistent data are more challenging to analyze and less relevant for policymakers, water experts and the public seeking to understand water use patterns.

Data source	Limitation	Cause	Effect
USGS	*Consumption:* USGS discontinued reporting of thermoelectric power plant and other water consumption data.	According to USGS, budget constraints have caused the agency to make cuts in data reporting.	Understanding of trends in power plant water consumption compared to other industries is limited. Analysis to compare thermoelectric power plant withdrawals to consumption is more complicated.
USGS	*Hydrologic code:* USGS discontinued reporting thermoelectric power plant and other water use by hydrologic code. It now only reports data by county.	According to USGS, budget constraints have caused the agency to make cuts in data reporting.	According to some data users, not having data by hydrologic code complicates water analysis, which is often performed by watershed rather than county.
USGS	*Timeliness:* Data are reported many years late. For example, data on 2005 water use have not yet been made available to the public.	According to USGS, budget constraints have led to limited staff availability for water use data collection and analysis, resulting in reporting delays.	Data are outdated and may be less relevant for analysis.

Source: GAO analysis of comments gathered during interviews with water and electricity experts, environmental groups, and federal agencies.

Appendix VI: Comments from the Department of the Interior

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

SEP 2 9 2009

Ms. Anu Mittal
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Ms. Mittal:

Thank you for providing the Department of the Interior (DOI) the opportunity to review and comment on the draft Government Accountability Office (GAO) Report entitled, "*ELECTRICITY AND WATER: Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use" (GAO-09-912).*

The DOI agrees with the recommendations made by the GAO. The USGS works in cooperation with local, State, and Federal agencies to compile and disseminate data on the Nation's water use. Enhancement of water-use information is a key element of the Subtitle F-Secure Water of the Omnibus Public Lands Management Act of 2009 (P.L. 111-11) and is a high priority component of the Water Census of the United States, one of six strategic science directions for the USGS. As information becomes available from the Energy Information Administration (EIA), the USGS will expand efforts to disseminate data on the use of alternative water sources by thermoelectric power plants. The USGS views water consumption data at thermoelectric plants as an important component of the Water Census and will reinstate its collection as future resources allow. The USGS will coordinate with EIA to establish a process to identify and implement steps to improve water-use data collection and dissemination by the two agencies.

We hope these comments will assist you in preparing the final report. If you have any questions, or need additional information, please contact Dr. Matt Larsen (703) 648-5215 or Mr. William Cunningham at (703) 648-5005.

Sincerely,

Anne J. Castle

Anne J. Castle
Assistant Secretary for
Water and Science

Appendix VII: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to the individuals named above, Jon Ludwigson (Assistant Director), Scott Clayton, Philip Farah, Paige Gilbreath, Randy Jones, Alison O'Neill, Timothy Persons, Kim Raheb, Barbara Timmerman, Walter Vance, and Jimi Yerokun made key contributions to this report.

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