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Report to the Ranking Member, Committee on Science, Space, and Technology, House of Representatives

September 2012

ENERGY-WATER NEXUS

Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs

GAO-12-880

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Highlights

Highlights of GAO-12-880, a report to the Ranking Member, Committee on Science, Space, and Technology, House of Representatives

September 2012

ENERGY-WATER NEXUS

Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs

Why GAO Did This Study

Water and energy are inextricably linked and mutually dependent, with each affecting the other's availability. Since 2009, GAO has issued five reports on the interdependencies between energy and water. These reports have shown that a considerable amount of water is used to cool thermoelectric power plants, grow feedstocks and produce biofuels, and extract oil and natural gas. Some of these sources of energy may also negatively affect water quality. In addition, developing oil and gas resources can produce wastewater—known as "produced water"—that must be managed or treated. Conversely, significant amounts of energy are needed to extract, transport, treat, and use water in urban areas.

GAO was asked to identify key energy-water nexus issues that Congress and federal agencies need to consider when developing and implementing national policies for energy and water resources. To conduct this work, GAO systematically reviewed its five reports to identify key nexus issues. GAO also used a content analysis of related literature and interviews with specialists to validate these themes.

What GAO Recommends

GAO is recommending that DOE take the actions necessary to establish a program to address the energy-water nexus, with involvement from other federal agencies, as described in the Energy Policy Act of 2005. DOE agreed with the recommendation and stated that it will work with other federal agencies and experts to implement it.

View GAO-12-880. For more information, contact Anu K. Mittal at (202) 512-6100 or mittala@gao.gov or Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

What GAO Found

As GAO's past work has shown, and other studies and specialists have confirmed, there are a number of key energy-water nexus issues that Congress and federal agencies need to consider when developing and implementing national policies for energy and water resources. Specifically:

- Location greatly influences the extent to which energy and water affect one another. For example, as GAO reported in November 2009, the impact of increased biofuel production on water resources will depend on where the feedstock is grown and whether or not irrigation is required. Consequently, it is important for Congress and federal agencies to consider the effects that national energy production and water use policies can have at the local level.
- Although technologies and approaches exist to reduce the impact of energy development on water resources and reduce the energy needed to move, use, and treat water, their widespread adoption is inhibited by barriers such as economic feasibility and regulatory challenges. In implementing energy and water policies, Congress and federal agencies will also need to be cognizant of the barriers when deciding whether to promote the adoption of these technologies and approaches.
- Making effective policy choices will continue to be challenging without more comprehensive data and research. GAO's past work has identified the need for more data and research related to the energy-water nexus, for example, to better understand hydrological processes, including aquifer recharge rates and groundwater movement. In the absence of such data and research, developing and implementing effective policies could continue to be a challenge for Congress and federal agencies.
- Improved energy and water planning will require better coordination among federal agencies and other stakeholders. GAO's work has demonstrated that energy and water planning are generally "stove-piped," with decisions about one resource made without considering impacts to the other resource. Improved planning will require federal agencies to work with one another and other stakeholders, such as state and local agencies, academia, industry, and environmental groups. Congress and some agencies have taken steps to improve coordination, but these actions are incomplete or in their early stages. For example, in the Energy Policy Act of 2005, Congress directed the Department of Energy (DOE) to establish a federal program to address the energy-water nexus, but DOE has not done so.
- Uncertainties affecting energy and water resources cannot be ignored because they could significantly affect the future supply and demand of both resources. For example, specialists GAO talked to and literature GAO reviewed identified climate change, population growth, and demographic shifts as significant uncertainties expected to exacerbate the challenges associated with managing both the supply and demand of water and energy. These uncertainties must, therefore, be accounted for when developing national policies that affect both of these resources.

Contents

Abbreviations

DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
Interior	Department of the Interior
RD&D	research, development, and demonstration
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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**United States Government Accountability Office
Washington, DC 20548**

September 13, 2012

The Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

Dear Ms. Johnson:

Water and energy are inextricably linked and mutually dependent, with each affecting the other's availability. Water is needed for energy development and generation, and energy is required to supply, use, and treat drinking water and wastewater. Water and energy are also essential to our health, quality of life, and economic growth, and consequently the demand for both of these resources continues to rise. Water is increasingly in demand to meet the needs of the public, farms, and industries, and for recreation and wildlife; and while freshwater flows abundantly in many of our nation's lakes, rivers, and streams, it is a dwindling resource in many parts of the country. Similarly, energy is increasingly in demand to support manufacturing and transportation, among other things. As the demand for water increases, the demand for energy is similarly expected to grow. While the growth rate in energy consumption in the United States has slowed over time, overall consumption continues to rise, with estimates from the Department of Energy's (DOE) Energy Information Administration (EIA) showing an expected growth of 10 percent between 2010 and 2035. To help meet this increased energy demand, domestic energy production is rising, along with its associated water usage. According to the Congressional Research Service, the energy sector has been the fastest growing water consumer in the United States in recent years and is projected to account for 85 percent of the growth in domestic water consumption between

2005 and 2030.[1] This increase in water use associated with energy development is being driven, in part, by rising energy demand, increased development of domestic energy, and shifts to more water-intense energy sources and technologies.

Since 2009, we have issued five reports on the interdependencies that exist between energy and water.[2] These reports have shown that a considerable amount of water is used to cool thermoelectric power plants,[3] grow feedstocks and convert them into biofuels, and extract oil and natural gas from geologic formations. Oil shale development would also require a great deal of water if commercial production of this energy source becomes economically feasible in the future.[4] Some of these

[1]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. Energy production (which includes biofuel production), together with thermoelectric power, are the second largest consumer of water in the United States, accounting for approximately 11 percent of water consumption in 2005. Irrigation was the largest consumer, at approximately 74 percent. (Elcock, D., "Future U.S. Water Consumption: The Role of Energy Production," *Journal of the American Water Resources Association*, vol. 46, no. 3 (2010): 447-460.). However, according to the U.S. Geological Survey, in terms of water withdrawal, thermoelectric power was the largest source of water withdrawals (49 percent) in 2005, followed by irrigation at 31 percent. Water withdrawal refers to water removed from the ground or diverted from a surface water source, such as an ocean, river, or lake.

[2]GAO, *Energy-Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use*, GAO-10-23 (Washington, D.C.: Oct. 16, 2009); GAO, *Energy-Water Nexus: Many Uncertainties Remain about National and Regional Effects of Increased Biofuel Production on Water Resources*, GAO-10-116 (Washington, D.C.: Nov. 30, 2009); GAO, *Energy-Water Nexus: Amount of Energy Needed to Supply, Use, and Treat Water Is Location-Specific and Can Be Reduced by Certain Technologies and Approaches*, GAO-11-225 (Washington, D.C.: Mar. 23, 2011); GAO, *Energy-Water Nexus: A Better and Coordinated Understanding of Water Resources Could Help Mitigate the Impacts of Potential Oil Shale Development*, GAO-11-35 (Washington, D.C.: Oct. 29, 2010); and GAO, *Energy-Water Nexus: Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production*, GAO-12-156 (Washington, D.C.: Jan. 9, 2012).

[3]Thermoelectric power plants use a fuel source—for example, coal, natural gas, nuclear material such as uranium, or the sun—to boil water to produce steam. The steam turns a turbine connected to a generator to produce electricity.

[4]Production of oil shale requires the heating of rock containing solid organic matter to between 650 and 1000 degrees Fahrenheit and injecting water into the formation to stimulate the oil to flow. To date, there has been no commercial production of oil shale resources, in part, because the energy requirements to heat the rock and the water needed to stimulate the flow of oil make the process too costly to compete with other sources of oil.

sources of energy—for example, biofuels, which require the use of large amounts of fertilizers and pesticides to grow the feedstock—may also negatively affect water quality. In addition, development of oil and gas resources can produce large volumes of wastewater—known as "produced water"—that must be disposed of or treated to allow for its reuse. Conversely, significant amounts of energy are needed to extract, transport, treat, and use water in urban areas, additionally contributing to energy demand. Two of these reports contained recommendations, which the agencies generally agreed with and are currently in the process of implementing.

In light of the challenges we have identified in increasing the development of various domestic energy sources while ensuring they do not have detrimental impacts on water availability and quality in the future, you asked us to provide an overview of the analysis from our five energy-water nexus reports and highlight areas that Congress and federal agencies should focus on in setting and implementing water and energy policy. Based on a review of our recent work in this area as well as a review of published literature and interviews with specialists, this report examines key issues for Congress and federal agencies to consider when developing and implementing national policies for energy and water resources.

To conduct this work, we systematically reviewed our five prior reports on the energy-water nexus and identified key issues that affect the development and implementation of national policies for energy and water resources. To validate these themes, we conducted a content analysis of key literature that examines this nexus, including peer-reviewed scientific periodicals, government-sponsored research and studies, and reports from nongovernmental research organizations. We also included in the content analysis interviews with a wide range of specialists whom we identified as having expertise related to the energy-water nexus in the United States. We selected these specialists using an iterative process, soliciting additional names from each person we interviewed. From among those identified, we conducted structured interviews with specialists who could provide a broad range of perspectives on the energy-water nexus, as well as specialists whom we identified during our systematic review of studies who have analyzed (1) the energy-water nexus in general or (2) particular segments (i.e., water use by thermoelectric power plants) of the nexus. These specialists represented a variety of organizations, including federal officials; university researchers; water and energy industry representatives from groups such as the American Water Works Association and the Electric Power

Research Institute; and nongovernmental organizations, such as the Pacific Institute.[5] Representatives from federal agencies included officials, scientists, and researchers from DOE's national laboratories and EIA, the U.S. Department of Agriculture (USDA), the Department of the Interior's (Interior) U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA). We also reviewed federal laws and regulations as applicable. To conduct the content analysis of key literature and information gathered through interviews with specialists, we reviewed each study and interview and coded statements within them based on themes we developed from the GAO reports. For the purposes of reporting the results of our analysis, we used the following categories to quantify the literature and responses of specialists: "some" refers to at least two studies or specialists, "several" refers to at least five studies or specialists, and "many" refers to eight or more studies or specialists. Appendix I discusses our scope and methodology in more detail.

We conducted this performance audit from March 2012 to September 2012, 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

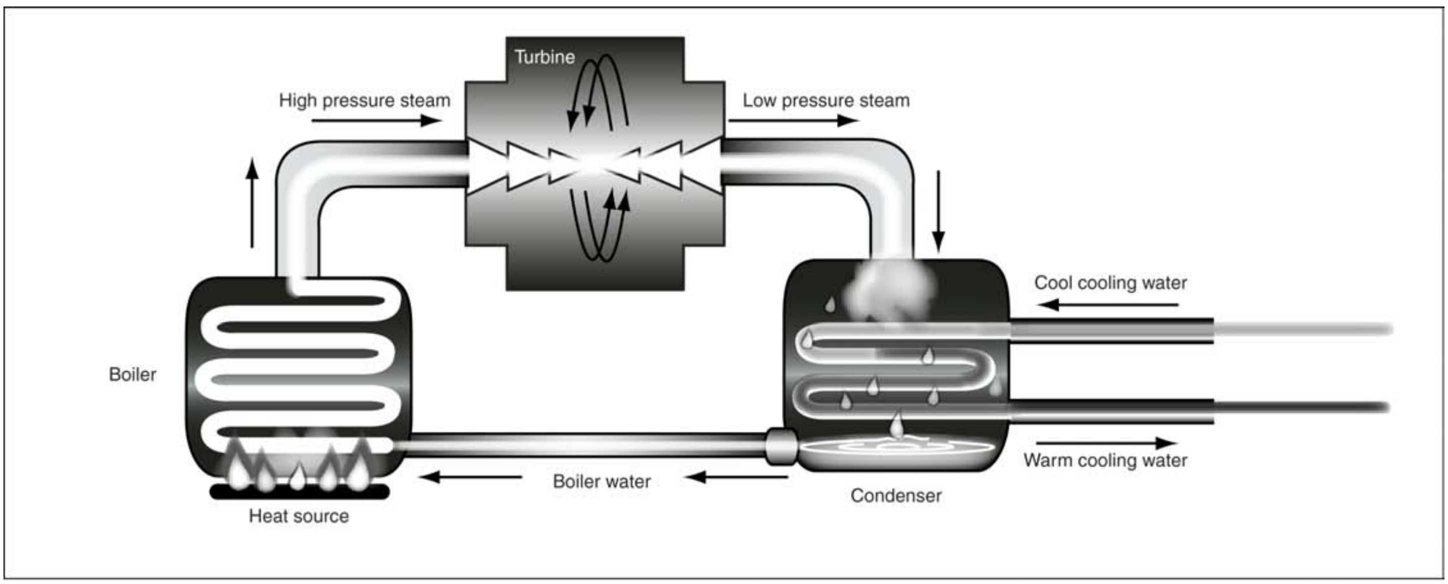
As our series of reports on the energy-water nexus has shown, many aspects of energy development and delivery, including resource extraction, refining and processing, generation, storage, and transportation, can affect water resources. Conversely, supplying water in an urban setting requires energy to extract, treat, and supply water to consumers. Specifically, our prior work related to the energy-water nexus focused on the following five areas:

- *Thermoelectric power plants*. In 2007, around three-fourths of the United States' electricity-generating capacity consisted of thermoelectric power plants, which rely heavily on water for cooling,

[5] The Pacific Institute conducts interdisciplinary research and partners with stakeholders to produce solutions that advance environmental protection, economic development, and social equity in California, nationally, and internationally.

as discussed in our October 2009 report.[6] Thermoelectric power plants use a fuel source—including coal; natural gas; nuclear material, such as uranium; or the sun—to boil water to produce 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) generally circulates in a closed loop. That is, the steam from the boiler water is cooled and 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, the water used to cool and condense the steam—known as cooling water—flows from a separate source. 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, such as reclaimed water from industrial uses.

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

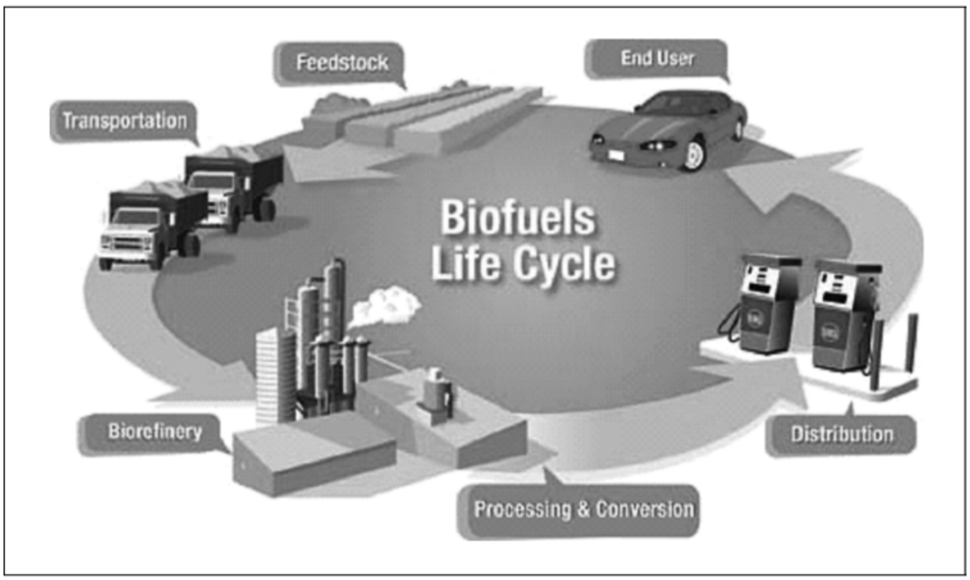


Source: GAO analysis of various national laboratory and industry sources.

[6]GAO-10-23.

- *Biofuels*. In recent years, the federal government has increasingly encouraged the use of biofuels and other alternatives to petroleum in response to concerns over the nation's dependence on imported oil, climate change, and other issues.[7] As we reported in November 2009,[8] water supply and quality can be affected by many stages of the biofuel life cycle, as can similar practices devoted to food production (see fig. 2). To cultivate feedstocks, crops can be either rainfed, with all needed water provided by natural precipitation and soil moisture, or irrigated, with at least some portion of these water requirements met through water applied from surface or groundwater sources. Water is also used in the fermentation, distillation, and cooling processes of converting the feedstock into biofuel.

Figure 2: Biofuels Life Cycle



Source: DOE.

[7]The Energy Policy Act of 2005 created a Renewable Fuel Standard that generally required gasoline and diesel in the United States to contain renewable fuels, such as ethanol and biodiesel. Pub. L. No. 109-58 § 1501 (2005). The Energy Independence and Security Act of 2007 expanded the Renewable Fuel Standard. Pub. L. No. 110-140 § 201 (2007).

[8]GAO-10-116.

- *Oil shale*. As we reported in October 2010,[9] it may become economically feasible to develop the vast amounts of oil generated from U.S. oil shale—a sedimentary rock containing solid organic material that converts into a type of crude oil when heated—and, if it does, this source could help satisfy the nation's future oil demands. Current known processes for producing oil from oil shale deposits, however, are not economically feasible—the oil costs more to produce than it could be sold for. However, if oil prices were to rise high enough to make oil shale production cost effective, and if other challenges associated with developing this resource were resolved, we reported that producing oil from oil shale could require large amounts of water. As a result, while water is expected to be available for the initial development of an oil shale industry, the ultimate potential size of any industry might be limited by water availability, among other things. Furthermore, in the absence of effective mitigation measures, water resources could be affected by ground disturbances caused by the construction of roads and production facilities; the withdrawal of water from streams and aquifers for oil shale operations; underground mining and extraction; and the discharge of waters produced from or used in oil shale operations.
- *Produced water*. The process of producing oil and gas yields several byproducts, including produced water that must be managed as part of the oil and gas operation's waste stream. Produced water may contain a variety of contaminants, including naturally occurring radionuclides, salts, and chemicals injected into some wells to help extract the oil and gas. In January 2012,[10] we reported that most produced water is reinjected into wells designed for this purpose because it requires little or no treatment and is often the least costly option,[11] but some produced water is deemed to be clean enough without extensive treatment to be used for other purposes, such as agricultural or livestock operations. However, if produced water is not appropriately managed or treated, contaminants in the water may present human health and environmental risks.
- *Energy for water supply*. Providing drinking water and wastewater services to an urban environment involves extracting, moving, and

[9]GAO-11-35.

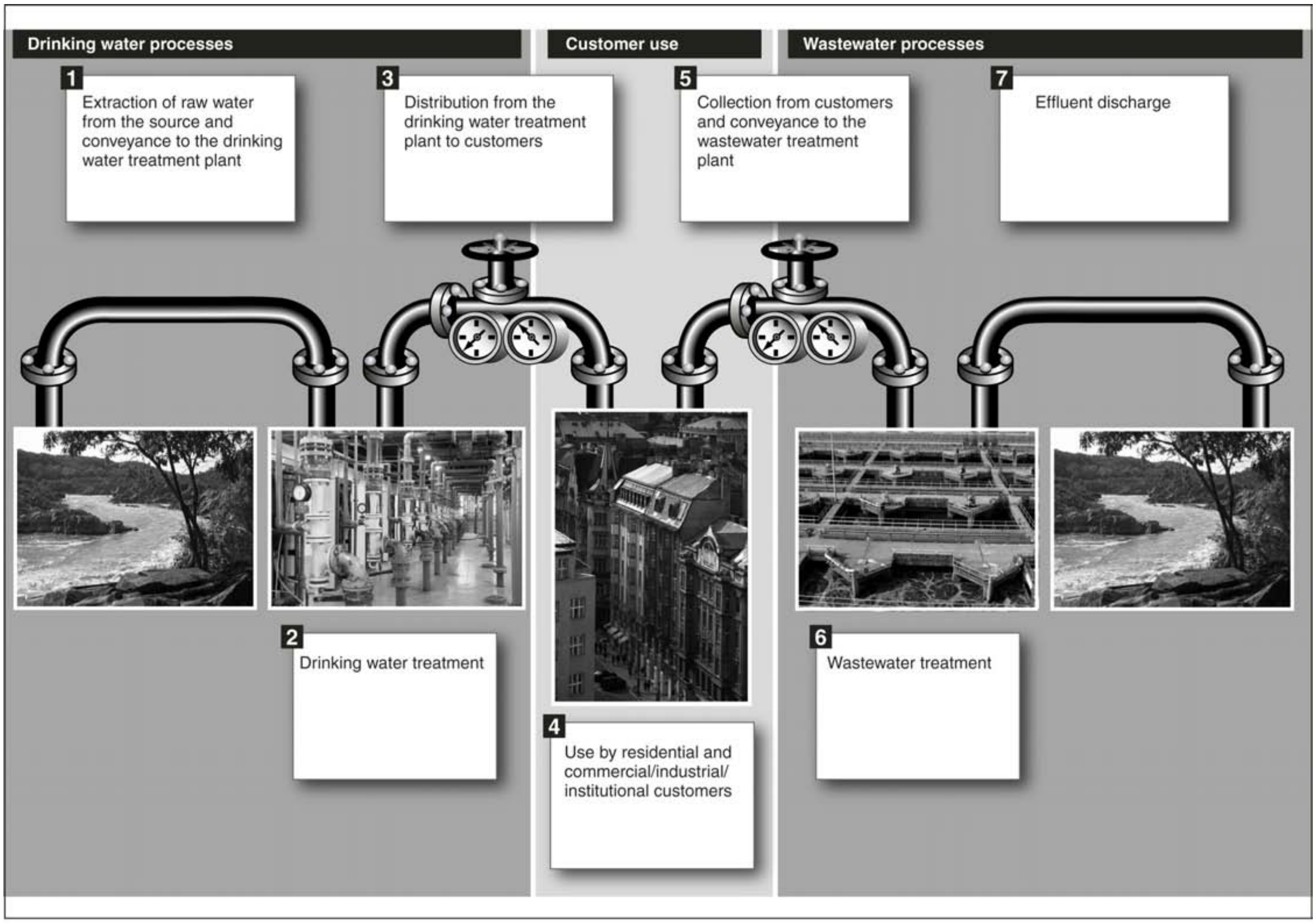
[10]GAO-12-156.

[11]According to federal estimates, more than 90 percent of all produced water is managed through underground injection.

treating water. As we described in our March 2011 report,[12] energy plays a crucial role throughout this life cycle. Energy is needed to extract raw water from the source—such as lakes, rivers, and underground aquifers—and convey it to the facility where it is treated and distributed as drinking water to customers. Furthermore, energy is needed to circulate, pressurize, and heat water for use inside households and businesses and for outdoor water-related uses by customers, such as for watering lawns. Finally, energy is required to convey wastewater to treatment facilities, treat the wastewater, and discharge the treated effluent into a receiving body of water. (See fig. 3 for the key stages in the water life cycle.)

[12] GAO-11-225.

Figure 3: Key Stages of the Urban Water Life Cycle



Sources: GAO analysis. Photos from left to right: GAO; US EPA Photo, Eric Vance; Art Explosion; DC Water; and GAO.

Key Issues to Consider When Developing and Implementing National Policies for Energy and Water Resources

Our past energy-water nexus work has identified a number of key issues for Congress and federal agencies to consider when developing and implementing national policies for energy and water resources. These include (1) the varying local impacts of federal energy and water policy choices, (2) the mitigation of barriers to using innovative technologies and approaches, (3) the challenge of making effective policy choices in the absence of more comprehensive data and research, (4) the importance of coordination among governmental and nongovernmental stakeholders in order to improve planning, and (5) the attention to the uncertainties that affect energy and water resources when setting and implementing federal policies for these resources. The importance of these issues was also emphasized by the literature that we reviewed and the specialists we spoke with.

Federal Energy and Water Policy Choices Can Have Varying Local Impacts

Our past work, as well as the literature that we reviewed and the specialists we spoke with, emphasized that the amount and quality of surface and groundwater used to produce energy resources, as well as the amount and quality of water produced during oil and gas extraction, varies considerably across different locations, and this variation greatly influences how energy and water affect one another. Consequently, we believe that it will be important for Congress and federal agencies to consider the effects that national policies related to energy production and water use can potentially have at the local level. For example:

- As we reported in November 2009 on biofuels,[13] the impact of increased biofuel production on water resources will depend on where the feedstock is grown and whether or not irrigation is required. Specifically, some of the largest increases in corn acres for biofuel production are projected to occur in the Northern Plains, which relies on irrigation and is already water-constrained. Furthermore, parts of the region draw heavily from the Ogallala Aquifer, where water withdrawals for agriculture and other uses are already greater than the natural recharge rate from precipitation. As a result, developing national policies that encourage additional biofuel production could have a greater impact on local water resources in certain areas than in others.
- Similarly, because both water and energy permitting and regulations vary by state, the extent to which these two resources will affect each

[13] GAO-10-116.

other depends on the state in which the development of these resources occurs. For example, as we reported in October 2009 on thermoelectric power plants,[14] some states, such as Arizona and Georgia, require thermoelectric power plant developers to obtain water use permits, while Alabama does not require such permits. As a result, the further expansion of the thermoelectric power industry in certain states can be more challenging than in others, in part, because of the need to meet state permitting and regulatory requirements for water use at those locations.

- In our January 2012 report on produced water,[15] we identified significant variations in the amount of water produced by oil and gas wells on the basis of location-related differences, such as variation in local or regional geology. For example, wells in the Barnett Shale formation in Texas, which is generally known to be a “wetter” formation than the Marcellus Shale formation in the Northeast, typically produce 3 to 4 times more water than shale gas wells in the Marcellus. We noted that even within the same formation, produced water volumes and quality can vary greatly. The quality of produced water also varies considerably across different formations. Some produced water can be used for livestock or agricultural applications because the water is generally of high enough quality to not require extensive treatment, while other produced water may not be used in this way because it is of poor quality; for example, it may contain contaminants, such as naturally occurring radionuclides, salts, metals, oils, and production chemicals. Such water is typically re-injected into wells designed for this purpose largely because it is less costly to do so than to treat the water sufficiently to enable other uses. It will be important for federal regulators to be cognizant of these location-related variations in the quantity and quality of produced water and their related disposal and treatment implications when they develop national regulatory policies for oil and gas development.
- As some of our energy-water nexus reports have documented, the energy needed to transport water is greatly influenced by location-specific factors like topography, distance, and the type and quality of the water source. For example, in our March 2011 report on energy for water supply,[16] we reported that because pumping water accounts

[14]GAO-10-23.

[15]GAO-12-156.

[16]GAO-11-225.

for 80 to 90 percent of the energy used to supply drinking water in some systems, moving water over hills and long distances can increase the level of energy consumption significantly. Consequently, when developing national policies for energy and water, policymakers need to consider the potential energy costs that can be associated with the transport and distribution of water in various settings.

In addition, the literature we reviewed and several specialists we spoke with stated that water is generally undervalued in the United States, and its prices do not reflect the true cost of providing the resource, which can result in its overuse. Some specialists also told us that the extent to which water is undervalued varies by location, with water-scarce areas being more likely to value their water resources. Furthermore, as one specialist told us, the price customers are charged for the water they consume does not reflect all of the costs required to extract, treat, and supply the water. Therefore, consumers may be unaware of the true costs of water and more likely to waste it, which in turn leads to unnecessary energy use to produce more water.

Realizing the Benefits of Innovative Technologies and Approaches Also Depends on Mitigating Barriers to Their Use

Our past work, supported by other literature we reviewed and specialists we spoke with, has identified a variety of technologies and approaches that can reduce the impact of energy development on water resources, as well as the energy use associated with water supply, use, and treatment. However, we also identified a number of significant barriers that Congress and federal agencies will need to be cognizant of when deciding whether to promote and ensure the more widespread adoption of these technologies and approaches, as the following examples illustrate:

- As we reported in October 2009 on thermoelectric power plants,[17] advanced cooling technologies, such as dry cooling that uses air rather than water for cooling, can reduce water use at thermoelectric power plants. However, these technologies may incur "energy penalties"—that is, the energy required to power the cooling systems may reduce the plant's net energy production to a greater extent than traditional cooling systems, potentially leading to higher electricity prices. In addition, advanced cooling technologies can have capital costs that are up to 4 times as expensive as traditional cooling systems, and they may operate less efficiently in dry, arid locations,

[17] GAO-10-23.

among other concerns. As a result, policymakers seeking to encourage the adoption of these technologies by thermoelectric power plants with the goal of reducing water use will also have to consider ways to increase their economic feasibility and reduce their costs to plant operators and electricity consumers.

- As we reported in our 2009 reports on thermoelectric power plants and on biofuels,[18] the use of alternative water sources, such as treated effluent or groundwater unsuitable for drinking or irrigation, can reduce dependence on freshwater at thermoelectric power plants and biofuel refineries but may present drawbacks, such as adverse effects on cooling equipment, the need for expensive treatment equipment, and regulatory challenges. For example, 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. Furthermore, the physical layout of power plants and biorefineries may need to be changed to accommodate the use of alternative water sources. Consequently, if the goal of national water and energy policy is to encourage the use of alternative water sources instead of freshwater sources for the production of energy, then it would also be important to focus on developing better information about the tradeoffs of using alternative water sources.
- As we discussed in our 2009 report on biofuels,[19] agricultural conservation practices can reduce the potential effects of increased biofuel feedstock cultivation on water resources, but there are barriers to their widespread adoption. For example, conservation tillage practices—such as "no-till" systems or reduced tillage systems, where the previous year's crop residues are left on the fields and new crops are planted directly into these residues—can help reduce soil erosion. Research conducted by USDA has shown a substantial reduction in cropland erosion since 1985, when incentives were put in place to encourage the adoption of conservation tillage practices. However, many farmers do not have the expertise or training to implement certain agricultural practices, and some practices may be less suited for some places. For example, farmers usually need a year or more of experience with reduced tillage before they can achieve the same crop yields they had with conventional tillage, and the amount of agricultural residue that can be removed varies by region and even by

[18] GAO-10-23. GAO-10-116.

[19] GAO-10-116.

farm. Consequently, a national policy encouraging additional biofuel production would benefit from continued education and outreach provided by the federal government to help farmers better understand the advantages of adopting such conservation practices.

- More energy-efficient equipment could reduce the energy required to move and treat water, but the adoption of such technology may be hindered by the costs of retrofitting water treatment facilities and other obstacles, as we discussed in our March 2011 report on energy for water supply.[20] For example, the use of variable frequency drives at water treatment facilities, which allow operators to accommodate variations in water flows and run pumps at lower speeds, can reduce energy use by 5 to 50 percent or more. However, installing the drives can be cost prohibitive, and they are not necessarily well suited in all instances, such as when water flow is relatively constant. Therefore, federal policies to reduce energy consumption would also have to recognize the challenges faced by treatment facility operators in reducing energy consumption at their facilities and explore opportunities to assist them with this transition.
- As we also reported in March 2011 on energy for water supply,[21] water conservation is an approach to reducing the energy needed for the urban water lifecycle. Specifically, decreased customer water use could directly translate into energy savings, and water conservation also reduces the amount of energy used to convey, treat, and distribute water to customers. Similarly, energy conservation measures would also decrease water use. Therefore, when considering the development of additional energy and water conservation measures, policymakers may want to consider not only those that can be used by utilities but also those that can be used by consumers.

Making Effective Policy Choices Will Continue to Be a Challenge in the Absence of Comprehensive Data and Research

Our past work, supported by other literature we reviewed and specialists we spoke with, identified a dearth of key data and research related to energy and water. We believe that developing and implementing effective policies will continue to be a challenge for Congress and federal agencies in the absence of such data and research. Support for this data development will be essential to improved decisionmaking, as the following examples demonstrate:

[20] GAO-11-225.

[21] GAO-11-225.

- As a number of our energy-water nexus reports have found, data on the availability of freshwater and alternative water supplies are limited, and the lack of such data makes it challenging to fully assess the impact that particular energy policy choices will have on water resources. Several specialists we spoke with raised concerns that such data will be even harder to obtain in light of decreased funding for USGS's monitoring efforts. Specifically, as we discussed in our October 2009 report on thermoelectric power plants,[22] some state regulators and water experts expressed concern about a reduction in the number of streamflow gauges, which they said may make evaluating trends in water availability and water planning more difficult in the future. Without accurate data on water availability, water planning and decisions involving allocation of water resources—including power plant permitting decisions—may be less informed, according to regulators and experts we spoke with. In addition, our past work and some specialists we spoke with identified a need for more data on the quantity and quality of existing water supplies. For example, in our October 2010 report on oil shale,[23] we reported that data on the water quantity and quality baseline conditions of groundwater and surface water supplies are not sufficient for monitoring the potential impacts of oil shale development in the future. We believe that effective decisions about withdrawing water from existing supplies for energy production cannot be made without first understanding how much water is actually available and the quality of these supplies, and that the federal government plays a key role in generating these kinds of important data.
- Additional research and data on hydrological processes are needed. Our reports and discussions with specialists identified a number of areas needing more research, including the interactions between groundwater and surface water, to understand the possible transport of contaminants from energy development, aquifer recharge rates and groundwater movement, and precipitation runoff, as well as how much water is available for and used by crops.[24] For example, as we previously discussed in our November 2009 report on biofuels,[25]

[22] GAO-10-23.

[23] GAO-11-35.

[24] An aquifer is a geologic formation or structure that stores and/or transmits water, such as to wells and springs. Aquifer recharge is the process by which water is added to an aquifer, such as through rainfall that seeps into the ground.

[25] GAO-10-116.

several specialists and agency officials have stated that research into hydrogeological processes is needed to understand the rate at which aquifers are replenished and the impacts of increased biofuel production on those aquifers. Although research suggests there should be sufficient water resources to meet future feedstock production demands at a national level, increases in this production may lead to significant water shortages in certain regions. Even in typically water-rich states, such as Iowa, concerns have arisen over the effects of increased biofuel production, and research is needed to assess the hydrology and quality of a state's aquifers to help ensure the state is on a path to sustainable biofuel production. Consequently, not only is there a need for baseline data on existing water supplies, but there is also a need for more information on how quickly such supplies are replenished and how they are affected by contaminants, so that as Congress and federal agencies are developing and implementing national energy policies they can ensure that they are considering sustainable water supplies for energy production over the long term.

- Research to determine how new technologies will affect the energy-water nexus has not been conducted to demonstrate the effects of these technologies at commercial scales. For example, according to many specialists we spoke with and some studies we reviewed, implementing carbon capture and sequestration technologies would consume large amounts of freshwater and could affect the quality of nearby water supplies,[26] but the extent of such effects is not well known.[27] In the case of biofuels, next generation feedstocks for biofuels—such as algae or cellulosic materials, including stalks, stems, branches, and leaves—have the potential for fewer negative effects on water resources, but the magnitude of these effects remains largely unknown because these feedstocks have not yet been grown on a commercial scale. For example, as we discussed in our November 2009 report on biofuels,[28] conversion of cellulosic

[26]Carbon capture and sequestration technologies separate and capture carbon dioxide from other gases produced when combusting or gasifying coal, compress it, then transport it to underground geologic formations where it is injected for long-term storage.

[27]In 2010, EPA promulgated a rule establishing minimum requirements under the Safe Drinking Water Act for the underground injection of carbon dioxide for the purpose of geologic sequestration. According to EPA officials, they are in the process of implementing the rule, and they believe the rule is fully protective of underground sources of drinking water.

[28]GAO-10-116.

feedstocks is expected to use less water compared with conventional feedstocks in the long run. However, commercial-scale production has not yet been demonstrated; therefore, any estimates on water use by cellulosic biorefineries are simply projections at this time. Focusing only on certain potential benefits of new technologies without understanding the full impacts of such technologies can have unintended consequences, a concern voiced by several of the specialists we spoke with. Therefore, along with federal support for data and research into new technologies it will also be essential for Congress and federal agencies to support data and research to gain a better understanding of how adopting these technologies will affect both energy and water resources as well as the environment more broadly.

- Data on water or energy use by existing technologies and research into how to optimize these technologies is needed, according to our past reports and specialists we spoke with. For example, as we previously discussed in our November 2009 report on biofuels,[29] research into biorefinery cooling systems could help reduce the water used during conversion of feedstocks into biofuels. According to DOE officials, research and development is also needed to improve hybrid wet-dry cooling systems for thermoelectric power plants. In addition, several specialists told us that analyses are needed on the amount of energy or water used throughout the entire life cycle of supplying water and producing energy. For example, in the case of thermoelectric power, a life-cycle analysis would look beyond just the water consumed in cooling towers and would assess the amount of water needed to mine, refine, transport, and burn the coal; however, such an analysis would require a level of detail beyond that which is currently available for water data, according to specialists we spoke with. Additional data gathering and research on existing technologies can help energy and water suppliers better understand the true impacts of existing technologies on energy and water resources and consider those impacts in comparison with the potential advantages of new technologies. Data gathering and research is another area where we believe that federal agencies could play an important role and assist with such analyses.

In addition, research into and development of better models and decision support tools would help inform decisions related to the energy-water nexus, according to some reports we reviewed and specialists we spoke

[29]GAO-10-116.

with. For example, as one specialist told us, while there are many national climate change models, regional models are needed to increase the accuracy of projections. Efforts are underway to develop downscaled models, but data may not be available to populate the models.[30] In addition, EPA officials told us that the U.S. Global Climate Research Program, which coordinates and integrates federal research on global environmental changes and their implications for society, is considering regional modeling and studies for cross-agency climate change in the future; however, these plans are not yet final. In the absence of improved models and decision support tools, Congress and federal agencies may be making decisions that affect energy and water supplies without fully understanding the impact of these decisions.

Coordination among Governmental and Nongovernmental Entities Is Key to Improved Planning

Our past work, the literature we reviewed, and specialists we spoke with noted that, in general, energy and water planning are "stove-piped" and frequently split across federal, state, and local levels, which results in decision making that does not adequately account for the interactions between energy and water. Improved energy and water planning will require federal agencies with oversight of these resources to coordinate with one another as well as with other stakeholders, such as state and local agencies, academia, industry, and environmental groups, as the following examples demonstrate:

- Our previous reports have highlighted the need for a better understanding of the energy-water nexus, and two of these reports recommended that federal agencies collaborate on research and data collection efforts related to it. Specifically, in our October 2009 thermoelectric power plant report,[31] we recommended that EIA and USGS establish a process for regularly coordinating with each other, other federal agencies, and water and electricity industry experts, among others, to improve the overall quality of data collected on water use from power plants. DOE and Interior generally agreed with our recommendation, and both agencies are currently in the process of implementing it. Specifically, EIA and USGS have held two meetings to discuss such matters. USGS organized the initial meeting in

[30] We reported on the need for downscaled climate information in *Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions*, GAO-10-113 (Washington, D.C.: Oct. 7, 2009).

[31] GAO-10-23.

November 2010, and EIA hosted the second meeting in March 2012. Invitees to the meetings also included representatives from federal agencies and national laboratories. USGS is scheduled to host the next meeting in October 2012. In addition, in our October 2010 oil shale report,[32] we recommended that the Secretary of the Interior coordinate with DOE and state agencies with regulatory authority over water resources on oil shale data collection and modeling efforts, and provide a mechanism for water-related research collaboration and results sharing. Interior generally agreed and has begun to take some steps to implement the recommendation. Specifically, Interior stated that it was working to improve coordination with DOE and state agencies with regulatory authority over water resources. The literature we reviewed and many specialists we spoke with concurred that federal agencies should collaborate to better understand the energy-water nexus. As some specialists told us, without such coordination and collaboration between federal agencies, it will be difficult to ensure that energy-water tradeoffs are properly considered.

- Our previous reports recognized that adequately addressing the energy-water nexus will require federal agencies to seek input from relevant stakeholders outside of the federal government. Specifically, we recommended in both our thermoelectric power plant and oil shale reports that federal agencies collaborate with entities outside of the federal government. In response to the recommendation in our October 2009 report on thermoelectric power plants,[33] DOE and Interior generally agreed with our recommendation and, as described earlier, EIA and USGS have since held two meetings. In addition to the federal agencies that participated, nonfederal invitees to the meetings included industry groups, such as the Nuclear Energy Institute; universities, such as Southern Illinois University; and environmental groups, such as The Nature Conservancy. In our October 2010 oil shale report,[34] Interior generally agreed with our recommendation to collaborate with entities outside of the federal government and has begun to take some steps to implement the recommendation. Specifically, Interior stated that it was working with state agencies that have regulatory authority over water resources. The literature we reviewed and many specialists we spoke with also

[32]GAO-11-35.

[33]GAO-10-23.

[34]GAO-11-35.

believed collaboration with stakeholders outside the federal government is needed. For example, in its 2006 report to Congress,[35] DOE reported that the lack of integrated energy and water planning and management has already affected energy production in many basins and regions across the country, and that collaboration on energy and water resource planning is needed among federal, regional, and state agencies, as well as with industry and other stakeholders. As some specialists told us, state and local agencies are primarily responsible for allocating and managing water resources; therefore, energy-water nexus discussions need to involve officials from other levels of government. Similarly, public utility commissions make energy decisions in many states, and the role of these commissions is important to consider when addressing the energy-water nexus.[36] Furthermore, as DOE officials noted, many political boundaries between states are formed by water bodies. Therefore, multiple counties and states can be involved in water management decisions, which can lead to conflicts and be an impediment to water planning. Because of the various stakeholders with a role in managing energy and water, we believe that it will be important for federal agencies to improve coordination including with their nonfederal partners in order to enhance energy and water planning and put the United States on a path that is more sustainable for the long run.

- Many specialists told us that, because of the stove-piped nature of energy and water issues in the federal government, a top-down emphasis on collaboration among federal agencies and with other groups outside of the federal government is needed. Some specialists pointed to a recent memorandum of agreement between three federal agencies on unconventional oil and gas research as a good model. Specifically, in March 2011, the White House released the *Blueprint for a Secure Energy Future*, a comprehensive plan to reduce America's oil dependence, save consumers money, and make the United States the leader in clean energy industries. The Blueprint instructed the federal government to conduct research to examine the impacts of hydraulic fracturing on water resources. To fulfill this

[35]DOE, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water* (December 2006).

[36]In many states, public utility commissions are 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 and, as a result, may consider whether specific technologies are reasonable.

directive, DOE, Interior, and EPA signed a memorandum in April 2012 describing their plans for multiagency collaboration on unconventional oil and gas research. According to the specialists we spoke with, direction from the White House is what led to action on the part of the agencies and the signing of the memorandum, and they believe a similar high-level push would be needed to spur meaningful collaborative action to address other energy-water nexus issues.

Recognizing the need for better coordination, Congress and some federal agencies have taken or are beginning to take some steps on energy-water nexus issues, but many of these actions are either in their early stages or incomplete, as the following examples illustrate:

- With the Energy Policy Act of 2005, Congress directed the Secretary of Energy, through DOE's Office of Science,[37] to carry out a number of programs related to a wide variety of energy sciences. In particular, the act directs the Secretary to carry out a program to address the energy-water nexus and assess the effectiveness of existing programs at DOE and other federal agencies to address the nexus.[38] The provision also directs the Secretary to consult with the Administrator of EPA, the Secretary of the Interior, the Chief Engineer of the Army Corps of Engineers, the Secretary of Commerce, the Secretary of Defense, and other federal agencies as appropriate, to carry out the provision. DOE officials told us, however, that to date they have neither received nor requested any funding specifically designated to carry out the provision, nor has the agency requested funds for this purpose for fiscal year 2013. Furthermore, according to DOE officials, the Office of Science is not the appropriate office within DOE to carry out the program because the office conducts research

[37]The Office of Science is the lead federal agency supporting fundamental scientific research for energy and the nation's largest supporter of basic research in the physical sciences.

[38]Energy Policy Act of 2005, Pub. L. No. 109-58, §§ 971, 979, 119 Stat. 594, 905 (codified at 42 U.S.C. §§ 16311, 16319 (2006)). Specifically, the act directs the Secretary to carry out a program of research, development, demonstration, and commercial application to (1) address energy-related issues associated with the provision of adequate water supplies, optimal management, and efficient use of water; (2) address water-related issues associated with the provision of adequate supplies, optimal management, and efficient use of energy; and (3) assess the effectiveness of existing programs within the department and other federal agencies to address these energy and water related issues. The program is to include, among other things, planning, analysis, and modeling of energy and water supply and demand.

on the fundamentals of science. Instead, officials stated that the Office of the Under Secretary, which oversees work in areas such as energy efficiency and renewable and fossil energy, would be the more appropriate office to conduct such research.[39] Regardless of which office is best suited for this activity, by not carrying out this provision, we believe that DOE is missing an important opportunity to provide information that could possibly help fill some of the research and data gaps we and others have identified.

- Congress is also considering pending legislation related to energy and water that calls for enhanced collaborative efforts. A House bill, the Energy and Water Research Integration Act of 2012, would direct the Secretary of Energy to (1) integrate water considerations into energy research, development, and demonstration (RD&D) programs and projects; (2) develop a strategic plan identifying RD&D needs for those programs and projects; (3) collaborate with other federal agencies, within DOE, and with nongovernmental entities in developing the plan; and (4) develop an Energy-Water Architecture Council consisting of federal agencies and nongovernmental entities to promote data collection, reporting, and technology innovation.[40] Another House bill, the Coordinating Water Research for a Clean Water Future Act of 2012, would, among other things, direct the President to begin implementation of a National Water and Research Development Initiative to, among other things, conduct research on how to ensure the systematic and coordinated collection of publicly available data on regional and national water resources and provide for interagency coordination of federal water research and development.[41]
- Some federal agencies have recognized the importance of collaboration on the energy-water nexus and have acted accordingly. For example, in April 2012, EPA proposed six principles to foster collaboration in the water and energy sectors to meet water and energy needs nationally and locally. One of the principles called for key stakeholders—governments, utilities, manufacturers, and consumers—in both sectors to move toward integrated energy and

[39]The Office of Science may be able to enter into inter- and intra-agency agreements, under authorities like the Economy Act, with other federal offices to assist in carrying out the provision to the extent those offices are able to provide relevant assistance. *See* 31 U.S.C. § 1535 (2006).

[40]H.R. 5827, 112th Cong. (2012).

[41]H.R. 5826, 112th Cong. (2012).

water management from source, production, and generation, to the end user. Actions to support the principle include breaking down institutional barriers, improving transparency, and maximizing efficiencies; encouraging government agencies to look across missions; and developing partnerships between government and service providers.

- DOE, led by Sandia National Laboratories, held a series of workshops on energy and water issues in 2005 and 2006, according to DOE's 2006 report to Congress. The effort, known as the Energy-Water Roadmap process, included representatives from a broad range of groups, including environmental organizations; policy and regulatory groups; industry associations; and federal, state, and tribal government agencies. It was intended to help DOE and the United States assess current energy and water issues and concerns and identify appropriate interactions and coordination approaches. As part of this effort, participants at the workshops identified (1) gaps between current federal and state energy and water research and management programs and (2) major science and technology research and development steps necessary to address the challenges and gaps. According to the website for the Sandia National Laboratories, the Energy-Water Roadmap process was expected to result in a report summarizing needs; prioritization criteria; major gaps; innovative technical approaches and associated research needs; research and development priorities and strategies; and associated policy, regulatory, and economic assessments. However, as of September 2012, no report has been issued.

Uncertainties that Affect Energy and Water Must Be Considered in Setting Federal Policies Related to These Resources

Uncertainties—including the future makeup of the nation's energy portfolio and the potential impacts of climate change—must be considered when developing and implementing national energy and water policies, according to our past work on the energy-water nexus, studies we reviewed, and specialists we spoke with. As the following examples demonstrate, these uncertainties could significantly affect the future supply and demand of both energy and water, and therefore are external factors that must be accounted for when developing national policies:

- The magnitude of the impacts on water resources stemming from the nation's future energy use will vary depending on what sources of energy are pursued. For example, developing unconventional energy sources, such as shale oil and shale gas,[42] could have significant impacts on the quality and quantity of water resources, but the magnitude of these impacts is unknown because of uncertainty about the future scale and scope of shale oil and gas development. Similarly, if oil shale becomes economically feasible to produce on a commercial scale, the industry could have significant impacts on water quality and quantity, but the magnitude of these impacts is unknown because of technological uncertainties and because the size of a future oil shale industry is unknown, as we discussed in our October 2010 report on oil shale.[43] In addition, a recent report from DOE's National Renewable Energy Laboratory looked at a variety of scenarios for the increased use of renewable energy sources to generate electricity. For example, the laboratory reported that if the country were able to switch to 80 percent renewable electricity by the year 2050, such a switch could reduce the power sector's annual water use by approximately 50 percent.[44] However, renewable energy sources also vary in their water use, so the type of renewable energy we use in the future will have varying impacts on water supplies. For example, solar photovoltaic panels and wind turbines consume minimal water during normal operation.[45] However, concentrating solar power plants that use wet cooling could significantly increase water demand, consuming up to twice as much water per unit of

[42]Shale oil and shale gas refers to product that is trapped within underground shale formations; these fine-grain sedimentary rocks can be rich sources of oil and natural gas. Unlike oil shale, shale oil and shale gas do not require heating for resource extraction.

[43]GAO-11-35.

[44]The report looked at a variety of scenarios, ranging from 30- to 90-percent renewable generation in 2050. The report focused on 80-percent renewable generation because the laboratory's analyses concluded that renewable energy generation from technologies that are commercially available today, in combination with a more flexible electric system, would be technically adequate to supply 80 percent of projected U.S. electricity generation in 2050, albeit at increased electricity prices compared with today's baseline. Nearly 50 percent of the renewable electricity in this 80-percent scenario consists of variable wind and solar photovoltaic generation. (National Renewable Energy Laboratory, *Renewable Electricity Futures Study: Exploration of High-Penetration Renewable Electricity Futures*, vol. 1 (2012).)

[45]Solar photovoltaic panels and wind turbines use small amounts of water for panel and blade washing, respectively.

electricity produced as traditional fossil fuel power plants.[46] Concerns with concentrating solar power plants are particularly acute in the Southwest—a prime location for siting these facilities because of abundant sunshine—because water supplies in the region are already limited.[47] Consequently, not fully understanding and accounting for the potential differences in the future energy portfolio's impact on water supply and quality when developing a national energy policy may result in negative unintended consequences.

- As we previously discussed in our March 2011 report on energy for water supply,[48] to address growing concerns about emerging contaminants and nutrients in the nation's water bodies, additional or more stringent regulatory standards could increase the energy demands of treatment processes in the future, but the degree to which energy use would increase depends on the regulations that are implemented. Specifically, promulgation of more stringent standards would most likely require additional levels of treatment, and the use of more energy-intensive technologies, such as ozonation and membrane filtration,[49] may be necessary to meet such new standards.[50] Regulatory changes could also increase energy demands at other stages of the urban water life cycle. For example, higher standards for effluent discharge from wastewater treatment plants could increase the energy required for treatment of the effluent. Furthermore, stricter water quality standards for receiving waters

[46]Concentrating solar power plants operate by using mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it to heat. This thermal energy is used to produce electricity via a steam turbine or heat engine driving a generator to produce electricity.

[47]According to DOE officials, concentrating solar power plants are generally being built with dry cooling systems in the Southwest to minimize water use. However, according to a 2009 DOE report to Congress, while dry cooling can eliminate over 90 percent of the water consumed by wet-cooled concentrating solar power plants, wet cooling is preferred to minimize cost and maximize efficiency.

[48]GAO-11-225.

[49]Ozonation is a water treatment process that destroys bacteria and other microorganisms through the infusion of ozone, a gas produced by subjecting oxygen molecules to high electrical voltage. Membrane filtration uses pressure to force untreated water through a semipermeable membrane, thereby filtering out bacteria and other microorganisms, particulate material, and natural organic matter.

[50]Such standards may include drinking water standards set under the Safe Drinking Water Act or standards for the treatment of wastewater discharged from municipal wastewater treatment plants under the Clean Water Act.

could necessitate that more plants employ advanced treatment standards, resulting in increased energy use for the additional treatment or to pump effluent farther away to other waters. As a result, policymakers will need to consider the energy inputs that will be required to meet new water quality standards when developing these regulatory choices.

According to the literature we reviewed and specialists we spoke with, climate change, population growth, increased competition for resources, and demographic shifts are expected to exacerbate the challenges associated with water and energy supply and demand, and shifts in any of these areas are expected to increase demand for both of these resources. Moreover, the effects of climate change are expected to vary by location and, in some locations, are expected to increase demand for both energy and water resources while simultaneously decreasing water supplies. According to the literature we reviewed, higher temperatures from climate change are expected to lead to additional demand for air conditioning and, therefore, electricity. This increased electricity demand will, in turn, lead to increases in water consumption associated with power generation. However, at the same time, climate change is expected to change the quantity and reliability of water supplies so that less water may be available in some regions, thereby resulting in reduced water supplies for use by the energy sector, according to some specialists we spoke with. In addition, as one specialist told us, higher temperatures from climate change will produce more evaporation from water reservoirs and other bodies of water, such as the Great Lakes, which can produce significant water losses. Furthermore, the literature we reviewed and specialists we spoke with noted that the impacts of climate change are uncertain with some areas receiving more precipitation than they currently experience, rather than drought.

Problems associated with climate change are only exacerbated by population growth and competition for water resources. Specifically, more people will consume more water, increasing the municipal sector's water demand. To meet these increasing demands, some states, especially those in areas that are already water stressed, such as Texas, have pursued alternative sources of water, such as desalinated water, which are more energy-intensive than traditional groundwater and surface water supplies. In addition, because of a warmer climate and decreased precipitation, farmers are expected to withdraw more water to irrigate crops. Minimum water levels are also necessary for other uses, such as recreation and industry, as well as to support wildlife and maintain ecosystems. Furthermore, demographic shifts, such as migration to the hot, arid Southwest, could place additional demands on both energy and water supplies. In light of all of these uncertainties, some specialists told us that water and energy policies must be resilient and flexible enough to adapt to changing circumstances. For example, these specialists told us that because of the uncertain effects of climate change, the development of plans and policies should be adaptable to account for variability over time and by location.

Conclusions

The growth in water and energy demands for development and other uses is occurring at a time when the nation's supplies are stressed by a growing population, a variety of new and changing uses, and environmental challenges such as climate change. A number of agencies have responsibility for managing specific aspects of the energy-water nexus, including DOE, EPA, USDA, and Interior, but these agencies do not consistently or strategically collaborate on these inextricably linked issues to ensure a harmonized approach to energy and water resource planning. This lack of coordination often results in a stove-piped approach to managing these resources that does not take into account all the possible tradeoffs and interrelationships. Some agencies have taken steps to examine this issue within their own agency, such as DOE and Interior's jointly organized meetings to improve thermoelectric power plant data in response to a recommendation from our October 2009 report. However, in general, federal efforts remain uncoordinated. Moreover, there is a need for enhanced research and data efforts that could benefit from greater interagency cooperation. The Energy Policy Act of 2005 requires DOE to implement a program of research, development, demonstration, and commercial action to address energy and water issues and assess existing federal programs, but DOE has not yet implemented this program. In not carrying out this directive, DOE is missing an opportunity to provide information that could help Congress, other federal agencies, and the public better understand the key energy-water nexus issues identified in our series of reports and take coordinated action to protect these invaluable resources.

Recommendation for Executive Action

To help address some of the research and data gaps that we and others have identified related to the tradeoffs associated with the energy and water nexus, and to ensure collaboration to address the nexus, we recommend that the Secretary of Energy take the actions necessary to establish a program to address the energy-water nexus, with involvement from other federal agencies as described in the Energy Policy Act of 2005.

Agency Comments and Our Evaluation

We provided a draft of this report to USDA, DOE, Interior, and EPA for review and comment. In its written comments, reproduced in appendix II, DOE agreed with our recommendation. Specifically, DOE stated that it already has a number of research activities underway related to the energy-water nexus, such as energy-water data collection and modeling. In addition, DOE stated that it will initiate more assertive engagement with program managers through an internal workshop to discuss existing activities and clarify priority areas for further data collection and analysis. As part of its efforts, DOE stated that it will continue to engage other agencies and collaborate with experts.

EPA provided technical comments, which we incorporated as appropriate. In its technical comments, EPA stated that the agency supported the findings of the report, but noted that more emphasis should be placed on the changes in population demographics that stress the supply of energy and water. Specifically, the agency identified increasing population shifts to coastal areas, desalinization, increased use of air conditioning, and agricultural irrigation as stressors of particular concern. We agree that these areas could affect the energy-water nexus, as we discuss in our report. EPA also identified the need for a comprehensive systems analysis of energy, water, and agricultural cycles and their feedback loops to help avoid unintended consequences. USDA and Interior did not provide any comments.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the Secretary of Energy, the appropriate congressional committees, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact Anu K. Mittal at (202) 512-6100 or mittala@gao.gov or Frank Rusco at (202) 512-3841 or ruscof@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 key contributions to this report are listed in appendix III.

Sincerely yours,

Anu K. Mittal
Director, Natural Resources and Environment

Frank Rusco
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

To conduct this work, we systematically reviewed GAO's five prior reports on the energy-water nexus to develop the key issues that Congress and federal agencies need to consider when developing and implementing national policies for energy and water resources. To validate these themes, we conducted a content analysis of 11 key studies and reports that examine this nexus, including peer-reviewed scientific periodicals, government-sponsored research and studies, and reports from nongovernmental research organizations. We also included in the content analysis 19 interviews with a wide range of 37 specialists whom we identified as having expertise related to the energy-water nexus in the United States. For the purposes of our interview analysis, each interview represents the views of one specialist even if more than one specialist was present at the interview. We selected these specialists using an iterative process, soliciting additional names from each person we interviewed. From among those identified, we conducted structured interviews with specialists who could provide us with a broad range of perspectives on the energy-water nexus as well as specialists whom we identified during our systematic review of studies who have analyzed (1) the energy-water nexus in general or (2) particular segments (i.e., water use by thermoelectric power plants) of the nexus. These specialists represented a variety of organizations, including federal officials; university researchers; water and energy industry representatives from groups such as the American Water Works Association and the Electric Power Research Institute; and nongovernmental organizations, such as the Pacific Institute.[1] Representatives from federal agencies included officials, scientists, and researchers from the Department of Energy's national laboratories and Energy Information Administration; the Environmental Protection Agency; the Department of the Interior's U.S. Geological Survey; and the U.S. Department of Agriculture. We also reviewed federal laws and regulations as applicable.

We conducted a content analysis on the key literature and interviews with specialists using NVivo software. Content analysis is a methodology for structuring and analyzing written material. Specifically, using our systematic review of GAO's energy-water nexus reports to identify key issues that Congress and federal agencies need to consider when developing and implementing national policies for energy and water

[1] The Pacific Institute conducts interdisciplinary research and partners with stakeholders to produce solutions that advance environmental protection, economic development, and social equity in California, nationally, and internationally.

resources, we reviewed each study and interview and coded statements within them based on themes we developed from the GAO reports. The coding was conducted independently by two GAO analysts after checking for intercoder reliability. We developed agreement statistics and discussed and resolved any discrepancies in coding. We used the following categories to quantify the literature and responses of specialists: “some” refers to at least two studies or specialists, “several” refers to at least five studies or specialists, and “many” refers to eight or more studies or specialists.

We conducted this performance audit from March 2012 to September 2012, 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: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

August 28, 2012

Mr. Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Mr. Rusco:

The Department of Energy (DOE) welcomes the opportunity to respond to the recommendation by the U.S. Government Accountability Office (GAO) for the agency to act to address the energy-water nexus. DOE recognizes America's national interest in sound management of all natural resources, including water and energy. The issues raised by the nexus between energy and water span beyond any one technology program at the DOE, and, in fact, they reach virtually every energy program.

Current DOE research activities relevant to the energy-water nexus include but are not limited to lifecycle cost analysis, energy-water data collection and modeling (including for transmission planning purposes), development of more water-efficient energy technologies and more energy-efficient technologies involving water, integration of renewable energy in the electric power grid, drought and climate change vulnerability assessments within the energy sector. Because of the variety of roles that water plays across different energy technologies, DOE can best address the issues by incorporating consideration of water directly into the specific energy programs, rather than creating a separate silo focused on the energy-water nexus.

Recognizing that there is much more yet to analyze, DOE accepts the GAO recommendation that additional effort be committed to help address some of the gaps in data and analysis for decision-makers. Because multiple DOE research program offices have an interest in the water input and output attributes of various energy technologies, these experts are already in dialogue, and DOE will benefit from improved awareness and communication about energy-water interdependencies. With the GAO recommendation, DOE will initiate more assertive engagement with program managers through an internal workshop to surface any further existing activities and clarify priority areas for further data collection and analysis. In addition to integrating considerations about the energy-water nexus into activities across the applied energy research and development programs, DOE will also continue to engage other agencies relevant to the energy-water nexus in order to coordinate and collaborate with experts who

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have complementary interests and information resources and will expand these efforts where appropriate.

DOE appreciates the contribution GAO has made to an important policy dialogue through its series of reports on energy and water, and particularly in this capstone report highlighting some of the persistent challenges and opportunities for the Federal government.

Sincerely,

for DBS

David B. Sandalow
Under Secretary of Energy (Acting) and
Assistant Secretary for Policy and
International Affairs

Appendix III: GAO Contacts and Staff Acknowledgments

GAO Contacts

Anu K. Mittal, (202) 512-6100 or mittala@gao.gov

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contacts named above, Elizabeth Erdmann (Assistant Director), Antoinette Capaccio, Janice Ceperich, Alison O'Neill, Steven Putansu, Rebecca Shea, and Lisa Vojta made key contributions to this report.

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