United States Government Accountability Office

GAO

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

March 2011

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

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Highlights

Highlights of GAO-11-225, a report to the Ranking Member, Committee on Science, Space, and Technology, House of Representatives

March 2011

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

Why GAO Did This Study

Providing drinking water and wastewater services are two key functions needed to support an urban lifestyle. To provide these services, energy is needed to extract, use, and treat water and wastewater. As the demand for water increases, the energy demands associated with providing water services are similarly expected to grow.

GAO was asked to describe what is known about (1) the energy needed for the urban water lifecycle and (2) technologies and approaches that could lessen the energy needed for the lifecycle and barriers that exist to their adoption. To address these issues, GAO reviewed scientific studies, government-sponsored research, and other reports and interviewed specialists from a variety of organizations, including drinking water and wastewater utilities; federal, state, and local government offices responsible for water or energy; and relevant nonprofit groups, about the energy needed to move, use, and treat water. GAO also selected three cities—Memphis, Tennessee; San Diego, California; and Washington, D.C.—as illustrative case studies to help understand the energy demands of the lifecycle in different areas of the country.

GAO is not making any recommendations in this report. A draft was provided to the Departments of Defense, Energy (DOE), and the Interior, and the Environmental Protection Agency (EPA). DOE and EPA provided technical comments, which we incorporated as appropriate.

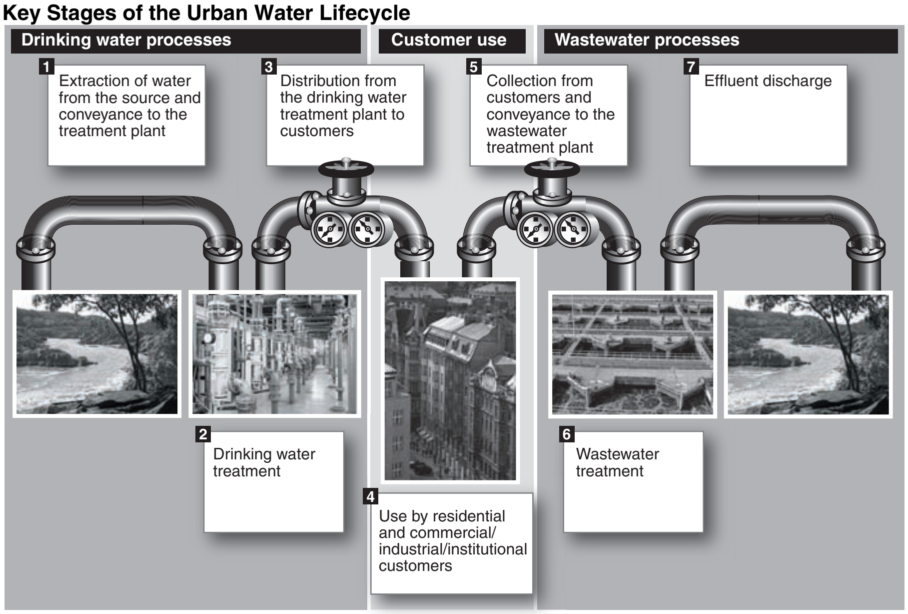
View GAO-11-225 or key components.
For more information, contact Anu Mittal or Mark Gaffigan at (202) 512-3841 or mittala@gao.gov or gaffiganm@gao.gov.

What GAO Found

Comprehensive data about the energy needed for each stage of the urban water lifecycle are limited. In particular, few nationwide studies have been conducted on the amount of energy used to provide drinking water and wastewater services, and these studies do not consider all stages of the lifecycle in their analysis. Specialists GAO spoke with emphasized that the energy demands of the urban water lifecycle vary by location. Considering location-specific and other key factors is necessary to assess energy needs. The specialists mentioned such factors as the topography of the area over which water is conveyed, the level and type of treatment provided, and the quality of the source water. For example, systems relying on groundwater as their source for drinking water generally use less energy than systems relying on surface water because groundwater usually contains fewer contaminants and, therefore, requires less treatment before distribution to customers.

A variety of technologies and approaches can improve the energy efficiency of drinking water and wastewater processes, but barriers exist to their adoption. Installing more efficient equipment, adopting water conservation measures, and upgrading infrastructure are among some of the approaches that can decrease energy use, according to specialists GAO spoke with and studies GAO reviewed. For example, technologies to identify potential pipeline leaks throughout water systems can reduce water loss and the energy required to pump and treat that “lost” water. However, according to specialists, adoption of technologies and approaches to improve energy efficiency may be hindered by the costs of retrofitting plants with more energy-efficient equipment and competing priorities at treatment facilities, among other barriers.

Key Stages of the Urban Water Lifecycle



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

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Abbreviations

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
NPDES	National Pollutant Discharge Elimination System
USGS	U.S. Geological Survey
VFD	variable frequency drive

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United States Government Accountability Office
Washington, DC 20548

March 23, 2011

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

Dear Ms. Johnson:

According to the U.S. Census Bureau, in 2005, 83 percent of the U.S. population lived in metropolitan areas, up 6 percent from 2000.[1] Two key resources necessary to support an urban lifestyle are drinking water and the infrastructure necessary to treat wastewater. The average American is estimated to use about 90 gallons of water and produce 66 to 192 gallons of wastewater each day, according to the U.S. Environmental Protection Agency (EPA). As the demand for drinking water and wastewater treatment in urban areas grows, it is expected that water utilities will have to increasingly seek out alternative sources of water and treatment methods to increase the water supply, especially in areas of water scarcity where demand outpaces supply. However, treating and using these alternative sources, such as seawater, come with a cost because, in addition to other factors, they tend to be heavily energy dependent.

Providing drinking water and wastewater services to an urban environment involves extracting, moving, and treating water—referred to as the urban water lifecycle (see fig. 1).[2] Energy plays a crucial role throughout this lifecycle in the following ways:

- *Drinking water processes*. Energy is needed to extract raw water from the source—such as lakes, rivers, and underground aquifers—and convey it to the drinking water treatment facility, treat the water to certain drinking water standards established under the Safe Drinking Water Act,[3] and

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[1] A metropolitan area, as defined by the Office of Management and Budget, consists of one or more counties containing at least one urbanized area of 50,000 or more people.

[2] For the purposes of this report, "urban" refers to areas of the country that are connected to community water systems and that receive wastewater services from municipal wastewater treatment facilities. It does not include agricultural water use or customers who self-supply water or rely on septic systems for waste disposal.

[3] 42 U.S.C. §§ 300f-300j-26 (2006).

distribute the treated drinking water to customers.

- *Customer use*. 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 watering lawns.
- *Wastewater processes*. Energy is needed to convey wastewater to treatment facilities, treat the wastewater to levels required under the Clean Water Act,[4] and discharge the treated effluent into a receiving body of water.

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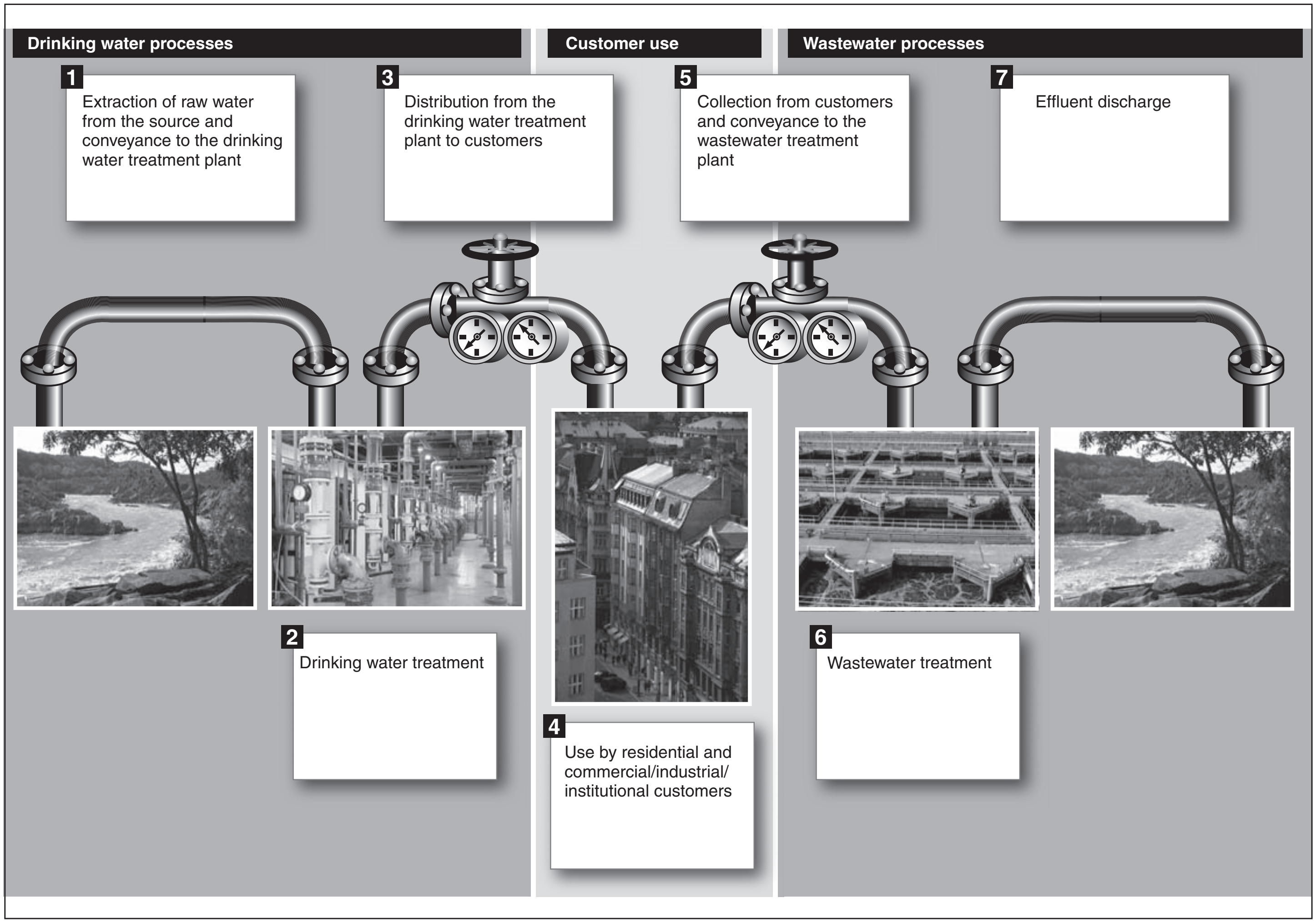
[4] 33 U.S.C. §§ 1251-1387 (2006).

Figure 1: Key Stages of the Urban Water Lifecycle



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

As urban populations increase and the demand for water grows, the energy needed for the urban water lifecycle is also expected to grow. In this context, you asked us to review the energy needs of providing drinking water and wastewater treatment services to urban users. Specifically, the objectives of this review were to describe what is known about (1) the energy needed for each stage of the urban water lifecycle and (2) technologies and approaches that could lessen the energy needs of the urban water lifecycle, as well as any identified barriers that exist to their adoption.

To address both of these objectives, we conducted a systematic review of studies and other documents that examine the energy required to extract, move, use, and treat water, including peer-reviewed scientific and industry periodicals, government-sponsored research, and reports from nongovernmental research organizations. We also selected a nonprobability sample of three cities to examine in greater depth and better understand regional and local differences related to urban water lifecycles: Memphis, Tennessee; San Diego, California; and Washington, D.C. We chose these cities as illustrative case studies based on criteria such as type of water source; water availability; type of wastewater system; unique characteristics, such as potential to treat seawater to help meet drinking water demands; and economic factors, such as energy costs. While the information derived from our analysis of these cities cannot be generalized to all U.S. cities, these examples provide valuable insights regarding the complexities of assessing the energy needs for the urban water lifecycle. For each of these case studies, we analyzed documentation from, and conducted interviews with, a wide and diverse range of specialists from organizations involved in all stages of the urban water lifecycle. These organizations included drinking water and wastewater treatment facilities, and state and local agencies responsible for water or energy.[5]

In addition to specialists associated with the illustrative case studies, we interviewed a range of other knowledgeable individuals whom we identified as having expertise related to the energy needs of all stages of the urban water lifecycle throughout the United States. We selected these specialists using an iterative process, soliciting additional names from each person we interviewed. From among those identified, we interviewed specialists who could provide us with a broad range of perspectives on the energy needs of the urban water lifecycle. We also interviewed specialists whom we identified during our systematic review of studies who have analyzed (1) the energy needed in one or more stages of the water lifecycle at the national or local level or (2) techniques available to reduce the energy demands for water. These specialists represented a variety of organizations, including drinking water and wastewater treatment

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[5] We requested interviews with representatives from the primary electrical utilities in each location. In San Diego and Washington, D.C., the utilities did not provide representatives to meet with us or told us they did not have relevant data. In Memphis, however, which has a combined water and energy utility, an energy official was present at our meeting with the utility, but the utility told us it does not track data on energy for water-related uses for some customer types.

facilities; state and local government offices responsible for water or energy; officials from EPA and researchers from some of the U.S. Department of Energy's (DOE) national laboratories, such as Sandia National Laboratory; university researchers; water and energy industry representatives from groups such as the American Water Works Association and the Water Research Foundation; and relevant nongovernmental organizations, such as the Pacific Institute, a nonpartisan research institute that works to advance environmental protection, economic development, and social equity. The specialists also included individuals with knowledge of the energy demands for water in other states, including Arizona, Colorado, Florida, New York, and Wisconsin, to provide a better understanding of water and energy issues in other regions around the United States.

We also interviewed other federal agency officials, scientists, and researchers and analyzed data and information from federal agencies that have responsibilities related to the energy needs of the urban water lifecycle—the Department of Defense's U.S. Army Corps of Engineers, DOE, the Department of the Interior's U.S. Geological Survey (USGS) and Bureau of Reclamation, EPA, and the National Science Foundation. We performed our work from January 2010 to January 2011 in accordance with all sections of GAO's Quality Assurance Framework that are relevant to our objectives. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.

Background

According to EPA, about 52,000 community water systems use energy to treat and deliver drinking water to over 290 million Americans.[6] In a typical drinking water treatment plant, large debris and contaminants are physically removed from the raw water using screens (see fig. 2). Next, dirt and other particles suspended in the water are removed through the addition of alum and other chemicals during the processes of coagulation and sedimentation. After these particles have separated out, the water

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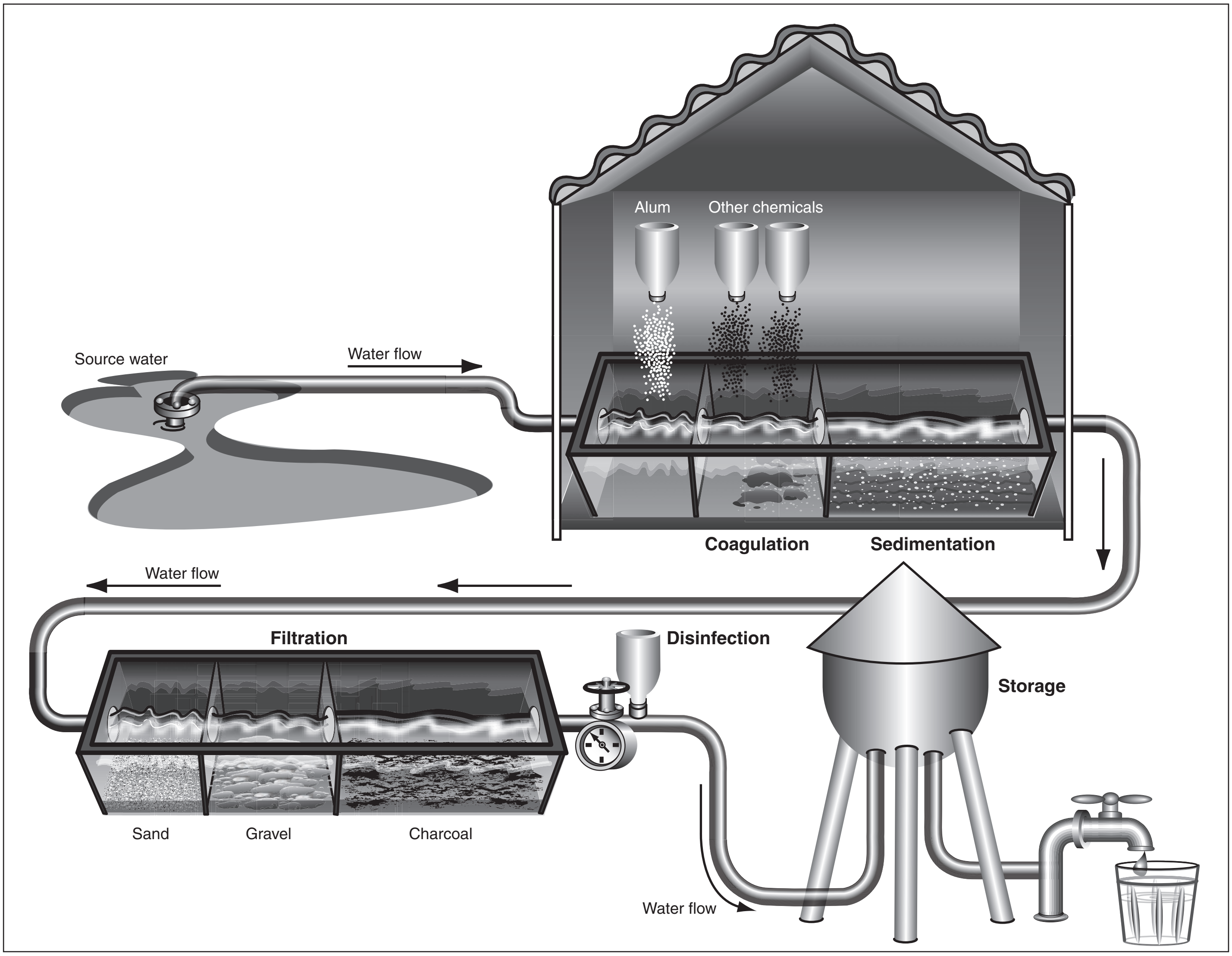
[6] A community water system is one that provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections, or regularly serves at least 25 people year-round. Customers not part of a community water system can receive water from other types of public water systems or from private wells.

passes through filters made of layers of materials such as sand, gravel, and charcoal to remove even smaller particles. At this point, the water is stored in a closed tank or reservoir, allowing time for disinfection which kills many disease-carrying organisms. The treated water is pressurized for distribution to consumers. The distribution infrastructure consists of pumps, pipes, tanks, valves, hydrants, and meters that support delivery of water to the customer and control flow and water pressure.

Figure 2: Typical Drinking Water Treatment Process



Source: GAO analysis.

Once water is delivered, residential consumers use it for a variety of purposes, including for drinking; bathing; preparing food; washing clothes and dishes; and flushing toilets, which can represent the single largest use of water inside the home. Energy is needed to accomplish many of these activities. For example, energy is used in homes to filter and soften water and to heat it for use in certain appliances, which accounts for 12.5 percent of a typical household's energy use, according to DOE. In addition to residential water users, commercial, industrial, and institutional customers use energy for water-related purposes. For example, energy is used to produce hot water and steam for heating buildings, to cool water for air conditioning buildings, and to generate hot water needed to manufacture or process materials, such as food and paper.

After water is used by customers, energy is needed to collect and treat wastewater, and to discharge effluent into a water body. Wastewater service is provided to more than 220 million Americans by about 15,000 municipal wastewater treatment facilities.[7] During a typical wastewater treatment process, solid materials, such as sand and grit, organic matter from sewage, and other pollutants, are removed before the treated effluent is discharged to surface waters. Systems for collecting, treating, and disposing of municipal wastewater vary widely in terms of the equipment and processes used, and wastewater may go through as many as three treatment stages—primary, secondary, and advanced treatment—before water is discharged (see fig. 3).

- *Preliminary and primary treatment.* As wastewater enters a treatment facility, it is screened to remove large debris and then passes through a grit removal system to separate out smaller particulate matter. After preliminary screening and settling, primary treatment removes solids from the wastewater through sedimentation. Solids removed during the treatment process may be further treated and used for other applications, such as fertilizer; incinerated; or disposed of in landfills.

- *Secondary treatment.* After primary treatment, the wastewater undergoes secondary treatment to remove organic matter and suspended solids through physical and biological treatment processes. Activated sludge is the most commonly used biological treatment process in secondary treatment of wastewater. This process relies on micro-organisms to break down organic matter in the wastewater. More specifically, aeration—

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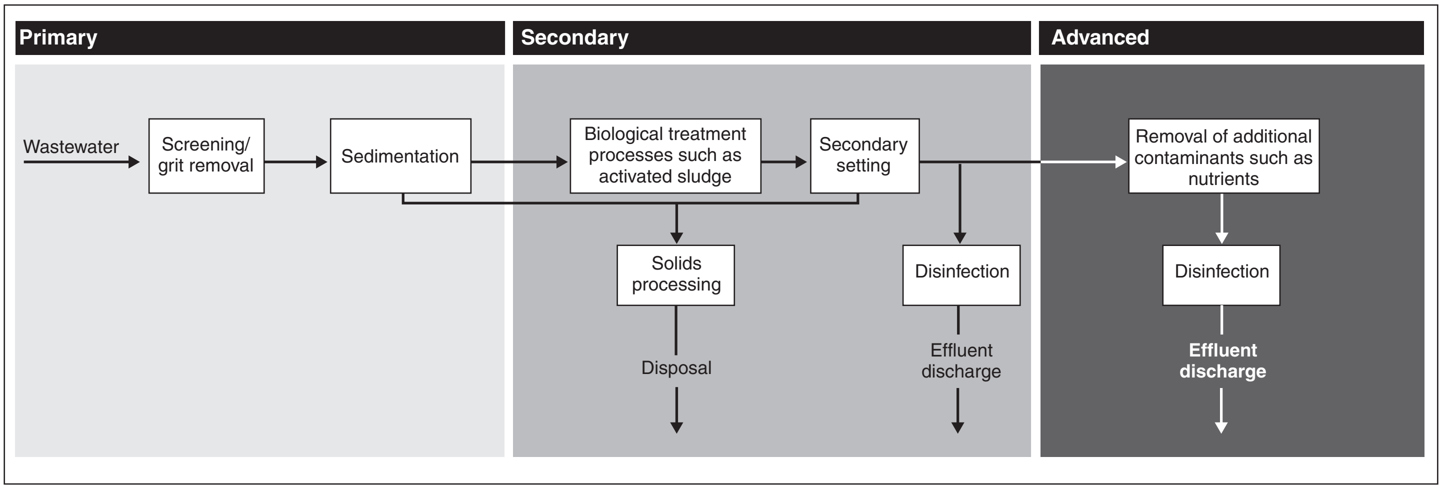
[7] Wastewater may be treated through other systems, such as septic systems, which serve approximately 25 percent of U.S. households.

whereby blowers or diffusers inject oxygen into the wastewater—enables the micro-organisms to digest the organic matter. After being pumped into an aeration tank to allow time for digestion, the wastewater is next pumped to a secondary settling tank for removal of digested material. After secondary settling, the effluent either is disinfected and discharged into a water body, or it undergoes advanced treatment.

- *Advanced treatment*. Most wastewater goes through at least secondary treatment. However, before treated wastewater can be released in some receiving waters, it may need to be further treated to reduce its effect on water quality and aquatic life after discharge. Over 30 percent of wastewater treatment facilities provide this kind of advanced treatment, which can remove additional contaminants.

Figure 3: Typical Wastewater Treatment Process



Source: GAO analysis.

Two key pieces of federal legislation—the Safe Drinking Water Act and the Clean Water Act—govern the treatment of drinking water and wastewater. Each municipality or water utility generally may choose amongst technologies for achieving a given standard. Under the Safe Drinking Water Act, EPA has established National Primary Drinking Water Standards for specified contaminants and has the authority to regulate additional contaminants that the agency determines may have adverse health effects, are likely to be present in public water supplies, and for which regulation presents a meaningful opportunity for health risk reduction. EPA's regulations establish a limit, or maximum contaminant level, for specific contaminants and require water systems to test the water periodically to determine if the quality is acceptable.[8] EPA has regulations in place for 89 contaminants, including disinfectants, byproducts of disinfectants, and microbial contaminants, but has not issued a regulation under the Safe Drinking Water Act for a new contaminant since 2000.

The Clean Water Act governs the discharge of pollutants into the waters of the United States, including the treatment of wastewater discharged from publicly owned treatment facilities. Specifically, industrial and municipal wastewater treatment facilities must comply with the National Pollutant Discharge Elimination System (NPDES) permits that control pollutants that facilities may discharge into the nation's surface waters. The act requires that municipal wastewater treatment plants provide a minimum of secondary treatment prior to discharge. In some cases, modification of secondary treatment requirements may occur, however, for discharges into marine waters under certain conditions. For example, the discharge may not interfere with that water quality which assures protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife and allows recreational activities on the water. In 2000, Congress amended the Clean Water Act to require permits for discharges from combined sewers—sewers that transport both wastewater and stormwater to the municipal wastewater treatment plant—to conform with EPA's Combined Sewer Overflow Control Policy, which requires systems to demonstrate implementation of certain minimum pollution control practices.[9] Combined sewers may overflow when there is heavy precipitation or snowmelt, resulting in the discharge of raw sewage and other pollutants into receiving water bodies.

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[8] EPA may promulgate a treatment technique in lieu of a maximum contaminant level, if the EPA Administrator makes a finding that it is not economically or technologically feasible to ascertain the level of a given contaminant in drinking water.

[9] 33 U.S.C. §1342(q) (2006) (implementing the Combined Sewer Overflow Control Policy signed by the Administrator on April 11, 1994; see 59 Fed. Reg. 18688 (Apr. 19, 1994)). The policy defines a combined sewer system as a wastewater collection system owned by a state or municipality that conveys sanitary wastewaters and stormwater through a single-pipe system to a publicly owned treatment works treatment plant.

Comprehensive Data about the Energy Needed for the Urban Water Lifecycle Are Limited, However Energy Needs Are Influenced by Location-Specific Factors

Comprehensive data about the energy needed for each stage of the urban water lifecycle are limited, and few nationwide studies have been conducted on the amount of energy used to provide drinking water and wastewater treatment services to urban users. However, specialists with whom we spoke emphasized that the energy demands of the urban water lifecycle vary by location; therefore, consideration of location-specific and other factors is key to assessing the energy needs of the urban water lifecycle. These factors include the source and quality of the water, the topography of the area over which water is conveyed and the distance of conveyance, and the level and type of treatment required.

Comprehensive Data on the Energy Needed to Support the Urban Water Lifecycle Are Limited

Providing a reliable and comprehensive estimate of the total energy requirements for moving, treating, and using water in urban areas is difficult, in part, because comprehensive data on the energy demands of the urban water lifecycle are limited and few nationwide studies have been conducted to quantify the amount of energy used throughout the lifecycle. Two studies most often cited by the specialists we spoke with were conducted by the Electric Power Research Institute (EPRI) on the energy needs of the urban water lifecycle. These studies concluded that 3 to 4 percent of the nation’s electricity is used to move and treat drinking water and wastewater. While some specialists noted that these studies provide reasonable estimates of the energy demands of the urban water lifecycle, other specialists raised a number of concerns with the studies. In particular, according to several specialists, the EPRI studies are outdated. The first study dates back to 1996, and the more recent study was conducted in 2002 but relied on projections of future water use based on statistics compiled in 2000. Some specialists also told us these studies do not reflect the treatment processes that have been implemented over the last decade, which have increased the amount of energy needed to treat water. In addition, the studies do not include all stages of the urban water lifecycle—specifically, they omit energy used by customers. Because they exclude end use, the EPRI studies underestimate the energy demands of the entire lifecycle because customer end use, including use by residential customers, can be the most energy-intensive stage of the entire lifecycle, according to some specialists we spoke with and studies that we reviewed. Some specialists also added that the studies underestimate total energy demands because they include only electricity, excluding other fuel types that can be used throughout the lifecycle. For example, the studies do not assess the use of natural gas, which can be a primary energy source at wastewater treatment plants for certain processes. Furthermore, some specialists explained that the studies do not use actual measured data, relying instead on previously published estimates of energy used for portions of the water lifecycle.

Furthermore, some specialists noted that there are limited data on the amount of energy associated with customer water use. Federal agencies like DOE's Energy Information Administration collect some data on energy used to heat water in residences and in the commercial sector, but these data are reported on a national level and do not allow for analysis at the local level. In addition, data needed to get a full picture of the energy needs for water in an urban setting may not be readily available at the local level. Specifically, water utilities may not have detailed data on their facilities' energy use, may not have conducted audits to understand how their facilities use energy, or may be reluctant to share data, according to specialists we spoke with.

Consideration of Location-Specific and Other Factors Is Key to Assessing the Energy Needs of the Urban Water Lifecycle

Many of the specialists told us that efforts to assess the energy needs of the urban water lifecycle on a national scale can be difficult, and the majority of the specialists we spoke with emphasized that to obtain a more accurate picture, one needs to consider location-specific and other factors that influence energy use. The specialists identified the following as key factors that must be considered for such an assessment.

Type of water source. Drinking water systems that rely on surface water are often designed to take advantage of gravity and use little to no energy to extract water from the source and convey it to the treatment facility. In contrast, systems that rely on groundwater require more energy for extraction because water must be pumped to the surface from underground aquifers, especially if they rely on deep underground aquifers. For example, Washington, D.C., which relies on surface water, withdraws its water from two locations—Great Falls Dam and Little Falls Dam—on the Potomac River. Most of the water is withdrawn at Great Falls Dam and conveyed via gravity to the treatment plant, using little energy during the extraction and conveyance process. In contrast, extraction of water is an energy-intensive process for Memphis, which relies on groundwater that is extracted from over 160 wells that draw water from aquifers including the Memphis Sand Aquifer, located 500 to 600 feet below ground.

Quality of water to be treated. The quality of water also impacts the amount of energy needed for treatment, with higher-quality water containing fewer contaminants and, therefore, requiring less treatment than lower quality water. For example, treating groundwater generally uses less energy than treating surface water because groundwater is typically of higher quality than surface water. As a result, cities that rely on groundwater as the source for their drinking water, such as Memphis, generally use less energy for treatment than cities that rely on surface water, such as Washington, D.C. However, the type of contaminants in water can also affect the energy required for treatment. For example, as one specialist noted, if groundwater contains arsenic, treating this type of contamination can require the use of more energy-intensive treatment technologies than treating surface water that is extracted from a protected watershed or clean snowmelt.

Topography and distance. Pumping water is one of the most energy-intensive aspects of the urban water lifecycle, accounting for 80 to 90 percent of the energy used to supply drinking water in some systems, and most of this energy is used to distribute water to customers. The energy demand of pumping is affected by the topography over which the water must be moved and the distance the water must travel to treatment plants after extraction and to customers after treatment.[10] For example, San Diego gets a large amount of its water from northern California. Transporting this imported water to southern California is energy intensive because the water must be conveyed hundreds of miles and lifted 2,000 feet over the Tehachapi Mountains. Furthermore, because of the hilly terrain in some parts of the city and the great expanse over which the customers are distributed, additional energy is needed to pump water from the treatment plants to consumers.

Condition of water system. The age of a system and the condition of its pipes and equipment can also impact the energy demands of providing drinking water and wastewater treatment services. Specifically, older systems can be less energy efficient if the equipment and infrastructure have not been properly maintained. The American Society of Civil Engineers recently evaluated America's drinking water and wastewater infrastructure and assigned both systems a grade of a D-. The assessment noted that these systems contain facilities that are nearing the end of their useful lives and need upgrades to meet future regulatory requirements. In

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[10] According to some specialists we spoke with, topography and distance can also affect the energy needed to pump and move wastewaster. However, the specialists noted that wastewater systems were often designed to rely on gravity, and wastewater treatment plants were located close to the receiving waters.

addition, the condition of pipelines also has energy implications. According to some specialists we spoke with, up to 50 percent of water is lost through leaking pipes, which results in a loss of the energy that was used to extract, convey, and treat the water. Furthermore, if pipelines are not routinely cleaned, blockages can lead to friction in the pipes, requiring additional energy to push water through these pipes.

Required treatment level. Energy needed for drinking water and wastewater treatment is affected by the treatment levels required to meet existing water quality standards, with each additional treatment level increasing energy demands. In the case of wastewater treatment, characteristics of the water body into which treated effluent is discharged can impact the required level of treatment. For example, San Diego officials told us the city's wastewater treatment facility has been granted a modified permit by EPA. According to these officials, this permit allows San Diego to treat its wastewater only to an advanced primary level in part because years of ocean monitoring have shown that the plant discharges have no negative impact to the Pacific Ocean.[11] If the city had to treat its wastewater to secondary treatment levels, city officials estimate that its energy usage would increase six to nine times as a result of having to use more energy-intensive technologies to meet these higher standards.

Type of treatment process. The type of treatment process used at drinking water and wastewater facilities also influences the energy demands of providing drinking water and wastewater services to urban users. For example, treatment plants that use the activated sludge process for secondary treatment use more energy than plants that use other processes, such as trickling filters or lagoon systems.[12] The activated sludge process can account for 70 percent of a wastewater treatment plant's energy consumption because of the energy needed to power the blowers that pump oxygen into the wastewater to sustain the micro-organisms. Furthermore, according to many of the specialists we spoke with, a number of the new technologies used in drinking water treatment plants are more energy intensive than traditional treatment technologies. For example, some treatment plants are installing ultraviolet light

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[11] Advanced primary treatment includes enhanced removal of solids and organic matter from wastewater, which is typically accomplished by chemical addition or filtration.

[12] A trickling filter is a bed of media, typically rocks or plastic, through which the wastewater passes. A lagoon system uses a scientifically constructed pond that allows sunlight, algae, bacteria, and oxygen to interact and treat the wastewater.

disinfection processes that are more energy intensive, accounting for 10 to15 percent of a plant's total energy use, than traditional disinfection with chlorine.[13] Other energy-intensive technologies that are increasing energy demands for water treatment include filtration using membranes and ozonation, a process that destroys bacteria and other micro-organisms through an infusion of ozone.

Water use and type of customer. Characteristics related to customer water use, such as how and where water is consumed, can also influence the amount of energy needed to provide water and wastewater services to urban users, according to specialists we spoke with. Large amounts of household energy are consumed by heating water for showering, dishwashing, and other uses. These uses would require more energy than other household uses, such as flushing toilets. In addition, some specialists told us that where the water is used influences the amount of energy consumed. For example, water used in tall apartment buildings or skyscrapers requires energy-intensive pumps to move the water to the top floors. Furthermore, according to some specialists we spoke with, the type of customer, such as whether the customer is residential or industrial, affects the energy demands of providing water and wastewater services. For example, Memphis has two wastewater treatment plants, one of which is located in an industrial section of the city and receives a higher percentage of its wastewater from industrial sources than the other facility, which receives a higher percentage of its wastewater from residential sources. Because the industrial wastewater contains increased levels of organic contaminants and thus requires more energy for treatment, the two facilities consume different amounts of energy on a per-gallon basis.

Water availability. As current water supplies diminish, some cities, especially those in areas that are already water stressed, are moving toward alternative water supply sources that will require more energy for treatment than processes used for surface water and groundwater. For example, to help meet future demands for water and reduce dependence on imported water supplies in San Diego, the region is pursuing energy-intensive seawater desalination, which can be 5 to 10 times more energy intensive than conventional processes to treat surface water and

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[13] Treatment plants may also install ultraviolet light disinfection technologies for reasons unrelated to water quality, such as concerns about plant safety and security when storing large quantities of chemicals on-site.

groundwater. Other areas, such as Tucson, Arizona, that do not have ready access to seawater are pursuing desalination of brackish groundwater—water that is less saline than seawater but that contains higher saline levels than found in freshwater. Although treating brackish water is less energy intensive than seawater desalination, it still can use two to three times more energy than conventional water treatment processes for freshwater supplies. Furthermore, San Diego is studying the viability of treating a portion of its reclaimed water—wastewater effluent that is treated to an advanced level and suitable for nonpotable water applications such as irrigation—for potable water use. To implement such a system, San Diego would need to add energy-intensive advanced treatment processes to its current wastewater treatment system. However, because this additional energy use would offset the energy demands for imported water, city officials told us the project is expected to result in a net reduction in San Diego's energy profile. Using reclaimed water can also increase energy demands for pumping, depending on the design of the existing wastewater system. That is, many wastewater collection systems were designed with treatment plants located in low elevation areas to take advantage of gravity in conveying the wastewater to the plant. However, if wastewater is recycled, energy could be needed to pump this water against the flow of gravity into the distribution system, but such increases may actually be less energy intensive than reliance on imported water.

Future regulatory changes. To address growing concerns about emerging contaminants and nutrients in the nation's water bodies, according to many specialists, additional or more stringent regulatory standards could increase the energy demands of treatment processes in the future. Specifically, any more stringent standards that are promulgated would most likely require additional levels of treatment, and energy-intensive technologies, such as ozonation and membrane filtration, may be necessary to meet such new standards. More stringent regulations in the future could also increase energy demands even for facilities that have already implemented such technologies. For example, according to officials of the Washington, D.C., wastewater treatment plant, while the facility already must meet the nation's most stringent permit requirements and uses advanced treatment processes, stricter standards are expected to increase the plant's energy demands, in part, because new energy-intensive technologies may need to be added to the plant's treatment process. Regulatory changes could also increase energy demands at other stages of the urban water lifecycle. For example, higher standards for effluent discharge from wastewater treatment plants could increase the energy required for treatment. Furthermore, stricter water quality standards for receiving waters could necessitate more plants to employ advanced treatment standards, resulting in increased energy use for the additional treatment or to pump effluent farther away to other waters.

Complexity of water systems. In addition to location-specific factors, the complexity of some urban water systems can make assessing the energy demands of the urban water lifecycle challenging. For example, some urban water systems like San Diego's are highly complex, involving a number of different entities that have responsibility for different parts of the system. Specifically, the City of San Diego currently imports 85 to 90 percent of its water from the Colorado River and northern California. In addition, the city's regional drinking water, wastewater, and recycled water systems are managed by a number of different organizations responsible for conveying drinking water, wastewater, and recycled water to multiple treatment facilities with over 160 pumping stations spread over 400 square miles within the City of San Diego's service territory alone. As a result, collecting consistent data on energy use from each of these organizations is challenging, according to San Diego water officials we spoke with.

Certain Technologies and Approaches Can Reduce Energy Use, but Barriers Could Impede Their Adoption

Specialists we spoke with and studies we reviewed identified a variety of technologies and approaches that can improve the energy efficiency of drinking water and wastewater processes associated with the urban water lifecycle, and determining the appropriate solution depends on the circumstances of a particular system. However, adoption of these technologies and approaches may be hindered by costs; inaccurate water pricing; barriers associated with operational factors, such as limited staffing levels at water utilities; competing priorities at drinking water and wastewater facilities; and lack of public awareness about the energy demands of the urban water lifecycle.

Certain Technologies and Approaches Can Reduce the Energy Use of the Urban Water Lifecycle

Several key technologies and approaches are currently available that can improve the energy efficiency of drinking water and wastewater processes, but determining the most appropriate solution depends on the circumstances of a particular system and requires an understanding of the system's current energy use. Many studies that we reviewed and specialists we spoke with identified process optimization, equipment and infrastructure upgrades, water conservation, and improved energy management as approaches that can help reduce the energy demands for water. In addition, the increased use of renewable energy could offset the energy purchased by water utilities from energy providers.

Process Optimization

According to some studies we reviewed, energy consumption by water and wastewater utilities can comprise 30 to 50 percent or more of a municipality's energy bill. Optimizing drinking water and wastewater system processes, including energy-intensive operations like pumping and aeration, was identified in many studies that we reviewed as an approach to reducing the energy demands of the urban water lifecycle. Implementing monitoring and control systems and modifying pumping and aeration operations are some ways to reduce energy use through process optimization.

- *Implementing monitoring and control systems.* Monitoring and control systems, also known as supervisory control and data acquisition systems, can be used to optimize drinking water and wastewater operations. Such systems provide a central location for monitoring and controlling energy-consuming devices and equipment, which provides plant operators with the ability to schedule operations or automatically start and stop devices and equipment to manage energy consumption more effectively and improve overall operations.

- *Modifying pumping operations.* A variety of modifications could increase the efficiency of pumping systems. For example, operating constant speed pumps as near as possible to their most efficient speed, using higher efficiency pumps as opposed to lower efficiency pumps, and operating multiple smaller pumps rather than a few large pumps to better match pumping needs can help maximize pumping efficiency. In addition, using devices to monitor and control pump speeds—known as variable frequency drives (VFD)—may allow facility operators to accommodate variations in water flows by running pumps at lower speeds and drawing less energy when water flows are low. Potential energy savings from the use of VFDs can range from 5 to 50 percent or more, according to studies we reviewed. However, these studies and some specialists we spoke with also noted that VFDs are not necessarily well suited for all applications—such as when flow is relatively constant—and that potential benefits of VFDs should be evaluated based on system characteristics, such as pump size and variability of flow.

- *Modifying aeration operations.* According to many studies we reviewed and specialists we spoke with, aeration in wastewater treatment consumes a significant amount of energy, and systems can be reconfigured and better controlled to improve energy efficiency. Specifically, blowers and mechanical aerators are typically powered by a large motor, and installing variable controls on blowers to enable operators to better match aeration with oxygen requirements can reduce energy demands. Likewise several studies noted that dissolved oxygen control systems can be used to match oxygen supply with demand by monitoring the concentration of dissolved oxygen in the wastewater and adjusting the blower system or mechanical aerator speed accordingly. In addition, probes can be installed to monitor dissolved oxygen levels within the wastewater and signal operators when the system may need adjustment.

Equipment and Infrastructure Improvements

According to many studies and specialists we spoke with, installing more efficient equipment—motors, pumps, blowers, and diffusers—for energy-intensive processes such as aeration and pumping can reduce energy use. In addition, ensuring the proper sizing and maintenance of equipment and infrastructure can improve energy efficiency.

- *Upgrading equipment.* Replacing less efficient equipment with more energy-efficient equipment can reduce energy use. For example, installing more efficient motors could reduce energy use by 5 to 30 percent, according to studies we reviewed. In addition, blower and diffuser technologies, including high-speed "turbo" blowers and fine or ultra-fine bubble diffusers, could decrease the energy demands of aeration. High-speed turbo blowers use less energy than other blower types, although, because these blowers are a new technology and relatively few are in use, efficiency claims are not yet well documented, according to a 2010 EPA report.[14] Energy-saving estimates for fine bubble diffusers, which have higher oxygen transfer efficiencies than coarse bubble diffusers, range from 9 to 50 percent or more, but some specialists and studies expressed concerns about maintenance requirements as well as the durability of this technology.

- *Right-sizing equipment.* Many wastewater treatment systems were designed to handle greater capacity in the future because of anticipated population growth. However, this growth has not always occurred and, as a result, existing equipment may be oversized and consume more energy than is needed to treat current flows, according to some specialists we spoke with. Proper sizing and selection of pumping and aeration equipment to more closely match system needs can help maximize efficiency. For example, in Washington, D.C., the operators of the wastewater treatment plant replaced a 75-horsepower motor with a 10-horsepower motor in one facility to better meet actual energy demands.

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[14] Environmental Protection Agency, *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities* (Washington, D.C., 2010).

- *Improving maintenance and leak detection technology.* Periodic inspections to assess pump performance and the need for replacement or maintenance of electrical systems and motors can increase the energy efficiency of the overall system, according to studies we reviewed. In addition, leak detection technologies can identify leaks throughout water systems, thereby reducing water loss and the related energy required to pump and treat that "lost" water. For example, acoustic leak detection systems use sensors to monitor for sounds that may indicate potential leaks and relay the data back to a central control room, which helps water utility staff identify actual leaks and schedule maintenance accordingly. The San Diego County Water Authority, which provides water to San Diego and other areas in southern California, has fiber optic lines in place to monitor its pipeline 24 hours a day to detect evidence of leaks.

Water Conservation and Efficiency

Many studies we reviewed and specialists we spoke with also identified water conservation as an approach to reducing the energy needed for the urban water lifecycle. Several studies noted that decreased customer water use could directly translate into energy savings. Furthermore, water conservation also reduces the amount of energy used to convey, treat, and distribute drinking water to the customers. Studies we reviewed and specialists we spoke with identified a variety of tools that utilities can use to promote water conservation, including enhanced metering, increased water prices, public education, and incentives to install water-efficient appliances. For example, San Diego is implementing advanced metering tools to better manage its system and to provide real-time information to customers regarding their water use in order to help them make choices that conserve water. In addition, EPA has developed water efficiency and performance criteria for several product and program categories through WaterSense, a federal water efficiency program.[15]

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[15] WaterSense is an EPA-sponsored partnership program that seeks to protect the future of our nation's water supply by promoting water efficiency and enhancing the market for water-efficient products, programs, and practices.

Energy Management

While many technologies and approaches have been identified to reduce the energy demands for water, determining the most appropriate solution depends on the circumstances of a particular system—including the type of facilities and treatment processes in place—and requires an understanding of current energy use. Several studies we reviewed identified improved energy management, including conducting energy audits of treatment facilities or systems, as a necessary first step to reducing energy demands. Specifically, specialists told us that by providing utility managers with information about their facilities' energy use, energy audits can help managers identify opportunities to change plant operations in ways that will save energy. For example, the energy supplier for one wastewater treatment plant in Memphis conducted an energy audit of the blower system, which used about 75 percent of the plant's total energy. As a result of this audit, operators changed their practices to run blowers at the lowest levels possible while still ensuring they continued to meet the effluent discharge standards required by the plant's permits.

Similarly, in 2000, San Diego established an in-house energy management program, which includes an audit team that looks for technologies and approaches to lessen the energy demands of the city's drinking water and wastewater systems. The team studies the efficiency of existing equipment and treatment processes and considers upgrading or replacing equipment with available energy-efficient technologies. For example, the energy audit team identified over a dozen energy conservation measures that could be applied to reduce energy consumption at two of the city's sewer pump stations, including installing timers to turn off lighting and upgrading, resizing, and replacing motors and blowers.

In addition, EPA's Energy Star program provides energy management tools and strategies to support the successful implementation of energy management programs. Officials told us that EPA also works with municipal drinking water and wastewater utilities to provide information on potential energy efficiency opportunities. EPA's online benchmarking tool, known as the Portfolio Manager, offers wastewater treatment plant managers the opportunity to compare the energy use of their plants with that of other plants using the EPA energy performance rating system. EPA has also published a variety of educational materials for drinking water and wastewater utilities to help identify, implement, measure, and improve energy efficiency and renewable energy opportunities.

Other Approaches

Specialists we spoke with and studies we reviewed identified two additional approaches for reducing the energy required to treat and distribute water: improving advanced treatment technologies and redesigning a city or region's water system.

- *Improving advanced treatment technologies.* According to EPA officials, and as previously noted by specialists, improving energy-intensive advanced treatment technologies—such as ultraviolet disinfection, ozone, and membrane technologies—is important because plants are increasingly using them. For example, the use of membrane materials that require less pressure to push water through to remove contaminants could decrease the energy demands of that technology. In addition, some specialists we spoke with told us that newer technologies are being developed, such as forward osmosis, that may offer alternative treatment approaches that are more efficient than the technologies currently used for desalination. Several specialists told us the federal government should conduct additional research to understand and improve the energy efficiency of water supply, treatment, and water use—for example, by conducting more research on energy-efficient desalination technologies.

- *Redesigning water systems.* Some specialists noted that redesigning water systems in ways that better integrate drinking water, wastewater, and stormwater management could improve the energy efficiency of water systems overall. Decentralizing treatment systems, implementing approaches to better manage stormwater, reusing wastewater, and using less energy-intensive processes for biological treatment can help reduce energy needed for providing drinking water and wastewater services. For example, current water systems primarily rely on a few plants with large capacities to treat drinking water and wastewater. Some specialists told us that systems could be redesigned to incorporate more treatment plants with smaller capacities and to locate these plants closer to the point of water use by customers, thereby reducing some of the energy required for pumping to the treatment site. In addition, some specialists identified improvements in stormwater management through strategies such as low-impact development—which involve land use planning and design to better manage stormwater—as a way to reduce the energy required for treatment. For example, by decreasing stormwater infiltration into some wastewater systems through low-impact development activities such as the capture and use of rainwater, flows into treatment plants would also be reduced, thereby decreasing the energy needed for treatment. In addition, reusing wastewater for purposes that may not require potable water, such as industrial processes or landscaping, may reduce overall energy use by decreasing energy used currently to pump, treat, and distribute potable water to these customers, according to some studies we reviewed. However, the potential for energy savings from reuse depends on the energy intensity of a given system's water supply as well as the level of treatment needed for potential uses. Furthermore, some studies we reviewed and specialists we spoke with noted that relying more on biological treatment processes that do not require aeration, such as using lagoons or trickling filters, may be an option to reduce energy demands. However, these approaches may be limited by available space in urban areas and therefore may not be applicable everywhere.

Renewable Energy

Many studies we reviewed and specialists we spoke with stated that drinking water and wastewater utilities could adopt renewable energy projects to reduce energy purchased from energy providers. Renewable energy projects may include solar, wind, and hydroelectric power as well as the recovery and use of biogas from wastewater treatment processes.[16] In addition, some studies we reviewed and specialists we spoke with identified hydro turbines as an option for recovering energy in the distribution system. For example, water systems with changes in topography that have pressure-reducing valves in place can install turbines that generate electricity as water flows past. This energy could then be recovered for use in powering equipment.

The city of San Diego has adopted a variety of renewable energy projects to power its drinking water and wastewater treatment operations. For example, the city installed a 945-kilowatt solar power system at the Otay Water Treatment Plant that produces enough electricity to meet the power needs of the plant's pumping operation (see fig. 4). In addition, at the city's Point Loma Wastewater Treatment Plant, both methane and hydroelectric power are recovered from wastewater processes. The plant uses digestion processes to treat organic solids resulting from its wastewater treatment processes. Methane, a by-product of the digestion process, is removed from the digesters and used to power two engines that supply all of the plant's energy needs, making it energy self-sufficient. In addition, the plant recovers hydroelectric power from the treated effluent that it discharges into the ocean. The effluent drops 90 feet from the wastewater treatment plant to the ocean, powering a 1,350 kilowatt hydroelectric plant. The city can sell any excess energy produced by the plant back to the electric utility.

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[16] Biogas is a mixture of gases including methane and carbon dioxide produced during the digestion of organic solids that result from the wastewater treatment process.

Figure 4: Solar Panels at San Diego's Otay Water Treatment Plant

Source: San Diego Public Utilities Department.

While renewable energy projects have the primary benefit of reducing the energy needed by water treatment facilities from outside providers, such projects could also reduce overall energy use. For example, solar power systems co-located at treatment facilities in San Diego may result in the offset of slightly more electricity than they produce, since electricity generated by the energy provider off-site and transferred over a greater distance results in some loss of energy during transmission.

Key Barriers Could Impede Adoption of Technologies and Approaches

Specialists we spoke with identified a number of key barriers to adopting the available technologies and approaches that could reduce the energy demands of the urban water lifecycle. These barriers fall into five categories: (1) costs associated with these technologies, (2) inaccurate water pricing, (3) barriers associated with how water utilities operate, (4) competing priorities at drinking water and wastewater facilities, and (5) the lack of public awareness about the energy demands of the urban water lifecycle.

Costs Associated with Energy-Saving Improvements

Energy-saving technologies may lessen the energy demands of the urban water lifecycle, but such improvements are often expensive to adopt. Many specialists told us that, as a result, utilities may not be able to justify the costs necessary to install energy-efficient equipment. For example, some specialists told us that upgrading to VFDs, higher-efficiency pumps, and ultra-fine bubble diffusers may lessen a water facility's energy demands, but the costs of installing these technologies can be prohibitive for some systems, and it can take years to realize the full energy-saving benefits. As a result, some utility operators may choose to wait until there is an immediate need to upgrade equipment because the costs can be justified more easily at that point. Similarly, some specialists told us that the cost of installing renewable energy projects, such as solar panels, can be a barrier to adoption for some treatment facilities. According to an energy specialist we spoke with, it may take over 30 years to fully realize the cost savings from such projects. However, a DOE official noted that while expensive in the past, the cost of solar panels has been decreasing in recent years. Furthermore, installing energy-efficient equipment and infrastructure upgrades, such as replacing leaking pipelines, can be particularly challenging for smaller water utilities because they often compete for limited funds against other municipal services, such as fire and police protection. In addition, in areas where energy costs are low, there may be little incentive for water utility operators to implement capital-intensive practices to save energy. To help overcome the barriers associated with the costs of upgrading facilities, some specialists told us that utilities should conduct cost analyses to account for the total savings incurred over the life of the energy-saving projects, not just focus on the short-term returns on investment. Some specialists we spoke with also suggested that utilities should take advantage of the federal funding available through the Drinking Water and Clean Water State Revolving Fund programs, which can be used to fund a variety of projects that improve water and energy efficiency. These programs provide financial assistance for drinking water and wastewater infrastructure projects, respectively, and for certain other purposes, such as installing water meters, installing or retrofitting water-efficient devices, and promoting water conservation. In addition, the American Reinvestment and Recovery Act of 2009 and EPA's fiscal year 2010 appropriation encourage states to use a portion of those funds for such energy and water efficiency projects.[17]

Inaccurate Water Pricing

According to many specialists with whom we spoke, the true cost of water is often not reflected in rates customers are charged. Specifically, specialists told us that water subsidies have kept water rates artificially low and do not reflect the actual cost, including energy costs, of pumping, treating, and moving drinking water and wastewater. The effect of this situation is two-fold. First, there may be little incentive for customers to use water more efficiently if they are not paying the true cost of it. Second, because these reduced water rates generally do not cover the actual costs incurred by drinking water and wastewater facilities, some utilities do not generate enough revenue to implement upgrades that could lessen their facilities' energy demands. Some specialists noted, however, that rate increases are not a politically popular approach and may be met with public and political resistance.

Operational Challenges

Other barriers to adopting energy-reducing technologies and approaches are operational in nature. Specifically, specialists we spoke with noted a number of such challenges, including utilities not having staff with adequate knowledge about technologies and access to energy-use data, reluctance to change, and lack of coordination between water and energy utilities. For example, several specialists told us that smaller utilities lack staff with knowledge about the energy-efficient techniques or may only have operators in place part time to manage or oversee new technologies. Because operators generally are the advocates for energy-efficiency upgrades, the specialists believe it could be difficult to gain support for such investments without knowledgeable operators. Further, operators may be unaware of the amount of energy their facilities use because, in many municipalities, these bills are received and paid by other

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[17] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115, 169; Interior Department and Further Continuing Appropriations, Fiscal Year 2010, 123 Stat. 2904, 2935.

departments and operators may not have access to these data. Consequently, operators may be unaware of the potential for energy savings from upgrades. Moreover, many specialists told us that operators are often resistant to alter the practices that they have employed for years to move and treat water and may be reluctant to adopt new technologies or approaches, especially if the effectiveness of such changes has not yet been adequately proven. Some specialists also told us that drinking water and wastewater utilities do not coordinate as closely as they could with energy utilities to identify opportunities to optimize their operations and, thereby, lessen their energy demands.

Energy Usage Considerations Are Secondary to Complying with Water Quality Regulations

Considering the energy demands of treatment can be an afterthought to complying with water quality regulations for treatment plant operators, according to some specialists with whom we spoke. One drinking water utility operator told us that energy is considered to the extent possible when decisions are being made about altering treatment processes to meet regulatory requirements but that the safety of the water supply is his primary concern. For example, when the city of San Diego's Public Utilities Department was considering which disinfection technology to employ, it chose to use ozonation because it would provide more effective disinfection for the plant and also reduces disinfection by-products, even though it is a more energy-intensive technology than the current disinfection process. In addition, to ensure that minimum effluent discharge standards are met, water utility operators may over-treat wastewater by, for example, running aeration blowers at higher levels than necessary to meet regulatory requirements. In light of the potential for more stringent standards in the future, some specialists noted that regulators should consider the energy demands associated with these increased water quality standards.

Lack of Public Awareness about the Energy Demands of the Urban Water Lifecycle

Many specialists told us that many customers are not aware of and do not understand the energy demands of drinking water and wastewater services. While some customers may be aware of their total energy use, it may not be clear to them how much of that energy use is for heating water and other water-related uses. In addition, customers may not be aware that water conservation saves not only water but also energy. Some specialists told us that federal programs such as EPA's WaterSense and Energy Star and some state efforts, such as in California and New York, have begun to educate the public on the energy demands of the urban water lifecycle; however, additional efforts may be needed to increase awareness of the energy-water nexus for providing drinking water and wastewater to urban users.

Agency Comments

We provided a draft of this report to the Departments of Defense, Energy, and the Interior and EPA for review and comment. DOE and EPA provided technical comments that we incorporated into the final report as appropriate.

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 of this report to the appropriate congressional committees; the Administrator of EPA; the Secretaries of Defense, 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 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 key contributions to this report are listed in appendix II.

Sincerely yours,

Anu K. Mittal

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Director, Natural Resources
and Environment

Mark E. Gaffigan

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Managing Director, Natural Resources
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Appendix I: Objectives, Scope, and Methodology

Our objectives for this review were to describe what is known about (1) the energy needed for each stage of the urban water lifecycle, and (2) technologies and approaches that could lessen the energy needed for the urban water lifecycle, as well as any identified barriers that exist to their adoption. We focused our work on community drinking water systems and publicly owned wastewater facilities located in the United States. We also focused on residential customers and, to the extent possible, commercial, industrial, and institutional customers.

To address both of these objectives, we conducted a systematic review of studies and other documents that examine the energy required to extract, move, use, and treat water, including peer-reviewed scientific and industry periodicals, government-sponsored research, and reports from nongovernmental research organizations. In conducting this review, we searched databases such as ProQuest, EconLit, and BioDigest, and used an iterative process to identify additional studies, asking specialists to identify relevant studies and reviewing studies from article bibliographies. We reviewed studies that fit the following criteria for selection: (1) the research was of sufficient breadth and depth to provide observations or conclusions directly related to our objectives; (2) the research demonstrated the energy demands of water supply systems in the United States; (3) the studies typically were published between 2000 and 2010; and (4) the studies were determined to be methodologically sufficient. We examined key assumptions, methods, and relevant findings within the studies related to drinking water processes, customer end use, and wastewater processes. We believe we have included the key studies and have qualified our findings, where appropriate. However, it is possible that we may not have identified all of the studies with findings relevant to these two objectives.

We also selected a nonprobability sample of three cities to examine in greater depth to better understand regional and local differences related to urban water lifecycles: Memphis, Tennessee; San Diego, California; and Washington, D.C. We chose these cities as illustrative case studies based on criteria such as their type of water source; water availability; type of wastewater system; unique characteristics, such as potential for desalination; and economic factors, such as energy costs. The results from our visits to these cities cannot be generalized to all U.S. cities, but they provide valuable insights as illustrative case studies. For each of these case studies, we analyzed documentation from and conducted interviews with a wide range of specialists to gain the views of diverse organizations covering all stages of the urban water lifecycle. These groups included relevant drinking water and wastewater treatment facilities, and state and local agencies responsible for water or energy. We requested interviews with representatives from electrical utilities in each location. In San Diego and Washington, D.C., the utilities did not meet with us or told us they did not have relevant data. In Memphis, however, which has a combined water and energy utility, an energy official was present at our meeting with the utility, but the utility told us it does not track data on energy for water-related uses for some customer types. In addition, we conducted site visits to drinking water and wastewater treatment facilities in each of these locations to better understand the role that energy plays in their operation.

In addition to the specialists we interviewed as part of our illustrative case studies, we also interviewed a range of specialists whom we identified as having expertise related to the energy needs of all stages of the urban water lifecycle in general. We selected these specialists using an iterative process, soliciting additional names from each person we interviewed. From among those specialists identified, we interviewed those who could provide us with a broad range of perspectives on the energy needs of the urban water lifecycle. We also interviewed specialists that we identified during our systematic review of studies who have analyzed (1) the energy needed in one or more stages of the water lifecycle at the national or local level or (2) techniques available to reduce the energy demands for water. These specialists represented a variety of organizations, including drinking water and wastewater treatment facilities; state and local government offices responsible for water or energy; officials from the EPA; researchers from some of the Department of Energy’s national laboratories, such as Sandia National Laboratory; university researchers; water and energy industry representatives from groups such as the American Water Works Association and the Water Research Foundation; and relevant nongovernmental organizations, such as the Pacific Institute, a nonpartisan research institute that works to advance environmental protection, economic development, and social equity. The specialists also included individuals with knowledge of the energy demands for water in other states, including Arizona, Colorado, Florida, New York, and Wisconsin, to gain a better understanding of water and energy issues in other regions around the United States. We also interviewed other federal agency officials and analyzed data and information from federal agencies that have responsibilities related to the energy needs of the urban water lifecycle—the Department of Defense’s U.S. Army Corps of Engineers, the Department of Energy, the Department of the Interior’s U.S. Geological Survey and Bureau of Reclamation, the Environmental Protection Agency, and the National Science Foundation.

To analyze information gathered through the interviews with specialists and the scientific studies, research, and other key documents reviewed, we conducted content analyses. Specifically, to conduct the content analysis of information gathered through interviews with specialists, we reviewed each interview, selected relevant statements, and identified and labeled these statements using a coding system that identified the topic area. Once relevant statements from the interviews were extracted and coded, we used the coded data to develop key themes. An independent reviewer then verified that the codes were accurately applied to the statements and the key themes were correctly developed. During the course of our review, we conducted over 60 interviews with over 100 specialists. 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 used the following categories to quantify responses of experts and officials: “some” refers to responses from 2 to 5 specialists, “several” refers to responses from 6 to 10 specialists, and “many” refers to responses from 11 or more specialists. We used a similar coding scheme to identify key themes resulting from our analysis of the scientific studies, research, and other key relevant documentation.

We performed our work from January 2010 to January 2011 in accordance with all sections of GAO’s Quality Assurance Framework that are relevant to our objectives. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.

Appendix II: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to the contact named above, Elizabeth Erdmann, Assistant Director; Colleen Candrl; Antoinette Capaccio; Janice Ceperich; Nancy Crothers; Abbie David; Angela Leventis; Katherine Raheb; Ellery Scott; Rebecca Shea; Jena Sinkfield; Kevin Tarmann; and Lisa Vojta made significant contributions to this report.

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