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Energy-Water Nexus: The Water Sector's Energy Use

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Summary

Water and energy are resources that are reciprocally and mutually linked, because meeting energy needs requires water, often in large quantities, for mining, fuel production, hydropower, and power plant cooling, and energy is needed for pumping, treatment, and distribution of water and for collection, treatment, and discharge of wastewater. This interrelationship is often referred to as the energy-water nexus, or the water-energy nexus. There is growing recognition that "saving water saves energy." Energy efficiency initiatives offer opportunities for delivering significant water savings, and likewise, water efficiency initiatives offer opportunities for delivering significant energy savings. In addition, saving water also reduces carbon emissions by saving energy otherwise generated to move and treat water.

This report provides background on energy for facilities that treat and deliver water to end users and also dispose of and discharge wastewater. Energy use for water is a function of many variables, including water source (surface water pumping typically requires less energy than groundwater pumping), treatment (high ambient quality raw water requires less treatment than brackish or seawater), intended end-use, distribution (water pumped long distances requires more energy), amount of water loss in the system through leakage and evaporation, and level of wastewater treatment (stringency of water quality regulations to meet discharge standards). Likewise, the intensity of energy use of water, which is the relative amount of energy needed for a task such as pumping water, varies depending on characteristics such as topography (affecting groundwater recharge), climate, seasonal temperature, and rainfall. Most of the energy used for water-related purposes is in the form of electricity. Water-related energy is estimated to account for about 4% of the nation's electricity generation, but many data gaps exist. Also, regional differences can be significant. In California, for example, as much as 19% of the state's electricity consumption is for pumping, treating, collecting, and discharging water and wastewater.

Energy consumption by public drinking water and wastewater utilities, which are primarily owned and operated by local governments, can represent 30%-40% of a municipality's energy bill. At drinking water plants, the largest energy use (about 80%) is to operate motors for pumping. At wastewater treatment plants, aeration, pumping, and solids processing account for most of the electricity that is used. Energy is the second-highest budget item for these utilities, after labor costs, so energy conservation and efficiency are issues of increasing importance to many of them. Opportunities for efficiency exist in several categories, such as upgrading to more efficient equipment, improving energy management, and generating energy on-site to offset purchased electricity. However, barriers to improved energy efficiency by water and wastewater utilities exist, including capital costs and reluctance by utility officials to change practices or implement new technologies.

Topics for research to better understand water-related energy use include studies of energy demands for water at local, regional, and national scales; development of consistent data collection methodology to track water and energy data across all sectors; development and implementation of advanced technologies that save energy and water; and analysis of incentives, disincentives, and lack of incentives to investing in cost-effective energy or water efficiency measures.

Contents

Energy for Water Use 2
Energy for Water Supply and Wastewater Facilities 5
Research and Information Needs..... 9

Figures

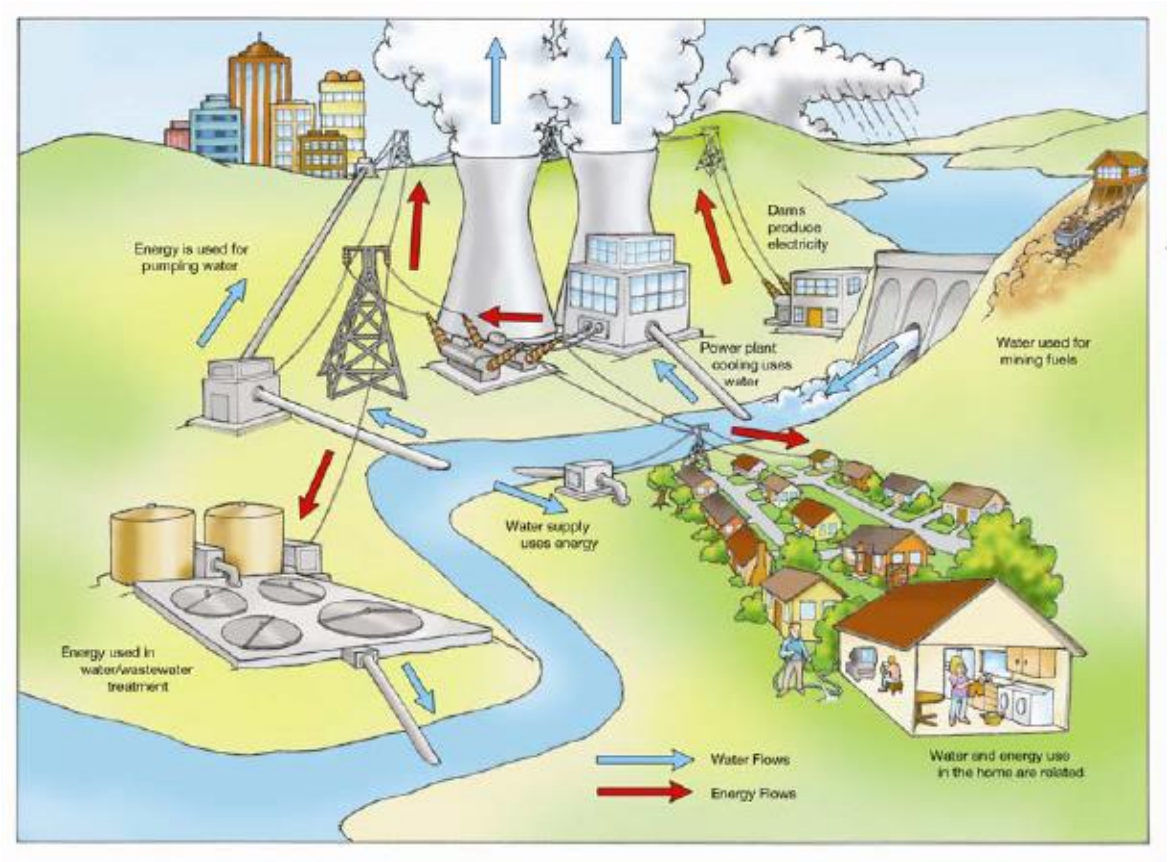
Figure 1. Examples of Interrelationships Between Water and Energy 1

Contacts

Author Information..... 10

Water and energy are critical resources that are reciprocally and mutually linked. Meeting energy needs depends upon the availability of water, often in large quantities, for mineral extraction and mining, fuel production, hydropower, and thermoelectric power plant cooling.[1] Likewise, energy is required for the pumping, conveyance, treatment and conditioning, and distribution of water and for collection, treatment, and discharge of wastewater. This interdependence, which is often described as the water-energy nexus, or energy-water nexus, is illustrated in the following graphic from a U.S. Department of Energy report.

Figure 1. Examples of Interrelationships Between Water and Energy



Source: U.S. Department of Energy, Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water, December 2006, p. 13.

This report first discusses water-related energy use broadly and then energy for facilities that treat and deliver water to end users and also dispose of and discharge wastewater. There is growing recognition that "saving energy saves water," and the report describes options and impediments for energy efficiency by these facilities. It also identifies several areas of research and information needs concerning energy for water uses.

[1]CRS Report R43199, *Energy-Water Nexus: The Energy Sector's Water Use*, by Nicole T. Carter, discusses the related topic of water needs for the energy sector.

Energy for Water Use

In the United States, more than 400 billion gallons of water are withdrawn daily from surface and ground water sources of freshwater and saline-water to supply domestic uses, agriculture including irrigation, industry, mining, and thermoelectric power.[2] Information about the energy—especially electricity—that is needed to pump, transport, deliver, and process that water is fragmentary and not well documented overall. In particular, as described further below, energy needs for self-supplied domestic, industrial, and energy water are largely unknown, but are likely to be large. Interest has been growing in better understanding of the energy-related needs of providing water to diverse sectors of the economy.

In a 2002 report, the Electric Power Research Institute (EPRI) estimated that nearly 4% of the nation's electricity use goes toward moving and treating water and wastewater by public and private entities.[3] EPRI's analysis covered public water supply agencies and publicly owned wastewater treatment facilities (accounting for 1.6% of U.S. electricity consumption in 2000) and self-generated private water and wastewater treatment (i.e., for industry and mining, agriculture, and commercial supply and treatment, accounting for 2.1% of U.S. electricity consumption in 2000). EPRI projected that electricity consumption by these sectors would increase by 23% in 2020 from 2000 levels and by 63% in 2050.

Today that 4% estimate is considered a good starting place for understanding the magnitude of energy demands for providing these water services, but deficient in several respects.

- It relied on secondary source data.
- It did not include future projections of electricity requirements for water supplies in the thermoelectric sector (because it assumed that energy for water use in this sector would decline).
- It did not consider on-site heating, cooling, pumping, and softening of water for end-use.
- It did not consider that in the future a large proportion of new water demands will be met by sources with greater energy intensities, such as groundwater pumped from greater depths and seawater desalination.

Others have attempted to expand on the EPRI analysis, using additional and updated data from a variety of sources, to develop a baseline estimate of water-related energy use in the United States. For example, a 2009 report by the River Network, a national advocacy group for freshwater conservation and watershed restoration, looked at data from the Energy Information Administration (EIA) concerning U.S. energy use for residential and commercial water heating, which comes from multiple fuel sources (e.g., electricity, natural gas, fuel oil). It found that more than 380 billion kilowatt hours (kWh) of energy is used for water heating by these sectors; 148 billion kWh, or nearly 40% of that energy, is supplied by electricity.[4]

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[2] Susan S. Hutson, Nancy L. Barber, and Joan F. Kenny, et al., *Estimated Use of Water in the United States in 2000*, U.S. Department of the Interior, U.S. Geological Survey, U.S. Geological Survey Circular 1268, 2004.

[3] Electric Power Research Institute, *Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment—the Next Half Century*, 1006787, Topical Report, March 2002.

[4] Bevan Griffiths-Sattenspiel and Wendy Wilson, *The Carbon Footprint of Water*, River Network, May 2009, pp. 18-19. Data on water heating in the manufacturing and industrial sectors are not available from EIA. Hereinafter, The Carbon Footprint of Water.

Researchers at the University of Texas at Austin have attempted to quantify the energy embedded in the U.S. public water supply, which is the primary water source of residential, commercial, and municipal users. One such analysis concluded that energy use associated with the public water supply is 4.1% of the nation's annual primary energy consumption and 6.1% of national electricity consumption, but this analysis excluded energy requirements associated with water for agriculture, industrial, and self-supplied sectors (e.g., agriculture, thermoelectric, and mining). In this analysis, electricity consumption by public drinking water and wastewater utilities for pumping, conveyance, treatment, distribution, and discharge was 56.6 billion kWh, or 11.5% of primary energy and 21.6% of electricity consumption for water end-use, respectively, in 2009.[5]

A second analysis by these researchers looked more broadly at energy needs for water supply, adding industrial and thermoelectric sectors to others considered previously.[6] Water-related energy use throughout the economy varies across sectors, and analysis of some sectors is complex and limited by incomplete data (e.g., cooking-related activities vary across residences and are not well documented). This analysis concluded that direct water-related energy consumption was 12.6% of national primary energy consumption in 2010. This amount of energy, 12.3 quadrillion BTUs, is the equivalent of annual energy consumption of about 40 million Americans. It also estimated that energy losses at the point of electricity generation, transmission and distribution, and end-use represent 58% of the total primary energy that was consumed for water-related purposes, reflecting varying efficiencies of water heating and boiler technologies. The estimate of waste heat losses is subject to uncertainty, the researchers said.

Because of inadequate data and other factors, missing from some analyses is water-related energy for several important end-use sectors.

- Self-supplied water, which is a high percentage of power plant use and of some industrial uses such as mining. Some of this energy-for-water is in the form of electricity, but much of it is likely direct use of fuels on-site. Privately operated residential water supply wells also utilize energy for pumping, none of which is accounted for.
- Agricultural use of water for livestock and irrigation—second in volume only to water use for thermoelectric power, according to the U.S. Geological Survey—is generally omitted from these analyses, although substantial energy, which generally is self-supplied, is needed for pumping.
- The transportation sector, although the majority of energy consumed is for petroleum-based transportation fuels, which is presumably reflected in water-for-energy analyses.
- The bottled water industry, which is a substantial drinking water source in the United States and consumes energy to collect, treat, bottle, and distribute its products.

Energy use for water is a function of many variables, including water source (surface water pumping typically requires less energy than groundwater pumping), treatment (high ambient quality raw water requires less treatment than brackish or seawater), intended end-use,

[5] Kelly M. Twomey and Michael E. Webber, "Evaluating the Energy Intensity of the US Public Water Supply," *Proceedings of the ASME 2011 5th International Conference on Energy Sustainability, ES2011-54165,* August 2011. Hereinafter, Twomey and Webber 2011.

[6] Kelly T. Sanders and Michael E. Webber, "Evaluating the energy consumed for water use in the United States," *Environmental Research Letters,* vol. 7, 034034 (2012).

distribution (water pumped long distances requires more energy), amount of water loss in the system through leakage and evaporation, and level of wastewater treatment (stringency of water quality regulations to meet discharge standards). Likewise, the intensity of energy use of water[7] varies depending on characteristics such as topography (affecting groundwater recharge), climate, seasonal temperature, and rainfall.

National data can obscure differences in water-related energy use that are regional or state-specific, as reflected in a 2005 study by the California Energy Commission, which found that "water-related energy use [in California] consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year—and this demand is growing." Pumps that move water from the San Joaquin Valley to southern California for domestic and irrigation water uses are the single largest power load in the state.[8] Because of important regional differences, the United States is a difficult country to generalize. For example, the lifecycle energy-intensity of water in cities nationally is estimated to be 3,300-3,600 kWh per million gallons delivered and treated, but ranges from 2,700 kWh/million gallons in New York, New York, to 5,000 kWh per million gallons in Austin, Texas.[9] Energy intensity varies within states, as well. In California, the energy intensity of the water use cycle ranges from 4,000 kWh per million gallons in the northern part of the state to 12,700 kWh per million gallons in southern California, reflecting differences in the volume of water pumped, lifted, and transported hundreds of miles and over mountains from points of collection to points of need in the southern part of the state.[10] The energy intensity of a particular activity's water use, also described as the embedded energy of the activity, can have disproportionate impacts elsewhere. For example, policies that promote the use of energy-intensive water supply such as pumping and distributing water over long distances, rather than policies that promote water conservation, water reuse, or aquifer recharge, adversely impact one sector to serve another.[11]

In every sector, there are opportunities for practices that would save energy and also save water. The Environmental Protection Agency's (EPA's) WaterSense program promotes this concept by emphasizing that "saving water saves energy."[12] Energy efficiency initiatives offer opportunities for delivering significant water savings, and likewise, water efficiency initiatives offer opportunities for delivering significant energy savings. In the commercial, industrial, and institutional sectors, potential water savings through energy efficiency and other measures could

[7] Energy intensity is the relative amount of energy needed to perform water management-related tasks such as treating and pumping water. It is typically expressed as the number of kilowatt-hours per million gallons of water.

[8] California Energy Commission, *California's Water-Energy Relationship, Final Staff Report*, CEC-700-2005-011-SF, November 2005, p. 1. Hereinafter, California's Water-Energy Relationship.

[9] Twomey and Webber 2011, p. 8.

[10] California's Energy-Water Relationship, pp. 9-11.

[11] Carey W. King, Ashlynn S. Stillwell, and Kelly M. Twomey, et al., "Coherence Between Water and Energy Policies," *Natural Resources Journal*, vol. 53, no. 1 (Spring 2013), p. 185.Hereinafter, King, Stillwell, and Twomey 2013.

[12] The WaterSense program offers a label for products and services that are certified to save water without sacrificing performance, thus promoting water efficiency and supporting a market for water-efficient products. WaterSense addresses residential and commercial water use. According to EPA, since the program's inception in 2006, WaterSense has helped consumers save a cumulative 487 billion gallons of water and $8.9 billion in water and energy bills. In addition, the Department of Energy has established minimum energy conservation standards for more than 50 categories of residential, commercial, and industrial appliances and equipment, including standards for several categories of appliances and devices that also specify maximum water use standards (showerheads and faucets; toilets and urinals; residential and commercial clothes washers; residential dishwashers; and prerinse spray valves). These standards were promulgated under the Energy Policy and Conservation Act of 1975, as amended.

be 15%-30% without reducing the services derived from the water. The potential for significant water and energy savings also exists in other sectors such as agriculture.[13]

Generating the energy associated with water use also produces carbon dioxide (CO_2) emissions that contribute to climate change. It has been estimated that water-related carbon emissions in 2005 were approximately 290 million metric tons, or 5% of all U.S. carbon emissions. Water-related CO_2 emissions were equivalent to the annual greenhouse gas emissions of 53 million passenger vehicles. By sector, water heating was responsible for 70% of the water-related carbon emissions, wastewater treatment was responsible for 18%, water supply was responsible for 8%, and agricultural activities were responsible for 6%.[14] Thus, saving water saves energy and also reduces carbon emissions.[15]

Energy for Water Supply and Wastewater Facilities

There are about 200,000 drinking water treatment systems in the United States, of which about 52,000 are community water systems that serve 25 or more year-round residents. Most U.S. drinking water is provided by relatively large community water systems. Nearly 85% of the U.S. population is supplied by about 5% of these systems; the remaining 95% include a large number of small and very small systems serving 3,300 persons or fewer. Public agencies own and operate most community water systems; a small number are privately operated. Smaller utilities use more electricity and pay more per unit of water produced than do medium and large utilities, due to economies of scale. Nearly all of the energy consumed is electricity, about 80% of which is used by motors for pumping.

There are approximately 15,000 U.S. wastewater treatment plants. Most are publicly owned, and they serve more than 75% of the U.S. population. Nearly 70% of facilities are small, serving only 10% of the U.S. population. Approximately 22% are large (with flow greater than 1 million gallons per day); they serve over 85% of the U.S. population. Wastewater systems generally consist of collection systems (sewers and pumping stations), treatment facilities, and effluent disposal. Like water supply utilities, nearly all of the energy consumed is electricity. Wastewater aeration, pumping, and solids processing account for most of the electricity used in wastewater treatment.

For both types of systems, greater amounts of energy are required for more advanced treatment levels. Similarly, the age of the system and equipment are important: as systems age, equipment decreases in efficiency, resulting in an increase in electricity requirements.

As described above, EPRI's 2002 study estimated that public water supply agencies and wastewater treatment facilities accounted for 1.6% of electricity use in 2000, or 51.6 billion kWh. A 2013 EPRI study found that electricity use by these sectors has increased in absolute and percentage terms—to 69.4 billion kWh, or 1.8% of total U.S. electricity use in 2011. The 2013 study reported a 39% increase for public drinking water systems and a 74% increase for the

[13] See Alliance for Water Efficiency, http://www.allianceforwaterefficiency.org/; the American Council for an Energy-Efficient Economy, http://www.acee.org; and The Carbon Footprint of Water, pp. 26-29.

[14] The Carbon Footprint of Water, p. 24. In this analysis, carbon emissions resulting from water supply and treatment assumed that all energy comes from electricity, with a carbon intensity of 1.36 lbs. CO_2/kWh. The carbon intensity of other energy sources varies, ranging from 0.12 lbs. CO_2 per cubic foot of natural gas to 22.4 lbs. CO_2 per gallon of fuel oil.

[15] See, for example, United Utilities, "Water and your carbon footprint," http://www.unitedutilities.com/water-and-your-carbon-footprint.aspx; and Wisconsin Department of Natural Resources, "Save Energy and Reduce Carbon Emissions," http://dnr.wi.gov/org/caer/ce/eek/teacher/globaltip.htm.

municipal wastewater industry compared with the earlier study, likely due to population growth and implementation of more energy-intensive advanced treatment technologies in the interim.[16] These data are important, because energy is the second-highest budget item for municipal drinking water and wastewater facilities, after labor costs, with utilities spending about $4 billion a year. Energy consumption by drinking water and wastewater utilities can comprise 30%-40% of a municipality's total energy bill.

Drinking water and wastewater utilities are highly regulated entities whose primary goals are to meet regulatory requirements for protecting public health and the environment and to provide services for reasonable and fair rates. The energy efficiency of these utilities generally has not been a primary goal or considered as an element of rate determinations. Nevertheless, as populations grow and environmental requirements become more stringent, demand for electricity at drinking water and wastewater utility plants is expected to grow by approximately 20%. Moreover, as electricity rates increase, energy conservation and efficiency are issues of increasing importance to many utilities. Nevertheless, opportunities for efficiency exist in several categories. Potential energy savings by drinking water and wastewater utilities could be 8% of 2010 usage by 2030.[17]

- **Optimizing system processes**, such as modifying pumping and aeration operations and implementing monitoring and control systems through SCADA (supervisory control and data acquisition) systems to increase the energy efficiency of equipment. EPRI has estimated that drinking water facilities can achieve energy savings of 5%-15% through adjustable speed drives and high-efficiency motors and drives and 10%-20% through process optimization and SCADA systems. In wastewater facilities, EPRI estimates that 10%-20% energy savings are possible through process optimization.[18]
- **Upgrading to more efficient equipment** and **right-sizing equipment** for the capacity of the facility (plants and pipes often are oversized, to accommodate future peak load). Pumps and other equipment used beyond their expected life operate well below optimal efficiency. In addition, energy is embedded through pipe systems, since leaking drinking water pipes require more energy to deliver water to the end user. Leaky sewer lines allow groundwater to infiltrate and increase the flow of water into the wastewater treatment plant. All water systems have losses, which are cumulative along segments of the water-use cycle. Projects to address water loss and improve end-use efficiency can be promoted as both water- and energy-savings investments.
- **Improved energy management**. It is widely recognized that water utilities need to develop better understanding of their current energy use, and public and private research and programs have focused on this goal. For example, some states have developed programs to help water utilities better manage energy use. The New York State Energy Research and Development Authority has done extensive work to help water utilities benchmark their energy use and supports a

[16] S. Pabi, A. Amarnath, and R. Goldstein, et al., *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries*, Water Research Foundation and Electric Power Research Institute, 3002001433, November 2013. Unlike the 2002 report, this document does not examine electricity use for privately supplied water (e.g., for industry and mining, or agriculture).

[17] Ibid., p. x.

[18] Consortium for Energy Efficiency, *CEE National Municipal Water and Wastewater Facility Initiative*, January 1, 2010, p. 8

range of initiatives through its Focus on Municipal Water and Wastewater Treatment program. It developed a best practices handbook for the water and wastewater sectors, including methods to track performance and assess program effectiveness.[19] The California Energy Commission also has been active on energy management issues. It has reported on case studies of water facilities throughout the state that implemented energy efficiency measures, including resulting energy and cost savings. In 2006, the California Public Utilities Commission (CPUC) directed the state's largest electric utilities to partner with water agencies, undertake specific water conservation and efficiency programs, and measure the results.[20] Because one of the largest end uses of electricity in California is in treating, heating, and conveying water, energy companies in that state are working with the water sector to help utilities and companies reduce their energy use and boost their efficiency. At the federal level, EPA has developed a number of tools for water utilities, including an energy management guidebook, energy conservation guides, and self-assessment and energy audit tools. Energy Star, a joint program of the Department of Energy and EPA, has developed a Portfolio Manager, an online benchmarking tool that allows drinking water and wastewater utilities to evaluate their energy use and compare their operations to similar facilities.[21] Others have contributed research on best practices, energy conservation, and benchmarking energy use, including the Water Environment Research Foundation, the Water Research Foundation, and the American Council for an Energy-Efficient Economy.

- Some water utilities are **generating energy on-site** to offset purchased electricity. Beyond efficiency measures, they illustrate ways in which water utilities are reducing their energy costs by recovering energy from municipal waste and using the resulting biogas to generate electricity, heat the plant, and in some cases sell electricity back to the grid.[22] For example, DC Water, the wastewater utility in Washington, DC, is constructing a project to convert residuals that remain after wastewater is treated into fuel for combined heat and power operations at the facility. The utility estimates that when the project is completed, it will save $10 million per year on electricity (powering one-third of the treatment plant) and another $10 million annually in solid waste management. Another example is the Gloversville-Johnstown, NY Joint Wastewater Treatment Facilities. In 2003, it began accepting dairy whey as a fuel for its own energy through a combined heat and power process. Reduced electrical costs save the utility about $550,000 per year, and accepting the dairy wastes results in additional revenue of $750,000 annually. Plants also are using other sources of renewable energy: solar panels at the Calera Creek Water Recycling Plant in

[19] See http://www.nyserda.ny.gov/BusinessAreas/Energy-Efficiency-and-Renewable-Programs/Commercial-and-Industrial/Sectors/Municipal-Water-and-Wastewater-Facilities.aspx.

[20] ECONorthwest, *Embedded Energy in Water Pilot Programs Impact Evaluation*, Final Report, Study ID:CPU0053.01, March 9, 2011.

[21] See http://water.epa.gov/infrastructure/sustain/waterefficiency.cfm. The Portfolio Manager can be used by a range of facilities, including K-12 schools, hospitals, hotels, and offices, to track and assess energy and water consumption. It was extended to wastewater utilities in 2007 and later to drinking water utilities.

[22] Conventional wastewater treatment generally uses microorganisms to consume the organic matter in the waste. When done under anaerobic conditions, the breakdown of organic matter produces biogas consisting of methane, carbon dioxide, and other gases. The biogas can be recovered and used to fuel engines that generate electricity, while capturing heat for additional uses.

Pacifica, California, provide 10%-15% of the plant's energy needs and save an estimated $100,000 per year. Savings from such projects are contingent upon recouping capital investment costs.

Several barriers to improved energy efficiency by water and wastewater utilities are apparent. Many of them derive from the culture of water utilities and outside constraints placed on them.[23]

- Cost. Utilities have limited resources. Their capital and operations budgets are constrained, while the up-front costs of installing more energy-efficient equipment can be prohibitive. Some funding sources to finance projects do exist (e.g., private sector, municipal bonds), but may not be suitable or well known to water utility officials. Federal and state funding for energy efficiency projects is limited.
- Municipalities that own and operate water utilities generally are risk-averse, reluctant to change practices, and hesitant to implement new technologies. Water utilities are slow adopters of new technology in part because of environmental and public health risks if new technologies fail to perform and in part because of the economic, political, and regulatory consequences of failure. The tendency is to wait until equipment fails rather than be pro-active.
- Facility operators who could advocate for energy efficiency often are disconnected from those in the utility who pay the electricity bill. Most water and wastewater facilities were built decades ago when electricity costs were low enough to be of little concern. Facilities and equipment were designed to run continuously, without regard for wasted energy. To the extent that water utilities can pass on energy costs to customers, there may be little incentive to investigate energy efficiencies. Utility managers may not understand how energy is used at a plant and how to reduce, or even control, energy costs.

Regulatory barriers also exist. Many state renewable portfolio standards require that a specified percentage of energy produced within the state comes from renewable sources. However, many of these state policies do not recognize biogas that is recovered from wastewater treatment as an energy source in renewable energy credit programs and renewable portfolio standards. This results in biogas use projects being ineligible for incentives for which other competing renewable energy projects are eligible. Further, some electric utilities restrict sale of excess power to the electric grid, impairing project economics. In some cases where excess power can be sold to the grid, the water utility musts accept low prices for wastewater-generated energy, which can be a disincentive to on-site energy generation projects.

Other barriers stem from a lack of coherence and coordination between water and energy policies, planning, and decision-making roles. Energy and water decisions have historically been made independently of each other. Water planners typically assume that they have the energy that they need, and energy planners assume that they have the water that they need. Both are likely to use different strategic planning: private companies acting under market forces dictate the location of energy infrastructure, while water infrastructure is often located using public interest criteria. A mismatch in planning objectives by different actors can prevent the beneficial siting and combining of technologies. Likewise, water policy in the United States is usually structured in a bottom-up fashion with decisions driven by local water authorities, because water supply

[23] See discussion in U.S. Government Accountability Office, *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, March 2011.

management is generally the responsibility of states. Energy policy, in contrast, is usually structured in a top-down fashion with federal agencies setting many standards and requirements.[24]

To overcome such barriers, a 2013 report recommends that the electricity, water supply, and wastewater sectors should foster cross-sector communication and engage in collaborative planning. The report suggests that, to reduce potential disincentives and risks of cross-sector coordination, states could implement policies that incentivize wastewater plants to install energy projects and give credits to electric utilities for incorporating those generation sources into their portfolios. Although some states do this now (for example, Massachusetts), the report states that new policies are needed to build the confidence of leaders in the water and electric power sectors and motivate them to "go beyond compliance."[25]

Research and Information Needs

Several areas of research and information needs concerning energy for water uses have been identified by a range of researchers and stakeholders.[26] They suggest:

- Data that could help decision makers and users fill what is now an incomplete picture of energy needs for water uses are lacking. This is apparent across sectors and also within individual sectors. The U.S. Geological Survey collects national water use data, but the level of detail is limited, and related energy use is not considered. The Department of Energy collects energy data and forecasts energy use, but its work to address energy for water use is limited.[27] No public or private entity systematically collects energy data from public water utilities, users who self-supply their water, or other end users of water. Data that exist are scattered and often are not available at a scale needed by decision makers, nor is there standardized terminology in reporting information that is needed to quantify energy use in the water industry.
- More integrated research is needed on water and energy operations. Information is needed to understand where energy is used in water and wastewater infrastructure facilities, what opportunities for improvement exist, and how to establish priorities for action. Ideally, consistent data collection methodology is needed to gather and track water and energy data across all sectors and within sectors, such as at the utility level, and to aid benchmarking. Standards for data collection, coordination, and quality control are lacking.
- Research is needed on advanced technologies that save energy and save water, and partnerships between government and the private sector that move research and development from bench-scale to implementation are needed. For example,

[24] King, Stillwell, and Twomey 2013, pp. 185-191.

[25] The Johnson Foundation at Wingspread, *Building Resilient Utilities, How Water and Electric Utilities Can Co-Create their Futures*, November 2013, p. 15.

[26] For discussion of research and information needs, see, for example, GEI Consultants, *Water-Energy Nexus Research, Recommendations for Future Opportunities*, Alliance for Water Efficiency and American Council for an Energy-Efficient Economy, Final Report, Project No. 130240, June 2013.

[27] DOE's Energy Information Administration (EIA) has conducted periodic Commercial Buildings Energy Consumption Surveys since the mid-1970s. A limited number of questions about water consumption were asked for the first time in the 2007 survey, including total volume of water consumed, cost, whether the volume was metered or estimated, and how much of the water was used outdoors. Sixteen commercial building categories (e.g., health care, lodging, food service) were surveyed. EIA reported on the results, without analysis, in 2012. See http://www.eia.gov/consumption/commercial/reports/2007/hospital-water-data-collection.cfm.

- technologies for energy recovery from wastewater generation are in their early stages of development and require more research, as well as onsite demonstration.
- Better understanding is needed of linkages between energy, water, land, and agriculture and risks of climate change and extreme weather events on water availability and energy supply.
- Policies and approaches are needed to encourage the water and energy sectors to move toward integrated resource management.
- Analysis is needed of incentives, disincentives, and lack of incentives to investing in cost-effective energy or water efficiency measures. One area of interest is regulatory barriers to co-implementation of efficiency programs in the water and energy sectors.
- Lowering end-use water demand can conserve both water and energy. Thus, more education and outreach to all types of water users, the general public, and public officials are needed on the water-energy nexus and how improving efficiency involves linkages between saving energy and saving water.

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