QUANTIFYING ENERGY USE IN THE U.S. PUBLIC WATER INDUSTRY—A SUMMARY

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Water is abundant on the earth, but it is often in the wrong location, in the wrong form, or at the wrong time for us to use. We use energy to compensate for these problems. We move water to the right location, treat it to the right form, and store it for the right time—all with energy.

This article summarizes previous and recent research on the energy requirements of public water and wastewater services in the United States and briefly discusses some tools and resources for engineers working in this field. The intent is to inform industry professionals in order to better manage both water and energy resources.

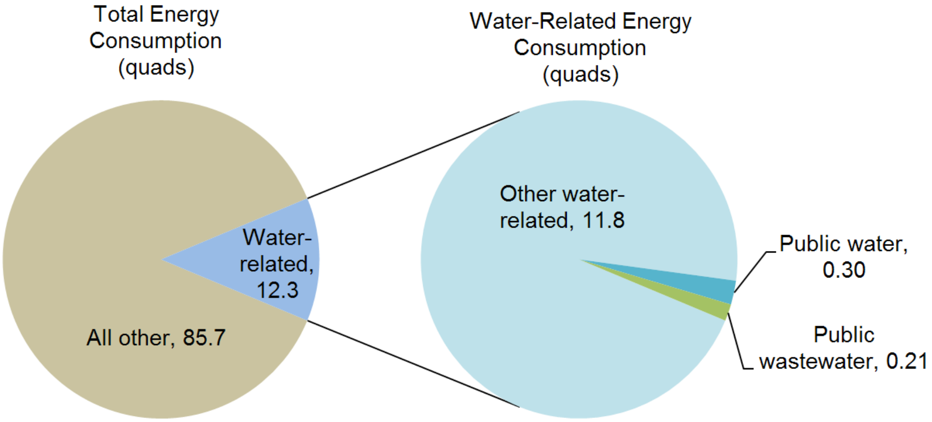


Figure 1: U.S. Energy Consumption, 2010 (EIA 2014; Twomey and Webber 2011; Sanders and Webber 2012)

Water-related energy consumption

In 2010 the United States consumed 98 quadrillion BTU (quads) of energy (EIA 2014). Water-related uses accounted for 12.3 quads, or 12.6% of national energy consumption (Sanders and Webber 2012, 1). See Figure 1. While a national average is useful, it blurs local variations, which can be more significant. California, for example, expends an estimated 19% of its electricity and 32% of its natural gas for water-related end-uses; the percentage in southern California is even higher (Klein 2005, 8, 106). One estimate for Utah suggests that 7% of the state's energy consumption is related to water (UDWR 2012, 27).

Of the water-related uses in the United States, an estimated 0.51 quads was attributed to public water and wastewater services, with 0.30 quads for public water supply (sourcing, treatment, and distribution) and 0.21 quads for public wastewater services (collection, treatment, and discharge) (Twomey and Webber 2011, 6). Thus the public water industry accounts for about 0.5% of total U.S. energy consumption. (For some users, the services are self-supplied or private; these data consider only public utilities.) The remaining 11.8 quads, or 12.0% of total U.S. consumption, was for other water-related uses such as water heating, direct steam, industry, and agriculture (Sanders and Webber 2012).

Running on electricity rather than primary fuels, public water and wastewater services consumed an estimated 56.6 billion kilowatt-hours (kWh) of the country's 3,740 billion kWh in 2009, or about 1.5–2.0% of total U.S. electricity (Twomey and Webber 2011, 5–6). Previous studies suggested 3–4% but included non-public services and on-site end-use conditioning. Other recent studies (EPRI 2013, 8-1, 9-1) confirm the 2% estimate.

Energy intensity

Energy intensity is a measure of unit energy consumption. Energy for public water and wastewater services is measured in kilowatt-hours of electricity, which is then normalized by water volume to express energy intensity in kilowatt-hours per million gallons (kWh/MG).

Energy intensities vary with climate, topography, source characteristics, proximity, and other factors. Figure 2 shows some of these differences. Southern California, for example, must often convey water hundreds of miles over two mountain ranges, being seven times more energy intensive than Massachusetts, where precipitation and reservoirs are abundant.

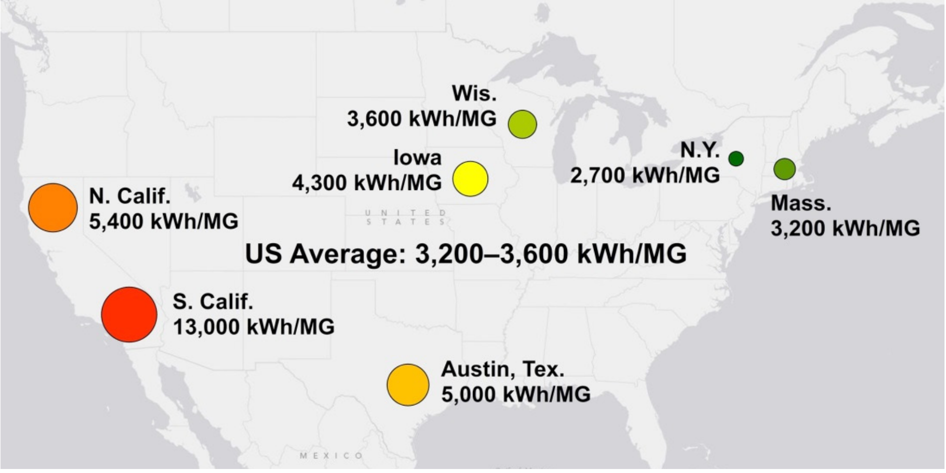


Figure 2: Energy Intensity of Water-Wastewater Cycles in the United States (Twomey and Webber 2011, 8; DOE 2012a, 2012b)

Energy intensity of water supply services

Supplying water requires energy for sourcing, treatment, and distribution. Nationwide, the entire process requires 1,900 kWh/MG on average, with the three components shown in Figure 3 (EPRI 2009, 2-4, 4-4; 2013, 4-14).

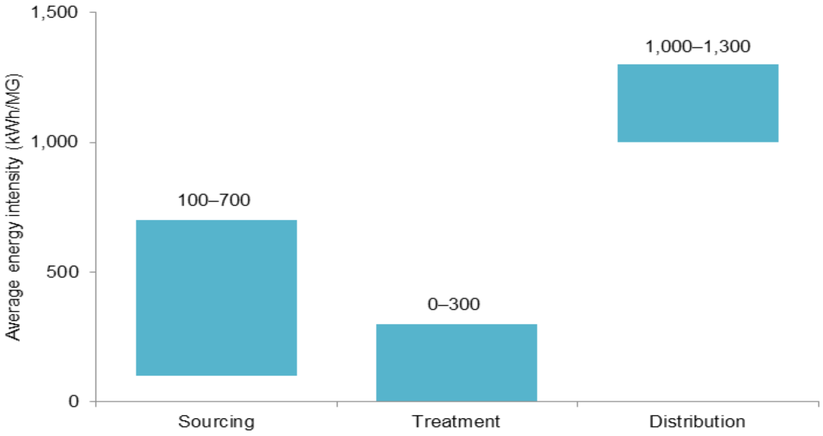


Figure 3: Energy Intensity of Water Supply Processes in the United States (EPRI 2009, 4-4)

Sourcing

Sourcing may include spring collection, surface water conveyance, groundwater pumping, and other methods to produce raw water. Groundwater is generally more energy intensive because of pumping to raise water from the subsurface. Surface water is typically gravity driven, but can become very energy intensive if pumped long distances. Groundwater pumping requires about 600 kWh/MG on average and varies with depth; surface water requires 1,200 kWH/MG on average (Twomey and Webber 2011, 9). More precise data are difficult to obtain since sourcing is often counted with treatment or distribution.

Treatment

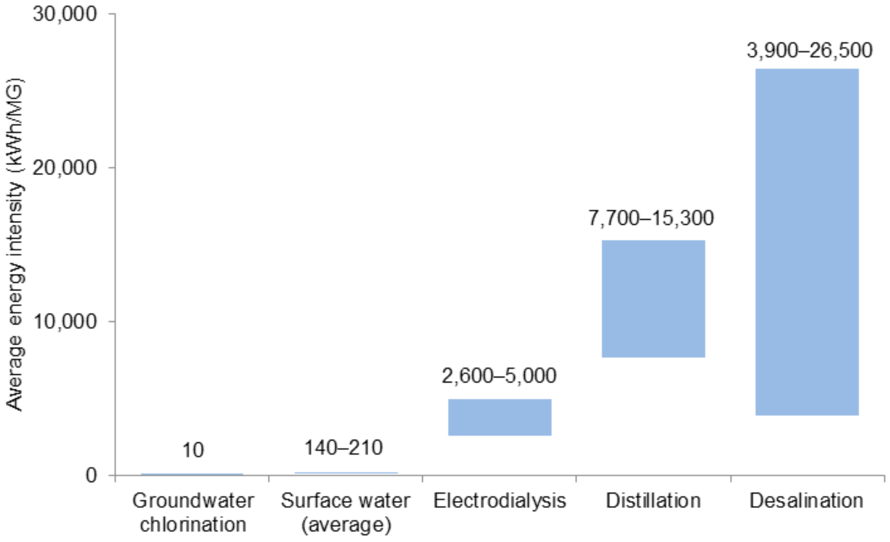
Energy intensity of water treatment depends on the level of treatment (Figure 4). Groundwater often requires disinfection only (a low-intensity operation), while surface water must be treated to remove solids and organic material and to condition the water for distribution. Desalination is the most energy intensive—one or two orders of magnitude beyond average surface water treatment—but represents only a small fraction of the U.S. water supply. This disparity underscores some benefits of water reuse, where water can be treated several times by low-intensity meth-ods before matching the energy intensity of desalination. For surface water, energy intensity does not vary significantly with treatment capacity, suggesting little or no economy of scale (EPRI 2002, 2-3).

Distribution

As is apparent in Figure 5, distribution pumping is the most energy-intensive component of the public water supply. Pressurizing and distributing water to end-users can consume as much as 85% of a utility's energy, with 67% being typical (EPRI 2002, 1-2; 2009, 4-3, 4-4; 2013, 4-2). Nationwide, distribution intensity averages 1,000–1,300 kWh/MG (EPRI 2009, 4-4).

Energy intensity of wastewater services

Wastewater services require about 1,400 kWh/MG on average (DOE 2012b). Energy intensity of wastewater treatment depends on the technology, increasing with the level of treatment (Figure 6). Wastewater collection, treatment, and discharge are included in these values, though treatment constitutes the bulk of the energy consumption since collection and discharge are usually by gravity. In a typical system (Figure 7), aeration consumes about half of the energy, followed by biosolids handing (EPRI 2013, 5-4).



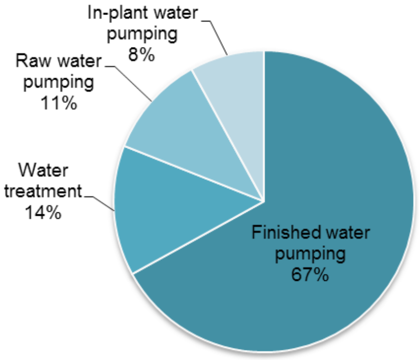


Figure 4 (above) - Energy Intensity of Water Treatment Technologies in the United States (Twomey and Webber 2011, 10)

Figure 5 (left) - Relative Energy Consumption in Water Treatment (EPRI 2013, 4-2)

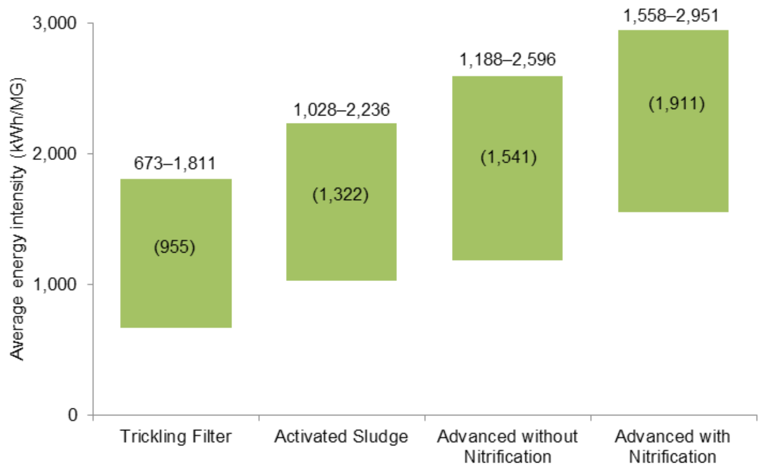


Figure 6: Energy Intensity of Wastewater Treatment Technologies in the United States (DOE 2012b)

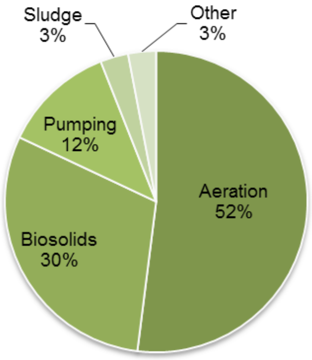


Figure 7: Relative Energy Consumption in Wastewater Treatment (EPRI 2013, 5-4)

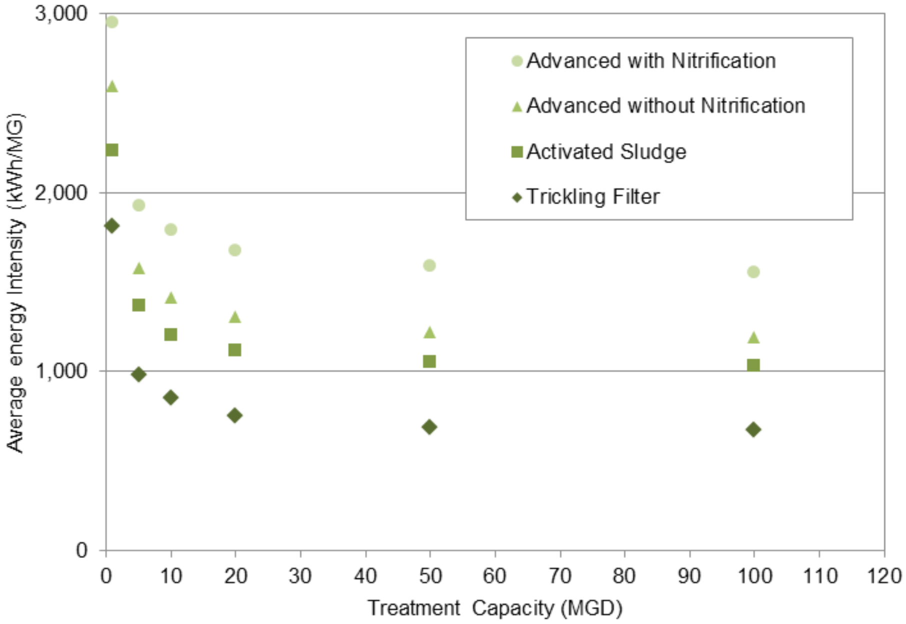


Figure 8: Energy Intensity of Wastewater Treatment Technologies in the United States According to Capacity (DOE 2012b)

The range of values shown in Figure 6 is directly attributable to capacity. Unlike water treatment, wastewater treatment exhibits considerable economy of scale. Large-capacity facilities are less energy intensive than smaller ones (Figure 8), making multi-city or regional wastewater facilities advantageous from an energy perspective. A facility with a capacity of 10 million gallons per day (MGD) requires 50–60% less energy than a 1 MGD facility to treat the same volume of wastewater. Most of the scaling benefit occurs up to 20 MGD; above 20 MGD there is little difference in energy intensity.

Managing both resources

Water-related uses constitute a significant portion—12.6%—of total U.S. primary energy consumption (Sanders and Webber 2012). Public water and wastewater services consume about 0.5% of total U.S. primary energy and 2% of its end-use electricity (Twomey and Webber 2011; EPRI 2013, 8-1, 9-1).

In the United States, public water and wastewater services have an average energy intensity of 3,200–3,600 kWh/MG (Twomey and Webber 2011, 8). Energy intensity of the entire cycle is likely to increase over time as less-accessible sources are developed and treatment standards rise. Climate change and population growth will further stress the water-energy nexus.

Much has been done to reduce energy consumption in the public water sector. To date, the focus has been on improving equipment efficiencies—pumps, motors, controls, valves, etc. Beyond equipment, system optimization has been largely untapped. Water system optimization further reduces energy consumption while improving hydraulic performance and water quality (Jones and Sowby 2014). Optimization-related savings can range from 10 to 25% (CEE 2010, 8; ASE 2014).

In recent years the Environmental Protection Agency (EPA) has developed tools for water utilities to benchmark and audit their energy use (EPA 2014). Audits help utilities understand how and where energy is consumed and also identify what equipment or processes could be improved. An EPA Region 9 pilot study identified an average of 17% savings in energy use and 26% savings in energy costs, regardless of the utility's size (Horne et al. 2014). Energy issues need to be managed continually, and new tools, such as energy audits and optimization studies, can help.

As we continue to study the water-energy nexus and balance its tradeoffs, opportunities will arise to better quantify water-related energy consumption and energy intensities on various levels. Currently, only limited data from a few states are available, and national estimates do not capture important local differences. This kind of information has substantial implications for economic development, resource management, policy, and technical decisions. Additional state and local data would provide a more accurate picture and help us better manage both water and energy resources.

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