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## **Energy Savings from Industrial Water Reductions**

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# **Energy Savings from Industrial Water Reductions**

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## **ABSTRACT**

Although it is widely recognized that reducing freshwater consumption is of critical importance, generating interest in industrial water reduction programs can be hindered for a variety of reasons. These include the low cost of water, greater focus on water use in other sectors such as the agriculture and residential sectors, high levels of unbilled and/or unregulated self-supplied water use in industry, and lack of water metering and tracking capabilities at industrial facilities. However, there are many additional components to the resource savings associated with reducing site water use beyond the water savings alone, such as reductions in energy consumption, greenhouse gas emissions, treatment chemicals, and impact on the local watershed. Understanding and quantifying these additional resource savings can expand the community of businesses, NGOs, government agencies, and researchers with a vested interest in water reduction.

This paper will develop a methodology for evaluating the embedded energy consumption associated with water use at an industrial facility. The methodology developed will use available data and references to evaluate the energy consumption associated with water supply and wastewater treatment outside of a facility's fence line for various water sources. It will also include a framework for evaluating the energy consumption associated with water use within a facility's fence line. The methodology will develop a more complete picture of the total resource savings associated with water reduction efforts and allow industrial water reduction programs to assess the energy and CO<sub>2</sub> savings associated with their efforts.

## **Introduction**

Water is used at every industrial facility. In many industrial processes, such as beverage manufacturing, rinsing, and certain chemical reactions, water is an irreplaceable input and as vital to the process as energy. To date, industrial water use reduction has not been a major focus of industrial companies and policy makers in the U.S. This may be changing. Increasing environmental concerns surrounding water availability, some arising due to recent prolonged droughts in the Western U.S., are causing the industrial community to focus on water conservation and management.

Both industrial companies and policymakers have an interest in developing industrial water management and conservation programs. For industrial companies that rely on water, establishing water management programs can help to mitigate the business risk of losing access to water. Reasons for loss of water access include physical scarcity, political inability to supply clean water, or community-imposed restrictions. A community may seek to limit or deny an industrial facility's right to draw from the local water supply if it is viewed as impeding the community's access to clean water or harming the local watershed. Even for industrial companies that are not located in water-stressed areas or do not have a heavy reliance on water, engaging in water conservation exhibits a commitment to preserving the environment of the local communities in which they operate. For regional, state, or federal governments, establishing industrial water conservation programs will assist in ensuring a clean and reliable supply of

water for their communities. Water conservation programs may also be established to support the health of the local watershed or rehabilitate watersheds that have been negatively impacted by water pollution.

A central barrier to developing industrial water conservation programs is a general lack of understanding of industrial water use. This use is often poorly metered or monitored. Even with the aid of free software tools<sup>1</sup> for evaluating the water stress level of a watershed, it is difficult for facilities to understand the impact of their water use on their local community. Water conservation advocacy groups and programs in the U.S. have not traditionally focused their efforts on the industrial sector, due in part to its lower water usage compared to other sectors such as the agricultural or residential sectors as shown in United States Geological Survey (USGS) water use estimates (Maupin 2014). Additionally, many facilities find it difficult to financially justify efforts to manage water. For many, water is inexpensive and constitutes a negligible share of overall production costs.

There are other costs, however, associated with water use including energy to move, heat, or cool the water, chemicals for water treatment, and costs associated with maintaining the water use systems. If the ancillary benefits of water reductions were better understood, then facilities would be able to view water use within the larger context of overall facility operating costs. Further, policymakers advocating the ancillary benefits, such as energy efficiency policymakers, would take interest in water reductions as a means to conserve other resources.

This paper seeks to gain a better understanding of industrial water usage by: summarizing the characteristics of industrial water use, and investigating the linkage between energy and CO<sub>2</sub> savings associated with water reductions through evaluation of the embedded energy associated with water use both inside and outside of the facility's fence. It is hoped that the results will engage a broader field of stakeholders interested in industrial water reduction and grow the available resources to better understand industrial water use. With increased understanding, tools could be made available to assist industry in establishing water management programs at their facilities.

## **Industrial Water Use**

Although limited, current data and information on industrial water use can be evaluated to better understand the total quantity of water used and the various sources from which it is drawn, and identify end uses and sectors that are reliant on water. This section is intended to provide an overview of industrial water use based on available literature.

### **Quantity and sources of use in 2010**

**Self-Supplied,** Every five years since 1950, the USGS has published estimates of overall U.S. water use by category of end use (e.g., industrial, public supply, domestic, irrigation) and source. The most recent USGS estimates cover water use in 2010. The 2010 estimates for the industrial sector are only for self-supplied sources, meaning that industry's share of publicly supplied water is not estimated. The USGS estimates that the industrial sector used 15,900 million gallons/day (MGD) in 2010 (Maupin 2014). Breakdowns by fresh, saline, ground, and surface are reproduced in Table 1.

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<sup>1</sup> Such as the World Resources Institute Aqueduct Tool and the World Business Council for Sustainable Development Global Water Tool

Table 1: USGS 2010 estimates for industrial self-supplied water intake (in MGD) from Maupin 2014

Groundwater (MGD)			Surface water (MGD)			All (MGD)		
Fresh	Saline	Total	Fresh	Saline	Total	Fresh	Saline	Total
2,900	48.4	2,950	12,100	937	13,000	15,000	986	15,900

The largest source of self-supplied industrial water intake identified in the 2010 estimates was fresh surface water, with its use over 4 times that of the next most common source (fresh groundwater). Saline water use is much less common than freshwater use, constituting only 6% of all industrial self-supplied water use.

The estimated 2010 self-supplied total is 12% less than the estimated total from 2005. The decline in industrial water withdrawals keeps pace with the decline in total water withdrawals over the same time period (13%). The USGS attributes the reduction between 2005 and 2010 to the economic downturn of 2008 causing large declines in water intense sectors such as wood products, paper, primary metals, and chemicals. The reduction between 2005 and 2010 is also part of a long term trend for industry, whereby industrial water use declined by 38% between 1985 and 2010. The USGS attributes the reductions since 1985 to increases in water recycling and process efficiency (Maupin 2014).

**Public Supply**, While the 2010 USGS estimates total public supply at the national level, it does not estimate the quantity of public supply used by industry. The 1995 USGS estimates projected that 12% of the total for public supply was used by industry (Solley 1998). Assuming that the share of public water supply used by industry has not changed, the industrial sector used 5,040 MGD in 2010. The U.S. DOE used a similar assumption when developing its estimates for the total industrial water use in 2005 (USDOE 2014).

**Total**, Combining the estimated self-supplied and public supply totals, total U.S. industrial water use in 2010 was approximately 20,940 MGD. The vast majority of use was self-supplied (~75%). Figure 1 below summarizes the distribution of industrial water by source. As can be seen, over half of industrial water is derived from surface water sources.

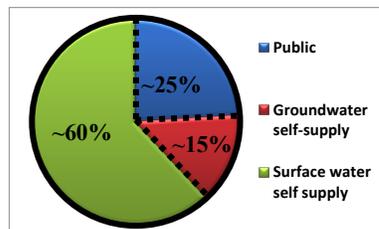


Figure 1: Sources of industrial water, approximate shares (adapted from Maupin 2014)

### How industry uses water

**Consumption versus intake**, Some industrial water uses result in the water being returned to the source or local watershed without being contaminated, evaporated, or excessively heated. An example of this is non-contact cooling with minimal temperature gain. Other uses may require the water to be treated before being returned to the source or local watershed. An example of this is water used for rinsing vessels. In both these examples, water is used but not

consumed. Water consumption involves water being removed from the local watershed. The USGS defines consumptive use as “that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment” (Solley 1998). Examples of consumptive use include water loss through evaporative cooling (e.g., a cooling tower) and in-product use (e.g., beverage or food manufacturing). Consumptive use removes water from the local watershed, which may be problematic in water stressed regions.

The most recent USGS estimates for consumptive industrial water use are from 1995. These estimates attribute 15% of all water use in 1995 (including self-supplied, public supply, saline, and fresh) to consumptive use (Solley 1998).

**Water reliant industrial sectors,** There are several criteria for evaluating which sectors are most reliant on water. In addition to total water use, other important factors are the inability to substitute water with another resource or material, access to water, and the extent of treatment required on the wastewater stream.

The Pacific Institute developed water use intensities for each two digit SIC manufacturing code in California. The results ranged from a low of 32 gallons/employee/day (GED<sup>2</sup>) for leather and leather products to a high of 11,399 GED for petroleum and coal products. After petroleum and coal products, the most water intense industries in California (in GED) are lumber and wood products (2,144), food and kindred products (1,967), textile mills (1,530), primary metal industries (1,318), stone, clay, glass and concrete production (1,304), and paper and allied products (1,000) (Gleick 2003).

**Water end uses,** Water is used within industry for a variety of purposes. Some of these purposes – domestic, cleaning, landscaping – are uses found across all sectors. However, industry also uses water within production processes, particularly cooling. Categories of water use in industry include: production processing and in-product use, auxiliary processes (e.g., pollution control, labs, and cleaning), cooling and heating (e.g., cooling towers and boilers), indoor domestic use (e.g., restrooms, kitchens, laundry), and landscape irrigation (EPA 2011).

Table 2 compiles estimates made by the Pacific Institute on water use within several industrial sectors in California. The Pacific Institute also estimated the savings potential for each sector based on a variety of sources including the authors’ best guesses. Nevertheless, the estimates illustrate that there is significant potential for water savings throughout these sectors. The report estimated a 74% potential for reduction in water use in the petroleum refining industry through the use of recycled water (Gleick 2003). Replacing potable water with recycled water for uses that do not require high-level treatment may have the potential to yield substantial savings in other sectors as well. Water for cooling towers and irrigation are two examples of potential uses for recycled water, although any potential benefit must be balanced with any potential health concerns (e.g. Legionnaires’ disease) or negative impact on system performance.

Although not a focus of this paper, it is important to better understand and quantify water use in the oil and gas extraction sector as hydraulic fracturing and other water intensive processes become increasingly prevalent in the sector.

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<sup>2</sup> While GED may not be the best representation of water intensity, the Pacific Institute noted that it was chosen due to data availability

Table 2: Water end uses and savings opportunity for several industries (source Gleick 2003)

Industry	Process	Cooling	Land-scape	Con-sumptive	Boiler	Domestic	Misc.	Savings Opp.
Meat processing	58%	33%	1%	-	-	8%	-	27%
Dairy	23%	71%	3%	-	-	3%	-	27%
Beverages	45%	5%	-	46%	-	3%	1%	15%
Textiles	90%	5%	-	-	-	-	5%	39%
Paper & pulp	88%	4%	-	-	4%	-	4%	33%
Fabricated metals	67%	15%	-	-	-	1%	17%	35%
High tech*	70%	20%	-	-	-	5%	5%	38%
Petroleum refining	6%	57%	-	-	34%	-	3%	74%

\*Includes computers and office equipment, electronic equipment and components (except computer equipment), and measuring analyzing, and controlling instruments

### Industrial water costs

Industrial partners in the US DOE's Better Buildings Challenge Water Savings Pilot were asked to provide water intake and sewer costs across their facilities, which spanned several geographic regions. The Water Savings Pilot engages industrial companies to commit to and publicly report progress towards a water reduction target, and share innovative strategies for overcoming barriers. 4 of the 7 Partners responded with the average cost being \$5.78 / 1000 gallons and ranging between \$4.00 - \$6.71 / 1000 gallons. Additionally, Partners were asked to estimate the share of production costs represented by water use, treatment, and sewer. 5 of the 7 Partners responding cited water costs to be "negligible" to less than 1% of overall production costs. It should be noted that none of the responders were from the traditionally water intense sectors, although two were automobile manufacturers.

Some industrial facilities are beginning to consider the "total cost of water". This involves considering the energy, chemical treatment, processing, and all other costs associated with using water. Cummins and Colgate-Palmolive are two companies that have developed software tools to assist their facilities to develop a "true cost of water" (Cummins 2012, Merolla 2014). Considering the "true cost of water" may be a strategy to improve the return on investment for water saving projects.

### Relating water savings to electricity and CO<sub>2</sub> saving

Water use in industry is enabled by energy consuming system(s) to extract, treat, distribute, process, and discharge water. Considering the energy consumption and the overall environmental footprint of the enabling system, in addition to the volume of water used, broadens the perspective on the impact of industrial water use. For an industrial company the result may be an interest in evaluating projects using the true cost of water. For policymakers the result may be expanding the range of utilities, advocacy groups, and researchers interested in

water use. This section will address equating water savings to energy savings, first at the facility-level and next throughout the water supply and wastewater treatment network.

### **Relating water savings to facility-level energy savings**

Within an industrial facility, water and energy can often be saved together. Water savings may be an ancillary benefit of an energy saving action or vice versa. The lack of data with regards to water use within industrial subsectors, much less water use at the system or process level, when combined with the diversity of the industrial sector limits the ability to develop quantitative metrics regarding the relationship between water and energy within an industrial facility (e.g., developing metrics or rules of thumb such as kWh of electricity per gallons of water used for a given condition and system). However, the systems that process water can be evaluated to better understand the relation between water and energy. Three such systems, pumping, steam, and process cooling with cooling towers, are evaluated to better understand how energy can be saved via water reductions.

**Pumping,** Water use at an industrial facility requires pumping systems to move the water through the facility. This electricity consumption can significantly contribute to a facility's overall electrical consumption. Electricity consumption for pumping systems (all liquids including water) represents 27% of all industrial electricity use (USDOE 2006).

The energy consumption of a pumping system is related to the flow rate of the liquid being pumped. For centrifugal systems with no static head, the energy for pumping is theoretically proportionate to the cube of the flow rate ('affinity law'). Reducing water requirements will reduce the flow rate of water through the system which can significantly reduce the energy requirements of the system. However, caution must be taken as the relationship between the energy consumption and the flow rate is highly dependent on the pump and system properties. The cube relation between energy consumption and flow rate does not apply for systems with significant static head.

The results from a pumping system assessment at a Campbell's Soup tomato processing plant provide an example of the energy intensity for water pumping systems. The energy intensity of one wastewater and two well water pumping systems at the facility was measured. One well water pumping system had an energy intensity of 2.4 kWh/1000 gallons of water pumped and the other had an energy intensity of 1.7 kWh/1000 gallons of water. Over the course of a year, the plant pumped a combined 357,297,000 gallons of water from these wells resulting in 747,472 kWh of electricity consumption. The energy intensity of the wastewater pumping system was found to be 0.42 kWh/1000 gallons. 337,500,000 gallons of wastewater were pumped over the course of a year resulting in 140,155 kWh of electricity consumption. These examples illustrate the energy implications of operating pumping systems and the wide range of pumping system energy intensities. The well water pumping systems were over 5 times as energy intensive as the wastewater pumping system. The well water systems had to overcome static head which most likely contributed to the higher energy intensities (Amon 2013).

**Steam,** The energy required to produce steam will depend on the desired steam conditions (pressure, temperature, and quality), the volume of steam, and the beginning state of the water. While eliminating steam use altogether would avoid water use, it may not be either practical or reasonable to do so for some facilities. Limiting make-up water use in a steam

system provides both an energy and water benefit. It requires more energy to produce steam from make-up water than it does from condensate return since make-up water is at a lower temperature. Some make-up water use is unavoidable to compensate for necessary maintenance functions such as blowdown. However, make-up water may also be used to compensate for the impacts of poor system operation, such as once-through systems, broken steam traps, and steam leaks. A study of steam use within U.S. industry estimated the industrial steam use consumes 3,780 TBTU of energy annually. Additionally, the study estimated that industrial steam systems use 354 MGD of water with some of the total steam system energy consumption being used to produce steam out of the make-up water. Of this amount, the following estimates were made for the uses of the water: direct injection of steam (286 MGD), blowdown (54 MGD), leaks (9 MGD), and deaerator venting (4.5 MGD) (Walker 2013). Examples of steam system actions that will yield energy and water savings together include repairing broken steam traps, eliminating continuous blowdown, repairing steam leaks, returning condensate, and substituting steam with an alternative process heating method where possible.

**Cooling.** Water is often used as the working fluid or for heat rejection in a process cooling system. When used for heat rejection, a chiller condenser may be cooled by a cooling tower. Make-up water is used to compensate for the consumptive water lost through evaporation in the cooling tower. As an approximation of the evaporative loss, a 10<sup>0</sup>F temperature difference across a cooling tower will result in 1% of the water being evaporated. Using the rule of thumb for chiller condenser flow rate of 3 gallons per minute per ton, a 10<sup>0</sup>F temperature differential will result in 1.8 gallons per hour per ton of water evaporation (EDF 2013, Muller 2013).

Understanding required chilled water loads and appropriately sizing the chiller and cooling tower system may lower evaporative losses. For example, if the chiller is removing more heat than is necessary, then the chiller will operate at a lower coefficient of performance and the overall system may require greater pumping energy compared to a chiller cooling the right sized load. Further, it will result in more water evaporation through the cooling tower than is necessary. In an example like this, increasing the chilled water set point can not only reduce the energy consumption of the chilled water system, but also reduce the amount of make-up water for the cooling tower.

Water losses also occur in a cooling tower due to drift and blowdown. Although neither is associated with increased energy consumption at the facility, they can both yield water savings.

### **Relating water savings to energy savings in the water network**

Delivering water to an industrial facility requires the water to be extracted from the water source, treated, and conveyed to the facility ('water supply'). Additionally, the facility's wastewater requires treatment before it can be returned to the source ('wastewater treatment'). Each of these steps requires energy to be consumed and is sometimes referred to as the "embedded energy" of the water supply and wastewater network. Estimates of the share of electricity consumption for the water supply and wastewater network as a percent of total U.S. electricity consumption vary depending on the estimation methodology with the Electric Power Research Institute estimating it to be 4% (including public and private systems) (EPRI 2002).

**Water supply description,** Extracting water from its source will require pumping system electricity consumption. The most common water sources are surface water and ground water.

There is a notable difference between the energy intensity of surface water and ground water extraction. Ground water extraction requires well-pumping to bring the water to the surface whereas surface water is already at the surface resulting in a lower energy requirement for surface water extraction. Some of this additional energy consumption is offset by the additional treatment requirements for surface water compared to ground water. Surface water is first filtered for raw debris, followed by treatment to kill any bacteria and to adjust taste. Next, smaller debris are flocculated followed by another round of disinfection. The energy intensity of surface water treatment is approximately the same across all sizes of treatment plants. The variation is within 5%, with energy intensities ranging from 1,407 kWh/million gallons (kWh/MG) for a 100 MGD treatment plant to 1,483 kWh/MG for a 1 MGD treatment plant (EPRI 2002). Ground water treatment requires fewer steps and may only require treatment with chlorine for disinfection and taste. Once the water (surface or ground) is treated, it is distributed using high pressure pumps to the end-use customers. Ocean water can be another water source, and serves about 3% of the U.S. population (EPRI 2013). Desalination of ocean water is more energy intensive than surface and ground water treatment, with a national average energy intensity of 12,000 kWh/MG (EPRI 2013). Due to its limited use, ocean water use is not considered in further detail in this paper.

**Wastewater treatment system description,** A wastewater treatment system consists of wastewater collection from the facility, treatment at a wastewater treatment site, and discharge to a water source. Pumping energy is required to move the water to and from the wastewater treatment facility. The California Energy Commission estimated that the energy intensity of pumping wastewater to the treatment facility is 150 kWh/MG and the energy intensity to discharge the treated water ranges from 0-400 kWh/MG (Klein 2005). The energy intensity of the treatment stage depends on the required level of treatment, with higher levels of treatment requiring greater amounts of energy. There are three levels of treatment (in increasing order of quality): primary, secondary, and tertiary. Four common wastewater treatment processes are (with the energy intensity in kWh/MG): trickling filter (955), activated sludge (1,322), advanced wastewater treatment (1,541), and advanced wastewater nitrification (1,911) (EPRI 2002). In addition to increasing with the level of treatment, the energy intensity will also increase with decreasing plant size (NYSERDA 2008, Klein 2005). If the water supply and wastewater treatment network has the customer base for recycled water, then it can be extracted from the wastewater facility after secondary or tertiary treatment (Klein 2005).

U.S. DOE, through its Better Plants Program, is working with eight water and wastewater treatment utilities to help them reduce the energy intensity of their pumping and treatment operations. Through this initiative, U.S. DOE also aims to better understand and refine the metrics used to measure energy intensity in the sector. Through initial conversations, water utilities appear to be using one of two metrics to measure energy intensity: a flow-based metric, typically expressed as kWh/MGD; and pollutant-based metric, usually expressed as kWh per pound of biological oxygen demand removed. U.S. DOE will work with these utilities to examine these and other metrics and develop guidelines on their use.

**Energy intensity of water supply and wastewater systems,** Table 3 compiles the energy intensity of the water supply and wastewater treatment network at the national and regional level as reported/estimated from various sources. Table 3 also includes the energy intensity for self-supplied water. EPRI has estimated the energy intensity of surface water self-supply to be 300 kWh/MG and 750 kWh/MG for ground water self-supply. Both estimates were

based on energy intensity estimates for municipal water pumping (278 kWh/MG for surface water and 605 kWh/MG for ground water) and corrected to account for reduced volume, (increases energy intensity) and facility-distribution pumping. Additionally, self-supplied surface water energy intensity estimates are adjusted for treatment (EPRI 2002). Note that industrial self-supply water is estimated to be much less energy intensive than municipal water supply.

Table 3: Energy intensities (kWh/MG) of the water supply and wastewater treatment network for several regions in the US and for industrial self-supply (EPRI 2013, EPRI 2002, Navigant 2006, NYSERDA 2008, Elliott 2003)

	Municipal	Self-supply	Nor. CA	So. CA	NY	WI
Extraction (surface/ground)	1,600/ 2,100*	300/750	2,117/2,117	9,727/9,727	470 – 1,380 / 820 - 1060	1,500 /1750
Conveyance (surface/ground)						
Water treatment (surface/ground)			111/111	111/111		
Distribution			1,272/1,272	1,272/1,272		
Wastewater collection	750 – 2,960**	2,500	1,911	1,911	1480	N/A
Wastewater treatment						
Wastewater discharge						

\*A weighted average energy intensity for water supply based on population served for each water supply source (including desalination) is estimated as 2,069 kWh/MG (adapted from EPRI 2013)

\*\*A weighted average energy intensity for wastewater collection, treatment, and discharge based on total volume treated by treatment method is estimated as 2,309 kWh/MG (adapted from EPRI 2013)

Private wastewater treatment, such as those found at an industrial site, tend to be designed for the specific waste stream in the water and are generally smaller than public wastewater facilities. For these reasons, they are estimated to be on average more energy intensive than publicly owned facilities. The energy intensity of private wastewater treatment plants is estimated to be 2,500 kWh/MG (EPRI 2002). NYSERDA estimated the national average of public wastewater treatment facilities to be 1,200 kWh/MG (NYSERDA 2008).

Not all industrial water use leaves the facility as wastewater. Water that is consumed (in-product use, evaporated) or used for outdoor landscaping, for example, will not be sent to a wastewater treatment plant. This has implications when evaluating the energy consumption related to a facility’s wastewater. It is sometimes assumed that all intake is eventually sent to the treatment plant, but a water balance should be conducted to estimate the amount of wastewater. As an example, the Campbell Soup facility cited in the preceding section had approximately 200,000 gallons less wastewater than water supply indicating that some of the water supply was either consumed or used for irrigation/landscaping.

### Water losses through the water supply network

Analogous to generation, transmission, and distribution losses for electricity supply, there are water losses throughout the water supply network. Water audit data of 26 water utilities in the U.S. and Canada collected and validated by the American Water Works Association showed losses in excess of 40% for some utilities (City of Griffin, GA and Washington County Service Authority, VA). Las Vegas Valley Water District (NV) reported the lowest losses of the 26 utilities at 3% (AWWA 2014). One report estimated that water losses accounted for 15% of all

public water demand (Griffiths-Sattenspiel 2009). Therefore, providing a facility with a gallon of water will require more than a gallon of water to be extracted, conveyed, treated, and distributed.

## Discussion

With a better understanding of how industry uses water and the energy intensity of the water supply and wastewater treatment network serving industry, a methodology for calculating energy savings and CO<sub>2</sub> reductions throughout the water supply and wastewater network related to facility-level water reductions can be developed.

*Step 1:* Determine facility-level water supply savings by water source (municipal, self-supplied surface, self-supplied ground)

*Step 2:* Determine facility-level energy savings associated with facility-level water savings. This will be aided by developing a relationship between the volume of water used and the associated energy consumption (e.g., kWh/gallon). Consider pumping system electricity savings, as well as the energy savings for any system where water use has been reduced, such as steam, cooling, and reverse osmosis. For the purposes of estimating CO<sub>2</sub> savings in Step 8, track electricity savings separately from other energy source savings.

*Step 3:* Determine wastewater savings. The difference between the savings in this step and the savings from Step 1 may be consumptive, irrigation/landscape, or recycled water use

*Step 4:* For municipal water supply savings, multiply water supply savings by water loss factor (one plus the percent water loss) for the municipal water provider. If water loss factor is unknown, use 1.15.

*Step 5:* Convert municipal water supply savings (Step 4) and self-supplied water savings (Step 1) to electricity savings by multiplying by the appropriate electricity intensity factor. See Table 3 for example electricity intensities.

*Step 6:* Convert wastewater savings (Step 3) to electricity savings by multiplying by electricity intensity factor. See Table 3 for example electricity intensities.

*Step 7:* Determine total electricity savings by summing electricity savings from Steps 2, 5 and 6

*Step 8:* Convert total electricity savings (Step 7) and other facility energy source savings (Step 2) to CO<sub>2</sub> savings by using CO<sub>2</sub> emissions factors. The U.S. DOE Energy Information Administration (EIA) provides emissions factors for electricity and various fuel sources<sup>3</sup>. Note that the EIA's electricity emissions factors already account for transmission and distribution losses.

In addition to determining the total energy savings in the water supply and wastewater treatment network, the electricity savings determined in Step 7 may yield further water savings at the power plant. Power plants that use evaporative cooling (e.g., coal, nuclear, natural gas) will intake and consume water. Using data from the U.S. DOE, Sovacool estimated that 25 gallons of water is withdrawn for every kWh generated by a thermoelectric power plant, with 0.5 of the 25 gallons consumed (Sovacool 2009). These values are averages across all thermoelectric plants in the U.S. and specific savings will vary depending on the plant type.

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<sup>3</sup> See [http://www.eia.gov/oiaf/1605/emission\\_factors.html](http://www.eia.gov/oiaf/1605/emission_factors.html)

## Conclusion

This paper provides an overview of the available information on industrial water use and proposes a methodology for estimating energy and CO<sub>2</sub> savings throughout the water supply and wastewater treatment network associated with facility-level water reductions. By linking water use to energy consumption and CO<sub>2</sub> emissions, the group of stakeholders interested in developing resources, assistance, and programs to help industrial companies reduce their water use may expand to include energy utilities, state and national energy and air quality agencies, and other organizations advocating for energy and CO<sub>2</sub> emissions reductions.

Further research is required, however, to better understand industrial water use, its connection to energy consumption, and opportunities for reduction. A major barrier to conducting further research is the lack of data on water use within industry, specifically at the industrial subsector level. By expanding the group of stakeholders, more information may become available to better understand industrial water use.

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