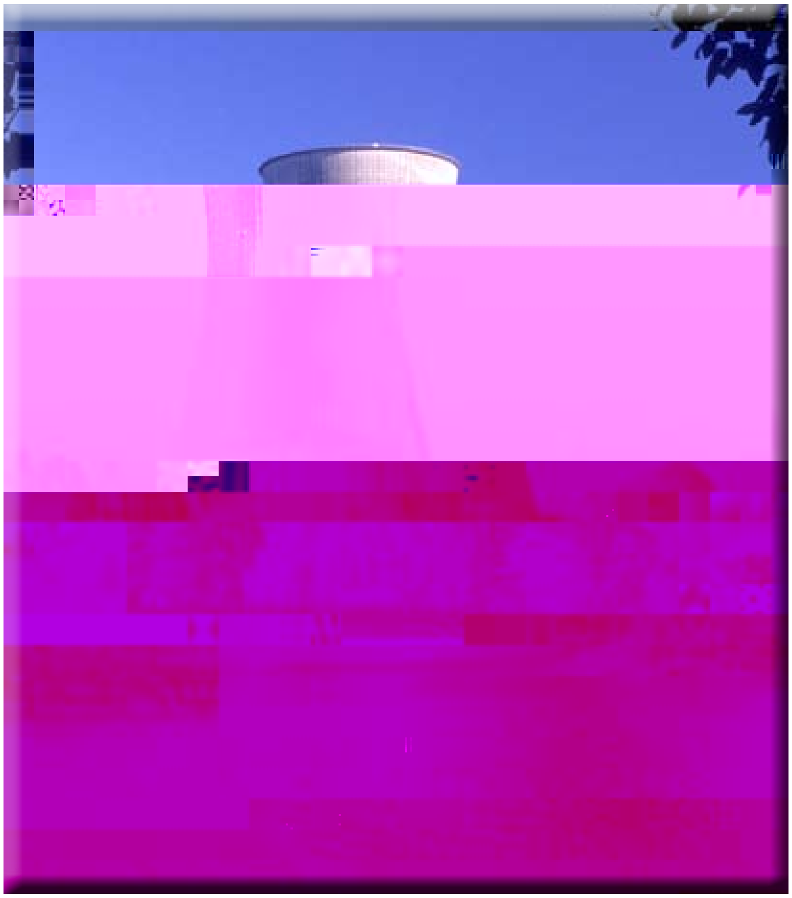
The Carbon Footprint of Water



The Carbon Footprint of Water

by Bevan Griffiths-Sattenspiel and Wendy Wilson

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adoption of higher water treatment standards at the state and federal levels will increase the energy and carbon costs of treating our water and wastewater.

Water conservation, efficiency, reuse and Low Impact Development (LID) strategies should be targeted

- If LID techniques were applied in southern California and the San Francisco Bay area, between 40,400 MG and 72,700 MG per year in additional water supplies would become available by 2020. The creation of these local water supplies would result in electricity savings of up to 637 million kWh per year and annual carbon emissions reductions would amount to approximately 202,000 metric tons by offsetting the need for inter-basin transfers and desalinated seawater.

The link between water and energy presents the climate change community with a valuable opportunity to better manage two of our most valuable resources. As the U.S. struggles to reduce its carbon emissions in response to global warming, investments in water conservation, efficiency, reuse and LID are among the largest and most cost-effective energy and carbon reduction strategies available. Furthermore, water is perhaps the most vital ecosystem service that our natural environment provides. As the inevitable impacts of climate change become evident, our freshwater resources and the ecosystems they support will become respectively less reliable and resilient. Smart water policies allow us to mitigate the worst aspects of global warming today, while the consequent improvements in water quantity and river health will provide a critical buffer as humanity and nature adapt to the climate of tomorrow.

> *"As the U.S. struggles to reduce its carbon emissions in response to global warming, investments in water conservation, efficiency, reuse and LID are among the largest and most cost-effective energy and carbon reduction strategies available."*

Introduction

Climate change and growing demands already strain our energy and water supplies. It has been projected that under a "business as usual" scenario, electricity demand in the United States (U.S.) will increase by 53% between 2003 and 2030. Much of the country is currently experiencing water shortages, with many of the fastest growing regions in the nation already withdrawing up to five times more water than is naturally replenished through precipitation.[1] Meanwhile, the Intergovernmental Panel on Climate Change predicts that global warming will result in less reliable water supplies, while the efforts to develop lower carbon energy sources could drive a shift toward a more water-intensive energy portfolio.[2] Given these trends, it is imperative that policies at all levels ensure the sustainable management of both water and energy.

The "water-energy nexus" is a broad label for the set of interactions caused when humans develop and use water and energy. The nexus manifests itself in many ways, revealing substantial tradeoffs and opportunity costs associated with the ways we use water and energy. Producing thermoelectric power, for example, requires large amounts of water for cooling, while nearly every stage of the water use

In California, for instance, water-related energy use in 2001 was estimated at 48 million MWh (or 48 thousand GWh) of electricity, plus 4.3 billion Therms of natural gas and 88 million gallons of diesel fuel. This energy use results in approximately 38.8 million metric tons of carbon dioxide emissions annually.[6] Water-related electricity alone accounts for 19% of California's electricity consumption, while natural gas use—primarily for water heating—accounts for 30% of the state's natural gas demand. The carbon emissions embedded in California's water as a result of these energy demands is equivalent to the carbon emissions of 7.1 million passenger vehicles, and would require approximately 9 million acres of pine forest to offset California's water-related carbon footprint.[7]

Unless our water supplies are properly managed, the carbon footprint of water use in the United States will continue to grow at a time when climate change necessitates reducing carbon emissions. With so many interconnections, what can we safely say is the "carbon footprint" of water use in the United States today? Furthermore, what policies or techniques are available to reduce water-related carbon emissions?

In order to answer these questions, River Network conducted a literature review of primary and secondary research on water use and its associated energy requirements in the United States. This report builds on River Network's initial estimate of nationwide water-related energy demands by utilizing updated sources and new considerations. To quantify water-related energy use in the U.S., we explored three key research areas:

1. The extent of water-withdrawals across the country by sector,
2. The range of energy intensities for water supply & treatment, and
3. Current estimates of energy in end uses of water.

In Section Four of this report we propose a new base estimate of U.S. water-related energy use and carbon emissions. After establishing the magnitude of water-related energy consumption, we conclude the report by exploring the carbon-reducing potential of various water conservation, efficiency, reuse and low-impact development programs.

Section One

Water Withdrawals by Sector

Evaluatin

Every five years, the United States Geological Survey (USGS) collects data on the nation's water withdrawals and compiles it in an authoritative report titled *Estimated Use of Water in the United States*. The most recent USGS report on water use contains data collected in the year 2000 and is used for most of this report. (As of 3/31/09 the 2005 report has not be released.)

The USGS defines water withdrawals as "water removed from a ground- or surface-water source for use." This broad definition refers to all human uses of water, regardless of whether or not the water is returned to the environment or available for later use. Water consumption—or consumptive uses of water—refers to, "that part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment." Differentiating between water consumed and water withdrawn is critical to understanding how much water is available for environmental and human uses, and hence necessary for water supply planning.

It should be noted that definitions of terms relating to water use are not always clear and aggregating water use figures from different reports can be misleading. Water may have been measured before or after it was delivered to end users. In many instances it is not metered at all. Return flows may be diverted by another user or returned to the environment to replenish groundwater. The terms "diverted," "withdrawn" or "consumed" may mean different things to different agencies. Even where water rights are carefully managed under specific beneficial use statues, conveyance losses may not be fully measured.

The way that water use is broken into sectors can also be confusing. Aside from public supplies, nationwide water use data is frequently categorized by end-user. Private end-users are broken down by economic sector (irrigation, industrial, thermoelectric power, mining, aquaculture and livestock) and "domestic use" (referring to self-supplied households). Therefore, to determine total national water withdrawals by end-use, the public water supplies must also be broken down by end-user.

Many reports do not differentiate between public and private supplies. The Pacific Institute, a well-known research institution focusing on water issues, typically categorizes water users as either urban or agricultural. In this case, urban use refers to the residential, commercial, institutional and industrial sectors, while agricultural uses include irrigating food, fodder and fiber crops.[8] Both urban and agricultural water use can be either public or private, although a large portion of agricultural water is self-supplied. These complications become evident when compared to USGS findings. While agriculture composes the vast majority of the irrigation sector referred to by USGS, uses likely considered urban such as, "Irrigation of golf courses, parks, nurseries, turf farms, cemeteries, and other self-supplied landscape-watering uses also are included."[9]

The USGS estimates that water withdrawals in the entire United States amount to approximately 408 billion gallons of water per day (GPD) or 149 trillion gallons per year (see figure 1.1). The vast majority of these water withdrawals come from freshwater and surface sources, representing 85% and 79% of total withdrawals, respectively. By sector, thermoelectric power generation accounts for 48% of all water withdrawals and irrigation accounts for 34%—making them the two largest water using sectors. Public water supplies rank third representing 11% of the total.[10]

Table 1.1 – Estimated Use of Water in the United States by Sector, 2000 (USGS)

Because the vast majority of water users receive their supply through public systems, we are particularly interested in where it comes from and how it is used. The USGS did not include data on deliveries in public supply systems for 2000, so information had to be gleaned from the 1995 survey. Approximately 56% of all water that made its way into public systems was delivered to domestic users, with commercial use ranking a distant second, composing 17% of 1995 public demand. Public use and losses accounted for 15%, industrial demand was 12% and thermoelectric power ranked lowest, representing less than 1% of public water demand.[12] Therefore, residential users account for more water demand on public supplies than all other sectors receiving public water combined. Public use and lost water is technically unaccounted for and represents 15% of all public water demands, a staggering volume that should be better tracked in order to minimize lost water.

Conclusions

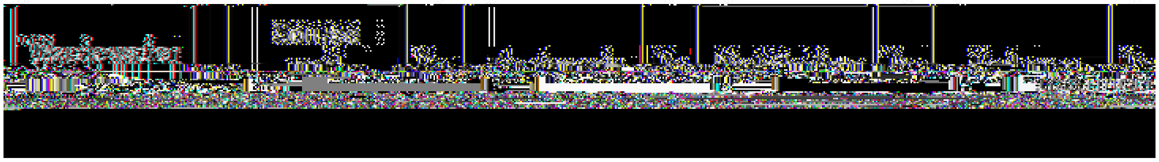
> *"Approximately 56% of all water that made its way into public systems was delivered to domestic users, with commercial use ranking a distant second,"*

- Our nation withdraws an estimated 149 trillion gallons per year. Public water systems withdraw 43 billion gallons of water each year and serve 242 million people, or eighty-five percent of the population.
- Residential users acquire more water from public supplies than all other sectors combined.
- Public use and lost water is unaccounted for and represents 15% of all public water demands, a staggering volume that should be better tracked in order to minimize lost water.
- Future research on the water-energy nexus would benefit from a national agreement on how best to measure water withdrawals (water diverted, used, consumed and/or replenished) and consistent definitions of the sectors being measured by end user and water source.

Section Two
The Energy Intensity of Water

The energy intensity of water use (also called virtual or embedded/embodied energy) is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.[13] This calculation can vary considerably based on a number of factors. Among the most important aspects are the type and quality of source water, the pumping requirements to deliver water to end-users, the efficiency of the water system and the energy embedded by specific consumer end uses.[14]

Energy intensity values are typically expressed in kilowatt hours because electricity is the predominant energy type for municipal water supply and wastewater treatment systems. While energy sources other



embedded by the consumer and is the only component not considered in the energy intensity of water supply and treatment. The reuse of wastewater represents an additional component that is found in a growing number of water systems.

Figure 2.2: From Klein, 7 and based on research by Robert Wilkinson

The energy intensity of each component of the water cycle can differ considerably, resulting in a wide variability of embedded energy values between water systems. Including wastewater treatment but not including end-use, the energy intensity of municipal water supplies on a whole system basis can range from a low of 1,050 kWh/MG to a hypothetical high upwards of 36,200 kWh/MG (*See Table 2.1*). For most utilities, energy use varies from 1250 kWh/MG to 6,500 kWh/MG.[17]

Table 2.1 – Range of Energy Intensities for Water Use Cycle Segments[18]

Water Use Cycle Segments	Range of Energy Intensity (kWh/MG)	
	Low	High
Water Supply and Conveyance	0	14,000
Water Treatment	100	16,000
Water Distribution	250	1,200
Wastewater Collection and Treatment	700	4,600
Wastewater Discharge	0	400
Total:	**1,050**	**36,200**

Water Supply Factors

The type, quality and location of a water supply are the primary factors influencing the energy and pumping costs are directly related to the elevation water must be lifted. Depending on pumping efficiency, between 40 and 80 kWh are required to lift one million gallons of water 10 feet.[20] Energy used for groundwater pumping is typically between 537 kWh and 2,270 kWh per million gallons, depending on pumping depth.[21] Although some gravity fed surface sources are located above the service area and require no additional pumping, energy is often needed to pump surface water sources as well. For instance, water delivered to Southern California from the Sacramento-San Joaquin Delta passes 2000 feet over the Tehachapi Mountains and requires 9,200 kWh/MG.[22]

The vast majority of water supplies come from fresh groundwater or surface sources such as rivers, lakes or streams.[23] Other sources of water include desalinated seawater, brackish groundwater and recycled wastewater. Table 2.2 provides some generic estimates of the energy intensity for water supplies.

Table 2.2 – Generic Energy Intensity of Water Supply Types[24]

In many cases, the analogy between water and electric utilities continues into the preference for least cost resources, which are always dispatched before more expensive resources if possible. This fact influences the carbon impact of water because the least cost electric resources for most utilities in this country are high carbon, fossil-based fuels such as coal. As major electricity users, utilities may receive a larger-than-average share of their electricity from the cheaper, dirtier sources supplying power to the local grid. Thus the more electricity embedded in water, the higher the carbon impact.

Wastewater Treatment Factors

The energy intensity of wastewater treatment depends on the pumping demands for wastewater collection, as well as the level of treatment and size of facility. For most wastewater treatment plants, energy use ranges between 1,000 kWh/MG and 3,000 kWh/MG, although outliers do exist. The largest energy intensity values are as high as 6,000 kWh/MG, or double the high-end of the typical range.[26]

While wastewater treatment plants are often sited in order to utilize gravity fed wastewater collection, not all plants are located downhill from consumers and many utilities incur pumping costs to move wastewater to the treatment plant. Pumping wastewater is inherently more inefficient than pumping freshwater because pumps are designed to accommodate solids in the wastewater stream.[27]

The energy intensity of treating wastewater increases with greater levels of treatment and decreases with scale. Table 2.3 consists of average energy intensity values illustrating the relationship between level of treatment, size of facility and energy intensity.

Table 2.3- Energy Intensity of Wastewater Treatment by Size and Level of Treatment[28]

Treatment Plant				

Growing water demand and decreased reliability of many water resources suggests that more water providers will be forced to rely on marginal water supplies with greater energy and carbon emissions costs. As the example of Portland, OR illustrates, marginal water supplies often require significantly more energy than primary supplies (In Portland's case, 6.5 times more energy is required to pump water from a marginal source compared to the primary supply). A study commissioned by the Portland Water Bureau in 2002 found that global warming will likely decrease the water available from Portland's primary source (the Bull Run) during the summer, when water demand is highest. In total, it was estimated that the Water Bureau will be required to supply an additional 1.3 billion gallons of water per year from alternative sources, such as the more energy intensive well field supply.[29] Assuming the 1.3 billion gallons of additional water is provided by the well field supply at an energy intensity of 3,675 kWh/MG, the energy required to supply Portland's water will increase by approximately 4.8 million kWh per year.

Many water utilities already reach or exceed the capacity of their current water supplies and are looking to develop new water sources. As local supplies become increasingly strained, water utilities are forced to pump groundwater from deeper depths or consider inter-basin water transfers or desalination. Seawater desalination is about seven times more energy intensive than groundwater,[30] while groundwater supplies are about 30% more energy intensive than surface water.[31] In California, a state facing a long-term drought coupled with a growing population, about 20 different water agencies are considering desalination.[32] If all of the desalination facilities currently proposed in California were built, desalination would represent 6% of California's year 2000 urban water demand and significantly increase the energy intensity of California's water supplies.[33]

Santa Fe, New Mexico offers another example of how new water supplies will likely increase the energy intensity of supplying water in the United States. In April 2009, five Eastern New Mexico farmers filed applications to transfer 2 billion gallons of water per year from their farmlands near Fort Sumner to consumers in Santa Fe. If approved, this water would be pumped nearly 150 miles and 4,000 feet in elevation to reach consumers in Santa Fe.[34] To put this lift in context, the State Water Project (SWP) in California currently has the highest lift of any water system in the world, pumping water 2,000 feet over the Tehachapi Mountains to convey water from northern to southern California.[35] The Santa Fe supply requires twice the elevation climb. Assuming a pumping efficiency of 70% (4.48 kWh/MG) and no water lost due to system leaks, the energy intensity of Santa Fe's proposed water supply would be about 18,000 kWh/MG for pumping alone. If the proposed 2 billion gallons of water annually is actually delivered through this supply, new energy costs would be about 36 million kWh annually with associated CO2 emissions of about 32,400 metric tons per year.[36]

When drinking water and wastewater discharge standards are made more stringent, the energy required for water and wastewater treatment generally goes up. For instance, in 2001 the U.S. EPA began imposing tougher standards on water providers to control microbial contaminants, such as cryptosporidium a parasite commonly found in lakes and rivers.[37] Recently, pharmaceuticals, endocrine disrupting compounds and personal care products have been detected in the drinking

Tougher standards are also being enforced for wastewater and stormwater treatment. The EPA has recently implemented tougher rules requiring onsite stormwater treatment.[39] As a result, millions of gallons of water that previously entered waterways as polluted runoff will now require energy as its treated to acceptable discharge levels. Table 2.3 shows how the energy intensity can more than double when switching between trickling filter to advanced wastewater treatment with nitrification. If tougher standards are adopted requiring more stringent wastewater treatment, the energy intensity of wastewater treatment should increase accordingly.

Conclusions

- The energy intensity of municipal water supplies on a whole system basis can range from a low of 1,050 kWh/MG to a hypothetical high upwards of 36,200 kWh/MG, while a more typical range between 1,250 kWh/MG and 6,500 kWh/MG is found for most water systems. Thus, the energy embedded in the water delivered by public utilities varies widely between systems and within a single system. The wide range of energy intensities suggests that the energy intensity should be determined for specific water systems in order to accurately assess the energy embedded in a community's water supply.

- The energy intensity of treating wastewater increases with greater levels of treatment and decreases with scale. A typical range for wastewater treatment and collection varies from 1,000 kWh/MG and 3,000 kWh/MG, with some utilities reporting energy intensities as high as 6,000 kWh/MG.

- Current trends indicate that the energy intensity of water supply and treatment in the United States will likely increase given shifts toward a greater reliance on marginal water supplies, the development of new energy-intensive supplies and regulatory standards requiring higher levels of drinking water and wastewater treatment.

Section Three

Estimating Energy in End-Uses

Once a water supply reaches a consumer, additional energy is often used to heat, cool, pressurize or purify the water in preparation for its intended use.[40] Energy from sources other than electricity is often embedded in water at end-use, most notably natural gas for water heating. Compared to the other five stages of the water use cycle, end use has the greatest potential for water and energy savings because it saves energy both “upstream,” and “downstream.” Upstream refers to all of the energy required to bring the water to its point of use, while downstream refers to the energy expended to treat and dispose of water.[41]

Energy associated with end-uses of water can be characterized by three typical types: heating, additional pumping and energy used in conjunction with water use that is not directly embedded in water (*See Table 3.1*).

Table 3.1- Types of Energy Embedded in Water at End-Use[42]

Heating	Baths or showers, washing hands, dishes and clothes, industrial processes
Additional Pumping	Cooling towers, recirculation hot water loops, car washes or high pressure spraying, pressurization for high rise buildings, irrigation pressurization or lifts from canals on farms
Indirect	Energy used to run an air conditioning compressors that are water cooled

Table 3.2 -Estimated Energy Intensity of Commercial End-Use[43]

Water Use Category	Energy Intensity (kWh/MG)
Kitchen Dishwashers	83,500
Prerinse nozzles	21,000
Laundries	35,800
Water-cooled Chillers	207,800
Single Pass Cooling	0
Landscape Irrigation	0

Not every gallon of water conserved by a consumer has the same energy impact. River Network has estimated that end-use energy for residential water use ranges between 0 kWh/MG (for outdoor irrigation or toilet flushing) to 203,600 kWh/MG (for dishwashers). This considers only water heating and might be higher if other energy inputs are considered. We first gathered data on the percentage of hot water typically used for different residential end-uses. From there, we applied the percent of hot water for each end-use to the energy required to heat a unit of water, which was assumed at 0.2036 kWh per gallon based on the energy required to heat water from 55 º to 130 º F (△75 º F) with an electric water heater. Table 3.3 shows the energy intensities for common residential end-uses.

Table 3.3- Estimated Hot Water Requirements and Energy Intensity of Residential End-Use

Water Use Category	Hot Water[44]	Energy Intensity (kWh/MG)[45]
Bath	78.2%	159,215
Clothes Washers	27.8%	56,600
Dishwasher	100%	203,600
Faucet	72.7%	148,017
Leaks	26.8%	54,565
Shower	73.1%	148,832
Toilet	0%	0
Landscape Irrigation	0%	0

These energy intensities are important for understanding and comparing the energy required—and potential savings through conservation—for common end-uses. However, it is difficult to extrapolate this data without detailed information on how much water is used per end-use. In order to come up with a national estimate of energy required for end-uses of water, we had to take a different approach.

We believe that of the three types of energy inputted at end-uses (heating, additional pumping, indirect), water heating represents the largest share. Due to insufficient data on water use and end-use energy inputs, we decided to look at estimates of total energy use for water heating rather than extrapolate figures based on the energy intensities mentioned above.

Total U.S. Energy Use for Water Heating

Data from the Energy Information Administration (EIA), an agency within the U.S. Department of Energy that collects statistics on energy use within the United States, was used to estimate the energy embedded in residential and commercial water heating. The agency also collects energy use information in the manufacturing and industrial sectors, but data on water heating in these sectors is currently unavailable.

The residential sector consists of single family and multifamily housing units. Ninety-nine percent (109.8 million) of the 111.1 households in the United States rely on four major fuels for water heating: electricity, natural gas, fuel oil and liquefied petroleum gas (LPG).[46] The two predominant sources of energy for water heating are natural gas and electricity, accounting for 50% and 40% of the energy (in kWh equivalent) used for residential water heating. Table 3.4 shows the energy use for water heating in the residential sector by fuel source, as well as the kWhe for each source.

Table 3.4- Residential H2O Heating by Fuel Source, 2005

Fuel Source	Annual Energy Use	kWh Equivalent (billion Kwh)
Electricity (billion kWh)	122	122
Natural Gas (billion cf)	1,368	153
Fuel Oil (million gallons)	986	13.4
LPG (million gallons)	1,642	15.8
Total		304.2

According to the EIA, "Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial or agricultural."[47] Using this definition, schools, correctional institutions, buildings used for religious worship and other building types not traditionally considered "commercial" are included under this category. The most recent data available on commercial water heating is from 2003; actual energy consumed for commercial water heating in 2005 is likely higher. Table 3.5 shows energy use for water heating in the commercial sector by fuel source, as well as the kWh for each source.

Table 3.5: Commercial H2O Heating by Fuel Source, 2003

Fuel Source	Annual Energy Use	kWh Equivalent (billion Kwh)
Electricity (billion kWh)	26	26
Natural Gas (billion cf)	338	37.8
Fuel Oil (million gallons)	131	1.8
District Heating (Trillion btu)	46	13.5
Total		79.1

To display different energy sources (such as natural gas or fuel oil) in a consistent kWh unit of measurement, it was assumed that the kWh equivalent equals the amount of electricity available for use if the fuel were used in a thermoelectric power plant. The efficiencies of thermal power plants were assumed to be 40% and 37% for natural gas and petroleum-fired power plants, respectively.[48] Heating fuel oil and LPG were assumed to have the same efficiency as petroleum. Line losses of 7.2% were also taken into account.[49] District heating as an energy source for commercial water heating is recorded in Btu's by the EIA. Because the specific fuel used for district heating was unspecified, a direct conversion to kWh was conducted at a rate of 3,412 Btu/kWh.

Energy embedded in water at end-uses typically represents the largest energy input in the water use cycle. In California, for example, residential, industrial and commercial end-uses of water account for an estimated 58% of the state's water-related electricity consumption, not counting the additional energy consumed through other fuels such as natural gas and diesel.[50] Even in San Diego—where water deliveries through the State Water Project and the Colorado River Aqueduct result in a relatively high energy intensity of 6,260 kWh/MG for conveyance—end-use still makes up 57% of the city's water-related energy consumption.[51] It is likely, given the sizeable energy requirements for California's unique system of moving water across the state, that end-use makes up an even larger share of water-related energy consumption in the rest of the country.

While residential water use may be similar from house to house, commercial and industrial uses are not. The mixture of business types and processes makes it hard to find accurate data on water-related energy use in the CII sectors. Information exists in many forms, the most complete covers the State in California, but has not been compiled nationally.

Conclusions

- The energy intensity of different end-uses of water varies drastically with some use requiring no additional energy (e.g. irrigation, toilet flushing) and others requiring up to 203,600 kWh/MG (e.g. dishwasher). Therefore, some water conservation measures will achieve significantly greater end-use energy savings than others.
- While the prospects for reducing energy through water-saving end use strategies may be quite high, national data is scarce.
- Energy embedded in end-uses includes 304 million MWhe for residential water heating, and 79.1 million Mwhe for commercial water heating. These numbers are what water-saving end .2 Td(t.-1.50at

Section Four

A New Estimate of National Water-Related Energy Use

In the spring of 2008, River Network estimated water-related energy use in the United States by combining data from a 2002 Electric Power Research Institute (EPRI) report on water supply and treatment with statistics on residential water heating in 2001 from the Energy Information Administration (EIA). This calculation was intended to provide a conservative estimate that could be used as for our efforts to raise awareness of the issue until more information became available. At that time River Network concluded that water-related energy consumption in the United States was equivalent to at least 360 million MWh, or 9% of total U.S. electricity demand. No quantification of the carbon emissions associated with water-related energy use was attempted at that time.

To determine the energy required for water supply and treatment, we relied on the findings from *Water and Sustainability* (Volume 4)*: U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century*, a report published by EPRI in 2002. This report sought to quantify the energy required for water supply and treatment in the United States in 2000, and provided projections of energy use for each water-using sector through 2050. The projections for 2005 were used in our analysis, however, given the wide variability of energy intensities presented in Sections II and III, there is reason to believe that the EPRI findings represent an unreliable, if not diminutive, estimate of the energy required to supply and treat water in the United States. Despite its potential shortcomings, the EPRI report offers the only available estimate of the aggregate electricity demands of water supply and treatment in the U.S.

Because the source data gathered from the EPRI study was derived from projections based on statistics compiled in 2000, we believe new research should be conducted to verify the precision of EPRI's findings. A new analysis that disaggregates energy use by source would also be useful, particularly for understanding the air emissions resulting from water supply and treatment. An assessment of the timing of peak energy use for water supplies on a national and regional basis could provide some useful insight for policy makers and resource planners attempting to integrate water and energy policies. *An analysis of the methodology and assumptions used in the EPRI report is provided as Appendix A.*

Having conducted a broader review, it is now clear that our initial analysis significantly underestimated the magnitude of water-related energy use in the U.S. By applying updated statistics from the EIA on residential and commercial water heating to the same methodology used in 2008, River Network is now proposing a more accurate baseline estimate 50% greater than our initial findings.

As of this date, a fully comprehensive national analysis of the energy demands associated with water supply, treatment and end-uses has yet to be conducted. This is due to a variety of reasons, including a general lack of awareness of the water-energy nexus, the difficulty obtaining detailed data from utilities and a lack of coordination between researchers and agencies looking at water and energy issues.

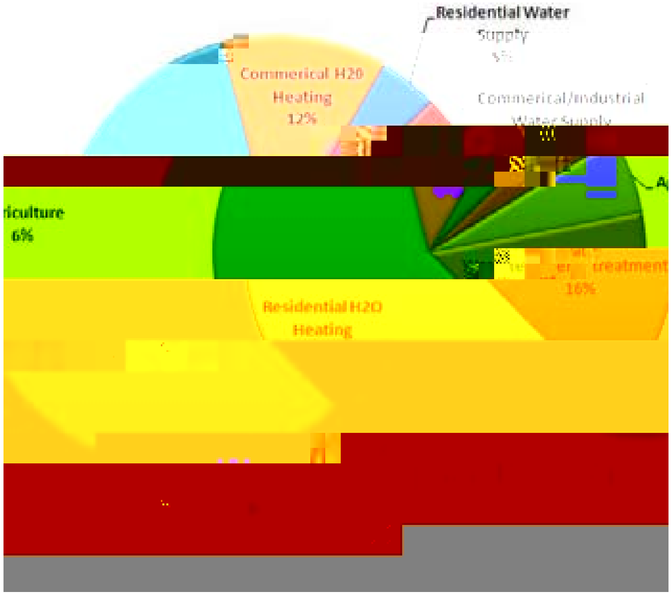
River Network's current estimate of 2005 water-related energy use and associated carbon emissions by sector (derived from EIA and EPRI data) is available in Table 4.1. We believe our estimate provides a baseline estimate of water-related energy use in the U.S. and shows what sectors are responsible for the greatest energy demands. The intent of our analysis is to illustrate the magnitude of water-related energy use by providing a minimum value until a more comprehensive analysis is conducted on the energy embedded in water.

Table 4.1- U.S. Annual Water-Related Energy Use and Carbon Emissions, 2005

Our findings represent a baseline estimate—not an accurate quantification—of water-related energy use in the United States. Although a much more detailed analysis is needed for a complete understanding of the energy demands of our water use, this effort has yielded a number of useful conclusions. We can now confidently say that nationwide water-related energy use is, at a minimum, equivalent to at 521 million MWh per year, or about 13% of the country's 2007 electricity consumption.[56]

The proportion of water-related energy made up by end-uses in our national estimate is higher than values indicated in previous studies such as NRDC's analysis of San Diego, where energy embedded at end-use accounted for 57% of total water-related energy use.[57] The large amount of energy embedded

Figure 4.2 - U.S. Water-Related Carbon Emissions, by Sector *(Chart design by River Network)*



To calculate carbon emissions, the total amount of energy used in each sector was multiplied by a carbon intensity factor specific to the energy source. It was assumed that all of the energy demands for water supply and treatment were met with electricity. U.S. EPA eGRID data from 2007 (version 1.1) provided the carbon intensity factor for the national electric grid. The carbon intensity assumed for each energy source is shown in Table 4.2.

Table 4.3- Carbon Intensity of Energy Sources

Energy Source	Carbon Intensity (in pounds)
U.S. Electric Grid (per kWh)	1.36
Natural Gas (per cubic foot)	0.12
Fuel Oil (per gallon)	22.384
Liquefied Petroleum Gas (per gallon)	12.669

In 2005 CO2 emissions were approximately 6 billion metric tons.[58] We estimate the carbon emissions related to water in 2005 were approximately 290 million metric tons, or 5% of all carbon emissions in the U.S. Water-related CO2 emissions are equivalent to the annual greenhouse gas emissions of 53 million passenger vehicles, or the annual electricity use of over 40 million homes.[59]

Conclusions

- In 2005 the annual water-related energy use in the United States was equivalent to at least 521 million MWh or 13% of 2007 electricity consumption.

- Residential water heating comprises the largest share of water-related carbon emissions.

- Water-related energy consumption is responsible for approximately 290 million metric tons of carbon dioxide emissions annually. This represents about 5% of the U.S. CO2 emissions in 2005.

- The energy embedded at end-use from water heating alone accounts for 74% of total water-related energy use. Because water heating was the only energy input considered in our estimate, end-use likely represents an even greater proportion of water-related energy use.

The following strategies would contribute to a national water-related energy reduction program:

1 Conservation and Efficiency

Every drop of water conserved reduces energy consumption and associated carbon emissions, although the exact amount of savings varies. As discussed in Sections II and III, the energy embedded in a given unit of water can vary drastically depending on the water system and the type of end-use. In 2005, the California Energy Commission found that investments in water conservation and efficiency improvements could yield 95% of the energy savings as traditional energy-efficiency programs at 58% of the cost.[62]

An analysis conducted by the Pacific Institute and the NRDC found that satisfying all growth in water demand with conservation would reduce the energy intensity of the California's water use by 13%.[63] In a separate report on water efficiency in the state, the Pacific Institute concludes that with today's technology, California could reduce urban water use by about 34% across all sectors.[64] As shown in Table 5.1, demand for residential, commercial, institutional and industrial water in California could be diminished by up to nearly 40% in each sector.[65]

Table 5.1: Urban Water Efficiency Potential in California

Urban Water Use by Sector	Potential to Reduce Use
Residential Indoor	39%
Residential Outdoor	25% - 40%
Commercial/Institutional	39%
Industrial	39%
Water System (unaccounted-for water)[66]	10%[53]
Total	**34%**

If we assume that similar water use reductions are achievable in each of these sectors nationwide, then the potential for water efficiency to reduce water-related energy demands in the United States is large. Where peak water use coincides with peak electric use, the water utility will pay higher costs for that electricity. This gives water utilities financial incentives to reduce these coincident peaks—especially for sources where significant energy is embedded.

A. Residential

Indoor

Indoor residential water use is relatively homogenous across the United States. Toilets, clothes washers, showers and faucets account for more than 80% of indoor water use for a typical single family home.[67] As such, the majority of indoor water conservation efforts rightfully focus on these end-uses. Overall, per capita indoor water use can be reduced by at least 35% with more efficient water using fixtures and appliances. This translates to annual savings of approximately 35,000 gallons of water for a family of four.[68]

A study of nearly 100 homes found that prior to retrofitting households with the water efficient fixtures and appliances listed above, only 45% of homes surveyed homes used less than 150 gallons per day. After the retrofit, the number of houses using less than 150 gallons per day nearly doubled to 88%.[69] Overall, it this study found that retrofitting toilets, clothes washers, kitchen and bathroom sink aerators, toilets and showerheads using existing technology can achieve indoor water savings of 39%, comparable to the magnitude of savings in California estimated by the Pacific Institute.

All indoor water saved in the residential sector results in energy savings from avoided water deliveries and wastewater treatment. Based on national averages, the EPA estimates that if just 1% of American homes replaced their older, inefficient toilets with WaterSense labeled models, the country would save more than 38 million kWh of electricity—enough to supply more than 43,000 households electricity for one month.[70] Furthermore, if every household in the U.S. replaced their major water using fixtures and appliances, the indirect energy savings due to water efficiency would amount to about 9.1 million MWh per year, with carbon emissions reductions of 5.6 million metric tons.[71]

Reducing water used for outdoor uses and landscape irrigation will offset the "upstream" energy required to deliver that water to the customer. In the summer months, outdoor water use drives peak demands 1.5 to 3 times higher than a typical winter day.[79] Many water supply systems, such as Portland, OR (*See Section 2*), are forced to use more energy intensive sources to meet these marginal demands. Therefore, water saved for outdoor irrigation often reduces peak demand and the energy needed to deliver the most energy-intensive water supplies. Because outdoor water use constitutes a large portion of residential water consumption and is typically used during periods when utilities rely on marginal water supplies, the national water and energy savings achievable through outdoor water conservation are likely very significant.

B. Commercial, Industrial and Institutional

The commercial, industrial and institutional (CII) sectors use approximately 36,690 million gallons per day and represent between 20 to 40% of billed urban water demand.[80] Potential water savings from efficiency and other conservation measures is typically between 15 to 30% for most communities, with savings as high as 50% possible.[81] While more information on end-uses of water in the CII sector is needed to better understand the direct energy resulting from water efficiency, examples exist shoer e2r wneer use co

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D. Agricultural

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In an area south of the Canadian River in New Mexico, groundwater levels in the Ogalla Aquifer declined 26 feet between 1980 and 1999.[87] Pumps extracting groundwater from the Edward's Aquifer in Texas have been known to cause groundwater levels to drop an entire foot in just one day.[88] If groundwater levels across the United States were to drop an average of 10 feet, energy demands for agricultural water use alone would increase by approximately 1.1 million MWh per year.[89] Assuming pumping energy is derived from the U.S. electrical grid at a carbon intensity of 1.36 pounds CO2 per kWh, associated carbon dioxide emissions would be approximately 680,000 metric tons per year.

While water in the agricultural sector can be saved through site selection, soil amendments, crop rotation and conservation-oriented pricing, at this time we only explore the effects of improving irrigation methods. The three primary types of irrigation systems are flood, sprinkler and drip, with average efficiencies of 73%, 78% and 89% respectively.[90]

Flood irrigation is often gravity fed, with certain systems using additional energy to lift water prior to flooding. Ground water pumping is a major energy input to agricultural water use. Sprinklers and drip irrigation require pressurization which in turn adds to embedded energy. Drip irrigation, the most efficient method of irrigation, adds 632 kWh/MG of embedded energy while flood irrigation typically adds no more than 92 kWh/MG to the energy already embedded from the water supply system.

Although drip irrigation is nearly seven times more energy intensive than flood irrigation, it provides significant water savings. Drip irrigation can result in a net energy savings depending on the source water and quantity considered. On-farm testing of pumps and conducting necessary repairs or improvements can often increase pumping efficiency by 5%-15%.[91] According to the California Energy Commission, "These measures can more than offset the new energy requirements that most often accompany drip system installations."

Table 5.2 Approximate On-Farm Energy Requirements of Different Irrigation Methods[92]

Activity	Approximate Energy Requirements (kWh/MG)
Flood irrigation without on-farm lift	0
Lifting water 10 feet for flood irrigation	92
Booster pumping for drip/micro-irrigation	632
Booster pumping for standard sprinklers	872

2 Water Reuse

The U.S. EPA defines water recycling as "reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin."[93] The two primary types of wastewater are known as greywater and blackwater. Blackwater is commonly known as sewage and is what people generally refer to as "wastewater." Greywater refers to wastewater that contains fewer concentrations of organic waste than water used for toilets or kitchen sinks, but is nonetheless considered non-potable.[94] In this report, rainwater harvesting is considered an LID technique.

Greywater can also be used to reduce energy use through an increasingly popular method called drain water heat recovery. This method uses a heat exchanger to recover heat from the hot water used in showers, bathtubs, sinks, dishwashers, and clothes washers. The energy used for water heating can be reduced by 30% or more with these devices, with an expected payback range from 2.5 to 7 years.[99]

3 Low Impact Development

Low Impact Development (LID) refers to comprehensive land planning and engineering design approaches that seek to maintain or enhance the pre-development hydrologic regime of urban and developing watersheds.[100] In other words, LID is a stormwater management approach and set of practices that are designed to reduce runoff and pollutant loadings by managing stormwater as close to its source as possible.[101] Green roofs, rainwater harvesting, bioretention areas (or rain gardens, bioswales), permeable pavement, and riparian habitat protection are among the most commonly used LID strategies.

LID strategies can reduce the energy required for stormwater treatment, avoid the carbon emissions associated with building traditional infrastructure, reduce aquifer drawdown and provide a "new" local water supply through aquifer storage or rainwater harvesting. While the full extent of energy savings attainable through LID techniques is currently unknown, we explore the potential for energy and carbon emissions reductions using specific examples below.

A study conducted by the Trust for Public Land and American Water Works Association found that 50 to 55 percent of a utility's treatment costs can be explained by the percentage of forest cover in the source area. The study further concluded that for every 10 percent increase in forest cover, treatment and chemical costs decreased by approximately 20 percent.[102] It is unclear precisely how much of these savings are attributable to energy reductions. Given that electricity constitutes between 25 and 40 percent of a typical wastewater treatment plant's budget and 80 percent of the costs of processing and distributing drinking water,[103] one can conclude that the energy savings associated with protecting source water and reducing the contaminant load of stormwater will be significant.

Both rainwater harvesting and aquifer recharge using LID techniques such as bioretention areas have the potential to make available large quantities of water that would otherwise go unutilized. Rainwater can be stored onsite using a simple rain barrel or a larger cistern. Harvested rainwater can be applied directly for outdoor irrigation or treated for a variety of potable uses. The full potential of rainwater harvesting as a water supply has not be quantified, however, a number of case studies exist that illustrate its effectiveness. For instance, Honda of America built a system to capture rainwater for use in the cooling towers of its Marysville Auto Plant in Ohio. The seven-acre, two-pond facility can store 22 million gallons of rainwater and has helped the facility reduce its groundwater usage by 40 million gallons a year.[104]

A study conducted by the NRDC took into account detailed land use analyses, water supply patterns and information on the energy consumption of local water utilities to determine the water, energy and carbon emissions reductions achievable through LID techniques in California. The study looked at limited portions of the San Francisco Bay Area and urbanized areas of southern California to conclude that if LID techniques were applied in just these areas, between 40,400 MG and 72,700 MG per year in additional water supplies would become available by 2020. The creation of these local water supplies would result in electricity savings of up to 637 million kWh per year.[105] Based on the carbon intensity of California's current electricity grid, the annual carbon emissions reductions would amount to approximately 202,000 metric tons.[106] The report's findings are believed to be conservative. According to its authors, "Far greater water and electricity savings—and associated reductions in greenhouse gas emissions—would additionally result from full application of LID practices statewide.[107]

Aquifer recharge through LID techniques also has the potential to maintain groundwater levels, thus avoiding additional pumping demands that result when groundwater levels drop. Depending on pumping efficiency, between 40 and 80 kWh are required to lift one million gallons of water 10 feet.[108] Utilizing LID to maintain aquifer levels could significantly reduce the energy required for pumping groundwater, especially in regions where groundwater represents the majority of water supplies.

Finally, if a project's entire lifecycle is considered, LID has the potential to avoid significant greenhouse gas emissions by avoiding a share of the construction costs associated with building traditional water infrastructure. The use of concrete and other materials with a relatively large carbon footprint can be minimized with onsite stormwater containment. Since LID approaches use plants, they have the potential to absorb carbon emissions over their lifecycle, while traditional infrastructure can increase impervious surfaces and increase the energy for treating water.

Conclusions

- If every household in the United States installed efficient fixtures and appliances, residential hot water use would be reduced by approximately 4.4 billion gallons per year. Resultant energy savings are estimated to be 41 million MWh electricity and 240 billion cubic feet of natural gas, with associated CO2 reductions of about 38.3 million metric tons. Based on national averages, indirect energy savings from residential indoor water efficiency is about 9.1 million MWh per year, with carbon emissions reductions of 5.6 million metric tons.
- Outdoor water use often drives peak water demands and requires the utilization of marginal

- If groundwater levels across the United States were to drop an average of 10 feet due to overuse, energy demands for agricultural groundwater pumping would increase by approximately 1.1 million MWh per year.[109] Assuming pumping energy is derived from the U.S. electrical grid, associated carbon dioxide emissions would be approximately 680,000 metric tons per year.
- An average sized 1,000 MWh power plant that installs a water reuse system for cooling tower blow-down recovery would reduce the energy demand to produce, distribute and treat water by a net 15%, or enough to power over 350 homes for a year.[110]
- If LID techniques were applied in southern California and the San Francisco Bay area, between 40,400 MG and 72,700 MG per year in additional water supplies would become available by 2020. The creation of these local water supplies would result in electricity savings of up to 637 million kWh per year and annual carbon emissions reductions would amount to approximately 202,000 metric tons.

The magnitude of water-related energy use in the U.S. is considerable. At 521 million MWh, water-related energy use is equivalent of 13% of U.S. electricity consumption and has a carbon footprint of at least 290 million metric tons. Substantially more water and energy use data is needed before national, regional and local decision-makers can gain a comprehensive understanding of the energy embedded in the nation's water supplies. Despite this lack of data, a plethora of water management and water policy options currently exist that could significantly reduce energy and carbon emissions. We recommend the following actions be included in a broad effort to reduce the energy and carbon emissions associated with water use in the United States:

- Explore ways to integrate water and energy policies at the federal, state and local levels to ensure the sustainable management of both resources.
- Develop a standard methodology for water utilities to quantify the energy intensity of their water supplies and benchmark their energy usage.

- Educate the public about the relationship between water and energy so that consumers can make informed decisions about their water use.

The link between water and energy presents the climate change community with a valuable opportunity to better manage two of our most valuable resources. As the U.S. struggles to reduce its carbon emissions in response to global warming, investments in water conservation, efficiency, reuse and LID are among the largest and most cost-effective energy and carbon reduction strategies available. Furthermore, water is perhaps the most vital ecosystem service that our natural environment provides. As the inevitable impacts of climate change become evident, our freshwater resources and the ecosystems they support will become less reliable and resilient. Smart water policies allow us to mitigate the worst aspects of global warming today, while the conseqs(nt)tinerovements in water

Notes

[1] Hightower, Mike, et al. "Emerging Energy Demands on Water Resources" pg. 9. Water Resources Impact, Vol. 9 Number 1. Water Resources Impact. AWRA. (Pg. 9)

[2] Webber, Michael E. "Trends and Policy Issues For The Nexus of Energy and Water." Testimony on behalf of Water-Energy Integration Act of 2009. 2009. Available at: <http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Testimony&Hearing_ID=b8d13106-0dae-8b3e-696f-ccf8582f616b&Witness_ID=d8a69c4d-9a71-4122-bfab44f8cb2e02cc>.

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[4] "EGRID | Clean Energy | U.S. EPA." U.S. Environmental Protection Agency. 01 Available at: <http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html>.

[5] ICF International. Water and Energy: Leveraging Voluntary Programs to Save Both Water and Energy. Mar. 2008. U.S. Environmental Protection Agency. Available at: <http://www.energystar.gov/ia/partners/publications/pubdocs/Final%20Report%20Mar%202008.pdf>. (Pg. 3-1)

[6] Klein, Gary, Ricardo Amon, Shahid Chaudhry, Loraine White, et al. California's Water-Energy Relationship: Final Staff Report. Publication. Nov. 2005. California Energy Commission. Available at: <http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF>. (Pg. 8) Assumes carbon intensity of California electric grid is 0.7 lbs CO2 per kWh (based on EPA eGRID2007 Version 1.1), 1.2 .lbs CO2 per cubic foot natural gas and 22.2 lbs. CO2 per gallon of diesel.

[7] "Greenhouse Gas Equivalencies Calculator | Clean Energy | U.S. EPA." U.S. Environmental Protection Agency. Available at: <http://www.epa.gov/cleanrgy/energy-resources/calculator.html>

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[10] Hutson et al, 11

[11] Ibid, 13

[12] Solley, Wayne B., Robert R. Pierce, and Howard A. Perlman. Estimated Use of Water in the United States in 1995. Rep. 1998. U.S. Environmental Protection Agency. Available at: <http://water.usgs.gov/watuse/pdf1995/html/index.html>. (Pg. 20)

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of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures. Santa Barbara, CA: University of California, Santa Barbara, Environmental Studies Program, 2000. (Pg. 6)

[14] Ibid, 5

[15] Carlson, Steven W. and Adam Walburger. Energy Index Development for Benchmarking Water and Wastewater Utilities. United States: AWWA Research Foundation; New York State Energy Research and Development Authority; California Energy Commission, 2007. (Pgs. 21 & 73)

[16] Klein et al, 7

[17] Carlson, 14 & 68

[18] Table derived from Klein, page 9. With modified low values for wastewater collection and treatment and water distribution. Modified values assume mostly gravity fed distribution and gravity wastewater collection with 50 MGD trickling filter treatment facility.

[19] Carlson, 14

[20] Assumes optimum pumping efficiency of 75% (4.2 kWh/MG/1ft lift) and low efficiency of 40% (7.9 kWh/MG/1ft lift), from The University of California Cooperative Extension, Tulare County Available at: <http://cetulare.ucdavis.edu/pubgrape/ig696.htm>.

[21] Cooley, Heather, Juliet Christian-Smith, and Peter H. Gleick. More with Less: Agricultural Water Conservation and Efficiency in California. Rep. Oakland: Pacific Institute, 2008. (Pg. 45)

[22] Wolff, Gary, Ronnie Cohen, and Barry Nelson. Energy Down the Drain: The Hidden Costs of California's Water Supply. Publication. Aug. 2004. Natural Resources Defense Council and Pacific Institute. Available at: <http://www.nrdc.org/water/conservation/edrain/contents.asp>. (Pg. 2)

[23] Hutson et al, 4

[24]

[33] Cooley et al, 2.

[34] Grimm, Julie A. “Private water pipeline plan gains steam.” Santa Fe New Mexican 9 Apr. 2009. Available at: <http://www.santafenewmexican.com/Local%20News/Private-water-pipeline-plan-gains-steam>.

[35] Wolff et al, 2

[36] Assumes electricity from NM grid at 1.99 lbsCO2/MG, supra note 5.

[37] “EPA Ground Water & Drinking Water Safe Drinking Water - Guidance for people with severely weakened immune systems.” U.S. Environmental Protection Agency. Available at: <http://www.epa.gov/OGWDW/crypto.html>.

[38] Stillwell, Ashlynn S., Carey W. King, Michael E. Webber, Ian J. Duncan, and Amy Hardberger. Energy-Water Nexus in Texas. University of Texas at Austin and Environmental Defense Fund. April 2009.

[39] Stormwater Phase II Final Rule: Small MS4 Stormwater Progrma Overview. Dec. 2005. U.S. Environmental Protection Agency. Available at: <http://www.epa.gov/npdes/pubs/fact2-0.pdf>.

[40] Wolff et al., 18

[41] Ibid, 18

[42] Ibid, 33

[43] Ibid, 33

[44] DeOreo, William B., and Peter W. Mayer. The End Uses of Hot Water in Single Family Homes From Flow Trace Analysis. Rep. Aquacraft, Inc. Available at: <http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf>. (Pg. 8)

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[47] “Energy Information Administration - Commercial Energy Consumption Survey.” Energy Information Administration - EIA - Official Energy Statistics from the U.S. Government. Available at: <http://www.eia.doe.gov/emeu/cbecs/contents.html>.

[48] Taylor, Peter, Olivier Lavagne Ortigue, Nathalie Trudeau, and Michel Francoeur. Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels. Rep. July 2008. International Energy Agency. Available at: <http://www.iea.org/textbase/Papers/2008/cd_energy_efficiency_policy/7-Energy%20utilities/7-En_Efficiency_Indicators.pdf>. (Pg. 5)

[49] U.S. Climate Technology Program

[50] Klein et al, 9

[51] Wolff et al., 33

[52] Carbon emissions resulting from water supply and treatment assume all energy comes from electricity with a carbon intensity of 1.36 lbs CO2/kWh, based on EPA eGRID 2007 Version 1.1.

[53] EPRI, 1-5.

[54] EIA 2005, Table WH3

[55] “2003 CBECS Detailed Tables: Summary.” Sept. 2008. Energy Information Administration. 01 Available at: <http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html>. (Table E1A-E11A)

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[57] Wolff et al., 32

[58] Supra note 8.

[59] Supra note 5.

[60] California Air Resources Board (February 11, 2008), "Technologies and Policies to Consider for Reducing Greenhouse Gas Emissions in California." Excerpt taken from Peter Gleick's testimony to the U.S. Senate Committee on Energy and Natural Resources, March 10, 2009.

[61] "U.S. Geological Survey Fact Sheet 2005-3051: Estimated Use of Water in the United States in 2000." USGS Publications Warehouse. 2005. Available at: <http://pubs.usgs.gov/fs/2005/3051/>.

[62] Klein et al, 128

[63] Wolff et al., 34

[64] Gleick et al., 2

[65] It should be noted that Pacific Institute's findings are specific only to California and it is unclear how they relate nationally. It could be assumed, however, that extrapolating California's figures nationally may underestimate the potential of water efficiency in the United States. California enacted legislation requiring 1.6 gallon per flush toilets and other water efficient fixtures in January 1992, preceding the enforcement of similar federal requirements by two years. Furthermore, the state is known for its longstanding and aggressive resource conservation and environmental protection policies, including incentives for water and energy conservation that are not available in many other states. The market for water efficient devices is likely more saturated in California than in other states, hence the potential to reduce water use in the United States as a whole is likely greater than the 34% estimated in California.

[66] ICF, 7-23

[67] Aquacraft, Inc. (2005) Water and Energy Savings from High Efficiency Fixtures and Appliances in Single-Family Homes. U.S. EPA Draft Report. Boulder, Colorado. (Pg. 14)

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[69] Ibid, 27

[70] "Benefits of Water Efficiency." U.S. Environmental Protection Agency. 8 Jan. 2009. Available at: <http://www.epa.gov/watersense/water/benefits.htm>.

[71] Assumes water savings of 68 gallons per household per day (Aquacraft, 3) and 111.1 million households (EIA). Energy intensity is estimated at 1,500 kWh/MG for water supply and 1,800 kWh/MG for wastewater treatment (EPRI). Carbon emissions based on national electric grid, 1.36 .lbs/kWh.

[72] Ibid, 5

[73] Assuming 111.1 million households, based on EIA 2005 Residential Energy Consumption Survey, Table WH3. Available at: <http://www.eia.doe.gov/emeu/recs/recs2005/c&e/waterheating/pdf/tablewh3.pdf>

[74] Assuming 54%of households use natural gas and 46% use electric water heating based on EIA "Water-Heating Energy Consumption in U.s. Households by Type of Housing Unit, 2001." Available at: <http://www.eia.doe.gov/emeu/recs/recs2001/ce_pdf/waterheat/ce4-4c_housingunits2001.pdf >

[75] Vickers, 141

[76] Ibid, 147

[77] Ibid, 222

[78] Greenhouse Gas Equivalencies Calculator, EPA

[79] Vickers, 140

[80] Ibid, 232

[106] Assumes carbon intensity of California electric grid is 0.7 lbs CO2 per kWh based on EPA eGRID2007 Version 1.1

[107] Horner, 1

[108] Supra, note 19

[109] Pumping is assumed to be 60% efficient (5.25 kWh/MG). Agricultural pumping efficiency is assumed to be less than that for public water systems due to the smaller scale of agricultural systems and the likelihood agricultural that pumps are not optimized or replaced as frequently.

[110] Bolze

Appendix ~

In 2002, the Electric Power Research Institute (EPRI) published a study on the electricity required to supply and treat water in the United States. The report looked at public water agencies, publicly and privately owned wastewater treatment facilities and self-supplied water to answer the following question: "Will there be sufficient electricity available to satisfy the country's need for fresh water?"[1] To this end, the report concluded that about 4% of the country's electricity is devoted to water supply and treatment. Electricity was the only energy source analyzed, and there was no attempt to develop a detailed assessment of the total energy demands of water supply and treatment. In short, the EPRI study was not intended to be a definitive report on the subject.[2] Despite the limited scope of the EPRI study, it nonetheless provides the best available assessment of the energy requirements of water supply and treatment in the United States.

Approach

The EPRI study based its analysis on publicly available, secondary sources and was completely transparent about the methodology employed. EPRI categorized sectors based on the same characteristics as USGS in its *Estimating Water Use in the United States* series; that is, between public supplies and private end-use sectors, with the addition of publicly and privately owned wastewater treatment works. To analyze the electricity demands of each sector, EPRI determined the per unit electricity requirements of surface water and groundwater withdrawals in each sector and applied these values to water use information from USGS the U.S. EPA. Projections were carried out based on population growth as characterized by the U.S. Census Bureau. The energy intensity and total projected energy use in 2005 for wastewater treatment and each end-use sector can be found in Table A.1.[3]

Public Supplies

It should be noted that the general trend in the U.S. is towards higher treatment standards.[7] Since the energy intensity of wastewater treatment is directly related to the level of treatment, higher

means that "on a percentage basis the projected purchased electricity requirement for water supply and wastewater treatment will be substantially less."

EPRI did not include projections of electricity requirements for water supplies in the thermoelectric sector. Despite being the largest water using sector, water-related electricity use in the thermoelectric power sector was not forecasted because water use in this sector is expected to decline on an absolute basis.[15] This could be a false assumption due to unforeseen trends in electricity production related to addressing climate change. The effects of certain forms of power production (such as carbon capture and sequestration) on water demands for thermoelectric power production are currently unknown, and might actually result in a net increase in water required for power production.[16] An updated analysis should consider multiple scenarios for future electricity production and cooling technologies in order to show how trends in the thermoelectric sector will affect the energy required to supply water.

In conclusion, the EPRI report provides an excellent starting place for understanding the magnitude of water-related energy demands, but more research is needed. Because the report was not intended to provide a definitive analysis, a new study with the explicit purpose of quantifying the current and future energy demands of water supply and treatment is long overdue. The EPRI report relied on data that is, in many cases, well over a decade old. As interest grows in this subject, a more detailed examination will be necessary to assess the full extent of water-related energy demands and their associated greenhouse gas emissions.

Appendix Notes ~

[1] EPRI, 1-1

[2] Appelbaum, Bruce. “RE: River Network Water-Energy Report, EPRI analysis.” E-mail to the author. 23 Mar. 2009.

[3] Public supplies go to a variety of end-use sectors, including residential, commercial, industrial, etc.

[4] Estimates for per unit electricity consumption are based on: *Water and Wastewater Industries: Characteristics and Energy Management Opportunities: A Report That Describes How Electricity is Used and Can Be Managed Efficiently in Water and Wastewater Treatment*, EPRI, Palo Alto, CA: 1996. Product ID # CR-106491. The report was not available for review.

[5] EPRI, 2-3 – 2-4

[6] Ibid

[7] Ibid, 3-12

[8] Ibid, 3-13

[9] Ibid, 1-5

[10] Supra, note 89

[11] Klein et al, 38

[12] Hutson et al, 4

[13] Cooley et al, 2.

[14] EPRI, 2-2

[15] EPRI, 1-6

[16] Bennett, Barbara, Massood Ramezan, and Sean Plasynski. Impact of Carbon Capture andSequestration on Water Demand for Existing and Future Power Plants. Issue brief. 2007. National Energy Technology Laboratory. Available at: <http://www.netl.doe.gov/publications/proceedings/07/carbon-seq/data/papers/wed_006.pdf>.

Acronyms & Abbreviations

CEC – California Energy Commission
CO2 – Carbon Dioxide
CII – Commercial, Industrial and Institutional Sectors
CSSWF – Columbia South Shore Well Field
eGRID – Emissions & Generation Resource Integrated Database
EIA – Energy Information Administration
EPA – Environmental Protection Agency
EPRI – Electric Power Research Institute
GPD – Gallons per day
GPF – Gallons per flush (toilets)
kWh – kilowatt hour
kWh/MG – kilowatt hours per million gallons of water
kWhe – kilowatt hour equivalent
LID – Low Impact Development
LPG – Liquefied petroleum gas
MG – Millions of gallons
MGD – Million gallons daily
NRDC – Natural Resources Defense Council
PI – Pacific Institute
POTW – Publicly-owned wastewater treatment works
REUWS – Residential End-Uses of Water Study
USGS – United States Geological Survey

River Network's mission
is to help people
understand,
protect and restore
rivers and their watersheds.

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