The Water-Energy-Greenhouse Gas Connection

Background

As documented in the California Energy Commission's 2005 Integrated Energy Policy Report (IEPR)[1], California has begun to take a serious look at the give-and-take relationship between the water and energy systems and how to synergistically improve the two. In addition, the Energy Commission is examining ways to improve the efficiency not only of energy use directly, but of water use that saves energy. In order to prioritize its efforts, the state first needs to understand the magnitude and character of the water-energy connection.

In its scoping order for the 2005 IEPR, the Energy Commission stated that "(f)or 2005, the Committee will continue the emphasis from the 2003 Energy Report on increasing the level of energy efficiency and diversity in the state's energy systems and understanding the limitations of the state's electricity, natural gas and transportation fuel infrastructure." … "The need for new water supplies in California and the West due to population growth and potential changes in the state's hydrological cycle has important implications for the state's energy system that are not yet fully understood. The 2005 Energy Report will need to evaluate this issue as part of pursuing the broader goal of sustainability."[2]

Working jointly with the California Department of Water Resources, the Energy Commission established a Water-Energy Working Group composed of key stakeholders to participate in the analysis and inform policy development. This group helped the Energy Commission examine many dynamic factors that effect energy demand of the water sector, including increased need for water treatment to address water quality degradation, increased pumping to provide reliable water supplies, and possible development of desalination facilities. We also looked at components of the water system that produce energy currently harnessed to supply the state's electricity demand as well as opportunities that have yet to be developed.

California has an elaborate system of manmade water storage, conveyance and delivery structures to augment natural features. Prior to use and again afterward, water must frequently be treated to meet environmental quality and public health protection standards. Energy is required at all of these stages of the water use cycle. For illustrative purposes, a "water use cycle" was developed to assist is determining the energy intensities[3] associated with each of the stages. The 2005 IEPR analysis identified a range of energy intensities for the various stages of the water use cycle as shown in Figure 1. Not counting recycled water supplies and their use, energy intensities for getting a unit of water through the cycle typically fall within the range of 2,000 to 20,000 kWh/MG)

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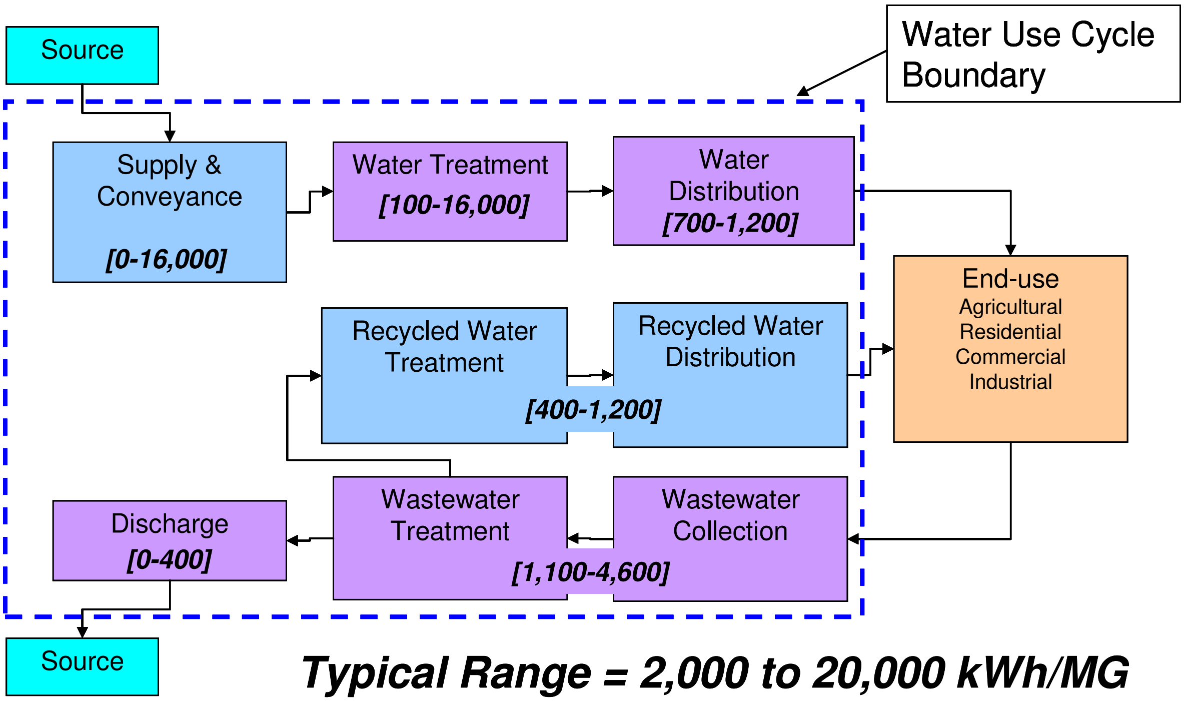
[1] SB 1389 (Bowen), 2002, requires the Energy Commission to conduct and integrated assessment of the major energy trends and issues every two years. Recommendations to address these trends and issues are made to the Governor and Legislature to ensure a reliable, secure, diverse and environmentally sound energy system for California.

[2] California Energy Commission, IEPR Committee Scoping Order, dated September 3, 2004, p. 2.

[3] Energy intensity is defined as the amount of energy consumed per unit of water to perform water management-related actions such as desalting, pumping, pressurizing, groundwater extraction, conveyance, and treatment (i.e., the number of kilowatt-hours consumed per million gallons of water.

Figure 1. Energy Use Cycles Energy Intensities (kWh/MG) Chart



The energy intensity of the water use cycle varies throughout the state. There is a key difference between northern and southern California. Much of the population in the San Francisco Bay area is supplied by gravity-fed systems and the energy intensity of conveyance is very low. However, two-thirds of the state's precipitation falls in the north, while two-thirds of the water is needed in the south. This water is conveyed to the south through the State Water Project which transports the water more than 400 miles and lifts it more than 3000 feet to get over the Tehachapi Mountains. Table 1[4] shows the effect of this on typical energy intensities.

Table 1 The Energy Intensity of the Water Use Cycle is Greater in Southern California

	Northern California kWh/MG	Southern California kWh/MG
Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Regional Total	3,950	12,700

[4] California Energy Commission California's Water-Energy Relationship, Final Staff Report, 2005.

According to the Department of Water Resources, California uses about 14 trillion gallons of water in a normal year. Approximately 79 percent of this use is for agriculture and the rest for urban uses.[5] Water used for urban purposes is treated before and, for indoor water, also after use. Water used for agricultural purposes is frequently not treated before or after use. Over the years an increasing amount of wastewater is being treated for re-use (recycled) and this trend is expected to continue in the future. The total energy demand associated with California's water-related energy use is shown in Table 2[6]. The greenhouse gas emissions are proportional to the energy sector emissions totalling more than 100 million metric tons.

Table 2. 2001 Water-Related Energy Use and Greenhouse Gas Emissions in California

	Electricity (GWh)	Natural Gas (Million Therms)	Diesel (Million Gallons)
Water Supply and Treatment			
Urban	7,554	19	?
Agricultural	3,188		
End Uses			
Agricultural	7,372	18	88
Residential			
Commercial	27,887	4,220	?
Industrial			
Wastewater Treatment	2,012	27	?
TOTAL	**48,012**	**4,284**	88
2001 Consumption	**250,494**	**13,571**	?
Percent of Statewide Energy Use	**19%**	**32%**	?
CO_2 e (Million Metric Tons)	**56**	**50**	

The water system not only uses energy, it produces a significant portion of the energy used in California. A vast network of reservoirs and dams, pumped storage and run-of-the-river facilities owned and operated by both public and private entities generate about 13 percent of the power used in the state and represent about 25 percent of the instate generation capacity. However, options to build more large-scale hydroelectric facilities in the state are extremely limited since most of the economically viable sites have already been developed. In addition, many of these sites several multiple purposes and the competition between these purposes is increasing (water supply, environmental support, power generation). Looking back on the 2005 effort, we realized that we did not account for the water used to generate electricity, nor did it account for the energy used to transport bottled water, both of which can be substantial and should be accounted for in future studies.

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5 California Department of Water Resources, Bulletin 160-2005.

6 California Energy Commission California's Water-Energy Relationship, Final Staff Report, 2005.

Water-Energy-Greenhouse Gas Emission Synergies

Our study found that several mutually beneficial strategies can be implemented to improve the overall efficiency of the water and energy sectors. Working together will capture the greatest benefits for both systems.

Save water to save energy

Roughly 20 percent of the state's electricity, 30 percent of the natural gas and 88 million gallons of diesel go to water in some form. You save more energy in Southern California than in Northern California because of the distance and elevation. Saving water used outdoors is good (pumping, treatment and delivery), saving water used indoors is better (no pressurization or wastewater removal, treatment and discharge) and saving hot water is better still (no energy to heat the water too).

One of the key assumptions in California's water plan is that roughly half of the new water supply will come from water use efficiency. Based on the energy intensity of the water use cycle, if this reduction in water use occurs in southern California, there will be a reduction in energy use. Our initial estimate, shown in Table 3, identifies significant untapped energy saving potential exists in programs focused on water use efficiency. Gross energy savings from these programs could be 95 percent of the savings expected from the 2006-2008 energy efficiency programs, at 58 percent of the cost. Peak savings could account for 60 percent of planned-for reductions in demand.[7]

Table 3: Comparison of Energy Efficiency to Water Use Efficiency Programs

	Energy Efficiency Programs		
	2004-2005	2006-2008	Water Use Efficiency (WUE)
GWh (annualized)	2,745	6,812	6,500
MW	690	1,417	850
Funding ($ million)	762	1,500	826
$/Annual kWh	0.28	0.22	0.13
WUE Relative Cost	46%	58%	

The conserved water is expected to be used by new people as the population grows, so while energy consumption may not go down, it will be spread over a larger base.

These potential energy savings only address what we expect can be saved from water use efficiency. Four additional areas need to be examined more closely to determine the magnitude of their impact:

7 California Energy Commission, California's Water-Energy Relationship, Final Staff Report, 2005. The numbers for the energy programs come from CPUC documents:2004-2005, CPUC Rulemaking R.01-08-028, Decision D.03-12-060, 2005-2006, CPUC Rulemaking R.-01-08-0228, Decision D.04-09-060. The numbers for the water use efficiency program are discussed in detail in Appendix D of the California's Water-Energy Relationship, Final Staff Report. The energy savings have been apportioned to Northern and Southern California based on population. The cost for the water efficiency measures assumes an average of $384 per acre-foot, based on a range of $58-$710.

Save energy to save water
Many large facilities use water based chillers for air conditioning. Reducing cooling loads reduces the water required for cooling. Also, most thermal electric power plants use water for cooling. All reductions in electricity result in less water needed for cooling.

Improve the efficiency of water use cycle operations
Beyond end-user water and energy efficiency, water and wastewater agencies can improve the efficiency of their operations. Larger diameter pipes, smaller, more efficient pumps are two key strategies.

Shift water use cycle operations off the energy peak
Much is already being done in this area by the state's water and wastewater treatment agencies. More is possible. Increase water storage to shift pumping and processing requirements off the energy system peak. Spread this storage throughout the delivery and distribution systems. Provide time of use price signals for water use that shift energy needed in the water use cycle off the energy system peak.

Develop renewable generation
Significant renewable generation opportunities exist to enhance the existing infrastructure for expanded power generation without further environmental damage or jeopardizing water supplies. These opportunities include development of additional in-conduit hydropower generators and pumped storage facilities. In addition, wastewater treatment facilities can be used to produce digester biogas that can be used to generate electricity. Other renewable power generation opportunities exist within the water system and at treatment facilities to help make them energy self-sufficient. Many of these locations are in existing or growing energy load centers, which are distributed throughout California's energy system. Identify and remove regulatory barriers so that all cost effective potential can be developed.

All of these actions will result in the reduction of greenhouse gas emissions.

Implementation

So much for the recommendations. What is actually being done to implement them?

The collaboration with the Department of Water Resources has continued for more than 3 years. Working together with the Water-Energy Working Group we were able to identify key stakeholders, willing participants, and many opportunities for mutually beneficial improvements. There have been several workshops held throughout the state to share ideas both during the IEPR proceeding and since. The California Public Utilities Commission issued a decision in 2006 to require the investor-owned water utilities, representing 20 percent of the state's water customers, to participate in the Best Management Practices utilized by the publicly-owned water utilities. A jointly sponsored symposium on the water-energy connection was held in Sacramento on March 28th, 2006

We also identified some barriers.

Sensors to measure nitrification in water distribution system storage tanks are not considered legitimate energy efficiency expenditures. The primary mission of water utilities is to provide water that meets water quality standards. Increasing energy efficiency takes second place. One strategy to shift pumping operations off the energy system peak is to allow the level of treated water in the storage tanks to drop a few feet further than is normally the practice. It is necessary to install sensors to measure key water quality indicators such as nitrification so that operations can recommence before water quality is adversely affected. To date, the cost to install these sensors has not been allowed by the California Public Utilities Commission as part of an energy efficiency program since they don't actually save energy. They are very similar to thermostats, currently an allowable expenditure, which also don't save energy, but without them, it is practically impossible to control the heating and air conditioning system. Energy efficiency program rules need to be changed to better understand the essential requirements of the water and wastewater systems.

More flexible water deliveries from the State Water Project are limited by the storage capabilities of the State Water Contractors and their customers. Starting during the energy crisis, the State Water Project is already one of the largest energy users to shift a significant percentage of their electrical loads off the energy system peak. With increased pressure to deliver more water to southern California to make up for the 1 million acre-foot shortfall due to the Colorado River Agreement, it will be difficult to maintain the high percentage of peak shifting. Additional peak shifting would be possible if it were possible to modify the water delivery schedule. Flexibility will be increased with relatively small changes in the height allowed in the water channels and localized storage in the State Water Contractors' delivery systems. This potential should be explored in collaboration with the State Water Project and the State Water Contractors.

As of 2005, energy efficiency programs did not allow the energy utilities to account for increasing water use efficiency. While there have been joint programs such as those for improved washing machines or spray rinse valves, the energy utilities were only allowed to capture the savings from the reduced need for hot water. Since reducing water consumption reduces the energy needed in the water use cycle, the energy utilities should be allowed to capture this additional benefit.

The Energy Commission and the California Public Utilities Commission are working to develop a method for incorporating this into the state's energy efficiency programs. Toward that end, the California Public Utilities Commission initiated a pilot program with all four of California's investor-owned utilities to better understand the embedded energy in water. The pilot programs were coupled with evaluation, measurement and verification efforts. The results are due in the second half of 2008, ideally in time for incorporation into the 2009-2011 energy efficiency program cycle.

The California Public Utilities Commission also regulates investor-owned water utilities, which supply water to roughly 20 percent of California's urban water customers. Following the pattern originally established with the energy utilities, they have decoupled sales from profits and required the utilities to implement water conservation programs. Implementation of both of these policies began in 2007 and we should begin to see results in 2009.

Again as of 2005, net metering rules had the effect of limiting the amount of renewable generation produced by water and waste water utilities. Many water utilities have in-conduit hydroelectric facilities. Many wastewater utilities generate electricity from biogas collected as a by product of the waste treatment process. The amount they generate is limited, not by technical potential, but rather by the amount of energy they use at the location where they generate the electricity, even if their total energy bill is much larger due to requirements at other locations in their service territory. Any excess electricity needs to be sold in the wholesale market. The risks of participating in this market are larger than most water and wastewater utilities are willing to bear. Changing the rules to allow for generation up to the total of the water or wastewater utility's energy bills would encourage additional renewable generation and help the state meet its Renewable Portfolio Standard goals.

In the 2007 legislative session, Assembly Bill 2466 (Laird) was passed and took effect January 2008. This bill authorizes a city, county, city and county, or joint powers agency formed by a city, county, or city and county to: receive a bill credit, as defined, to a benefiting account, as defined; for electricity supplied to the electric grid by an eligible renewable generating facility, as defined; and requires the Public Utilities Commission to adopt a rate tariff for the benefiting account. While this bill is a first step, more work is needed.

Two other bills of note have also been approved by California's Legislature. AB 1560 (Huffman) requires the Energy Commission to develop regulations for water efficiency and conservation standards for new residential and non residential buildings. AB 662 (Ruskin) requires the Energy Commission to develop regulations for energy and water efficient appliances. The implementation of both of these legislative mandates has begun.

One of the most far reaching piece of environmental legislation passed in recent years in California was AB 32, which requires that greenhouse gas emissions be reduced to 1990 levels by 2020. A key outgrowth of that bill was the formation of the Climate Action Team, comprised of several state agencies working together to establish and implement policies designed to achieve that goal as well as the additional target set by Governor Schwarzenegger in Executive Order S-3-05 of reducing GHG emissions to levels that are 80% below 1990 levels by 2050.

Governor Schwarzenegger declared that California was officially in a drought on June 3, 2008. The last time a drought was declared was in in 1991.

Conclusions

The staff report and the 2005 IEPR provided a good first order estimate of the potential for energy system improvements by increased water use efficiency. Although discussed, those documents did not attempt to quantify the potential from several other key aspects of the water-energy connection.

The magnitude of the first order connection led us to conclude that we cannot wait. While not all of the interconnections in the relationship were not clear, we began in 2006, doing what we already knew how to do. One of our key observations was that the energy system gets the largest benefits if we focus on increasing water use efficiency in southern California and in other areas of the state with similarly energy intensive water use cycles.

The Energy Commission needs to continue to collaborate with the California Public Utilities Commission and the California Department of Water Resources to develop a coordinated statewide approach. We need to foster collaboration and cooperation among the energy, water and wastewater utilities, both public and investor owned so that all opportunities for mutually beneficial improvements can be addressed most cost effectively. Changes are being made to the regulatory rules so that the 2009-2011 energy efficiency program portfolios can incorporate water use efficiency and a better understanding of what is needed by the water and wastewater utilities for them to invest in energy efficiency.

The Energy Commission should direct the Public Interest Energy Research Program to accelerate its efforts to better understand the interrelationship between the energy, water and wastewater systems, and to develop a portfolio of innovative solutions designed to increase overall efficiency.

While this paper has focused on California, some observations can be made that apply to the rest of the United States and to other countries. When we began the investigation, most of the policy makers thought that the water-energy-connection represented about 5 percent of California's electricity consumption. Subsequently we learned that it represents roughly 20 percent of the electricity, 30 percent of the natural gas, and some direct diesel consumption. To my knowledge no similar study has been done for the United States, but I estimate that approximately 20 percent of the stationary (non-transportation) energy goes to water in some way. When making this estimate, I took into account some of the differences between California and the rest of the United States. No other state expends as much energy transporting water, but most other states do not have as much gravity-fed water either. On average, water is lifted up several hundred feet, so the percentage of electricity going to the water-use cycle is less nationally than it is in California. On the other hand, water heating is split 55:45 gas to electric, (plus some fuel oil) in the rest of the country, while in California, more than 85 percent is natural gas.

Regardless of what the numbers and percentages are in the United States or California, the important question is what is the water-energy-greenhouse gas connection where you live? I suspect it is larger than you think and I also suspect it will prove to be a very large source for increases in energy efficiency and reductions in greenhouse gases. I look forward to assisting you as you "mine" this resource.