The Water-Energy Connection in California

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ABSTRACT

As documented in the California Energy Commission's 2005 Integrated Energy Policy Report, California has begun to take a serious look at the water-energy relationship in the state. A Water-Energy Working Group composed of key stakeholders was convened to inform the policy discussion.

In short: 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. Saving water saves energy. Saving energy saves water. 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 waste removal, treatment and discharge) and saving hot water is still better (no energy to heat the water too). Beyond end-user water and energy efficiency, water and wastewater agencies can improve the efficiency of their operations; water storage can be better used to shift pumping and processing requirements off the energy system peak; and significant renewable generation (in-conduit hydropower, biogas generation, solar and wind) opportunities exist.

This paper will discuss the magnitude of the water-energy connection in California, describe the variability of this relationship in different regions in the state and share what is being done in California to promulgate policies and to develop and implement programs that simultaneously improve the efficiency of the water-energy connection.

Introduction

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 [Jones, Smith & Korosec, 2005]. 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

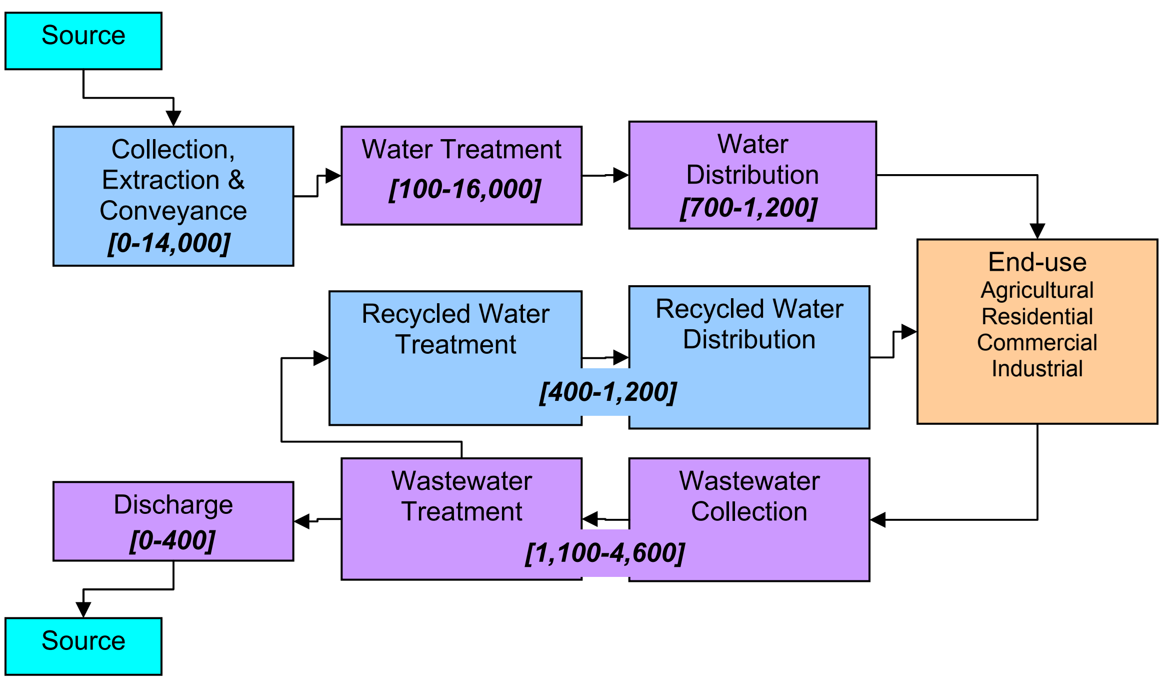
[1] SB 1389 (Bowen), 2002, requires the Energy Commission to conduct and integrated assessment of the major energy trends and issues every two years. Recommendations to address these trends and issues are made to the Governor and Legislature to ensure a reliable, secure, diverse and environmentally sound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

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 first-order analysis presented in the 2005 IEPR 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 can vary from the 2,000 to 20,000 kWh/MG[4].

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



[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.
[4] In practice, the extremes of the ranges shown in Figure 1 are not additive.

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 over 3000 feet over the Tehachapi Mountains. Table 1 shows the effect of this on typical energy intensities [Klein, 2005].

Table 1 Regional Variation in the Energy Intensity of the Water Use Cycle

	Northern California	Southern California
	kWh/MG	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

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 [Guivetchi, 2005]. Water used for urban uses is treated before and after use, whereas, 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 [Klein, 2005].

Table 2. 2001 Water-Related Energy Use 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%	?

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).

Our study found that several mutually beneficial strategies can be implemented to improve the overall efficiency of the water and energy sectors. In the course of our discussions with the working group and other stakeholders we identified some barriers to achieving these goals and recommendations to address these barriers. Working together will capture the greatest benefits for both systems. These findings and recommendations included:

- Saving water can save energy
  - Improve operational efficiency of systems
  - Retrofit infrastructure with better designs and technologies
  - Lower demand of end users
- Reduce Peak Demand
  - Advanced metering
  - Time-Of-Use rates and improved price signals.
  - Shifting load
- Develop clean, cost-effective energy generation opportunities in the water system
  - Develop system resources (in-conduit hydro, biogas)
  - Develop other renewable resource
  - Remove net metering constraints and regulatory disincentives

Potential Magnitude of the Energy Savings

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 imported water must travel. 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, or 2 million acre-feet, will come from water use efficiency [Guivetchi, 2005]. 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.[5]

[5] 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.

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

	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%	

If the conserved, energy-intensive water supplies are not used for other purposes, we could actually see energy savings of this magnitude. However, conserved water is assumed to be a new source of water for future demands and, thus, net energy savings are likely to be less. How much less is now being analyzed by the Energy Commission's PIER program.

Even though we may determine the net savings that could be achieved if we focused on water savings to save energy, current restrictions on existing state and utilities programs limit their use. For example, current energy efficiency programs do 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.

The staff report and the 2005 IEPR provide a good first order estimate of the potential for energy system improvements by increased water use and system efficiency. The potential energy savings presented above only address what we expect can be saved from 2 million acre-feet of water use efficiency. Although discussed, those documents did not attempt to quantify the potential from several other key aspects of the water-energy connection. Expanding further on concepts introduced in the 2005 IEPR and the staff's final report, four additional areas need to be examined more closely to determine the magnitude of their impact:

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 and cooling demand result in less water needed for these processes.

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. Several programs currently address these issues, but not in a coordinated fashion. Both utilities and the Energy Commission have programs that can assist water utilities with equipment upgrades and some on-site efficiency improvements, but incorporating fundamental efficiency concepts in designs and operation could improve overall performance.

Shift Water Use Cycle Operations off the Energy Demand Peak

Much is already being done in this area by the state's water and wastewater treatment agencies. More is possible. For example, in some cases water storage can be increased to shift pumping and processing requirements off the energy system peak. In other cases, increased storage may be spread throughout the delivery and distribution systems to increase system flexibility, service reliability and energy efficiency. Use of advanced meters can provide time of use price signals for water use that shift energy needed in the water use cycle off the energy system peak.

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 became 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.

Under current regulations, investor owned energy utilities are not permitted to invest in measures that strictly save water or allow water managers to operate their systems more effectively. For example, pumping operations could be shifted off the energy system peak if the level of treated water in the storage tanks was allowed 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 directly. They are very similar to thermostats, currently an allowable expenditure, which also don't save energy directly, but without them, it is practically impossible to control the heating and air conditioning system. A greater understanding of the water systems and how technology and operational changes can enhance energy efficiency system wide is needed. Energy efficiency programs need to be modified or adjusted to account for energy savings throughout the water use cycle. Rules need to be changed to better understand the essential requirements of the water and wastewater systems.

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. The state needs to identify and remove regulatory barriers so that all cost effective renewable potential can be developed.

Current net metering rules have 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.

Actions for the Future

The magnitude of the first order connection between water and energy in California leads us to conclude that we cannot wait to take action. We must begin now, doing what we already know how to do. The energy system gets the largest benefits if we begin by focusing on increasing water use efficiency in southern California and in other areas of the state with similarly energy intensive water uses.

The Energy Commission is collaborating with the California Public Utilities Commission and the California Department of Water Resources to develop a coordinated statewide approach. We are fostering 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 must be made to the regulatory rules so that the 2006-2008 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. We have started this dialogue and are working with the utilities to determine what changes are to be made.

While we are working on implementing known improvements, the Energy Commission is also accelerating its research efforts through the Public Interest Energy Research Program 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.

The collaboration with the Department of Water Resources has continued for almost 18 months. 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 its Water Action Plan in December 2005 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. As a result of this event, the California Public Utilities Commission, in consultation with the Energy Commission, is conducting further public workshops to address the mechanisms needed to incorporate energy efficiency through water efficiency in the investor owned utilities' energy efficiency portfolios.

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