**CALIFORNIA
ENERGY
COMMISSION**

California's Water – Energy Relationship

Prepared in Support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

As California continues to struggle with its many critical energy supply and infrastructure challenges, the state must identify and address the points of highest stress. At the top of this list is California's water-energy relationship: water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year – and this demand is growing.

As water demand grows, so grows energy demand. Since population growth drives demand for both resources, water and energy demand are growing at about the same rates and, importantly, in many of the same geographic areas. This dynamic is exacerbated by the fact that Northern California has two-thirds of the state's precipitation while two-thirds of the population resides in Southern California. Water demand and electricity demand are growing rapidly in many of the same parts of the state stressing already constrained electricity delivery systems. When electric infrastructure fails, water system reliability quickly plummets and threatens the public health and safety.

The state water plan concludes that the largest single new supply available for meeting this expected growth in water demand over the next 25 years is water use efficiency. The remainder must be provided by the development of new water supplies including water recycling, and desalination of both brackish and seawater[1], all of which will increase energy demand over current levels.

Worse, the times when the highest energy intensity water supply options will be most needed are most likely to occur during multi-year drought periods when surface water supplies are low and groundwater levels drop, requiring even more energy for pumping each gallon of water. To compound the problem, reduced surface water supplies and snowpack in high elevations are likely to reduce the availability of valuable hydroelectric supplies. Yet, these are also the times when the most aggressive water conservation efforts are implemented, reducing overall water use, which helps reduce the total impact on energy demand. Although the net effects of this dynamic are not fully understood, this report presents current knowledge to assist with further analysis.

This is an urgent time of both challenge and opportunity. The primary finding of this paper is that a major portion of the solution is closer coordination between the water and energy sectors. A meaningful solution cannot be reached in the current regulatory environment where water utilities value only the cost of acquisition, conveyance, treatment, and delivery; wastewater utilities value only the cost of collection, treatment, and disposal; electric utilities value only saved electricity; and natural gas utilities value only saved natural gas. The state must both develop and expand best practices and existing programs to realize the substantial incremental benefits of joint water and energy resources and infrastructure management.

1 State Water Plan, B160-05.

While many nuances of this complex statewide problem are still unclear, staff's analysis shows that significant energy benefits can be reaped through the twin goals of the efficient use of water by end users and the efficient use of energy by water systems. It is also clear that not nearly enough has been done to ensure that California's water supply strategies are synchronized, hand-in-hand, with its energy strategies. Nor has enough been done to forge partnerships between the water and energy sectors so that their natural synergies, joint resources, and assets can be effectively leveraged for the benefit of all Californians.

The state has the opportunity now to reap near-term energy benefits by helping California's water and wastewater utilities become more energy self-sufficient, which will ease pressures on California's already stressed electric system. By adjusting existing policies, programs, and resources, water and wastewater utilities could be converted from high energy users to net renewable energy producers.

California's water and energy policymakers need to commit today to the joint planning and management of these critical resources. The state's water plan and resource strategies are being reviewed with all key stakeholders, and implementation plans are already on the drawing table. At the same time, the California Public Utilities Commission has approved substantial utility ratepayer expenditures in energy efficiency programs for the 2006-2008 program cycle. The state must waste no time in taking advantage of these rapidly evolving events.

The state can meet energy and demand-reduction goals comparable to those already planned by the state's investor-owned energy utilities for the 2006-2008 program period by simply recognizing the value of the energy saved for each unit of water saved. If allowed to invest in these cold water energy savings, energy utilities could co-invest in water use efficiency programs, which would in turn supplement water utilities' efforts to meet as much load growth as possible through water efficiency. Remarkably, staff's initial assessment indicates that this benefit could be realized at less than half the cost to electric ratepayers of traditional energy efficiency measures.

This staff report examines how energy is used – and how it can be saved – in the water use cycle. The strategies and goals for a comprehensive statewide water-energy program would achieve incremental energy benefits for water and energy utilities. The overarching goal of establishing a comprehensive statewide water-energy program would create a dynamic, living process where key stakeholders have incentives to continuously identify and implement strategies optimizing the state's water and energy resources and assets on an integrated, coordinated, and collaborative basis. This opportunity must not be lost since the need is so great. Because of all these factors, staff recommends that an action-oriented approach structured to achieve near-term results be developed immediately.

INTRODUCTION

The California Energy Commission's (Energy Commission) *California's Water Energy Relationship* staff report is part of the *Integrated Energy Policy Report* (*Energy Report*) proceeding. It was prepared to promote greater understanding of the critical symbiotic relationship between the water and energy sectors, especially electricity. In its scoping order, 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." [2]
- "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.[3]
- "To meet the challenge of sustainability, California's energy and environmental agencies, along with key private and public stakeholders, must work together to address critical issues that include:

  > Impacts of water demand and supply strategies, including the need for increased pumping to provide reliable water supplies, increased need for water treatment, and possible development of desalination facilities..."[4]

This report examines the dynamic give-and-take relationship between California's water and energy resources. Among many other issues, this staff report examines the state's water sector and its energy use, along with changes likely to occur in the future. The staff considered various components of the system and the energy implications, or characteristics of these components, for both energy use and generation. With the participation of a broad base of key stakeholders, the staff evaluated actions and methods that can boost the synergistic efficiencies of both the energy and water sectors. This report is meant to inform and provide technical support for decision makers, water and energy industry professionals, and the general public about critical energy supply and demand issues plaguing the state's water sector today.

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[2] California Energy Commission, Integrated Energy Policy Report Committee Scoping Order, dated September 3, 2004, p. 2.
[3] Ibid.
[4] Ibid, p.7.

This study presents the best, most updated available information on linkages between California's energy and water sectors. The process to develop this report included two public workshops, several meetings of an ad hoc working group[5] formed for the study, and interviews with scores of water professionals. This outreach included two meetings with members of the Association of California Water Agencies, which represents about 90 percent of the state's water agencies (many of which also operate wastewater treatment facilities), members of the California Municipal Utilities Association, and participation in the annual plenary of the California Urban Water Conservation Council.

The following key concepts form the basis of the analysis in this paper:

- ***Water and energy relationship:*** Refers to the types and magnitude of water and energy interdependencies requiring documentation and evaluation for various types of water resources, end uses, systems, and processes in order to fully understand the water-energy tradeoffs under different resource planning scenarios. In this report staff uses ***water and energy utilities*** when encompassing all water, wastewater, electricity, natural gas, and diesel fuel suppliers, utilities, and districts, both public and private.

- ***Water use cycle:*** Refers to the overall process of collecting, developing, conveying, treating, and delivering water to end users; using the water; and collecting, treating, and disposing of wastewater.

- ***Energy intensity:*** 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 - for example, the number of kilowatt-hours consumed per million gallons (kWh/MG) of water. This concept is applied to water supplies, to components of the water use cycle, and to the total energy intensity of a unit of water throughout the entire water use cycle.

- ***Energy self-sufficiency:*** Refers to an entity that supplies its own energy requirements. This would typically be done through a combination of energy efficiency and self-provision of power, whether purchased or produced.

- ***Integrated water and energy resource management:*** Refers to the comprehensive body of policies, practices, methods, tools, and procedures

[5] The Water-Energy Relationship Working Group consists of representatives from state water and energy-related government agencies, local and regional water agencies, industry organizations, environmental and citizen groups, and other key water professionals. It was established to help guide and critique this Staff Paper, but its life is expected to extend beyond the WER study process to work on other planning efforts, such as DWR's Water Plan process, and perhaps a planning effort related to optimization of pumped-storage opportunities in the state. The transcripts of all Water-Energy Relationship Working Group meetings on pumped-storage will be made available to the public and will become part of the record of evidence for the 2005 Energy Report.

that collectively comprise “statewide integrated water and energy resource planning and management.” Appendix A summarizes most of the existing organizations, programs, and research. Optimal integration is presently beyond the reach of both water and energy resource management best practices.

Chapter 1 describes California’s water-energy relationship – what it is and what it means within the context of California’s current energy circumstances. Chapters 2, 3, and 4 examine the primary components of the entire water cycle and address their energy intensity. Chapter 5 discusses the potential development of new renewable energy resources by water and wastewater utilities. Chapter 6 explores different types of future changes likely to affect the energy intensity of water supplies; water treatment and distribution; water end use; and wastewater treatment and disposal. Findings and recommendations are contained in Chapter 7. Appendices appearing at the end of the report provide additional detail, and a glossary of terms is included.

CHAPTER 1 - WHAT IS THE WATER-ENERGY RELATIONSHIP?

The nation's water and energy resources are inextricably entwined. Energy is needed to pump, treat, transport, heat, cool, and recycle water. On the flip side, the force of falling water turns the turbines that generate hydroelectric electricity, and most thermal power plants are dependent on water for cooling. In California, an elaborate system of manmade storage, treatment and conveyance structures exist to augment natural hydrologic features. This system not only helps produce needed electricity supplies but requires large amounts of energy to deliver quality water where Californians need and want it.

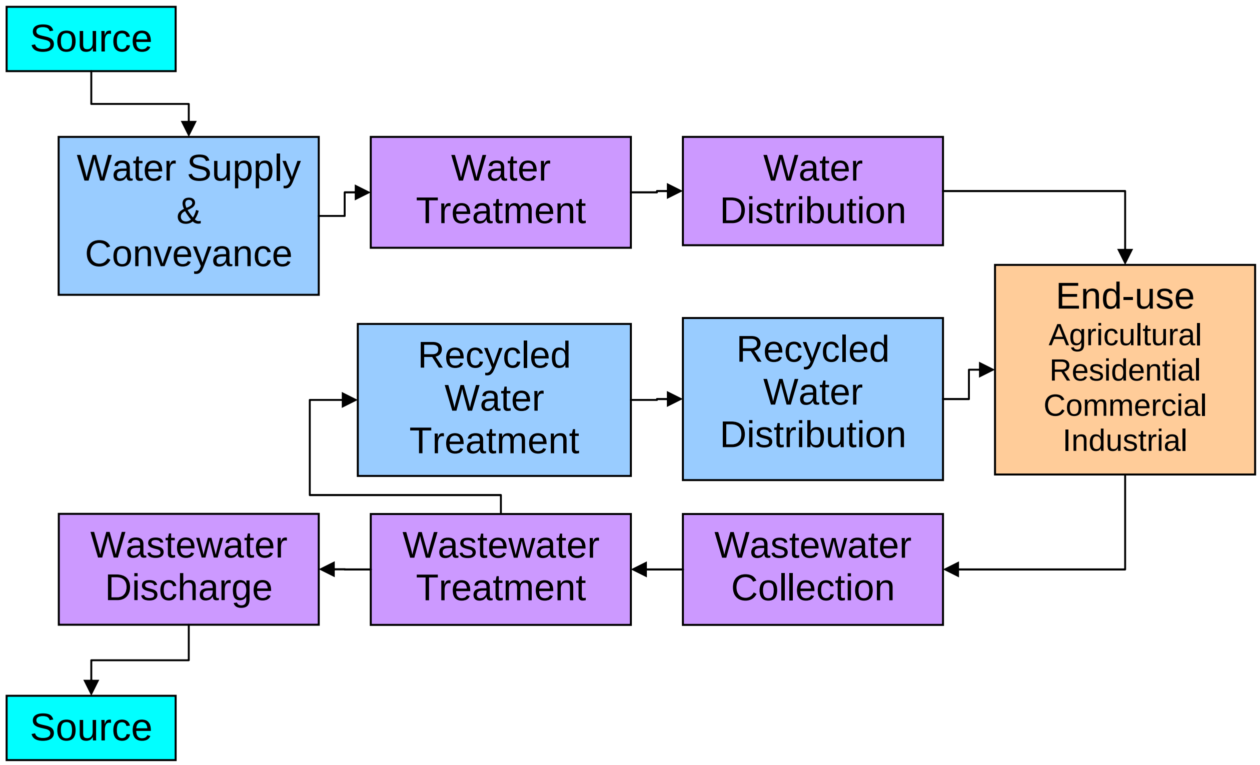
This chapter describes the overall water use cycle and introduces the concept of energy intensity. The energy intensity framework in the water use cycle helps identify opportunities for changing the pattern and magnitude of water-related energy consumption in California.

The Water Use Cycle

The Water-Energy Relationship Working Group discussed the state's water use cycle at length. While there are exceptions, Figure 1-1 illustrates the state's typical cycle.[6] Turquoise blue represents sources of water, water supplies are shown in light blue, water and wastewater treatment are shown in purple, and end use is shown in beige.

[6] This schematic is based on work by Dr. Robert Wilkinson (Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency) and on Wilkinson and Gary Wolff in current work on the energy intensity of water in California with additions by Energy Commission staff.

Figure 1-1: California's Water Use Cycle



Water is first diverted, collected, or extracted from a source. It is then transported to water treatment facilities and distributed to end users. What happens during end use depends primarily on whether the water is for agricultural or urban use. Wastewater from urban uses is collected, treated, and discharged back to the environment, where it becomes a source for someone else. In general, wastewater from agricultural uses does not get treated (except for holding periods to degrade chemical contaminants) before being discharged directly back to the environment, either as runoff to natural waterways or into groundwater basins. There is a growing trend to recycle some portion of the wastewater stream – recycled water – and redistributing it for non-potable end uses like landscape irrigation or industrial process cooling.

Water-Related Energy Use

Energy is required at all stages of the water use cycle. It is difficult to measure the amount of water-related energy that is actually consumed. Better information is available about energy consumption by water and wastewater utilities. However, energy consumption by water users is harder to determine since electric and gas meters do not separately measure water-related uses.[7]

The data presented in Table 1-1, with supporting details in Appendix B: 2001 California Energy Consumption by End Use, are based on information provided by the state's energy utilities to the Energy Commission for use in demand forecasting.[8] The Water-Energy Relationship Working Group and other stakeholders participated in extensive discussions to help staff estimate the magnitude of water-related energy consumption by water and wastewater utilities, and agricultural and urban water end users. As shown in Table 1-1, these estimates indicate that total water-related consumption is large – 19 percent of all electricity used in California, approximately 30 percent of all natural gas, and more than 80 million gallons of diesel fuel. The Energy Commission is funding a research project to refine the numbers, and results are expected in early 2006.

Table 1-1: Water-Related Energy Use in California in 2001

<table>
<tr><th></th><th>Electricity (GWh)</th><th>Natural Gas (Million Therms)</th><th>Diesel (Million Gallons)</th></tr>
<tr><td colspan="4">Water Supply and Treatment</td></tr>
<tr><td>Urban</td><td>7,554</td><td>19</td><td>?</td></tr>
<tr><td>Agricultural</td><td>3,188</td><td></td><td></td></tr>
<tr><td colspan="4">End Uses</td></tr>
<tr><td>Agricultural</td><td>7,372</td><td>18</td><td>88</td></tr>
<tr><td>Residential</td><td rowspan="3">27,887</td><td rowspan="3">4,220</td><td rowspan="3">?</td></tr>
<tr><td>Commercial</td></tr>
<tr><td>Industrial</td></tr>
<tr><td>Wastewater Treatment</td><td>2,012</td><td>27</td><td>?</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Total Water Related Energy Use</td><td>48,012</td><td>4,284</td><td>88</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Total California Energy Use</td><td>250,494</td><td>13,571</td><td>?</td></tr>
<tr><td>Percent</td><td>19%</td><td>32%</td><td>?</td></tr>
</table>

Source: California Energy Commission

The data in this table have been organized to align with the water use cycle in Figure 1-1. Water supply and treatment corresponds to the part of the water use

[7] Meters are typically installed to record all the electricity or natural gas use by an entire household, building or other type of facility.
[8] Agricultural data in this table is taken from Tables 1-4 and 1-5 in this chapter.

cycle between the source and end-user. Water supply and treatment account for 22 percent of water-related electricity consumption; 70 percent is required by urban water users and 30 percent by agriculture. On-farm agricultural water use consumes additional energy, estimated at 15 percent of water-related electricity demand. Residential, commercial, and industrial end uses combined represent 58 percent of the electricity consumed. Wastewater treatment accounts for 4 percent. The vast majority of water-related natural gas consumption is by residential, commercial, and industrial customers, primarily for heating water. Natural gas consumption in the agricultural sector is primarily for irrigation pumping. Agriculture is the only sector where diesel fuel consumption, which is also used for water pumping, is quantified. Question marks in the table indicate areas where additional information is needed.

The Energy Intensity of the Water Use Cycle

Each element of the water use cycle has unique energy intensities (kilowatt hours/million gallons (kWh/MG)). Table 1-2 illustrates the considerable variability in both the range of intensities for each segment and the components of the water use cycle. End use energy demand was excluded since the focus is on the energy requirements in the remaining conveyance, treatment, distribution, and wastewater treatment processes. Details supporting this table are in Appendix C: Energy Impact Analysis of Existing Water Management Practices.

Table 1-2: Range of Energy Intensities for Water Use Cycle Segments

	Range of Energy Intensity kWh/MG	
Water-Use Cycle Segments	**Low**	**High**
Water Supply and Conveyance	0	14,000
Water Treatment	100	16,000
Water Distribution	700	1,200
Wastewater Collection and Treatment	1,100	4,600
Wastewater Discharge	0	400
Recycled Water Treatment and Distribution	400	1,200

<u>Water Supply and Conveyance</u>

Energy intensity for this portion of the water use cycle is determined primarily by the volume of water that is transported, the distance, and the changes in topography along its route. California's water supply varies significantly with annual and seasonal hydrologic conditions, and with climate, geography, and topography. Nearly 70 percent of the state's total stream runoff is north of Sacramento, but 80 percent of the water demand is south of Sacramento. This creates challenges that policymakers have struggled to resolve for nearly a century.

The energy intensity of collection, extraction, and conveyance of raw water supplies can be near zero for gravity-fed systems from the Sierra to both urban areas in Northern California and agricultural districts in the Central Valley. However, other systems use very large pumps to transport large volumes of water hundreds of miles from points of collection to points of need. As a consequence, the energy intensity of water supplies in Central and Southern California is typically much higher than in Northern California, with Southern California the highest due to the need to transport water more than 3,000 feet up over the Tehachapi Mountains.

Water Treatment

Some sources of water need very little treatment, so their energy intensity is low. Other sources, such as brackish groundwater or seawater desalination, require much more treatment so their energy intensity is significantly higher. The energy intensity also varies depending on the intended end user. For example, most agricultural and some industrial end users can use water that requires little or no treatment, while most residential and commercial users need water treated to potable standards.

Energy use for water treatment will increase as more stringent water quality rules are implemented under the Safe Drinking Water Act and the Clean Water Act. These new rules require multi-stage disinfection - including treating potable water more than once to ensure the removal of harmful organisms that may grow during storage and transport - and improved disinfection technologies that reduce risk of carcinogens and other potentially harmful disinfection by-products. These improved disinfection technologies – principally, ultraviolet treatment and ozonation – are much more energy intensive than prior chemical methods.[9]

Water Distribution

Some fresh water distribution systems are gravity fed, but most require some pumping. The primary driver of increased energy for water distribution is urban growth.

Wastewater Collection

Some wastewater collection systems use gravity to bring the wastewater to a treatment plant. Others need energy to lift or transfer the wastewater.

Wastewater Treatment

All wastewater treatment systems require energy, though some require more than others depending on the quality of the waste stream, the level of treatment required, and the treatment technologies used. Energy use for wastewater treatment is expected to increase with adoption of more stringent water quality rules under the

[9] There may be some energy savings that are not considered here due to the reduction in needed chemicals for treatment.

Clean Water Act. However, by increasing the quality of wastewater effluent, more recycled water can be added to the state's water supply portfolio.

Wastewater Discharge
Some wastewater discharge systems use gravity to return wastewater to the environment. Others need energy to lift or transfer the wastewater.

Recycled Water and Distribution
Depending upon the level of wastewater treatment in existing facilities, the effluent may be recyclable without requiring additional treatment to displace potable water sources used for non-potable applications. More energy is needed if additional treatment is required. Most recycled water distribution systems require additional energy to pump water uphill to intended users.

As noted previously, since there are so few options to make new water, the increased use of recycled water is a major strategy in the state's water plan.

Energy Intensity in Northern and Southern California

Due to significant variations in energy used to convey bulk water supplies from one place to another, the average energy intensity of the water use cycle in Southern California is much higher than in Northern California. This is due to the fact that Southern California imports about 50 percent of its water supplies from the Colorado River and from the State Water Project (SWP) – each of which is more energy intensive than any single source of water supply used in Northern California.

Table 1-3 shows the combined energy intensity of the water use cycle for typical urban communities in Northern and Southern California. Details supporting this table can be found in Appendix C.

Table 1-3: Electricity Use in Typical Urban Water Systems

	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	150	8,900
Water Treatment	100	100
Water Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700
Values used in this report	4,000	12,700

Staff recognizes that no two water treatment, distribution, or wastewater treatment systems are identical, so the relative energy intensities reflected above are prototypical. However, within these processes, variability is lower in magnitude than with conveyance and is not linked to a north/south differentiation. The primary north/south regional variation that causes the state's unique and important water energy dynamic is linked to the magnitude of energy required to convey Northern California water supplies to Southern California.

On average, water conveyance requires more than 50 times the energy for Southern California than it does for Northern California. This is also five times the national average. Southern California depends heavily on water imports from the Colorado River and from Northern California. This water travels hundreds of miles through pipelines and aqueducts and, in some places, must be pumped over mountain ranges before reaching its destination. Conversely, 40 percent of Northern California's population is served by gravity-fed systems, with the balance supplied by surface supplies or relatively shallow wells. Recognizing that the actual energy intensity in each component of the water use cycle will vary by utility, the energy values reflected above appear to be reasonable and conservative. This paper assumes that 4,000 and 12,700 kWh per million gallons are consumed for water that is supplied, treated, consumed, treated again, and disposed of in Northern and Southern California, respectively.

Water End Use Energy

California uses about 14 trillion gallons of water in a normal year, with about 79 percent used for agriculture and the remainder in the urban sector. Once water is delivered, customers use it in a variety of applications. Combined agricultural, residential, commercial, and industrial water-related end uses account for 58 percent of all water-related electricity and 99 percent of water-related natural gas use.

Agriculture

Agricultural water use can be both energy intensive, requiring extensive pumping and, in some cases, treatment; but it can also be essentially energy-free, using gravity alone to flow raw surface water onto fields. Each year, California's agricultural sector uses roughly 34 million acre-feet of water to grow food and fiber commodities. It takes more than 10,000 GWh of electrical power to pump and move this water. The energy is used by large state and federal water projects, by irrigation districts, and by on-farm requirements, as outlined in Table1- 4 below.

Table 1-4: Energy Consumed in Agriculture for Water

Category	Energy Consumption (GWh)[1]
Conveyance to Irrigation Districts by the State and Federal water projects[2]	1,720
Conveyance to Irrigation Districts by the Western Area Power Administration	400
Irrigation District surface water pumping	822
Irrigation District ground water pumping	246
On-farm ground water pumping	4,499
On-farm booster pumping[3]	2,873
Subtotal	10,560
Electric equivalent for diesel and natural gas engine driven water pumping[4]	1,231
Total	11,791

[1]Values shown in this table only include agricultural water pumping to meet crop applied water demands. Other agricultural water uses not included in this table include water used for livestock and food processing that is not considered to be commercial. Source: California Agricultural Water Electrical Energy Requirements, ITRC Report No. R 03-006, Irrigation Training and Research Center, 2003 http://www.itrc.org/reports/cec/energyreq.html
[2] Energy used to pump surface water through state and federal water projects to supply irrigation and water districts.
[3]This includes groundwater and surface water pumping to supply pressurized irrigation systems such as sprinkler, drip, and micro spray.
[4]Diesel and natural gas are the second and third most prevalent energy sources used to pump agricultural water. These sources are used to run engines that directly run the water pumps, typically for on-farm groundwater and booster pumping. Emissions requirements typically prevent the use of diesel for pumping in irrigation districts.

The numbers in Table 1-4 represent energy consumption for a typical weather or water year. These numbers will change with different water year scenarios. For example, during a wetter-than-average year with larger surface water deliveries, the energy used for groundwater pumping will decrease. During a period of several back-to-back dry years, a significant amount of additional energy will be used because of increased on-farm groundwater pumping.

In general terms, the electricity used for water represents more than 90 percent of the total electricity used for crop production in the agricultural sector. This applies mostly to field crops, but also to the state’s fruit and nut trees and vineyards.

Dairy farms use electricity and other fuels for pumping water for crops, heating water for cleaning and disinfecting barns, and transporting wastewater for lagoon disposal and aerators. Most of the remaining electricity is used for milking equipment and refrigeration. Fans are also used for animal cooling. Greenhouses and nurseries use electricity and other fuels for watering crops, ventilation, and heating. Other agricultural on-farm electricity use goes to food processing including washing, packaging, and refrigeration. However the majority of food processing is in large-scale processing facilities typically classified as industrial. Their energy requirements are discussed in the section describing industrial water users.

Although most agricultural electricity use is during the summer months, there are many year-round operations including dairies, nurseries and greenhouses, feedlots, and other animal production farms.

As shown in the previous table, diesel and natural gas are also used to pump water. Table 1-5 provides an estimate of the breakdown between diesel and natural gas used for agricultural water use in California (Cal Poly 2003).

Table 1-5: Estimates for Diesel and Natural Gas Engine Driven Water Pumping in California Agriculture

Type	Number of Engines[1]	Fuel Required	Conversion to kWh[2]	Equivalent Electricity (GWh)
Natural Gas	1,932	17.5 Million Therms	6.76 kWh/Therm	118
Diesel	12,535	88 Million Gallons	12.8 kWh/gallon	1,113
Totals	14,467			1,231

[1] These data were generated by Cal Poly ITRC during the analysis for the *California Agricultural Water Electrical Energy Requirements Report* (2003). However, it was not published in that report (Cal Poly ITRC unpublished data, 2005). It was subsequently submitted as testimony in the June 21, 2005, IEPR workshop.

[2] The total number of diesel-and natural gas-engine-driven water pumps was obtained from the 2003 USDA Farm and Ranch Irrigation Survey. In comparison, the estimate used for the 2005, AG-ICE proceeding with the CPUC (A.04-11-007/008) provided by the California Air Resources Board (CARB) reported about 8200 diesel driven irrigation pumps. The estimate from CARB is low compared to the USDA survey. We chose the USDA data because they survey more farms throughout California [http://www.nass.usda.gov/census/census02/fris/tables/fris03_20.pdf].

[3] The conversion from kWh to therms and gallons of diesel is based on the Nebraska Performance Standards for Irrigation Energy Sources (Source: Dorn, T.W., P.E. Fishbach, D.F. Eisenhauer, J.R. Gilley, and L.E. Stateson, *It Pays to Test Your Irrigation Pumping Plant*. Publication EC-713. Lincoln: University of Nebraska, Cooperative Extension Service).

Changes to air quality regulations in agricultural regions will likely lead to conversion of many of these pumps, primarily the diesel-powered ones, to electric pumps. If they were all converted to electric, this would increase the electric requirements of the agricultural sector by more than 10 percent. Although the total number of potential conversions is limited by regulation and available program incentives, the state's planners and electric utilities will need to account for and supply the additional peaking capacity and electricity needed for these pumps. This is discussed in more detail in Chapter 4.

Residential, Commercial and Industrial

Staff has only recently focused on water-related energy consumption in the residential, commercial, and industrial sectors, collectively referred to as urban water users. Table 1-6 presents the aggregated data for each sector. Detailed information can be found in Appendix B.

Table 1-6: End-Use Energy Associated with Urban Water Users

Sector	Electricity (GWh)	Natural Gas (Million Therms)
Residential	13,528	2,055
Commercial	8,341	250
Industrial	6,017	1,914
Total	**27,887**	**4,220**

Source: California Energy Commission

The residential sector accounts for 48 percent of both the electricity and natural gas consumption associated with urban water use. Residential water uses include personal hygiene (shower, bath, sink), dish and clothes washing, toilets, landscape irrigation, chilled water and ice in refrigerators, and swimming pools and spas. Residential energy uses related to these activities include water treatment (filtering and softening), heating (natural gas or electric water heaters), hot water circulation loops, cooling (icemakers and chilled water systems for HVAC and chilled drinking water), circulation (spa pumps, as one example), and, in some cases, the groundwater pumping of private wells.

Commercial water-related energy use represents 30 percent of the electricity and 6 percent of the natural gas use. Industrial water-related energy use represents 22 percent of the electricity and 45 percent of the natural gas. Commercial and industrial water uses include all those found in residences, plus hundreds more. Some of the more energy-intensive applications related to commercial or industrial water use include high-rise supplemental pressurization to serve upper floors, steam ovens and tables, car and truck washes, process hot water and steam, process chilling, equipment cooling (x-ray machines, for example), and cooling towers. In the commercial sector, the major water-related end uses that use electricity are cooling and water heating. Cooling towers for air conditioning are large water users. In the industrial sector, water-related energy use is very dependent upon specific processes. Except for oil and gas extraction, no single industrial category stands out as a major user of electricity or natural gas. Water heating and process heating are the largest users of natural gas.

In general, urban water use in California is more energy intensive than agricultural water use. This is because every urban water system requires energy for water and wastewater treatment, both of which are not generally required for agriculture. The vast majority of urban water systems also require energy for distribution.

Hydropower Production, Energy Recovery, and Renewable Resources

Hydropower

The most widely recognized aspect of the water-energy relationship is hydropower production. As discussed in Chapter 2, California is served by a vast system of reservoirs and dams, pumped storage, and run-of-river facilities. These facilities are operated by investor-owned utilities (IOU), publicly owned utilities (POU), state and federal agencies, irrigation districts, and other entities, mostly to serve multiple purposes including power generation, water supply, recreation, and flood control. California's hydropower system provides valuable peaking reserve capacity, spinning reserve capacity, load following capacity, and transmission support, all at low production costs.[10] California's combined total hydroelectric capacity is more than 14,000 megawatts (MW)[11] or about one-quarter of the in-state generation capacity. Hydro-generated energy was about 29,000 GWh, or 13 percent of the in-state generation in 2004.[12] The state has conducted extensive studies on traditional hydropower, both in the contexts of its value to the California electric system and issues relating to environmental impacts. Staff refers the reader to these existing reports reference herein, all of which are available on the Energy Commission's Web site.

[10] California Energy Commission Staff Report, *California Hydropower System: Energy and Environment*, Appendix D, *2003 Environmental Performance Report*; prepared in support of the Electricity and Natural Gas Report under the Integrated Energy Policy Report Proceeding (02-IEP-01), October 2003 [Publication 100-03-018].
[11] California Energy Commission, *2003 Environmental Performance Report*. Appendix D, *California Hydropower System: Energy and Environment*, Sacramento, CA. 100-03-018, March 2003, p. D-6.
[12] California Energy Commission, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States*, June 2005, consultant report, Prepared in support of the *2005 Integrated Energy Policy Report*, Publication No. CEC 700-2005-010.

Energy Recovery from the Water Use Cycle

In-Conduit Hydropower

The state's large water conveyance projects already take advantage of the energy in the water flowing through their pipelines. Wherever there is flowing water, there exist both energy and the potential to capture and utilize that energy. Pipelines that convey water supplies by gravity have energy that could be captured, but care must be taken to make sure that sufficient 'head', or force, remains to carry the water to its final destination. Wherever pressure-reducing valves or stations are used to reduce the energy in moving water, there is an opportunity for energy production. At any point in a water or wastewater system where influent is delivered for treatment or wastewater effluent is discharged, there may be further opportunities for power production. Barriers and challenges to additional development of in-conduit hydropower that recovers energy from the water delivery and conveyance process are discussed in more detail in Chapter 5.

Biogas

Another option for developing generation in the water sector is to increase beneficial use of digester gas produced by the sewage wastewater, dairy manure, and food processing wastes/wastewater. Biogas, composed primarily of methane, can be used for combined heat and power (CHP) production.

California has 311 sewage wastewater treatment facilities, 2,300 dairy operations, and 3,000 food processing establishments. Currently, about 50 percent of sewage sludge, 2 percent of dairy manure, and less then 1 percent of food processing wastes/wastewater generated in the state are used to produce biogas. Converting these wastes into energy can help operating facilities offset the purchase of electricity and provide environmental benefits by reducing discharged air and ground water pollutants.

The Energy Commission is working with Commerce Energy Inc. and Inland Empire Utility Agency (IEUA) to develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks (sewage sludge, food processing wastes, and dairy manure) and gas production.

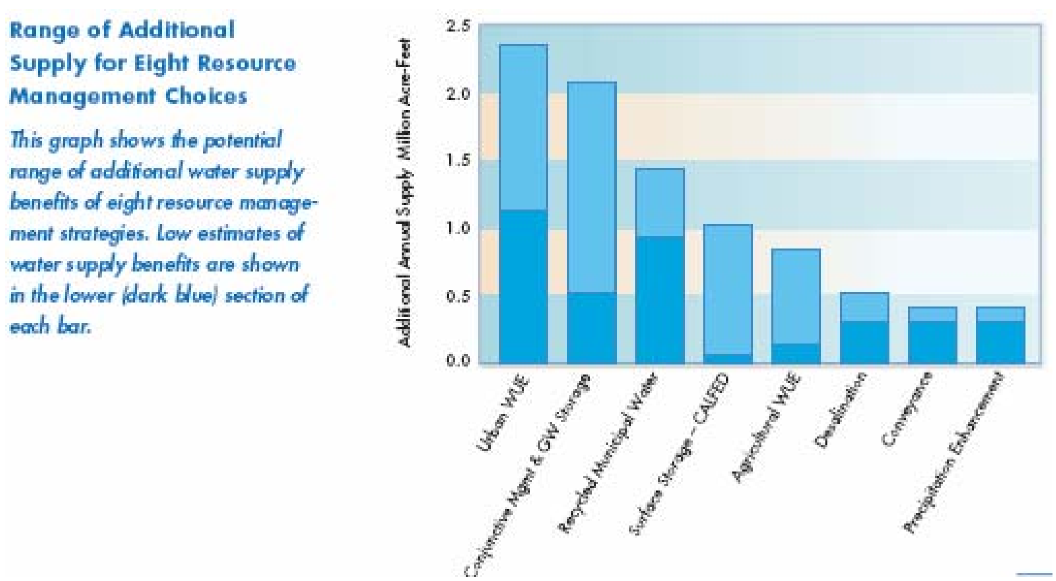
Other Renewable Energy Resources

Water and wastewater agencies typically have very large landholdings with characteristics that readily lend themselves to the development of renewable resources, especially wind and solar. These resources could be used to help California meet its aggressive Renewable Portfolio Standard (RPS) goals. For example, regional water and wastewater agencies have hundreds of miles of rights-of-way, often in areas suitable for solar production. These agencies also have watershed lands that collect water for end-use applications, either potable or for agricultural or industrial use. In order to protect the water quality, large portions of these watershed lands are inaccessible to public recreational use. Many are remotely located, which make their visual impact of little public concern. Watershed lands are also at higher elevations, where wind resources are typically of fairly good quality. Some wastewater utilities also have extensive lands, which are used to dispose of treated effluent and are inaccessible to the public. Municipal or governmental control over these lands could accelerate their use as sites for renewable energy generation

A Loading Order for Water Resources

The *California Water Plan Update 2005,* prepared by the Department of Water Resources (DWR), established a strategic plan that prioritized resource measures to meet new load growth and other water supply challenges. As shown in Figure 1-2, first among the strategies is increased urban water efficiency. Appendix D provides an excerpt of the plan from the Water Plan Update. Thereafter, the plan depends upon increased reliance on conjunctive management and groundwater, followed by recycled water. Agricultural water use efficiency is also an important strategy.

Figure 1-2: New Water Supplies for California



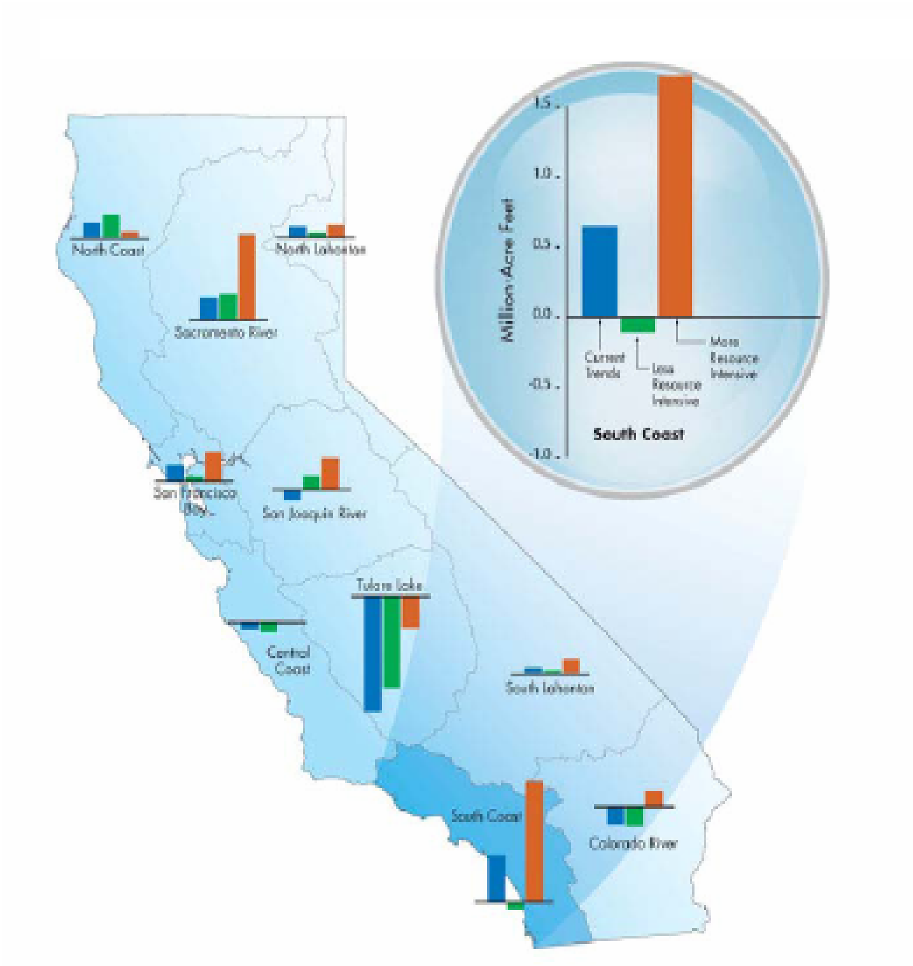
Source: *2005 State Water Plan Update*, DWR.

In many respects, the *2005 Water Plan Update* mirrors the state's adopted loading order for electricity resources described in the Energy Commission's *Integrated Energy Policy Report 2005* and the multi-agency *Energy Action Plan*. The first three strategies all concern the efficient use of existing resources. These strategies encompass efficient use, efficient operations and management, and efficient reuse. Including agricultural water use efficiency, the state's water resources strategy targets will meet 70 percent of future growth in water demand through efficiency measures.

This is a very important concept. Specifically, like energy utilities, water utilities already apply integrated resource planning tools and techniques in their future plans. Similar to energy utilities, they also already apply strategies of "least-cost, best-fit." Thus, in order to optimize the state's water and energy resources on an integrated basis, the primary concept that needs to be integrated into California's water planning on the supply side is the energy intensity of various water supply options. On the demand side, the primary concept is recognition of the energy embedded in various types of water end use throughout the entire water use cycle. Just as energy efficiency increases available supplies and avoids incremental infrastructure costs and environmental impacts, every unit of water not consumed can displace a more energy-intensive water source.

In many cases, the areas of the state that are most stressed with respect to water supplies are also areas with transmission congestion and shortages of local energy supplies. Not surprisingly, since load growth is largely driven by population growth, the geographic areas most resource constrained are the same for both water and for energy. Figure 1-3 shows the projected water demand as estimated by DWR for three different future scenarios and demonstrates the sizable gap between the less and more water-resource-intensive projections. This makes a compelling case for close coordination between water and energy planning and synchronization of both resources and infrastructure goals.

Figure 1-3: Net Change in Average-Year Water Demand for 3 Scenarios by Region, 2000-2030

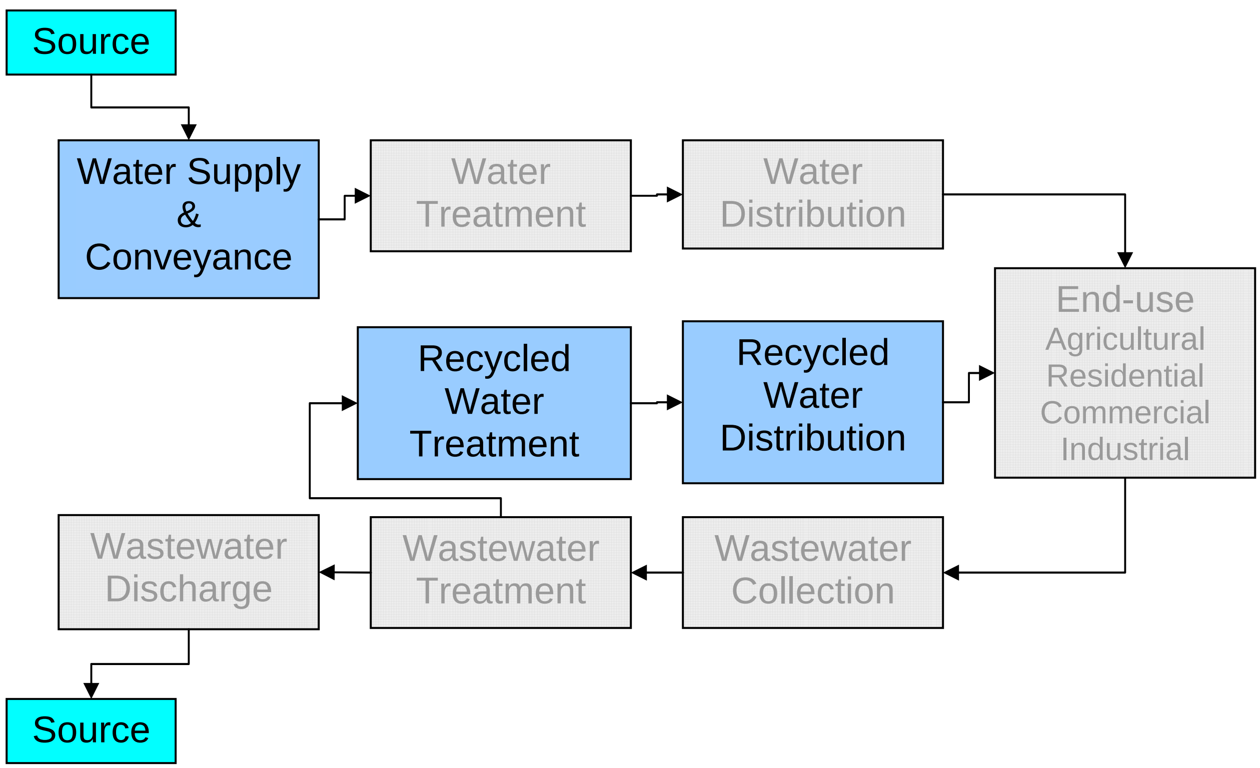


Source: *2005 State Water Plan Update*, DWR.

CHAPTER 2 – WATER SUPPLY AND CONVEYANCE

This section discusses the energy intensity of different water supply sources, all the way through the cycle to conveyance for water treatment. Recycled water, a by-product of wastewater treatment, is also discussed here as an additional source of supply.

Figure 2-1: Water Use Cycle - Supply Source



Primary Sources of California Water

Californians collectively use about 43 million acre-feet (about 14 trillion gallons) of developed water for urban and agricultural use in a normal year. Of this total, 34 million acre-feet go to agriculture (about 11 trillion gallons and 79 percent) and 9 million acre-feet (about 3 trillion gallons and 21 percent) go to the urban sector.[13]

Understanding the energy implications of water use in California requires a basic knowledge of the various water systems that collect, store, and transport water

[13] DWR *2005 Water Plan Update* Volume 1, Table 3-1.

supplies. These supplies can be roughly categorized as surface water, groundwater, desalted water, and recycled water.

- Surface water comes from precipitation, rain and snow, captured and stored in natural lakes and streams, and manmade reservoirs, canals or aqueducts. Most surface water storage is fed from runoff coming from the state's large mountain ranges. The greatest source of surface water supplies is the Sierra snowpack, which holds more water than all of the state's lakes and reservoirs put together, and conveniently melts during the warmer and drier months when California most needs water.

- Groundwater is precisely that – water stored in the ground. Rain directly irrigates farms and gardens but also feeds groundwater basins and aquifers.[14]

- Recycled water, also known as "reclaimed" water or "reuse", is water produced from wastewater effluent. Water quality regulations specify approved uses for recycled water. The level of use depends upon the level of wastewater treatment applied.

- Ocean or brackish water is used for some industrial purposes but must be treated to remove salts and dissolved solids (desalted) for agricultural and urban purposes.

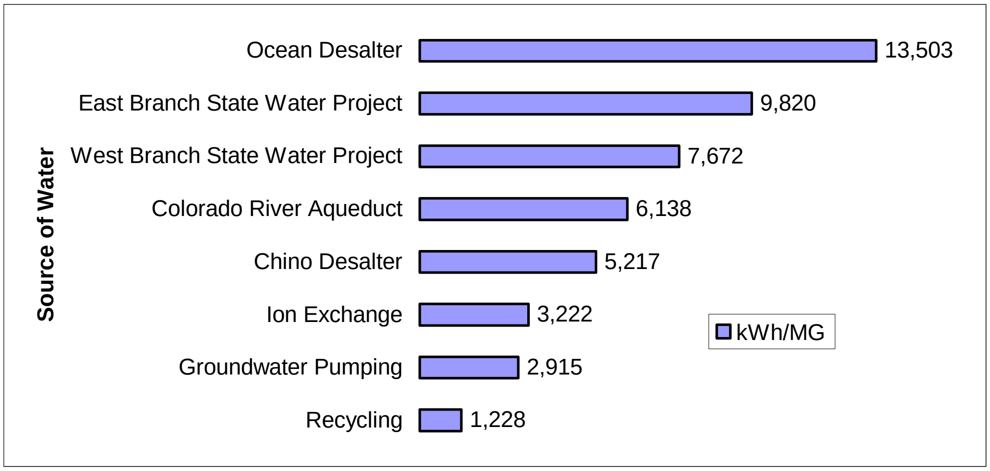
According to DWR's *2005 Water Plan Update*, surface water accounts for more than 60 percent of the state's water use in a typical hydrology year. Groundwater accounts for about 30 percent, although this is highly variable since groundwater makes up most of the state's water supply shortages in dry years. Use of desalted and recycled water, while still a very small percentage of California's total water supply portfolio, is increasing -- both as a means to supplement limited water supplies and provide a hedge against drought risk.

The Energy Intensity of Water Supplies

Every source of water has a different energy intensity. Figure 2-2 shows the relative energy intensity of water supply options for one Southern California regional water and wastewater utility, the Inland Empire Utilities Agency (IEUA).

[14] An aquifer is a body of permeable rock that can contain or transmit water.

Figure 2-2 Energy Intensity of IEUA Water Supply Options



Source: Dr. Robert Wilkinson, Environmental Studies Program, University of California, Santa Barbara, and Martha Davis, IEUA.

Of the above IEUA options, the East Branch State Water Project source is second only to ocean desalination in energy intensity. Recycled water is the least energy-intensive supply option. The relative energy intensity of supply options varies for each water utility, depending upon the nature and characteristics of its water supplies.

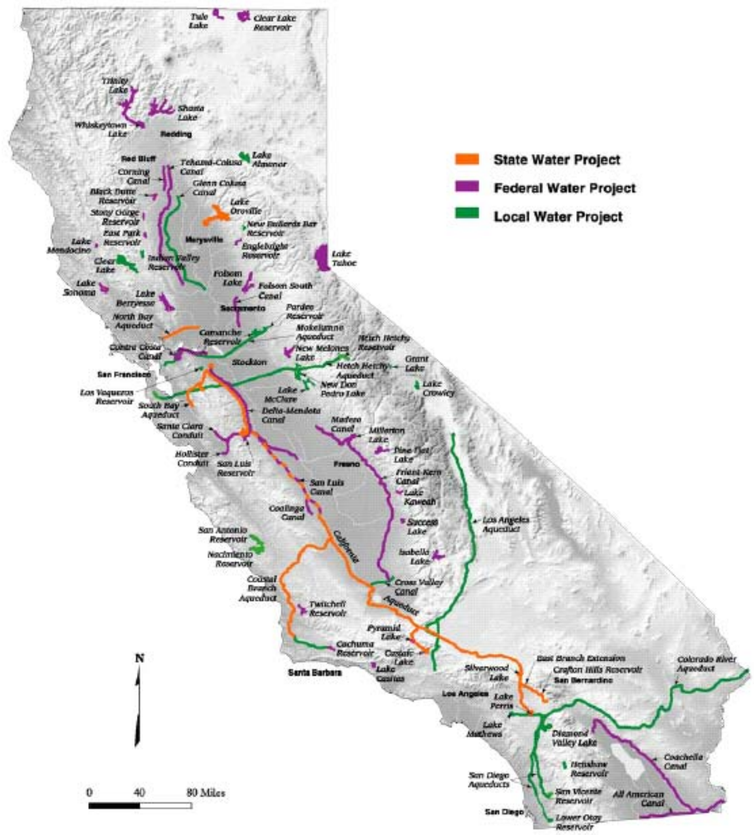
The sections below describe the relative energy intensities of various water supply sources. This concept is important to the discussions in the following chapters since the energy intensity of supply is the most significant sector in which near-term action can positively affect the state's energy circumstances.

Surface Water

The energy intensity of surface water supplies is mainly in the conveyance of raw water for either agricultural and some industrial uses or to treatment facilities for potable urban water use.

California's water supply varies significantly with annual and seasonal hydrological conditions, as well as geography and topography. The major water sources are in Northern California, while the major urban centers and agricultural lands are in the Northern Bay Area, Central Valley, and Southern California. Surface water conveyance systems were built to balance statewide water supplies with demands. These conveyance systems were designed to move water to areas of need outside the basin in which water is collected. This process – known as "interbasin transfers" – accounts for most of the energy embedded in California's surface water supplies. The energy intensity of various interbasin transfers depends on the distance and elevation over which the water must travel. The map in Figure 2-3 shows the state's interbasin transfer systems.

Figure 2-3 Interbasin Transfer Systems in California



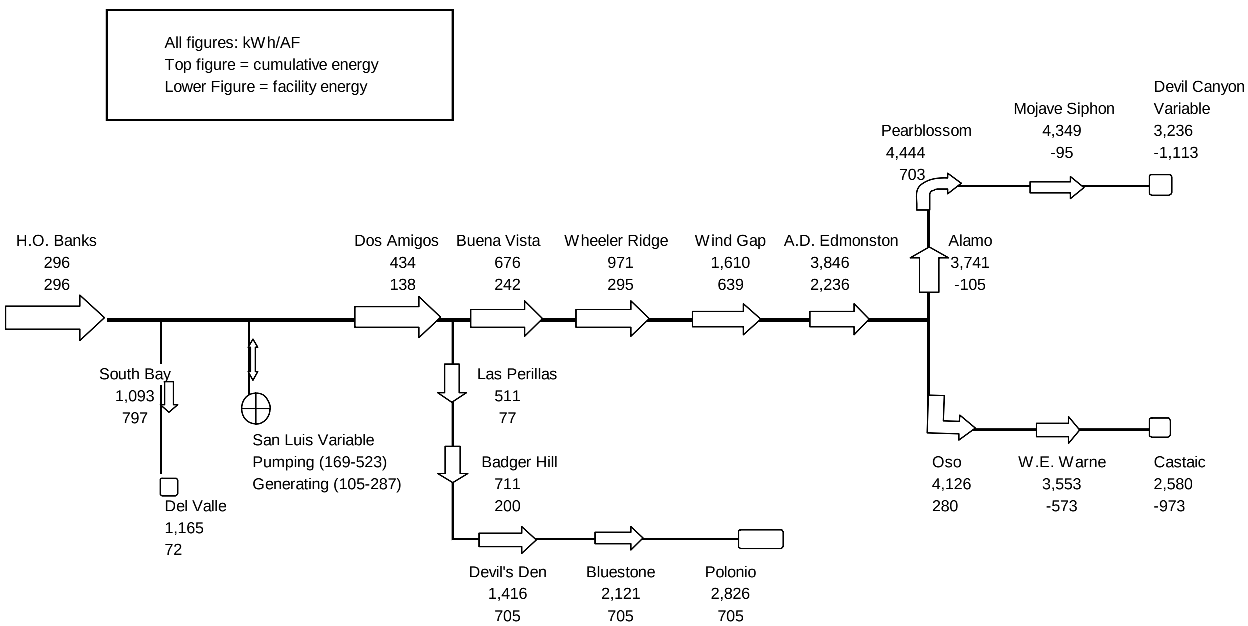
Source: *2005 State Water Plan Update*, DWR.

It is the pumping of this water that accounts for the relative energy intensities of different surface water sources. Note that some systems originate in mountain ranges and use gravity to naturally deliver water to points of need. These systems use very little energy. Other systems must transport water long distances on relatively flat valley floors. The State Water Project must also pump water more than 3,000 feet over the Tehachapi range to reach end users in Southern California.

SWP, the largest state-built multipurpose water project in the U.S., was planned, designed, built, and is now operated and maintained by the DWR. The SWP was constructed for the primary purpose of transporting water from Northern California to arid areas, both agricultural and urban, in Central and Southern California. The SWP delivers water to 29 water agencies and irrigation districts, which then distribute the water to 20 million people and 900,000 acres of crops. SWP water is distributed about 50/50 to agricultural and urban water uses.[15]

The elevation diagram below (Figure 2-4) illustrates the relative energy intensity of delivered SWP water at various points along the California aqueduct. The numbers are shown in kilowatt-hours per acre-foot (kWh/AF). They include transmission losses and, where applicable, energy recovery.

Figure 2-4: State Water Project Pumping Energy



Source: Dr. Robert Wilkinson, PhD, University of California, Santa Barbara, based on DWR data.

Depending on the point at which SWP water is delivered, the embedded energy may range from a low of 676 kWh/AF (676 x 1,000,000 gallons/325,851 gallons/AF = 1,330 kWh/MG) at Dos Amigos, to a high of 3,236kwh/AF (9,930 kWh/MG) at Devil Canyon.

Many of the state's interbasin transfer systems also have significant hydroelectric generation. The Central Valley Project, the East Bay Municipal Utility District's (EBMUD) Mokelumne Aqueduct, and San Francisco's Hetch Hetchy Regional Water System, are all net energy producers. Despite its significant hydroelectric capacity, the State Water Project is a net energy consumer. The Colorado River Aqueduct is also a net energy consumer in California, although the project itself includes significant federal hydroelectric projects on the Colorado River.

[15] Presentation by Bill Forsythe, DWR, to Committee Workshop January 14, 2005.

Groundwater Sources

Groundwater supplies about 30 percent of the state's water needs on average but as much as 60 percent during times of severe drought.

Several hundred million acre-feet of water are stored in 450 groundwater aquifers in the state, compared with approximately 45 million acre-feet in California's 1,200 surface water reservoirs.[16] These aquifers are recharged either naturally or artificially. Natural recharge generally consists of runoff that percolates into the soil, or migration of surface water through a lake or streambed. Almost all of the 450 groundwater aquifers in the state are in decline or overdrafted, forcing users of that water to pump from greater and greater depths, requiring greater amounts of energy in the process.

The process of artificially storing groundwater for future withdrawal is known as aquifer storage and recovery (ASR). Closely related to ASR are "conjunctive use" and "artificial recharge," terms that are often used interchangeably. Water agencies around the state store water in aquifers for both daily and seasonal use and for emergency drought supplies. In general, surplus water is pumped into wells or allowed to percolate into aquifers from ponds and lakes, then pumped from wells when needed.[17]

Less is known about groundwater than about any other water source. This is because each groundwater basin is unique and production characteristics of wells are often interlinked. Since groundwater use is largely unregulated, the actual quantity of energy used for groundwater pumping statewide is also not readily determinable.[18]

In a 2003 study, the Electric Power Research Institute (EPRI) estimated national averages ranging from 700 to 1,800 kWh/MG, depending on use and customer sector.[19] Dr. Robert Wilkinson, director of Water Policy Program at the Bren School of Environmental Science and Management, University of California, Santa Barbara, estimated 2,915 kWh/MG, for groundwater pumping in the Chino Basin.[20] This number reflects the fact that the groundwater aquifers in Southern California, where the Chino Basin is located, are relatively deep compared to those in the northern and central part of the state.

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[16] ACWA Water Facts website.
[17] USGS 2005, Introduction to Aquifer Storage and Recovery, [http://ca.water.usgs.gov/issues/6.html].
[18] Hundreds of thousands of groundwater wells are privately owned, and serve residences, farms, businesses, and small water systems. The electricity used for pumping from private wells is often not separately metered and is not captured in the Energy Commission's and electric utilities' energy use data.
[19] "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century", EPRI Topical Report, March 2002.
[20] Dr. Robert Wilkinson's presentation to the January 14, 2005 *Energy Report* Committee workshop.

It is reasonable to expect wide variability in the energy intensity of different groundwater sources, depending upon both the depth at which the groundwater resides and the efficiency of the pumps and motors used to pump it. In the context of energy intensity and benefits to the state, the primary benefit of groundwater is its ability to offset the high energy intensity of SWP deliveries in the fall. In Southern California, some water agencies already pump groundwater during the summer and recharge aquifers with SWP imports during the non-summer months. Even at the upper end of energy intensity, using local groundwater supplies to defer summer deliveries of SWP water to Southern California results in significant energy and reliability impacts for the state overall.

Ocean and Brackish Water

Treating ocean or brackish water -- desalination -- began in California in 1965. In 1999, there were 30 desalting plants operating in California for municipal purposes, with total capacity of 80,000 acre-feet per year. Table 2-1 illustrates the expected growth in desalination in California.[21] If all of the planned new capacity is built, total production of desalination will increase from about 80,000 acre-feet per year to nearly 600,000 acre-feet.

Table 2-1: Desalting in California for New Water Supply

	Plants in Operation		Plants in Design & Construction		Plants Planned or Projected	
Feedwater Source	No. Of Plants	Annual Capacity	No. Of Plants	Annual Capacity	No. Of Plants	Annual Capacity
Groundwater	16	79,100	6	29,500	6	61,700
Seawater	7	1,500	1	300	13	415,100
Total	23	80,600	7	29,800	19	476,800
Cumulative			30	110,400	49	587,200

1. Capacity in Acre-feet per year. No. of Plants is the number of new plants.
2. Design & Construction – Construction underway or preparation of plans and specifications has begun for new plants or plant expansions.
3. Planned – Planning studies underway for new plants or plant expansions.
4. Projected – Projected new plants or plant expansions.
5. Sources: "Water Desalination Report" and Worldwide Desalting Plants Inventory series by International Desalination Association as cited in the DWR Bulleting 160-05.

Source: 2005 State Water Plan Update, DWR

[21] *California Water Plan Update 2005* Volume 2, Resource Management Strategies, Chapter 6 Desalination.

Recycled Water

The fastest growing new source of water in the state is not a new source at all; it's recycled water from wastewater systems, commonly referred to as reclaimed water or reuse. Californians have used recycled water since the late 1800s. Faced with increasingly stringent requirements governing disposal of wastewater and limited water supplies, many agencies are installing additional treatment facilities that can purify wastewater to the point where it can be substituted for fresh water in many applications, including power plant cooling and landscape irrigation.

The primary benefit of increasing the use of recycled water, from an energy perspective, is the displacement of other, more energy-intensive water supplies.

- By using local recycled water to recharge depleted groundwater aquifers in Southern California, the amounts of energy-intensive seawater desalination and SWP imports could be reduced.

- When recycled water is distributed to local end users for landscape irrigation, significant energy savings accrue:

  - First, from displacing the energy intensity of the highest marginal water source.

  - Second, from avoiding the energy used to treat the water unnecessarily to potable water standards.

Since recycled water is often a by-product of existing secondary and tertiary wastewater treatment processes, it is the least energy-intensive source in the state's water supply. While incremental energy is typically required to pump recycled water uphill to redistribute it to end users, this incremental energy is offset in part or in whole by displacing higher energy intensity water supplies, as well as reducing potable water treatment and distribution.

The actual net energy benefit of any proposed project also needs to consider the incremental energy that might be needed to treat the wastewater to higher standards than normal, such as targeted end use water quality requirements. Table 2-2 describes the level of treatment needed for different types of reuse.

Table 2-2: Demand Sectors and Minimum Treatment Levels

Demand Sectors and Examples of Minimum Treatment Levels for Specific Uses to Protect Public Health

Types of Use	*Treatment Level*		
	Disinfected Tertiary	*Disinfected Secondary*	*Undisinfected Secondary*
Urban Uses and Landscape Irrigation			
Fire protection	☑		
Toilet & urinal flushing	☑		
Irrigation of parks, schoolyards, residential landscaping	☑		
Irrigation of cemeteries, highway landscaping		☑	
Irrigation of nurseries		☑	
Landscape impoundment	☑	☑*	
Agricultural Irrigation			
Pasture for milk animals		☑	
Fodder and fiber crops			☑
Orchards (no contact between fruit and recycled water)			☑
Vineyards (no contact between fruit and recycled water)			☑
Non-food bearing trees			☑
Food crops eaten after processing		☑	
Food crops eaten raw	☑		
Commercial/Industrial			
Cooling & air conditioning - w/cooling towers	☑	☑*	
Structural fire fighting	☑		
Commercial car washes	☑		
Commercial laundries	☑		
Artificial snow making	☑		
Soil compaction, concrete mixing		☑	
Environmental and Other Uses			
Recreational ponds with body contact (swimming)	☑		
Wildlife habitat/wetland		☑	
Aquaculture	☑	☑*	
Groundwater Recharge			
Seawater intrusion barrier	☑*		
Replenishment of potable aquifers	☑*		

**Restrictions may apply*

Source: DWR's Water Facts 23 issued October 2004.

In most circumstances, from an energy perspective, recycled water made as a by-product of the wastewater treatment process is the most preferred option. Primary barriers to increasing the use of recycled water include the incremental cost of dual piping systems to deliver this source of non-potable but usable water and public apprehension about using water recovered from the sewage treatment process.

The Energy Intensity of the Water Resource Portfolio

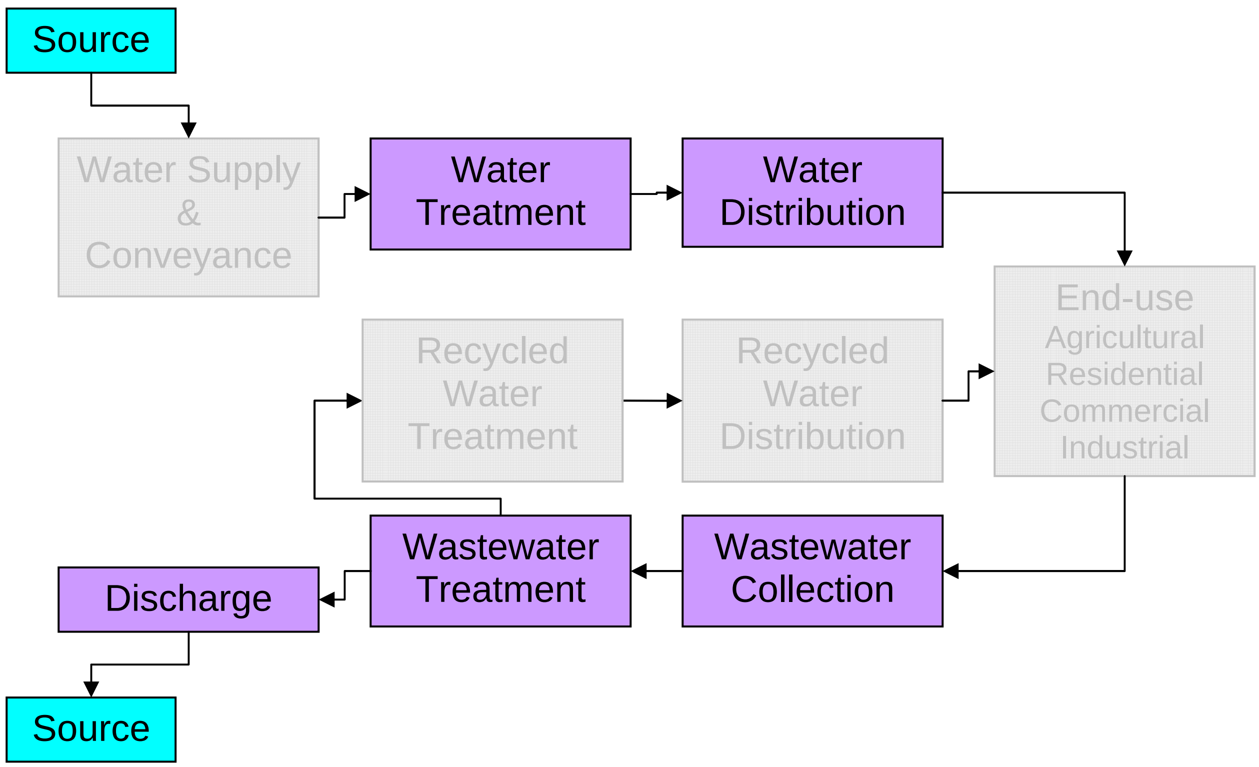
Ultimately, all of these resource choices come together in a water utility's water resource portfolio. Similar to energy utilities, water utilities conduct integrated resource planning (IRP) on a "least cost/best fit" basis. Since energy is typically the highest cost of water supply resources, embedded energy in delivered water supplies is generally reflected in the preferred loading order of water resources in the state's *2005 Water Plan Update.* Using water more efficiently frees up current resources to meet some of the future demand growth.

This is particularly critical in Southern California, where its water mix is roughly half from local sources, and half from imported sources. While water utilities are working hard to develop more local supplies and improve water use efficiency, there are not many options to develop new water sources. Presently, the primary available options are recycled water and seawater desalination.

CHAPTER 3 – WATER AND WASTEWATER TREATMENT AND DISTRIBUTION

This section will discuss, due to their similarities, both the energy intensity of potable and waste water treatment and distribution and the distribution of recycled water.

Figure 3-1: Water Use Cycle – Treatment and Distribution



Energy use for water distribution loads is primarily for pumping water and maintaining sufficient pipe pressure to assure that flows can be made at scheduled rates while maintaining sufficient pressure for fire service.

Water and wastewater treatment processes also use large quantities of energy. In water treatment, energy requirements depend primarily on the characteristics of the raw water, plant size, treatment process, and the distance and elevation of the treatment plant in relation to water sources and water distribution systems. In wastewater treatment, the characteristics of the influent and the level of treatment (primary, secondary or tertiary) are principal drivers of energy consumption.

Electric loads at water and wastewater treatment plants consist primarily of pump motors but also include air blowers, injection equipment, controls, lighting, and, in some cases, ultraviolet light disinfection and ozonation. Wastewater treatment plants also require activated sludge and sludge handling systems that consume large quantities of energy. The Energy Commission Demand Office estimates that a total of about 9,000 GWh of electricity is used annually by both water and wastewater facilities. This is based on both electric and water meter data and assumptions from engineering handbooks and other sources about the electricity use of certain equipment. Because the meter data is not reported in separate categories it cannot be disaggregated to separate water from wastewater treatment.

The Association of California Water Agencies (ACWA) estimates that the state's water and wastewater treatment facilities collectively draw about 3,000 MW at peak, with 1,800 MW occurring in Southern California Edison's (SCE) service territory, with the rest geographically distributed throughout the state more or less in proportion with population.

Both water and wastewater treatment processes require pumps and motors to transport water before, during, and after treatment. Pumping is not as significant a portion of the load for wastewater as for water because wastewater treatment processes are significantly more energy intensive, and both wastewater collection and disposal typically rely heavily upon gravity. Thereafter, the treatment processes and their relative energy intensities vary considerably.

Water treatment has historically been a comparatively modest user of energy, relying primarily upon settlement and passive filtration to remove particles from water, and chemical treatment (chlorination or chloramination) for disinfection. As new water quality regulations are implemented, energy-intensive technologies such as membranes, UV and ozonation will require large quantities of energy. Wastewater treatment requires much more energy, with each progressive level of treatment requiring still more. In secondary treatment, most of the energy is used for biological treatment; pumping of wastewater, liquid sludge, biosolids and process water; and processing, dewatering, and drying of solids and biosolids. Tertiary treatment requires additional energy for aeration, pumping, and solids processing. All of these processes present opportunities for energy reduction.

To reduce energy costs, many utilities have already replaced pumps and motors with newer, more efficient equipment. The addition of variable frequency drives and customized pumping algorithms provide the capability to further reduce energy requirements by more closely matching pumping capacity with loads. In addition, both water and wastewater utilities have recently demonstrated that significant reductions in energy consumption could be achieved by employing interim storage to shift processing to off-peak periods and balance processing loads among multiple plants to optimize plant efficiencies.

In the mid-1990s, EPRI and HDR Engineering, Inc. conducted an audit of the energy savings potential for water and wastewater facilities in California. At that time, they estimated that more than 880 million kWhs could be saved by implementing several measures: load shifting, variable frequency drives, high-efficiency motors and pumps, equipment modifications, and process optimization with and without Supervisory Control and Data Acquisition (SCADA) systems. These estimates did not include incorporating interim storage to shift loads and optimize plant efficiencies. Industry experts estimate that untapped energy efficiency opportunities through the optimization of water and wastewater treatment processes could be as high as 30 percent of existing processes.

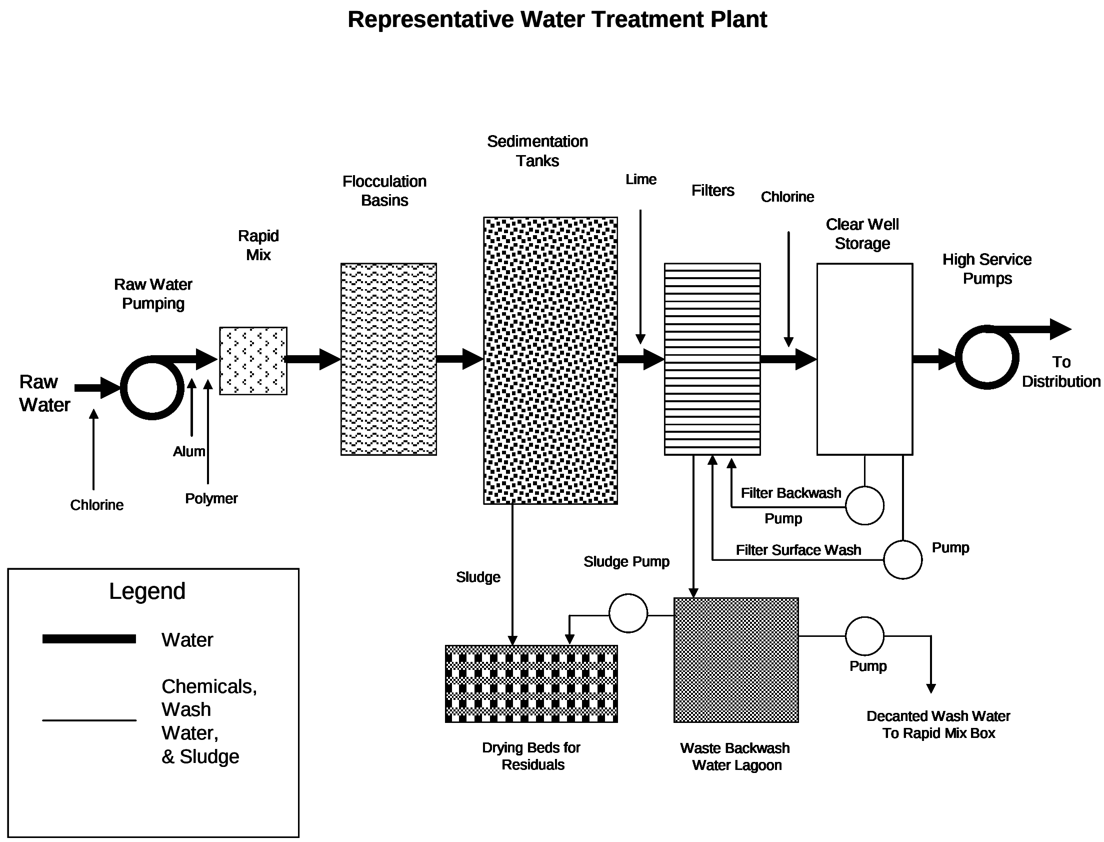
The sections below will describe energy uses for water treatment and distribution, and for wastewater treatment.

Water Treatment

Source water quality and the end use of the water dictate the level of treatment required. For potable uses, a typical sequence of operations for surface water treatment is described in the following steps (refer to Figure 3-2).

- Raw water is first screened, pre-oxidized using chlorine or ozone to kill organisms.
- Alum and/or polymeric materials are added to the water.
- Flocculation and sedimentation remove finer particles.
- A second disinfection step kills remaining organisms.
- The clear tank allows contact time for disinfection.
- Treated water is distributed to consumers by high-pressure pumps (disinfectant residue is carried into the distribution system to prevent organism growth). Sludges and other impurities removed from water are concentrated and disposed of.

Figure 3-2: Sequence of Operations in Surface Water Treatment



Source: Electric Power Research Institute

As shown in Table 3-1, although no two treatment facilities are identical, the following survey of more than 30,000 public supply systems in the United States[22] indicates little variation in water treatment energy intensity for plant capacities of at least 1 million gallons per day[23].

[22] Inventory of public water supply systems maintained by the U.S. Environmental Protection Agency in the Safe Drinking Water Information System.
[23] *Water & Sustainability* (Volume 4): *U.S. Electricity Consumption for Water Supply & Treatment*, EPRI March 2002, Figure 2-1, page 2-2,

Table 3-1 Energy Use by Surface Water Treatment Plants

Plant Size (Million Gallons per Day)	Energy Intensity (kWh/MG)
1	1,483
5	1,418
10	1,406
20	1,409
50	1,408
100	1,407
Average	**1,422**

Source: Electric Power Research Institute

Water treatment energy requirements are driven principally by the characteristics of incoming raw water and by the distance and elevation of the treatment plant in relation to water sources and the distribution system. Actual energy demand is highly variable by water utility. Lowest is pristine Hetch Hetchy water, which is exempted from filtration by the U.S. Environmental Protection Agency (US EPA)[24]. However, most surface and groundwater sources require treatment to meet regulatory standards and the taste and odor preferences of the public. Some treatment plants also have unique requirements, such as the removal of industrial chemicals from well water that require more energy. Net energy demand is expected to change as more energy-intensive disinfection processes are used to address water quality concerns and meet increasingly stringent potable water rules under the federal Safe Drinking Water Act (see discussion in Chapter 6).

Despite extensive data searches, staff found only a few studies that attempted to determine the exact electricity use for water treatment facilities. One of the most comprehensive and innovative studies came from an effort in Sonoma County to address greenhouse gas emissions. This study included energy use by municipal facilities, including the county's wholesale water agency, the Sonoma County Water Agency, and all of its municipal system water customers.

The Sonoma County Water Agency provides domestic water to 540,000 domestic water users in Sonoma, Marin, and Mendocino counties. Its only source of water is the highly variable flow of the Russian River and storage in two reservoirs on tributaries of the Russian, Lake Sonoma, near Healdsburg, and Lake Mendocino, near Ukiah. The EPA has listed the Russian River as impaired because of dissolved solids and nutrients. To both avoid these impairment issues and comply with federal

[24] The high quality Hetch Hetchy's water supply, produced by Sierra snowmelt in a protected watershed, has been granted a filtration exemption from the U.S. Environmental Protection Agency (U.S. EPA) and the California Department of Health Services (DHS).

Endangered Species Act limitations on stream withdrawals, many of the county water agency's municipal customers mix the river water with about equal amounts of groundwater, which is generally less costly.

The Sonoma County Water Agency required nearly 2,600 kWh/million gallons to pump and treat water from the river over the period of April 2000 to September 2002. Pumping costs were essentially linear throughout the year (that is, the electricity use per million gallon rate was essentially constant) except for spikes in January and February, when large amounts of surplus water were transferred to storage in reservoirs, especially in Marin County (Rosenblum 2003). Data are insufficient to determine the amount of energy used for pumping the water (which corresponds to the "Collection, Extraction and Conveyance" portion of the water use cycle described in Chapter 2) as opposed to energy used solely for water treatment.

In addition to Hetch Hetchy, EBMUD is an example of an agency with energy intensity of water treatment on the lower end of the spectrum. EBMUD gets 95 percent of its water from the Mokelumne River, delivered by gravity through the Mokelumne Aqueduct. The Mokelumne water is relatively high quality at its source, requiring little treatment; and the EBMUD's treatment facilities are located high in the East Bay Hills, using elevation to help pressurize its distribution system. Because of these factors, EBMUD's electricity use is a low 150 kWh/million gallons for conveyance, and 275 kWh/million gallons for treatment (EBMUD 2000 and Navigant Consulting 2004).

Desalination

Desalination involves removal of salts and dissolved solids from seawater or brackish water. Most desalination processes are based on either thermal distillation or membrane filtration technologies, both of which are very energy intensive.

The primary benefit of desalination is its ability to increase potable water supply by reclaiming water of poor quality. The most significant challenge of desalination is that it is a very energy-intensive source of water, and its highest use will likely coincide with extended drought periods when hydropower production is lowest.

Unlike every other type of water facility, where staffing edges out energy use as the main expense, desalination's primary operating cost is for energy, with seawater desalination being considerably more energy intensive (9,780-16,500 kWh/million gallons) than brackish groundwater desalination (3,900–9,750 kWh/million gallons).[25] The difference between seawater and brackish desalination ranges is due primarily to the difference in the initial water quality, and within each range the variance is due primarily to the plant design and technology employed. Most desalination plants operate continuously, so this electricity is used during all seasons and at all times of

[25] California Department of Water Resources Desalination Task Force Final Report 2003.

the day. Current plants are operating 90 percent of the time, with downtimes only for maintenance (DWR, 2005).

According to the *2005 Water Plan Update*, a 50 MGD seawater plant (approximately 50,000 acre-feet per year, or 16.25 billion gallons, assuming operations 90 percent of the time) would require about 33 MW of power.[26] This translates to about 5,200 kWh per acre-foot, or 16,000 kWh per million gallons, which is the upper-end of California's energy intensity of water supplies. Multiple efforts are underway to increase the energy efficiency of desalination through improved membranes, dual pass processes, and additional energy recovery systems.

Present estimates indicate that existing desalination facilities use 370-890 GWh per year. As stated in Chapter 2, if all of the planned new capacity is built, total production of desalination will increase from about 70,000 acre-feet per year to nearly 300,000 acre-feet. Assuming an average of 3,900 kWh/acre-foot (about 12,000 kWh per million gallons),[27] an incremental 230,000 acre-feet would require about 897 GWh. In the IEUA example, desalination of local brackish groundwater supplies can produce a net energy benefit when displacing higher energy intensity desalted seawater or SWP imports.

Desalination of seawater has the highest energy intensity of all water treatment options.

Water Distribution

Once treated to potable standards, the water must be distributed to customers, generally through a network of storage tanks, pipes, and pumps. During distribution, water must be kept moving and under pressure to minimize corrosion and biological contamination. Storage tanks and water mainlines must be flushed periodically to prevent oxidation and control biofilms (AWAARF 2000). Even the farthest reaches of the network must be kept under adequate pressure and constantly flushed since low pressure and low flow allow microbes to flourish (ACWA workshop April 14, 2005).

On average, staff estimates that city water agencies use about 1,150 kWh/million gallons of electricity just to deliver water from the treatment plant to their customers. The energy required for distribution pumping is mainly driven by the distribution system configuration, its relative size, elevations, and system age.

The water supply diagram and the results of the EPRI survey in Table 3.1, above, reflect little variation in the amount of energy required to treat and distribute a unit of water for systems requiring at least 1 million gallons per day. For this large survey

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[26] *California Water Plan Update 2005* Volume 2, Resource Management Strategies, Chapter 6 – Desalination.
[27] The average of the Chino desalter and seawater desalination in IEUA's water supply options.

size of approximately 30,000 public water supply systems, distribution pumping of treated water remained fairly constant at between 80 to 85 percent of total energy requirements when treatment and distribution energy loads are combined. For purposes of this paper, staff adopted this ratio and assumed prototypical water distribution energy intensity to be about 1,200 kWh/MG.

Cities with hilly terrains can use hilltop tanks both as storage and to provide pressure into the distribution system; San Francisco is perhaps the best example of this, serving virtually all of its customers from hilltop tanks. But the water must first be pumped up to the tank, often several hundred feet in elevation. In addition, though water agencies loathe wasting water and energy, they often must flush water from the tanks to prevent microbial contamination and then fill them up once again through the pumping station. In fact, this flushing accounts for the bulk of electricity used in EBMUD's distribution system.

Wastewater Treatment

Other than water devoted to landscape irrigation, or lost through evaporation (such as in cooling towers and other processes), almost all the water entering homes and businesses in California eventually leaves as wastewater. Wastewater treatment is similar to freshwater treatment. But most wastewater treatment systems have the additional step of using biological reactors that use bacteria to break down waste. Wastewater pumps are inherently more inefficient because they must pump both liquids and solids, and must have greater clearances between the pump impeller and the casing, allowing much of the pumped water to return to the intake plenum. Energy use in a wastewater system is primarily from use of very large electric pumps and blowers and use of natural gas to heat the anaerobic digesters.

Digester biogas (approximately 60 percent methane and 40 percent CO_2) is produced by anaerobic bacteria. The gas can be collected and used to generate electricity, usually powered by an internal combustion engine and used to run the facility itself. Waste heat recovered from the engine can be used to heat the digesters and displace natural gas use.

The number of water and wastewater treatment techniques and the combinations of techniques are expected to increase over time as more complex contaminants are discovered and regulated.

Wastewater consumes electricity in three stages: transport to the facility, treatment, and disposal/recycle. The first stage, transporting from the customer to the wastewater treatment facility, requires about 150 kWh/million gallons of electricity on average to pump the water, depending on topography, system size, and age. When they have a choice, agencies prefer to place water treatment facilities above their customers and the wastewater treatment facilities below, to harness the pull of gravity where possible, and to place water intakes above wastewater outfalls on rivers.

There are levels of treatment, and each progressively requires higher levels of energy use. These steps may consist of physical processes, biological processes, or chemical processes.

Physical Processes
The initial steps involved in the sewage wastewater treatment are physical processes, which separate larger solids from liquid using screening or grit removal. Steps that remove larger solids are termed preliminary treatment. The solids separated from the preliminary processes are usually disposed of in a landfill. After removal of larger solids, primary treatment follows to separate the smaller solids. Some chemicals may be added to assist with solids removal.

Biological Processes
The physical processes are followed by biological aerobic treatment in which extended aeration (oxygen) and environmental conditions are provided for microbes to break down organic material into carbon dioxide and water. Equipment used for the aerobic treatment includes tricking filter, aeration basin, and others. This biological aerobic treatment is commonly called secondary treatment.

After the aerobic treatment, the wastewater is separated with a sedimentation tank to separate the sludge and the clear effluent. The sludge is then sent to an anaerobic digester where the organic material is broken down into biogas, which is primarily methane and carbon dioxide.

Chemical Processes
The clear effluent, after the secondary treatment is further treated with physical filtration, chemical, or ultraviolet disinfections. This further treatment is commonly called tertiary treatment. The tertiary effluent can be used for beneficial reuse or discharged to surface water.

The progressive levels of treatment are commonly referred to as “primary”, “secondary” and “tertiary”, with primary being the lowest level, and tertiary the highest. Effluent from both secondary and tertiary treated water can be reused. The levels of treatment required for types of reuse (i.e., recycled water) are described in Table 2-2 in Chapter 2.

The major driver of unit energy consumption is the degree of treatment required. As noted above, there has been a trend toward more thorough treatment, with upgrades or replacements of older systems that could not provide this higher level of treatment. This trend is seen in comparing the estimated unit electricity consumption in 1988 with consumption in 2000: the baseline unit energy consumption was estimated to increase at an average compound rate of about .08 percent per year. This upward trend in unit electricity consumption is expected to continue as more thorough treatment is required.

Unlike water treatment and distribution systems, unit volume energy requirements for wastewater treatment plants vary greatly depending upon plant size. Energy intensity for a 1 MGD wastewater treatment plant can be approximately three times that of a 100 MGD wastewater treatment plant[28]. As expected, unit electricity consumption rises as the degree of treatment and complexity of the process increases. For example, advanced wastewater treatment with nitrification is three times as energy intensive (due to additional pumping requirements) than that of a relatively simple trickling filter plant.[29] Further complicating the assessment of prototypical unit volume energy intensity are unique operational environments, discharge limitations, influent characteristics, permitted effluent limitations, and variations in plant permitting cycles.

Table 3-2 Energy Intensity of Wastewater Treatment Facilities

Source of Data	kWh/MG
Inland Empire Utilities Agency	2,971
City of Santa Rosa	2,920
East Bay Municipal Utilities District	2,001
Metropolitan Water District	2,655
Methodology for Analysis of Energy Intensity in California's Water Systems	1,911
Energy Down The Drain, The Hidden Costs of California's Water Supply	2,302
Energy Benchmarking Secondary Wastewater Treatment	2,625

Source: Multiple, see Appendix C

Table 3-2 shows wastewater treatment plant energy intensities reflecting a range of energy intensity for facilities operating in California and cited in studies. Based on this range, 2,500 kWh/ MG has been adopted as the prototypical wastewater treatment energy intensity (for more detailed discussion and references see Appendix C).

One of the most interesting opportunities for reducing energy use for wastewater treatment is to improve storm water management. During rainy weather, a considerable amount of runoff ends up in wastewater systems, greatly increasing treatment costs. Even communities that do their best to keep stormwater out of their sewer systems see nearly double the flow during a winter storm than during the dry summer months. This “infiltration/inflow” of stormwater into the sewer system has on

[28] *Water & Sustainability* (Volume 4) *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI 2002, Pages 3-4 & 5 and Table 3-1.
[29] *Water & Sustainability* (Volume 4) *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI 2002, Pages 3-4 & 5 and Table 3-1.

occasion forced many communities to discharge raw or minimally treated wastewater directly into local waters.

For example, Sonoma County's largest wastewater facility, the Laguna Wastewater Treatment Plant, operated by the City of Santa Rosa, experienced a peak inflow of nearly a billion gallons per month in January and February of 2000 and 2002, while average inflow in the summer months was just over half that amount (Rosenblum 2003, Figure 7). Its wastewater treatment electricity use is proportionate to these flows, and therefore nearly twice as high in winter than in summer.

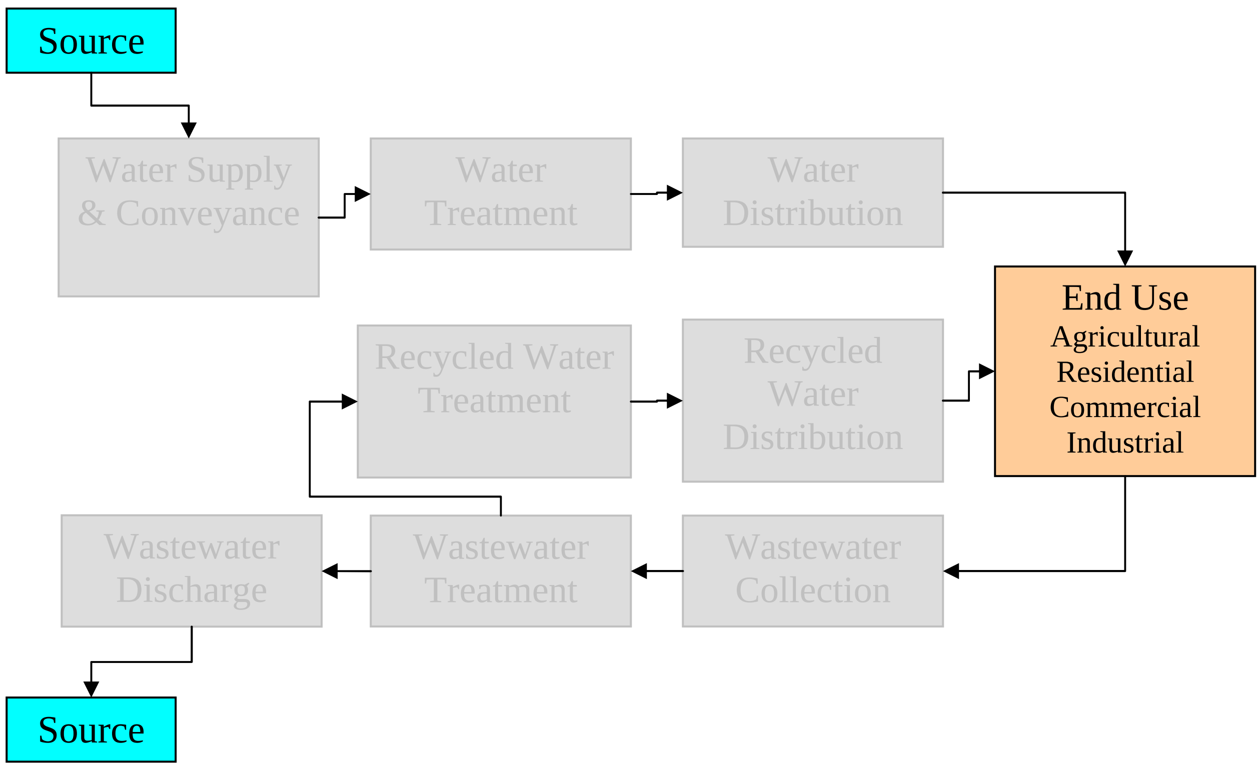
Conclusions

In this chapter, staff has generally described water energy intensity for water treatment, wastewater treatment, and water distribution. Staff has also identified areas that will require additional information and analysis to better understand these systems and how modifications or improvements could benefit the energy sector. Future regulatory changes made in response to health and water quality concerns will affect the overall energy demand of these systems.

CHAPTER 4 – WATER RELATED END-USE EFFICIENCY

This chapter addresses opportunities to increase water and energy end-use efficiency.

Figure 4-1: Water Use Cycle – End Use



The Energy Impact of Water Use Efficiency

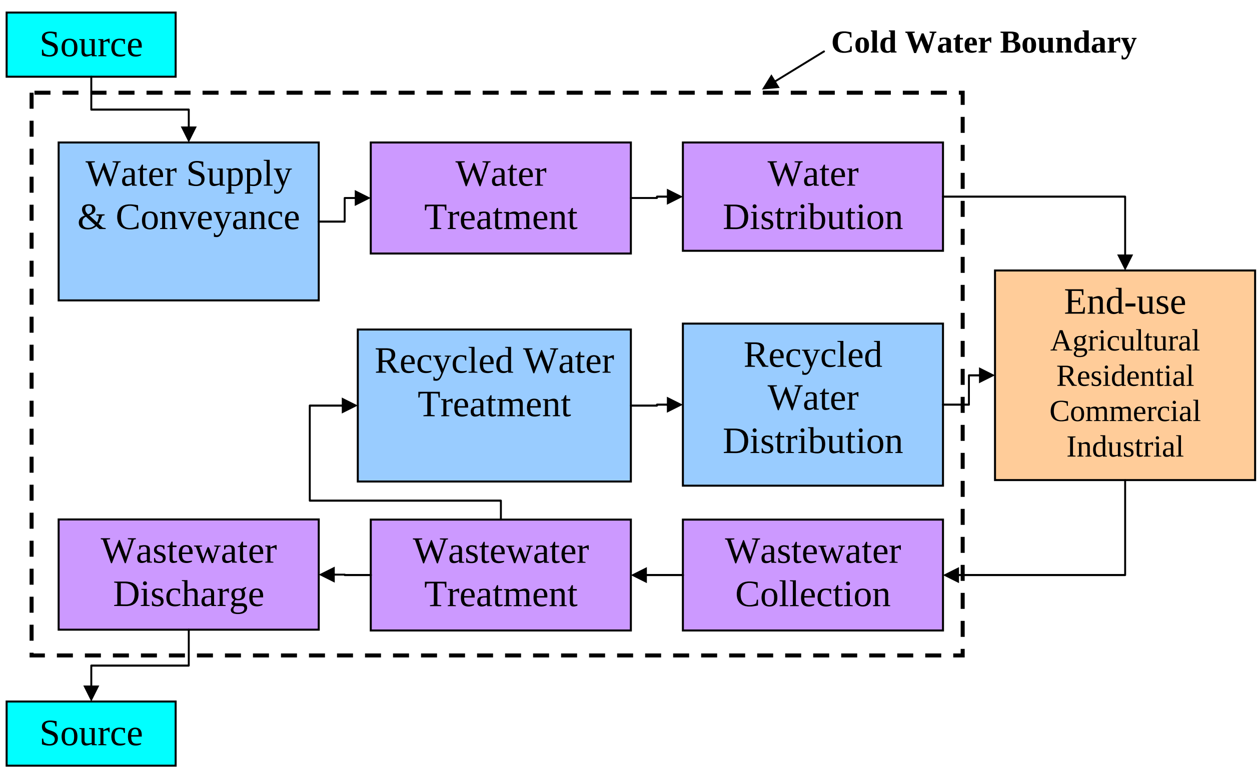
Water end-use applications in California use more energy than any other part of the state's water use cycle. Energy efficiency water programs have traditionally focused on either saving energy in water and wastewater treatment facilities or saving energy in end-use applications including water heating, clothes washing and drying or process heating. Water use efficiency programs have similarly focused on saving water in end-use applications. In both cases, end-use efficiency measures are beneficial, to both utilities and end users, when the value of the saved energy or water exceeds the cost of the measure.

For the most part, these efficiency improvements have been pursued separately by water and energy utilities, although there are some examples of close coordination, including the effort to introduce high-energy-efficiency and low-water-factor clothes washers to the consumer market. What appears to be missing is the recognition that saving water also saves energy throughout the conveyance, treatment, distribution and wastewater treatment processes of the water use cycle.

The energy intensity of water use varies depending on its end use and location in the state. For example "statewide average," agricultural end uses are less energy-intensive than either "statewide average" urban end uses or agricultural end uses in Southern California that rely upon SWP or Colorado River Aqueduct water deliveries. All are more energy-intensive than those in Northern California. On average, urban water uses in Southern California are more than three times as energy-intensive as those in Northern California.

While these relationships are useful for policy development and planning, it is important to recognize that the actual energy intensity of the water use cycle is very location- and application-dependent; this information is important as specific projects are considered. Figure 4-2 shows the overall cold water boundary. To apply the concept of energy intensity, the cold water boundary must be identified for specific locations and applications. Further details are in Appendix C.

Figure 4-2 Cold Water Boundary in the Water Use Cycle



Conserving a unit of cold water avoids using the energy that would have been needed to supply, treat, deliver, consume, collect, treat, and dispose of it as wastewater. The actual amount of energy saved depends upon the type and source of water supply, the distance the water has to travel, the nature and extent of its treatment, and the type of end use.

In California, saving cold water, both indoors and outdoors, saves energy. The energy saved is primarily electricity. Saving outdoor water saves the energy it takes to extract, convey, treat, and distribute water to customers. Saving indoor water saves the additional energy, again mostly electricity, used to collect, treat and dispose of the waste water. Saving indoor hot water saves the additional energy needed to heat this water. In California, this additional energy is mostly in the form of natural gas.

From an energy perspective, saving cold outdoor water is good. Saving cold indoor water is better. Saving hot indoor water is better still.

Saving end-use energy can also save water and the energy associated with the applicable portion of the water use cycle. For example, when air conditioning is reduced in large buildings that use cooling towers to remove the heat, every unit of energy that does not need to be removed means that less water is needed in the process. Also, saving electricity in any fashion saves water at power plants that use cooling water.

Agricultural Water Use Efficiency

About 79 percent of the state's water is used by the agricultural industry to grow more than 200 crops that generate more than $29 billion dollars a year for the state's economy (CDFA, 2003). Because water conveyance and pumping are very costly, efficient irrigation technologies and farming practices hold promise for reducing both the amount of water needed and the energy intensity of crop production.

While a unit of agricultural water is not as energy intensive as a unit of urban water, the agricultural industry strives to meet water conservation objectives, save money, and preserve water resources. Many times the adoption of natural resource conservation practices creates new energy expenditures. The industry can reduce these costs by participating in energy efficiency and demand response programs through the public goods charge funds administered by their investor-owned utilities (IOU).

Energy Efficiency and Conservation Measures

Since the mid-1990s, the agricultural industry has adopted multiple water conservation practices, among which are installation of drip- and micro-irrigation technologies. The use of on-farm pressurized irrigation methods has increased from about 1.4 million acres in the early 1980s to more than 4.2 million acres today.[30] These changes can result in better crops, reduced water use, and the reduced use of fertilizers and chemicals, all of which result in greater productivity and energy efficiency.[31]

To be more productive, farms must also improve the efficiency of their water pumping systems. Since the 2000-2001 energy crisis, thousands of farmers and irrigation districts have used state- and ratepayer-funded pump test and repair program incentives. Many of the pumps were repaired to boost their pumping plant efficiencies.[32] When pump tests are performed and cost-effective pump repairs are completed, pump efficiencies can increase by 5 to 15 percentage points. This improved efficiency provides increased pumping capacity. Where previously a farmer might have used seven days to water his fields, it might now instead take five or six days to do the same work. Most farmers will adjust their irrigation set times to reflect the new water output and reduce the total number of hours of operation, saving both water and energy.

These measures can more than offset the new energy requirements that most often accompany drip system installations. Although there will be a higher demand for connected load from the installation of booster pumps, the total hours of operation will depend on the source of water and the irrigation system that is being converted to drip. Most often farms are required to pump from groundwater sources to satisfy the on-demand, clean, and flexible water delivery needs of the drip systems, possibly increasing their energy costs. Studies have shown that the conversion from surface irrigation to drip/micro- and sprinkler-irrigation technologies has lead to increased on-farm groundwater pumping on the east side of the San Joaquin Valley.[33]

Adoption of Time of Use (TOU) Agricultural Electric Rates

Large numbers of both Pacific Gas and Electric (PG&E) and SCE agricultural customers have signed on to TOU electric rate schedules. In the PG&E service area 81 percent of agricultural revenues and 89 percent of agricultural kWh sales are on TOU rates, representing 40,000 accounts of the total 80,000 agricultural accounts[34]. In the SCE service area, 71 percent of agricultural kWh sales are on TOU rates, generated by 18 percent of the utility’s customer accounts[35].

[30] CalPoly ITRC, Memorandum, 2005
[31] CalPoly San Luis Obispo University, ITRC Report No. R 96-001, Row Crop Drip Irrigation on Peppers Study - High Rise Farms, 2006
[32] Nexant, M&V report from the California Energy Commission Agricultural Peak Load Reduction Program, 2003
[33] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003
[34] Personal communication with Keith Coyne, PGE, 8 4 2005
[35] Personal communication with Cyrus Sorooshian, SCE, 8 11 2005

Although there are many accounts on TOU rates, farmers still use energy during peak-period hours. If crop water needs require irrigating during peak periods, the farmer will exercise the option to use on-peak power and pay the penalties, leading to higher average energy costs. The farmer's goal is to provide water to crops when it's needed, in the proper amount, using high distribution uniformity for optimal crop growth. It is not always possible to meet all of these requirements and take maximum advantage of TOU rates.

Staff recognizes that, to pump water during off-peak hours, farms will require larger pumping plants with properly designed irrigation systems, improved control systems, and flexible working hours. To take full advantage of these changes farmers will have to maintain high efficiencies in their pumping and irrigation systems in addition to adopting scientific irrigation scheduling management practices.

Agricultural electricity end users would benefit from energy policies that allow end users to choose the demand response practice that best meets the requirements of their business. The industry will also be more inclined to invest in peak load reduction measures with both flexibility and strong stable price signals.

Other Factors Affecting Agricultural Water Energy Use in California

There are several trends to watch that affect the future use of energy to provide water to agriculture, including:

- Sustained adoption of drip and micro irrigation technologies. Although there are more than 4 million acres under drip irrigation, from a total of less than 9 million acres of irrigated land reported for the state, it is reasonable to assume that, over time, another 3 million acres could be converted to drip irrigation. The agriculture industry will make the conversion partly to meet water conservation goals but mostly by recognizing the production benefits from the technology. CalPoly ITRC forecasted an increase of 2.9 million kWh from the doubling of drip irrigation acreage.[36]

- Continued reliance on ground water, with reductions in surface water. There is a high probability that farmers will continue to pump from wells to supply groundwater to drip systems until irrigation districts provide surface supplies with flexible schedules.

- An increase in agricultural water conjunctive use programs with transfers to urban regions. There are many water transfer agreements already in place, with more to come as the urban sector finds that the agricultural industry can provide storage services as well as new water transfers from achieved

[36] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003.

conservation measures. There are significant energy expenditures to accomplish the process of banking the water, pumping it for extraction and delivering it to the water account owner[37].

- Conversion from diesel-powered pumping systems to electric motors. On August 1, 2005, a new rate schedule (AG-ICE) became available for current agricultural diesel-driven irrigation pumps in both PG&E's and SCE's service territories. The rate encourages the switch from engines to electric motor-driven systems for agricultural customers with diesel engines of greater than 50 horsepower for irrigation pumping before September 1, 2004. In the PG&E territory it is possible that 200 to 300 MW of new coincident peak load could be added to its system during the course of the two-year open enrollment period.[38]

The Energy Commission's *2005 California Energy Demand Forecast* shows that agricultural electricity consumption is expected to increase by 1.4 percent a year through 2016.[39] The actual amount will fluctuate depending upon the total number of irrigated acres, the crop patterns, the source of water and, obviously, the price of electricity.

From a state energy policy perspective, the agricultural industry's effort to achieve electricity use efficiency and demand response savings would satisfy the first target in the state's loading order. The agricultural industry also has the opportunity to adopt the second item in the loading order with installation of renewable energy systems.

The agriculture industry does have great potential to develop renewable energy sources. However, investment recovery will require the aggregation of electricity account meters so that the generated power can be applied to all existing accounts. Today, these accounts can only apply the power produced to the single connection attached to the power system. Therefore only a limited amount of power can be sold at the retail price, with the remainder sold at wholesale prices. This situation is similar to that faced by water and wastewater utilities. These issues affect many customers in the state and are being considered by the CPUC as it attempts to balance a wide variety of factors related to distributed generation in California.

The agricultural industry's economic sustainability greatly depends upon nature's water cycle. During dry years, the amount of energy used to deliver water increases. In drought years, groundwater sources are used extensively to supplement lower surface water deliveries. Several consecutive dry years can also lower the groundwater subsurface level of the water table, requiring more energy to overcome the lift needed to pump the water up to the surface. Typical groundwater lifts vary by

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[37] CalPoly ITRC, California Agricultural Water Electrical Energy Requirements, 2003) [http://itrc.org/reports/energyreq/energyreq.pdf].
[38] Personal communication with Keith Coyne, PG&E August 4, 2005.
[39] *California Energy Demand 2006-2016, June 2005*

region throughout the state, which influence both motor size and power usage. The state has been fortunate in that there has not been a continuous series of dry years since the 1988-1992 drought. Since then, new groundwater recharge basins have been developed to serve as infrastructure for water transfer transactions. These measures are important both for water management flexibility and energy efficiency.

Additional small-scale water storage systems located in irrigation districts and on farms could help increase the flexibility of water deliveries. Surface and tank storage facilities can store water during off-peak periods and reduce the need for on-peak electricity consumption.

Urban Water Use Efficiency

Approximately 21 percent of the state's water is for urban uses. Urban water use efficiency includes improvements in the residential, commercial and industrial sectors. It includes opportunities to increase the efficiency of water-related end uses that use either electricity or natural gas.

In November 2003, the Pacific Institute published a study[40] that estimated the minimum cost effective urban water conservation at around 2 million acre-feet (651 billion gallons) per year, about 22 percent of all urban water use -- without technological change. The California Urban Water Conservation Council (CUWCC) recently posted the results from 32 percent of the agencies that signed on to their memorandum of understanding to institute best management practices (BMPs) in their water agencies. Taking only those BMPs for which water savings could be quantified, the reporting agencies saved more than 27 billion gallons of water in 2004, resulting in significant electricity energy savings, as shown in Table 4-1. The water savings from the BMPs, reported in 2004, are roughly 4 percent of the potential described by the Pacific Institute.

[40] *Waste Not, Want Not: The Potential for Urban Water Conservation in California,* The Pacific Institute, November 2003.

Table 4-1: Energy Value of Saved Water Due to Implementation of 2004 BMP Measures

Statewide	Annual Savings Water (MG)	Annual Savings Electricity (kWh)	Useful Life (Years)	Life-Cycle Electricity Savings (kWh)	NPV Electric Avoided Cost ($)
BMP 1 Water Survey Programs MF/SF	1,897	17,114,500	5	85,572,500	6,220,866
BMP 2 Residential Plumbing Retrofit	311	2,814,000	5	14,070,000	1,022,865
BMP 4 Metering & Commodity Rates	1,587	14,317,200	11	157,489,200	9,472,790
BMP 5 Large Landscape Conservation Programs	5,320	34,595,450	10	345,954,500	21,149,701
BMP 6 High-Efficiency Washing Machine Rebate	317	2,860,100	15	42,901,500	2,346,888
BMP 9 Conservation Programs CII	4,814	43,433,300	12	521,199,600	30,567,522
BMP 9a CII ULFT	258	2,328,300	25	58,207,500	2,522,363
BMP 14 Residential ULFT	12,987	117,184,600	25	2,929,615,000	126,950,010
Statewide Total	27,492	234,647,450		4,155,009,800	200,253,005

Source: California Urban Water Conservation Council (CUWCC) Reporting Database, April 2005 with 86 of 269 Reporting Units (32%) reporting BMP expenditures in 2004. Reporting Units include: water utility districts, water agencies, irrigation districts, city and county water departments and water service companies implementing BMPs.

Saving this water also saved more than 234 million kWh of electricity. Taken over the lifetime of each measure, the net present value of the energy for this saved water is more than $200 million. The saved energy was computed using the urban use energy intensity of 4,000 kWh/MG in Northern California and 12,700 kWh/MG in Southern California. These values assume that all water delivered to these uses is also treated as wastewater and applies to all of the BMPs (except the landscape conservation programs, which used a lower number to account only for the water delivery portion of the water use cycle). The computations were done separately for Northern and Southern California and aggregated to arrive at the statewide totals shown in the table. Details of this analysis can be found in Appendix C.

The energy saved from the saved water was passed on to the California water and wastewater treatment utilities that participated in implementing the BMPs. It also showed up as reduced electricity sales and some peak demand reduction. However, energy savings from savings in the water use cycle were not recognized by either the CPUC or by the energy utilities as fundable energy conservation measures.

Members of the Water-Energy Relationship Working Group presented testimony on this topic, suggesting it would be valuable to assess how large the energy value of the conservation potential identified by the Pacific Institute might be in comparison with energy efficiency programs currently approved by the CPUC. Table 4-2 presents the comparison of programs funded in 2004-2005 with those planned for 2006-2008. The water use efficiency (WUE) program is based on the Pacific Institute's expressed water saving potential.

Table 4-2: Comparison of Energy Efficiency Programs Resource Value to Water Use Efficiency

	Energy Efficiency Programs		
	2004-2005	2006-2008	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%	

Source: California Public Utilities Commission, with WUE estimates from Appendix C

The numbers for the energy programs are from CPUC documents.[41] The numbers for the WUE program are discussed in detail in Appendix C. The energy savings were assigned to Northern and Southern California based upon their respective populations. The cost of water efficiency measures assumes an average of $384 per acre-foot, based on a range of $58-$710.

There is clearly significant untapped energy savings potential in programs focused on water use efficiency. If all of the identified urban water savings could be achieved, the energy savings would achieve 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 the utilities' expected demand reductions.

TOU Water Tariffs and Meters

The idea of TOU water tariffs and meters was suggested several times during the proceedings as a means to give customers a more accurate assessment of the value of the water they use. Historically, water agencies have treated their product as a commodity; water flows and people use it. Before the 2000-2001 energy crisis, even though water agencies were on standard TOU and demand rates, the incremental costs between on and off peak were not large enough to affect their decision making. They did not attach time value to water until SWP and the state water contractors became sensitized to hourly energy costs in the highly volatile bulk power market. At the retail level, it is important to recognize that many water customers in the state do not even have water meters, although legislation is changing that. Currently, TOU water meters do not exist. Water agencies are also grappling with how to develop tariffs and rate schedules that both properly reflect the value of water at different times during the day and account for delays between

[41] 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.

energy consumption and water use. The Energy Commission is funding a project to look at the feasibility of these meters and associated tariffs.

Because the vast majority of the financial benefits of water use efficiency go to customers instead of water, wastewater, or energy utilities, informing customers of the financial upside of more efficient appliances and practices could be very effective. The new "Flex Your Power at the Tap" campaign is one example. In the longer term, water and energy bills could also serve as informational pathways leading customers to efficiency investments and choices that are best for both them and the greater society.

Water Storage for Peak Electric Load Shifting

Water and wastewater treatment require approximately 3,000 MW of peak load. There is a minimum level of electrical consumption needed to operate their systems during peak periods. Beyond that, virtually all of the on peak energy use is discretionary - if there is sufficient storage. For example, the El Dorado Irrigation District reduced its on-peak electric usage by more than 60 percent by allowing their tanks to drop to a lower minimum level and installing an additional 5-million-gallon storage tank. An estimated 250 MW of peak demand could be saved if water agencies statewide viewed their storage as an energy asset as well as a water asset. Another 1,000 MW of peak demand could be saved from increased treated water storage in urban areas. In total this represents more than one-third of the water use cycle load.

Investing in Water and Energy Efficiency

California has water-related energy programs to increase the energy efficiency of existing water and wastewater utility operations; increase the energy efficiency of the appliances that move water; and increase generation from renewable resources. These programs include building and appliance standards, technical support and loan programs, and incentive programs funded through the state’s energy utilities. The state also conducts research to modify existing treatment processes; develop more efficient water and wastewater treatment and water supply technologies; increase the efficiency of heating, cooling, and moving water for end users; and improve the effectiveness of renewable energy sources.

However, since the state’s largest energy utilities have no authority to invest in programs that save cold water to capture the upstream energy benefits, these benefits are not realized. If the CPUC authorizes investment in cold water savings, the state will have a new source of energy savings.

Because of the interconnectedness of water and energy resources in California, the fact that cost-effectiveness is determined solely from a single utility and single resource perspective is a glaring problem. Water utilities value only the cost of treating and delivering water. Wastewater utilities value only the cost of collection, treatment and disposal. Electric utilities value only saved electricity. Natural gas utilities value only saved natural gas. This causes underinvestment in programs that would increase the energy efficiency of the water use cycle and increase agricultural and urban water use efficiency.

By valuing a unit of water on its total value – the water resource itself, plus its energy intensity and externalities throughout the entire water cycle -- many water and energy programs and measures that could not meet the earlier cost-effectiveness threshold are now possible. California could reap large energy benefits by encouraging greater collaboration between energy, water, and wastewater utilities.

Conclusions

In this chapter, staff has generally described the water energy intensity for agricultural and urban end uses. Staff recommends additional research to provide needed information to better understand these systems and how modifications or improvements could benefit the energy sector. Future regulatory change will also affect the overall energy demand of these systems. To ensure high-quality water supplies for the state, energy and water utilities should collaborate to efficiently operate water and wastewater treatment facilities. Water and wastewater utilities can take advantage of current energy efficiency programs for near-term retrofits and design modifications to increase efficiency now, with existing technology. Additional research is needed on technologies and system designs.

CHAPTER 5 – RENEWABLE ENERGY GENERATION POTENTIAL

The most widely recognized aspect of the water-energy relationship is power production in large scale hydroelectric dams. However, water and wastewater utilities have other opportunities to develop energy supplies. These include biogas cogeneration at wastewater treatment plants and development of local renewable resources on water and wastewater utilities' extensive watersheds and rights-of-way. For purposes of this paper, we will address the potential for new renewable generation by water and wastewater utilities for two distinctly different types of opportunities:

- Distributed generation
- Utility scale generation

These energy generation opportunities require different types of permits, approvals, metering, and interconnections, and have different production characteristics, economics, and operating and financial risks. Detailed aspects of distributed generation and large-scale hydroelectric generation are addressed separately in the *Energy Report*. [42]

Table 5-1 illustrates the range of renewable power production opportunities for water and wastewater utilities.

Table 5-1: Renewable Power Production Opportunities

Energy Resource	Distributed Generation	Utility Scale Generation
Hydropower	Energy Recovery through In-Conduit Hydropower	▪ Relicensing ▪ Pumped Storage ▪ Repowering
Biogas	Biogas Co-Generation	Biosolids Waste-to-Energy plants that utilize methane from sewage digesters, dairy manure, agricultural and food processing wastes, and other organic materials
Solar	Photovoltaics for irrigation pumps & motors	Central concentrating solar power plants (solar thermal and photovoltaics)
Wind	Modest site specific applications	Wind farms on watershed lands
Advanced Generation, including Fuel Cells and MicroTurbines	Potential applications for small pumping loads	n/a

[42] For a complete listing of all documents and reports associated with the IEPR proceeding, including distributed generation, please see [http://www.energy.ca.gov/2005_energypolicy/documents/index.html].

The potential, issues, and challenges of these opportunities are discussed below.

Distributed Generation

The term distributed generation is used to describe both customer-side and utility-scale generation. For purposes of this staff report, distributed generation refers to generation facilities sited on the customer side of the meter that are used primarily to serve a customer's own energy requirements, specifically a water or wastewater utility. This discussion is limited to opportunities for water and wastewater utilities to self-generate power, and the barriers and hurdles that prevent them from generating more. These facilities include in-conduit hydropower, biogas combustion, and other small-scale distributed generation facilities.

In-Conduit Hydropower

Wherever there is flowing water, there is both energy and the potential to capture and utilize that energy. In-conduit hydropower captures the energy from flowing water in a pipeline with a turbine or generating device installed directly in the conduit. Most of the state's large water conveyance projects already take advantage of the energy in water flowing through their pipelines, canals, and aqueducts. Additional opportunities remain to develop new or retrofitted generation in the state's water systems, if costs and risk can be minimized. These are environmentally attractive because they are built in existing water and wastewater systems.

In most cases, in-conduit hydropower potential ranges from very small – 1 or 2 kW to a high of about 1 MW. Often, the hydropower site is not near loads, requiring construction of expensive transmission or distribution lines to interconnect to the electric system. Even in cases where it may be cost-effective to construct such lines, existing rules do not allow the produced power to be credited against the water or wastewater utility's total energy bills. Instead, wherever such self-produced power cannot be directly connected to an existing load, it must be sold into the wholesale bulk power market. The costs and complexities of participating in the wholesale bulk power and transmission markets are daunting, even for large generators. They are prohibitive for very small generators.

A recent Energy Commission Public Interest Energy Research (PIER) study estimated the statewide developable potential of hydropower capacity in manmade conduits (including pipelines, irrigation ditches, canals and aqueducts) at about 255 MW - 231 MW at coincident peak - with annual production of approximately 1,100 GWh. The potential was about evenly split between municipal and irrigation district systems.[43]

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[43] *California Small Hydropower and Ocean Wave Energy Resources*, Mike Kane, Energy Commission PIER, April 2005.

The PIER study focused on identifying the statewide potential for RPS-eligible small hydropower (less than 30 MW). Under SB1078, RPS-eligible hydropower must be constructed on or after September 12, 2002, and must not require a new diversion or a new appropriation of a water right.[44] Consequently, staff determined that the most likely class of hydropower to be developed under the present RPS is small hydropower within conduits. The PIER study only considered sites with potential of at least 100 kW since projects of lesser size tend to be uneconomic.

Changes in technology may reduce the economic threshold of in-conduit hydropower to less than 100 kW. New packaged systems are being developed that could be dropped into pipelines and other types of conduits – like canals and aqueducts - without expensive civil works or permitting costs. However, the challenge of siting in-conduit hydropower close to local loads remains.

Another way to look at in-conduit hydropower is to view it as an increase in the energy efficiency of the water delivery system. Without water agency investment in the water delivery system in the first place, this resource would not be available. Currently in-conduit hydropower is treated like any conventional energy generation resource owned and operated by a non-utility generator. This classification seems inappropriate since there is no prime mover and no new natural resource is used to generate the electricity.

Existing energy efficiency programs can be tailored for special circumstances, using customized incentives and standard performance contracting. Water agencies have taken advantage of these incentives for energy efficiency improvements, including increasing pipe diameter to reduce friction losses and the requisite pumping requirements; installing a parallel pipe system; and changing pump impellers and lining pipes to reduce friction losses. In-conduit hydropower could be looked at in a similar fashion and be included as an element of these tailored programs. Again, the issues of interconnection and the sale or application of the power to multiple accounts will still need to be addressed.

Biogas

Another option for developing generation in the water sector is to increase beneficial use of digester gas produced by the sewage wastewater, dairy manure, and food processing wastes/wastewater. Biogas, primarily composed of methane, can be used for a combined heat and power production.

California has 311 sewage wastewater treatment facilities, 2300 dairy operations, and 3000 food processing establishments. Currently, about 50 percent of sewage sludge, 2 percent of dairy manure, and less then 1 percent of food processing wastes/wastewater generated in the state are utilized to produce biogas. Converting

[44] *Renewables Portfolio Standard Eligibility Guidebook*, Energy Commission Publication Number 500-04-002F1, adopted August 11, 2004.

these wastes into energy can help operating facilities offset the purchase of electricity and provide environmental benefits by reducing air and groundwater pollutants discharged.

Unused biogas is typically flared to the atmosphere. Not only is this a waste of a renewable resource – flared biogas creates odors and air emissions.

Biogas producing facilities can be near significant loads, for example the wastewater treatment plant itself. However, this load may be on multiple meters and current rules discourage full use of the available biogas for maximum generation for onsite or offsite loads. Currently, there are provisions under regulated tariffs that enable dairy operations to produce electricity from biogas resources at one location and use it to offset electricity use at multiple locations, under multiple accounts, for one customer. This same approach would significantly increase opportunities for biogas-fired (and other renewable) generation in water and wastewater agencies.

The Inland Empire Utilities Agency (IEUA) is a leader among regional wastewater treatment agencies for innovative and proactive energy management. IEUA's facilities process 65 million gallons of wastewater into high-quality recycled water. IEUA's wastewater treatment system has three anaerobic digesters. Dairy manure is collected from seven nearby dairies and processed through two of IEUA's digesters. At one facility, biosolids from the sewage treatment process are combined with dairy manure. At another facility, dairy manure alone is used to produce the methane that is piped to the Chino Basin desalter, where it is used to produce electricity for desalination of groundwater.

IEUA believes there is significant potential for increasing biogas production by combining different types of biosolids. For example, by blending dairy manure with food waste, IEUA expects this year to double its amount of biogas production (from 0.5 MW to the total load of the Chino desalter of 1 MW).

IEUA's biogas power production is expected to continue to grow as it adds another 15 MGD wastewater treatment plant next year, and it plans to develop another 10 MW in renewable biogas generating capacity with a centralized biodigester that will take dairy waste, green and food residuals (generally used to make compost) and biosolids to produce biogas for power generation and compost. IEUA is also considering using its excess biogas to heat water and sell a new product, hot process water, to industrial customers.

While IEUA has been much more successful than other wastewater utilities in the innovative development of biogas power production, it has not been simple.

Other Distributed Generation Options

Other distributed generation options include solar thermal, photovoltaics, small wind power, and advanced generation technologies including fuel cells and advanced microturbines. These distributed generation opportunities are discussed at length in the *Energy Report* proceeding.

Utility Scale Generation

Many water and wastewater utilities have the opportunity to develop utility-scale power production facilities that produce more power than utilities need for their own processes. With technical and funding support and removal of major barriers, water and wastewater utilities could become net exporters of power. Whether conventional hydropower facilities developed in conjunction with large water conveyance systems - like the Oroville Hydroelectric Facility, owned and operated by DWR on behalf of the State Water Project, or wind farms constructed on watershed lands – substantial untapped renewable resource potential resides with water and wastewater utilities that have little incentive, and, in fact, many barriers and disincentives, to develop these resources.

Large-Scale Hydropower

In addition to the in-conduit hydropower opportunities described above, utility scale generation consists of conventional hydropower (less than 30 MW) produced by water releases from natural or manmade impoundments like reservoirs and dams.

Opportunities for new hydropower dam and storage projects are extremely limited in California for a variety of reasons. Most economically viable sites have already been developed; but even where suitable sites exist, development is limited by lack of availability of unallocated water rights, environmental protection measures (such as Wild and Scenic Rivers, Endangered Species, and Wilderness Area designations), and strong opposition from environmental advocates.

Staff has investigated ways to balance the electric system benefits offered by hydropower with their significant adverse environmental impacts. Both the Energy Commission's *2003 IEPR*[45] and staff's *California Hydropower System: Energy and*

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[45] *2003 Energy Report*. California Energy Commission, *2003 Integrated Energy Policy Report*, December 2003, Docket No. 02-IEP-1, Publication No. 100-03-019, page 43.

> "Hydroelectricity has historically played an important role in meeting California's electricity needs. Its low production costs and unique ability to meet critical peak demand have long benefited the state's ratepayers. Some hydroelectric projects unfortunately have serious environmental consequences, such as significant, ongoing impacts to many California rivers and streams, native salmon and trout populations, and the water quality needed to support sustainable riverine ecosystems.
>
> The restoration of imperiled salmon and trout fisheries is one of California's environmental policy objectives. ... [D]ecommissioning of high environmental impacts hydroelectric facilities that supply little power is a possible method of restoring important aquatic habitat."

Environment[46] provide key findings with respect to hydropower's value and impacts. Staff provides recommendations to minimize the adverse environmental impacts of these facilities.

At this time, only two utilities are expected to develop hydroelectric resources. [47] The Sacramento Municipal Utility District (SMUD) proposes the Iowa Hill Project to add 400 MW of pumped-storage capacity to its Upper South Fork American River Project. This may be especially helpful for integrating wind energy produced in the Delta, since the Delta breeze on a hot summer day usually begins a few hours after the daily load peak, which is driven by air conditioning. For San Diego Gas and Electric (SDG&E), about 40 MW of new hydro are planned, beginning in 2008, from San Diego County Water Authority projects.

Long lead times are needed to plan new hydro projects, prepare appropriate environmental documents, obtain a license from the Federal Energy Regulatory Commission (FERC), and build the project. However, opportunities for incremental development, such as adding or improving generation facilities attached to existing dams, water conveyance facilities, and powerhouses, remain an option for increasing California's hydropower production.[48] These opportunities include pumped storage and retrofit.

Pumped Storage

Pumped storage typically involves pumping water from a water source into a reservoir or tank, to be held for later scheduled hydropower production. Water is pumped uphill during off-peak hours and provides peaking capacity during on-peak hours. Pumped storage has high energy value since it is virtually the only viable means to store energy. There are several significant pumped storage projects currently under development:

- The proposed 500 MW Lake Elsinore Advanced Pumped Storage Project (LEAPS)[49].

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[46] California Energy Commission, *California Hydropower System; Energy and Environment*, Appendix D to the *2003 Environmental Performance Report*, prepared in support of the *2003 Integrated Energy Policy Report*, October 2003, Publication No. 100-03-018. Prepared in support of the *Electricity and Natural Gas Report* under the Integrated Energy Policy Report proceeding (02-IEP-01), October 2003, Publication 100-03-018.

[47] *California and Western Electricity Supply Outlook Report* Draft, California Energy Commission, July 15, 2005, pages 74-76, posted on the website of the California Energy Commission.

[48] Excerpt from the *California and Western Electricity Supply Outlook Report* Draft pages 74-76, in progress for posting to the website of the California Energy Commission, July 15, 2005. For information about California's overall hydropower outlook, please refer to the Energy Commission's 2005 report, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States*, prepared in support of the *2005 Integrated Energy Policy Report* proceeding (Docket # 04-IEPR-01G).

[49] EVMWD Web site (www.evmwd.com).

- SMUD's proposed 400 MW Iowa Hill Pumped Storage Development.
- The US Bureau of Reclamation is also exploring several pumped-storage options in the Upper San Joaquin River Basin.[50]

As with any dam or reservoir, development of new pumped-storage facilities faces major challenges. Some of the issues associated with conventional hydroelectric power generation and typical on-stream pumped hydroelectric storage facilities include:

- Water resources impacts - hydroelectric facilities may change stream flows, reservoir surface area, the amount of groundwater recharge, and water temperature, turbidity, and oxygen content.
- Biological impacts, including the possible displacement of terrestrial habitat with a new lake environment, alteration of fish migration patterns, and other impacts on aquatic life due to changes in water quality and quantity.
- Possible damage to, or inundation of, archaeological, cultural, or historic sites (primarily if a reservoir is created).
- Changes in visual quality.
- Possible loss of scenic or wilderness resources.
- Increase in potential for landslides and erosion.
- Recreational resource impacts/benefits.

Another possibility for developing new pumped-storage projects is to connect two or more existing reservoirs or lakes with new pipelines or penstocks for water pumping and power generation. A U.S. Department of Energy (DOE) study identified dozens of such potential reservoir pairs in California, requiring construction of an average of about 10 miles of pipeline to connect each pair. (Lamont 2004). Though this type of development would increase operating flexibility and peaking capacity without need to construct new reservoirs, it would still involve construction of large pipelines through difficult terrain on protected lands, which could require significant expense for environmental mitigations and permitting.

Because of the costs associated with new pumped-storage facilities using existing or new reservoirs, development of modular pumped storage (MPS) may have greater potential in the near future. MPS systems are not dependent upon

[50] USBOR website 2005a.

natural waterways and watersheds and can be sited in areas that avoid many of the issues described above. In fact, they are generally purposely sited away from sensitive areas to avoid the regulatory and operational complexity often associated with conventional pumped hydroelectric storage facilities. MPS systems can also be added to existing water systems wherever the necessary elevation difference exists. They could also be developed in places like abandoned mines, taking advantage of elevation differences and storage created by mine shafts and open pits. If their capacity was less than 30 MW, these pumped-storage facilities could also qualify for supplemental energy payments under the RPS.[51]

Retrofit[52]

Retrofitting existing hydroelectric facilities, specifically replacing turbine runners and generators with new, more efficient equipment, may increase the capacity of these facilities. To the extent that retrofit does not result in changed flows, no permits may be needed. Hetch Hetchy Water and Power increased the capacity of its system 48 MW by replacing turbine runners and generators with newer, more efficient equipment – at a capital cost of $8 million, less than 17 percent of the cost of installing a new unit of comparable capacity. Since the purpose of these retrofits was to increase the efficiency of hydropower production using the same amount of flows, no permits or approvals were required.

Existing hydropower facilities can be upgraded to increase both capacity and output without changing flows. Below are the primary means for attaining such efficiency gains:

- <u>Tunnels</u>. Most power tunnels in California were built using drill and shot methods for rock excavation. The resulting rough rock linings have high friction losses and capacity issues. Existing unlined tunnels could be lined to decrease friction losses and produce more power with the same amount of water. Existing lined tunnels can be made smoother by relining or coating abraded surfaces. Some tunnels can be enlarged or made smoother by selectively trimming tunnel walls. The longer the distance of the tunnel and the greater the friction, the greater the opportunity for incremental gains in power production. Some tunnel lining projects have increased hydropower production up to as much as 7 percent.

- <u>Penstocks and Pipelines</u>. Similarly, penstocks and pipelines could be relined or replaced to reduce friction losses during times of high flows. The decision to reline or replace is an economic one that depends in large part upon the remaining useful life of the hydropower facility itself. The potential benefit also

[51] Aspen 2004
[52] Matthew Gass, Engineering Manager, Hetch Hetchy Water and Power, San Francisco Public Utilities Commission.

depends upon the length of the penstock or pipeline, and the amount of friction losses. Here, again, benefits of up to 7 percent have been documented.

- Turbines. The easiest and frequently most economical improvement could be to replace a turbine's runner. Computerized design, manufacture, and improved testing and modeling methods have increased the efficiency of turbine runners. Minimum efficiency gains for replacements of turbine runners installed in the 1970s and 1980s have been reported at 1 percent. When older designs are replaced by customized efficiency designs, increased output as high as 30 percent has been reported.

Other types of hydropower efficiency gains are attainable through improved planning, controls, and management. Most large hydropower plants in California are multi-unit facilities. In many cases, there are opportunities to optimize operations by balancing the loads of individual units. Specialized computer selection software has helped attain performance improvements of 1-3 percent. In addition, improved controls and monitoring systems allow more efficient operations and reduce downtime from unplanned outages. All of these things have potential to increase net power production. Applied to the state's hydropower inventory, these minor tweaks could cost-effectively increase the state's total hydropower production by at least 3 percent within just a few years.[53] However, FERC rules regarding system modifications and upgrades will need to be reviewed to confirm the trigger points that could reopen a license to scrutiny.

There is constant tension among competing interests for water supply, water quality, hydropower production, and flood control. A better understanding of opportunities for optimizing the state's hydropower supplies and the key stakeholders needed to attain those incremental benefits would provide a useful framework for identifying feasible options and resolving points of conflict.

Other Renewable Resources

Both water and wastewater utilities have extensive watershed lands and rights-of-way with potential for wind and solar development.

- In spring 2005, the Semitropic Water Storage District completed installation of a 1 MW solar facility that provides peaking power for local pump loads.[54]

- At the Solar Power 2004 Conference and Exposition, San Francisco announced that it will soon build a 225 kW solar facility covering 20,000 square feet at its Southeast Water Pollution Control Plant.

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[53] Matthew E. Gass, P.E., Engineering Manager Hetch-Hetchy Water and Power.
[54] Boschman 2005..

- IEUA will install solar panels on its new LEED Platinum headquarters, which was designed to reduce energy use by 90 percent and water use by 70 percent compared with its previous building. IEUA expects its headquarters to be completely energy independent by next year.[55]

- Hetch Hetchy conducted a wind resource assessment of its Calaveras watershed that indicated a potential of more than 30 MW.

The developable renewable energy potential owned by water and wastewater utilities is not yet known. It would be beneficial to identify, assess and prioritize these resources, and provide technical and financial assistance to help develop renewable energy for the benefit of all California ratepayers.

Barriers to Energy Production

Even when transmission is available to move the power out of a water agency's conduit hydropower, biogas, or solar facility, the water professionals interviewed for this paper expressed frustration with their limited ability to deliver self-generated power to their various facilities. Water and wastewater facilities are often dispersed over large distances. These facilities typically take electric service at multiple points and are metered separately at each point.

During public workshops and working group meetings, water and wastewater utilities cited the following primary barriers to self-generation:

- Complex, costly and long lead time interconnections.
- Prohibitive stand-by costs.
- Disincentives to fully utilize available renewable or distributed resources.

Issues of interconnections are being addressed by both the CPUC and the Energy Commission with respect to Rule 21.

Present regulations do not allow aggregation of a customer's electric metered loads within a single facility, much less with metered loads at their other facilities. Therefore, the only means for a water or wastewater utility to deliver self-generated power to itself anywhere on its system is to own and operate its own transmission and distribution systems -- essentially, to operate its own electric utility contiguous with its water service territory boundaries. Of course, this would be cost prohibitive.

At the April 8, 2005, *Energy Report* Committee workshop, IEUA identified the following barriers to its efforts to become energy self-sufficient and possible solutions to these barriers (Table 5-2).

[55] Davis 2005.

Table 5-2: Barriers to Energy Self Sufficiency

Barrier	Solution
Presently, IEUA is metered at multiple points, making it difficult to understand, plan and manage its total energy requirements.	The ability to aggregate all of IEUA's electric loads into a single consolidated load would enhance IEUA's ability to self supply its loads. In addition, it would enhance IEUA's ability to develop creative approaches, whether through modified system design and/or operations, to further reducing peak period consumption.
CPUC "single premise rules" discourage building generation greater than connected load.	IEUA would increase the size of its generation facilities if it had ability to wheel self generated power to itself.
Energy utility programs often fail to capture opportunities to encourage energy efficient design principles in water agencies' facilities.	IEUA and other water agencies have substantial continuous capital programs and, thus, opportunities to incorporate non-conventional energy efficient design principles into large facilities. For example, most of the cost of a new or replaced pipeline is in the trenching. The incremental cost of oversizing a pipeline is fairly modest and should be encouraged wherever cost-effective in reducing energy consumption. Some Energy Performance Contracting programs can be accessed for these types of projects; but applying for and collecting incentives are often difficult.
IEUA and other water agencies have unique opportunities for renewable energy development (e.g., biogas; pipeline conduit hydro; extensive rights of way and watershed lands); but the development costs and risks are often daunting for an entity for which energy is not its primary business.	IEUA is hosting various pilot programs that test and refine renewable energy technologies. Energy utilities could partner with water agencies to optimize development of their renewable energy potential, first to offset their own loads, and then potentially to also become net exporters of renewables and help energy utilities meet RPS and achieve other environmental benefits, including greenhouse gas reductions. Incentive programs are key to testing new technologies at scale. Net metering program (SB 728) will be essential to capturing value of renewable energy.

Source: IEUA testimony

Conclusions

Given the state's energy and capacity shortages, it would be beneficial to help water and wastewater utilities develop all potential renewable and distributed resources. This can be facilitated by allowing these utilities to aggregate their metered load and remove net metering caps. Excess power could then be sold to the energy utilities. Ultimately, the tension between energy utilities and their customers needs to be resolved through policy. The fundamental issue is whether customer-sited distributed generation provides an energy system benefit that reduces total societal costs.

CHAPTER 6 – POTENTIAL EFFECTS OF FUTURE CHANGES

Several factors are causing changes to California's water supply portfolio; legislative, regulatory, market, and technological changes will affect both water-related energy consumption and energy production.

The following discussion addresses a variety of known and anticipated energy impacts, the primary drivers of these impacts, and the extent to which the magnitude and timing of these impacts can be predicted. The primary drivers to be discussed are:

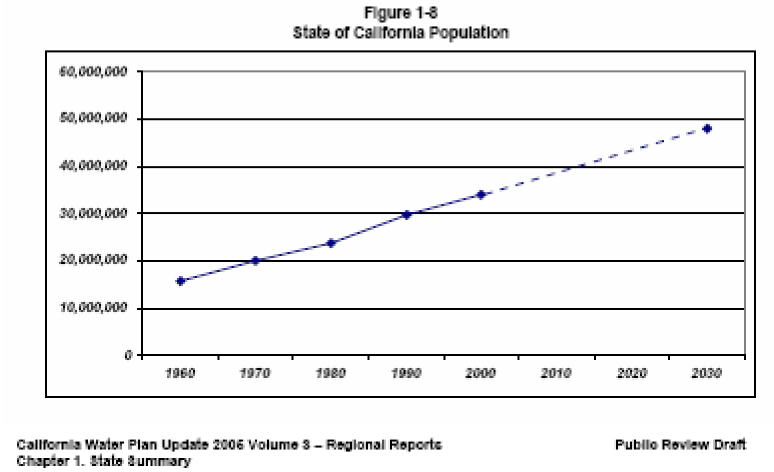
- Increased water demand
- Changes in water end use
- Changes in regulation and legislation
- Changes in water and energy markets
- Hydrology
- Technology
- Policy

Where reasonable bases exist for estimating these impacts, they will be described. If their impacts cannot be reasonably projected, staff identifies needed additional information.

Increased Water Demand

DWR, in the *2005 Water Plan Update,* based its estimates for water demand growth on data from the Department of Finance (DOF) that estimates California's population will increase more than 40 percent by 2030 - from about 34 million in 2000 to 48 million in 2030 (Figure 6-1). Absent mitigation, water-related energy consumption attributable to urban water use is expected to match this growth. The plan projects that, without mitigation, urban water use will increase substantially - as much as 6 million acre-feet, or 67 percent, by 2030.

Figure 6-1: Projected Population Growth in California



The actual impact of water demand growth on energy is difficult to predict for the following reasons:

1. The water supply portfolio planned to meet water demand growth is significantly different from the state's existing portfolio. Consequently, a simple extrapolation of the current average energy intensity of water supplies makes no sense.

2. The state water plan indicates that the largest new supply available to provide for the expected growth in water demand over the next 25 years is water use efficiency. To the extent that the state may not attain its targeted level of efficiency, any shortfalls in water supplies will need to be made up from other sources, most likely recycled water and desalination. Both of these options require new infrastructure that will need to be developed years before it is actually needed. If these are not in place in time, forced conservation, such as the shortage allocations during the 1987-1992 drought, may need to be implemented.

3. Industry experts predict there will be an increase in water market transactions. Some broad generalizations about water market transactions can be made. For example, to the extent that these transfers result in a net increase in physical deliveries of Northern California water supplies to Southern California or agricultural water use is converted to urban water use, energy consumption for water conveyance will increase. However, the net energy impact of increased water transactions cannot be determined. There are many variations in the types of transactions that could occur and no certainty as to which will or will not occur.

4. The recent Colorado River Quantification Settlement Agreement (QSA) requires that California beneficiaries of Colorado River water reduce their use over the next 14 years to California's basic annual allocation of 4.4 million acre-feet. A number of specific actions are being taken by Southern California water utilities to implement the QSA and make up for reductions in Colorado River imports.

> Strategies include increased water use efficiency, increased imports from the State Water Project, development of 126,000 acre-feet of desalinated ocean water, managing the San Bernardino Basin as a groundwater facility, increased use of recycled water, and paying farmers to fallow their land. It seems likely that these strategies will have significant impacts on energy use. However, the net impacts of all of the combined strategies and any offsets, such as reduced energy due to lower Colorado River imports, are not yet known.

In order to assess its range of potential impacts, staff estimated the energy implications of the water supply portfolio strategy illustrated by DWR for low and high growth scenarios. Table 6-1 shows that energy associated with the water plan strategy will increase water sector energy use by 12.3 percent in the low-growth scenario, to as much as 25.8 percent in the high-growth scenario, over the period 2000 to 2030. The energy impacts were derived by multiplying the energy intensity numbers for each type of incremental water source from Figure 2-2 in Chapter 2, by DWR's projections.

Table 6-1: Estimated Energy Impacts of Proposed Incremental Water Supplies[56]

Resource	Low Growth Projection				High Growth Projection			
	Water		Energy		Water		Energy	
	MAF	%	GWh	%	MAF	%	GWh	%
Conjunctive Management	0.5	21.3%	475	19.2%	2.1	36%	1,995	40%
Recycled	0.9	38.3%	352	14.2%	1.4	24.1%	547	11%
Surface Storage	0.05	2.1%			1.0	17.2%		
Inland - Desalter	0.2	8.5%	340	13.7%	0.3	5.8%	570	11%
Ocean - Desalter	0.1	4.3%	440	17.8%	0.2	2.8%	726	15%
Conveyance	0.3	12.8%	870	35.1%	0.4	6.9%	1,160	23%
Precipitation Enhancemer	0.3	12.8%			0.4	6.9%		
	2.35	100.0%	2,477	100.0%	5.8	100.0%	4,998	100.0%
Current - Base	43		19,345		43		19,345	
Total Projected	45.35	5.5% Growth	21,822	12.8% Growth	49	13.5% Growth	24,343	25.8% Growth
Water Use Efficiency								
Urban	1.1				2.3			
Agriculture	0.2				0.9			
Total	1.3				3.2			

Source: 2005 State Water Plan Update, DWR for water projections. Appendix C for energy calculations

DWR's plan calls for urban and agricultural water use efficiency to make the largest contribution to the state's water supplies. However, conserved water will be redistributed to new users as the population increases. Recycled water, planned to provide almost 40 percent of incremental water supplies in the low-growth projection, will contribute 14 percent to incremental energy use. At the other extreme, ocean desalting is planned to provide only 4 percent of the incremental water, but will require almost 18 percent of the energy. These estimates are indicative of the need to better understand the energy implications when developing the state's future water supply portfolio.

[56] Low-growth projections reflect a 2030 water demand scenario where current trends continue, resulting in reduced agricultural irrigated crop area and reduced agricultural production. Urban water demand increases are linked to population increases and corollary increases in employment sectors. Under this scenario, per-household as well as per-employee water demand decreases slightly. Environmental water demand increases, and naturally occurring conservation decreases slightly. Population growth is based on Department of Finance (DOF) 2004 projections for growth and density.

High-growth projections reflect a 2030 water demand scenario where agricultural irrigated crop areas hold constant with year 2000; urban related water demand grows significantly, linked to population growth exceeding DOF projections by 12 percent, and lower overall population density and greater population growth occurs in inland and in southern hydrologic regions. Per-household and per-employee demand is elevated, and naturally occurring conservation decreases slightly. Urban water prices continue current trends.

Changes in Water End Use

A number of factors are driving changes in water end use. Changes impact both the urban and agricultural sectors. There are many types of changes – some that may increase energy consumption and some that may decrease energy consumption. Net impacts are difficult to predict. The discussion below about changes in agricultural water use illustrates the complexity of evaluating the net energy impacts of changed water use patterns.

Changes in Agricultural Water Use

As discussed in Chapter 4, changes in crops and irrigation methods affect overall energy demand. In the future, staff expects that periodic changes in crops will occur. Staff cannot predict what those changes will be. Consequently, only general statements can be made about the energy impacts of different trends. The *California Water Plan* projects that the agricultural sector will reduce overall water demand, predominantly through conservation. Any saved agricultural water will likely be applied to higher energy intensity urban uses.

Other signs point to decreased energy use in the agriculture sector, including efforts to conserve water and energy, following the example of urban agencies that universally follow a set of BMPs in managing their systems. For example, some irrigation districts have signed on to a program sponsored by DWR that requires implementation of Efficient Water Management Practices (EWMPs) that address energy management (Efficient Water Management Practices by Agricultural Water Suppliers in California, Memorandum of Understanding, January 1, 1999). That effort was prompted by the Agricultural Water Suppliers Efficient Water Management Practices Act of 1990. However, unlike urban water systems where water conservation also brings energy conservation, agricultural water conservation can often lead to increased energy demand. Reuse of tailwater, for example, requires installation of additional pumps, and drip and microspray irrigation need more electricity than other irrigation methods. Some of these uses, however, such as reuse of tailwater, could have the benefit of avoiding long-distance conveyance energy use.

Utilities and agencies are also addressing agricultural energy use through several energy efficiency programs. A good example is the Agricultural Pumping Efficiency Program (APEP), run by the Center for Irrigation Technology, which is part of the California Agricultural Technology Institute at the College of Agricultural Sciences and Technology, California State University, Fresno. The program receives funding from the Public Goods Charge on utility bills and provides free pump efficiency evaluations for farmers and irrigation districts served by the state's three large investor-owned utilities. Since 2002, the program has resulted in at least 15 GWh of savings from approximately 350 pump retrofit/repair projects.[57]

[57] Canessa 2005

Taken together, no definite conclusion can be drawn concerning the future trend of energy use in the agricultural sector. It is necessary to look at all applicable portions of the water use cycle when assessing the net energy impacts. More work is needed.

Changes in Regulation and Legislation

There are a number of regulatory and legislative actions that will impact both energy consumption and energy production by the water sector.

Water Quality Regulations

Energy use for water treatment will increase as more stringent water quality rules are implemented under the federal Safe Drinking Water Act. These new rules require multi-stage disinfection including treating potable water more than once, which ensures removal of harmful organisms that may grow during storage and transport, and improved disinfection technologies that reduce the risk of carcinogens and other potentially harmful disinfection by-products. These improved disinfection technologies – principally, ultraviolet treatment and ozonation[58] – are much more energy intensive than prior chemical methods.

Energy use for wastewater treatment is also expected to increase because of new requirements under the Clean Water Act for treating effluent before discharging it into natural waterways. However, by increasing the quality of wastewater effluent, more recyclable water can be added to the water supply portfolio. Therefore, any increased energy use for wastewater treatment may be accompanied by a decrease from increased use of low energy intensity recycled water that can be used to displace higher energy intensity water supplies.

The actual impact of these new regulations is not yet known, and water agencies are still making decisions as to which treatment processes and technologies to adopt. In addition, the net impacts need to be better understood. However, a 2002 EPRI study estimated that these new water quality rules could increase energy consumption by wastewater treatment facilities by 20 percent between 2000-2005 and another 20 percent between 2006 and 2050.[59]

FERC Relicensing

FERC licenses 119 hydropower projects in California representing 11,930 MW, or 85 percent of the state's hydroelectric capacity. Thirty-seven percent of the state's entire hydropower system, totaling 5,000 MW, will be relicensed by 2015.

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[58] Ozonation requires about twice the amount of electricity used by chloramination to disinfect the same quantity of water. In addition, the requirement for multi-stage disinfection increases the number of processes and overall electricity use.

[59] *Water & Sustainability* (Volume 4): *U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI, March 2002.

Typically, the FERC relicensing process results in increased requirements for in-stream flows. This has the result of decreasing overall hydroelectric generation. The National Hydropower Association reported a decrease of about 8 percent on average for the nation as a whole. The California experience has been less – a loss of about 2 percent in in-state hydroelectric energy production to date. An odd twist is that hydroelectric capacity actually tends to increase during FERC relicensing, as old units are either repowered or replaced.

In its *2003 Integrated Energy Policy Report*, the Energy Commission reported findings from analyses of six projects being relicensed. The analyses included studies of changes in energy capacity and production from the perspective of statewide and regional electricity supply adequacy and the reliability and cost of replacement power that would result if the proposals were implemented. The study concluded that combined annual energy production losses from relicensing would represent approximately 1 percent of the state's total annual hydroelectric production. The study concludes that "Specific decommissioning proposals would need to be fully evaluated on a case-by-case basis to identify potential local area reliability effects."[60]

Both the Energy Commission's *2003 IEPR* and staff's *California Hydropower System*: *Energy and Environment* provide key findings, as of October 2003, with respect to the potential energy and environmental impacts of FERC hydroelectric relicensing.

[60] California Energy Commission, *2003 Environmental Performance Report*. Appendix D, *California Hydropower System: Energy and Environment*, Sacramento, CA. 100-03-018, March 2003, p. D-4.

2005 Energy Policy Act

The 2005 Energy Policy Act (EPAct) recently signed into law by President Bush contains significant provisions that could affect both water-related energy use and production.

Water-Energy Relationship

- Funding for research, development, demonstration, and commercial applications to address water-energy issues including energy-related issues in optimal management and efficient use of water, and water-related issues in optimal management and efficient use of energy [Section 979].

Hydropower Incentives

- Ten-year production incentive payments for hydroelectric power from generation additions to existing dams or conduits completed within the next 10 years, limited to $750,000/year per facility [Section 242].

- Incentive payments for up to 10 percent of capital improvement costs for hydroelectric facilities that increase efficiency by more than 3 percent, not to exceed $750,000 per facility [Section 243].

- Inclusion of qualifying hydropower production (due to efficiency gains or capacity expansions placed in service after the date of the Act and before 2008) for Section 45 tax credits [Section 1301].

Other Renewable Energy Technology Development & Incentives

- Funding of more than $2.2 billion for fiscal years 2007-2009 for research, development, demonstration, and commercial application on renewable energy issues, including efficiency, cost and diversity, addressing a variety of renewable energy technologies (solar, wind, geothermal, hydropower, and other technologies) [Section 931].

- Funding of more than $750 million for fiscal years 2007-2009 to support a program of research, development, demonstration, and commercial applications for distributed energy resources and systems reliability and efficiency [Section 921].

- Funding for a State Technologies Advancement Collaborative (STAC) to research, develop, demonstrate, and deploy technologies where there is a common federal and state renewable energy interest [Section 127].

- Extension of in-service date deadlines to October 1, 2016, for facilities to receive renewable production incentive payments for solar, wind, biomass, geothermal, plus the addition of landfill gas, livestock methane, and ocean-related energy resources [Section 202].

- Extension of in-service date deadlines for two years, to December 31, 2007, for renewable energy production tax credits under Section 45 of the Internal Revenue Code of 1986 for qualifying facilities: wind, closed and open-loop biomass, geothermal, small irrigation power, landfill gas, and trash combustion [Section 1301].

- An increase in the Business Solar Investment Tax Credit, from 10 percent to 30 percent [Section 1337].

- Amendment of the Public Utilities Regulatory Policy Act (PURPA) of 1978 to add the requirement that each electric utility shall make available to any electric consumer a net-metering service relative to an eligible on-site generating facility [Section 1251].

Where significant tax incentives exist, there is the opportunity to develop public-private partnerships that bring private investment to help develop renewable energy resources. The impacts of the 2005 EPAct on renewable energy development of water and wastewater utilities' resources and assets cannot be determined.

Changes in Water and Energy Markets

Changes in both water and energy markets have potential to impact energy consumption and production by the water sector. For both, the primary driver of change is economics.

Water Markets

California's water markets are changing. The ability to sell water under some circumstances without losing water rights will likely increase transactions. The provisions of the Colorado River Quantification Settlement Agreement are driving Southern California water utilities to make changes in their water supply portfolios. Further, changes in the mix of crops being planted in California and economic pressures to convert agricultural land to urban use will affect water-related energy consumption.

As discussed previously, because the wide variety of potential transactions, it is difficult to project the net impacts of water market transactions on future energy use. Not all water transactions result in more transported water. Transactions often involve exchanges of water rights among multiple interconnected parties that merely allow the downstream purchaser to take more water from existing sources for a price that compensates each party involved in the transaction. The transaction can sometimes result in a net energy benefit, especially when reducing SWP or other energy intensive imports.

Energy Markets

The 2005 Energy Policy Act will certainly have an impact on the pace and types of renewable energy development. In addition, other impacts - natural gas and diesel price volatility, the impact of competition for renewables to meet RPS goals, and the cost of bundled versus unbundled delivered energy to various load centers - will all affect how agriculture and water and wastewater utilities use energy.

One example is the agricultural pumping switch from diesel to electric. Thousands of diesel-powered pumps are now operating in the Central Valley. With diesel prices soaring and air quality rules tightening, farmers are being encouraged to consider switching back to electric motors. ITRC estimates that converting all of those diesel engine pumps back to electric would increase energy consumption by 1,131 GWh (ITRC 2003). On August 1, 2005, both PG&E and SCE's "AGICE" (Agricultural Internal Combustion Engine) incentive programs went into effect. They are available to owners of pumps of 50 horsepower and above, provide a 20 percent discount over other agriculture rates, increase at 1.5 percent per year until eliminated, and offer an environmental adder that will reduce the costs to the customer of extending distribution lines to the pump. PG&E's program is capped at $27.5 million per year in total incentives, including discounts and environmental adders.[61] SCE's program is capped at $9.2 million. In the PG&E territory, it is possible that 200-300 MW of new coincident peak will be added to its system during the course of the two-year open enrollment period.[62].

Hydrology

There are two primary types of hydrological conditions that could affect both energy consumption and energy production by water and wastewater utilities: drought and climate change.

Drought

Changes in hydrology significantly affect the availability of water supplies and water use from year to year. The worst case scenario, from both a water supply and energy perspective, is a multi-year drought. During past droughts, surface water deliveries dropped in some places to less than half of average year deliveries, forcing water users to rely much more on groundwater pumping and emergency conservation measures.

During prolonged droughts, certain types of electricity use increase. For example, when surface water supplies are low, more groundwater is pumped. During

[61] Mayers, 2005
[62] Keith Coyne, PG&E, August 4, 2005

sequential dry years, water must be pumped from even greater depths as aquifer levels fall. Periods of drought also significantly increase pumping from existing and future conjunctive use field, as agencies tap emergency water supplies. An extended multi-year drought could also spark the rapid development of additional desalination facilities.

Estimating the water-related energy impact of a multi-year drought, however, is more complicated than simply adding up projected increases of energy consumption. During droughts, water shortage policies and plans place limits on water use by various market sectors and customer groups to allocate limited supplies. In addition, SWP and other large water systems will not have as much water to pump. The combination of these impacts would need to be netted out against incremental energy consumption for water supplies - like groundwater pumping and desalination - to understand the true energy impacts.

In evaluating water-related energy consumption from prior years, staff has been unable to find data that definitively support the premise that water-related energy consumption increases during dry years. In general, staff can say that an increase in water-related consumption and a decrease in energy supply are likely during a dry year. However, water industry experts are divided as to whether there is a net positive or net negative impact in energy consumption during a prolonged multi-year drought where serious reductions in water storage could trigger mandatory water use reductions.

Climate Change

A change in the patterns of rain and snow could have significant effects on both electricity production and consumption. Climate change scenarios show that global warming trends may result in more rain, but less snow. As a result, even when total precipitation is near normal levels, spring runoff will likely occur earlier in the year, resulting in early "spills"[63].

The Energy Commission has already conducted substantial research into the effects of climate change and is taking a lead role for the state in developing strategies to reduce greenhouse gas emissions. These efforts, as well as other statewide studies, were summarized in two recent Energy Commission reports prepared in support of the *2005 Integrated Energy Policy Report*. The first report, *Climate Change Impacts and Adaptation in California,* summarizes available scientific literature and provides a brief overview of the research agenda. The second report, *Global Climate Change*, provides background and context to guide the formulation of policy options for reducing greenhouse gas emissions in California.

[63] Overfilling of reservoirs in spring months, with spills bypassing turbines and reducing energy production and sometimes, also reducing summer peaking capacity.

A third report, *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States,* evaluated the potential effects of climate change on hydropower operations and production. This study included the following findings and recommendations:

- Climate change studies to date have depended upon broad trend analyses and are not yet useful in predicting impacts at the local watershed level.

- California is experiencing a warming trend. This could precipitate earlier snowmelts, reduce summer hydropower production and capacity, and increase summer air-conditioning loads.

- Although more work is needed to predict local impacts, warmer temperatures could cause earlier snowmelts, reducing stored water supplies.

Reduction of stored water has several potentially adverse impacts:

- Less availability of surface water supplies (which could lead to increased use of more energy intensive supplies).

- Less hydropower peaking capacity.

- Lower head (reducing hydropower energy production as well).

Clearly, climate change impacts will need to be studied over many years before the true net impacts on both energy consumption and energy production can be accurately measured.

Technology

Changes in technology could change energy consumption and energy production, though the net impact of such changes is undeterminable. Below are some examples of potential changes in technologies that could affect water-related energy consumption or energy production:

- In addition to continually seeking more efficient water and energy systems and processes (e.g., desalination and disinfection technologies), research continues into streamlining system processes and plant designs.

- In addition, research continues into improving the efficiency of pumps, motors, and equipment to reduce energy consumption and increase operating flexibility to shift loads off-peak.

- Specific research into modifying the reverse osmosis process used in desalination to reduce energy requirements is occurring in multiple forums.

- New technologies are improving the design of turbine runners, making it possible to increase both capacity and output of existing hydropower systems through retrofits. In addition, research continues into developing packaged systems that can be dropped into existing pipelines without need for costly civil works and low head turbine technologies.

- Automated controls technologies also optimize water releases to better balance hydropower production with water supplies and electric loads, and allow more efficient pumping in water and wastewater treatment plants.

The American Water Works Association Research Foundation (Awwa-RF) and PIER are already collaborating on a portfolio of research and development projects related to the interdependencies of water and power.

Policies

Several policies have been adopted for both the water and energy sectors. Policies to reduce water and energy consumption will certainly impact both the water and energy sectors, but the net energy benefits may differ. Energy demand could go up as a result of water decisions. Ultimately, it matters tremendously what policy options are implemented and how well these policies are coordinated for mutual water and energy benefits. Thoughtful policies can mitigate the potential adverse impacts of water decisions on energy resources and infrastructure.

Conclusions

The common theme of all of these potential changes is that there are both threats and opportunities. In order to better understand these and develop plans and measures that leverage opportunities and mitigate threats, more information is needed by water and energy policymakers and implementing entities. Ultimately, the *net* energy impacts of various water policies and strategies need to be well understood in order to tailor effective mitigation measures.

CHAPTER 7 – STAFF RECOMMENDATIONS

Findings

During these proceedings, state and federal agencies, water and energy utilities, industry associations, research organizations, and a wide variety of other stakeholders came together to consider the state's water-energy relationship and what it means to the state's energy resources and infrastructure. While acknowledging there is much yet to be learned about the nature and extent of the state's water-energy relationships, some things are clear.

- The relationship between the water sector and the energy sector is complex and highly interdependent.

  - ✓ In-state hydroelectric power generation in 2004 accounted for approximately 11 percent of the state's in-state energy resources. When hydropower imports from the Pacific Northwest and the Desert Southwest are included, hydropower accounted for as much as 15 percent of the state's energy in 2004.

  - ✓ The water sector is the largest consumer of energy in California, estimated to account for 19 percent of total electricity and 32 percent of total natural gas consumed in the state.

- Saving a unit of water reduces the amount of energy used to collect, treat, deliver it, consume it, treat it, and dispose of it as wastewater. If used elsewhere, this saved water may displace the need to develop new, more costly water sources.

  - ✓ With few exceptions, the avoided energy value embedded in a unit of water throughout the applicable portion of the water use cycle is not accounted for by either water or energy utilities.

  - ✓ Presently, the magnitude of this total energy savings cannot be fully calculated, though sufficient information exists to compute a proxy to support near-term programs.

  - ✓ The state's current energy programs (codes and standards, incentives, and rebates) focus on energy saved at a single location from increasing water and process heating efficiency – not on energy that can be saved from reductions in water use. Not including cold water savings misses significant energy savings opportunities upstream in the water use cycle.

  - ✓ There are significant differences in the energy intensity of the water use cycle between Northern and Southern California because of differences in the energy intensity of water supply portfolios that are heavily dependent on imported resources.

- ✓ Options for new water resources in the future are limited. The least energy intensive option for future supplies is water use efficiency. The most energy intensive option is ocean water desalination.
- ✓ Water that is not consumed generally becomes available to offset highest marginal cost supplies.

- Modifications to the operations or design of the water system infrastructure present opportunities to reduce water system peak electric demand.
  - ✓ Some existing surface storage facilities can be modified to maximize generation opportunities and increase operational (peaking, load following) flexibility.
  - ✓ Many existing and most new water and wastewater treatment plants can be designed to detain water for treatment during off-peak hours.
  - ✓ Increased conjunctive use programs may allow for greater ability to shift energy demand seasonally.
- Currently, most water and energy systems are internally optimized on a single utility basis. Systems are rarely optimized in coordination with other systems (water, wastewater, electric and natural gas) or with their customers, missing opportunities to reduce total energy consumption, shift loads off-peak, or maximize energy generation.
- Opportunities within a utility system to develop additional generation resources (in-conduit hydroelectric generation, biogas combustion, and other renewable development) exist. However, significant barriers frustrate development of these resources.
- Energy demand in the water sector will likely increase over time due to a number of factors, including population and urban load growth, increased water and wastewater treatment because of more stringent water quality regulations to protect water quality, and market, economic, regulatory, and legislative changes.
- Several actions can be taken now to significantly reduce energy demand throughout the water use cycle and slow its future growth. This is particularly true in areas, like Southern California, which have tight energy supplies and constrained transmission systems.

The state's water and energy utilities separately seek to optimize their respective water and energy resources within their own portfolios. There are strong similarities between their IRP goals, methods and techniques. However, in developing its water resource strategy, DWR did not synchronize its water resource planning goals and objectives with those of the Energy Commission to assure, for example, that local energy supplies and infrastructure can support greater desalination production. Where seawater desalination plants may be planned at points downstream of electric transmission congestion zones, the energy solution may be to build new generation in combination with the desalination plant. Another solution may be joint water and energy investments in recycled water infrastructure processing that could displace the need to build desalination facilities in the first place. This is one example of the types of water and energy tradeoffs that should be examined.

The most significant finding of this paper is that the greatest potential for positively impacting the state's energy circumstance is beyond current water and energy best practices. The opportunity is fortuitous, and the need is great. To accomplish mutually beneficial results will require increased coordination between programs and agencies, as well as a more complete understanding of the needs of both systems and customers. At a minimum, the state's future water plans should be coordinated with the state's energy management plans to both identify and reconcile potential areas of conflict and take advantage of points of synergy. Optimizing the systems and operations of both water and energy utilities throughout the state on a holistic societal value basis will provide the greatest net benefits.

Staff Recommendations

Based on the findings in this analysis, staff recommends an action-oriented approach that is structured to attain near- and long-term results. This approach should include policy integration that seeks to optimize the mutual and synergistic benefits of the water and energy systems and resources. A key aspect of this approach is the development and implementation of a comprehensive, statewide water-energy program that integrates water and energy resource planning and management. The following essential elements have been identified for a successful program.

1. Save energy by saving water.
2. Reduce water system net power requirements.

Importantly, while this is a significant undertaking, near-term benefits could be attained while longer-term plans and studies begin at the same time.

Save energy by saving water

Even though water efficiency programs and conservation efforts exist in the state, there are many missed opportunities to save energy and manage load. These include energy savings throughout the water use cycle through water use efficiency; changes in systems and operations to reduce peak time-of-use and seasonal demands; and changes in water management to reduce use of the highest energy intensive supplies. This is particularly unfortunate in areas where energy resources are tight or peak energy demand is a problem. In fact, since load growth is the primary stressor of both water and energy resources, those areas that are shortest in water supplies are also energy constrained, making it even more crucial that the state's water and energy resources be managed on an integrated basis.

Staff concludes that the state could achieve nearly all of its energy and demand reduction goals for the 2006-2008 program period by simply allowing energy utilities to realize the value of energy saved for each unit of water saved. In that manner, energy utilities can co-invest in water use reduction programs, supplementing water utilities' efforts to meet as much load growth as possible through water efficiency. Remarkably, staff's initial assessment indicates that this benefit could be attained at less than half the cost to electric ratepayers for traditional energy efficiency measures. Staff should work with the CPUC and the energy and water utilities to evaluate the achievable savings and implementation strategies.

Staff therefore recommends that the state pursue policy options that achieve greater energy efficiency and saving through a more aggressive and comprehensive statewide water efficiency program. This program should target both site-specific efficiencies and actions that will result in net system energy savings. These actions could be a key part of the utility energy efficiency portfolios that accomplish savings needed to meet the CPUC's goals. Key elements of such a program include:

- Allowing energy utilities to count energy savings related not only to those achieved on site, but, where appropriate, those that can be identified throughout applicable portions of the water use cycle.

- Working with the Task Force, CPUC, DWR, and other stakeholders, refine data related to energy use and generation associated with the various parts of the water use cycle for use in accounting for the net energy impacts of this system and in calculating the effects of various programs designed to attain synergistic benefits.

- Target end user water efficiency measures that result in net energy savings – both on premises and in the water use cycle. For example, in addition to programs that save hot water, include programs that seek to maximize cold water savings in homes and businesses and count the net energy benefits attributable to a unit of avoided water consumption embedded in the entire water use cycle.

- Establish a collaborative with DWR, the CPUC, and the Energy Commission to achieve the state's least energy resource intensive water future by 2030. Align programs and policies to complement one another and remove barriers to mutually beneficial results.

- Invest in research that develops more water and energy efficient appliances, processes, designs, demand side management methods and technologies, and treatment systems.

- Establish a water resource loading order that incorporates the societal value of an avoided unit of water consumption that mirrors the preferred energy resource loading order in the *2005 Energy Report* and the Joint Agency *Energy Action Plan*.

- Establish a public goods charge equivalent for public purpose water conservation and efficiency programs that attain targeted net energy benefits.

- Require the state's energy and water planners to collaborate on plans and strategies to reduce net water sector energy consumption while meeting projected water and energy load growth with environmentally preferred resources and strategies.

- Commit public goods charge funds for expanded water efficiency programs and innovative technology development to reduce the net energy demand of the water use cycle in current 2006-2008 IOU energy efficiency portfolios.

Reduce water system net power requirements

The state should adopt a comprehensive policy to facilitate water and wastewater utility energy self-sufficiency by reducing water system net power requirements. This policy should include reducing operational energy requirements, shifting loads off-peak, and increasing energy generation from water- and wastewater-related resources and renewable opportunities. Implementing this policy is consistent with the objectives of the *2005 Energy Report* and the *Energy Action Plan* loading order and helps achieve the state's RPS goals.

- Develop cost-effective, environmentally preferred in-conduit, biogas and other renewable options for water and wastewater systems. To accomplish this, the Energy Commission should facilitate greater participation of water utilities in its loan and rebate programs by targeting planned retrofits at existing facilities and providing design assistance for planned facilities.

- Remove barriers to energy self-sufficiency by allowing water and wastewater utilities to self-generate power and provide this power to themselves anywhere on their systems; expedite and reduce costs of interconnections; eliminate economic penalties such as prohibitive standby charges; and remove caps on size of facilities eligible for net metering.

- Identify and implement retrofits in the water system that attain energy benefits, including but not limited to treatment system upgrades, turbine and pump replacements, and delivery system modifications.

- Require water and wastewater utilities to assess the energy impacts attributable to new or changed infrastructure and operations and evaluate feasible alternatives to reduce overall energy demand associated with these decisions.

- Provide incentives for incremental and/or joint infrastructure improvements that reduce total and peak energy requirements for water and wastewater conveyance and treatment.

- Facilitate collaboration among water and energy utilities and other local and state entities for the joint development of resources and infrastructure to further leverage benefits of their combined assets.

- Provide incentives for water, wastewater and energy utilities to optimize their joint resources beyond traditional discrete single utility service boundaries - water, wastewater, electricity, and natural gas.

In developing this report, Energy Commission staff established the Water Energy Relationship Working Group, which helped identify issues, evaluate possible resolution of those issues, and provide input on future policy options. This group demonstrated the need for the committed involvement of key stakeholders and an ongoing dialogue about the water-energy relationship. This cooperation and communication are vital to achieving the mutually synergistic benefits of water and energy systems.

Recommended Joint Actions

The Energy Commission, the DWR, the CPUC, the Air Resources Board, the State Water Resources Control Board, and the California Department of Health Services, should:

- Establish a valuation methodology for the water use cycle that accounts for embedded energy and externalities. This methodology is needed to capture these diversities in a manner that would assist planners in prioritizing their investments.

    - ✓ Incorporate a societal valuation approach in both water and energy utilities' resource pricing methodologies, water and energy efficiency program portfolios, and investment criteria.

    - ✓ To facilitate early results, establish a proxy for the societal value while a detailed methodology is being developed.

- Seek opportunities for joint investment that could produce incremental energy benefits but are not deemed cost-effective on a single-utility resource cost test.

- Leverage work already in progress by others, including the U.S. Department of Energy National Laboratories' Water-Energy Nexus Program, Pacific Institute, California Urban Water Conservation Council, and the Irrigation Training and Research Center. Work closely with these (and other) entities to:

  - ✓ Inventory, characterize, and measure California's water and energy interdependencies.

  - ✓ Develop pilot programs to test tools and methodologies for evaluating tradeoffs among these interdependencies.

  - ✓ Develop analytical models and tools for policymakers, regulators, utilities and other key stakeholders to use in developing cost-effective joint water and energy programs.

  - ✓ Research opportunities and technologies that improve the energy performance of the water use cycle and increase the generation capabilities of the water system.

Conclusion

While all of the nuances are not yet understood, it is clear that significant energy benefits are attainable through water use-efficiency and through increased energy efficiency in the water use-cycle. It is also clear that not nearly enough has been done to make sure that California's water supply strategies are synchronized with its energy strategies. Nor has enough been done to forge partnerships between the water and energy sectors and leverage the natural synergies of their joint resources and assets for the benefit of all Californians.

The state has the timely opportunity to reap near-term energy savings benefits by helping California's agricultural industry and water and wastewater utilities become more energy efficient. The CPUC could direct IOUs to invest current PGC funds for 2006-2008 energy efficiency programs in existing water infrastructure to improve operations, switch operations off-peak, and partially fund retrofits of equipment such as pumps and treatment equipment. These funds could also be used in conjunction with water conservation dollars to leverage greater water end use efficiency to realize net energy savings in the water use cycle. In addition, near-term actions could include minor adjustments to existing policies, programs, and market rules, to facilitate renewable and distributed generation development at water and wastewater facilities as well as agricultural resources to convert them from high energy users to net renewable energy producers.

For the long-term, California's water and energy policymakers need to commit today to joint planning and management of these critical resources. Conflicting policies and objectives need to be identified and conflicts resolved. Water resource plans need to include an accounting of energy impacts and evaluate alternatives to decrease overall energy demand of water systems. The state's energy resource portfolio needs to consider and facilitate the development of all cost-effective and environmentally preferred water system related options. Water and energy agencies and utilities need to work together to identify mutually beneficial research and develop opportunities that the state can pursue to improve both systems, followed with market transformation strategies to accelerate adoption of resource efficient behavior. To achieve mutually synergistic benefits in the water and energy sector, policymakers, agencies, and utilities will need to work together and make long-term commitments of funds and programs.

APPENDICES

APPENDIX A: EXISTING ORGANIZATIONS, PROGRAMS, AND RESEARCH

The California Water Plan

The Department of Water Resources (DWR) is responsible for updating the *California Water Plan (Plan)*, which provides a framework for water managers, legislators, and the public to consider options and make decisions regarding California's water future. The *Plan*, which is updated every five years, presents basic data and information on California's water resources, including water supply evaluations and assessments of agricultural, urban, and environmental water uses to quantify the gap between water supplies and uses. The *Plan* also identifies and evaluates existing and proposed statewide demand management and water supply augmentation programs and projects to address the state's water needs. Often referred to as Bulletin 160, the most recent version is scheduled to be published in late 2005.

DWR is also responsible for managing the State Water Project, including the California Aqueduct, and managing the contracts for electricity created following the 2000-2001 energy crisis. The department also provides dam safety and flood control services, assists local water districts in water management, conservation, recycling and desalination activities, and promotes recreational opportunities.

Energy Use in the Water Cycle

Energy is used in every phase of water use within the state, from extraction through conveyance, treatment, use, and disposal. The Energy Commission has funded several projects to define this interaction between water and energy.

Electricity and Water Flows with California
The purpose of this project, conducted by the University of California, Santa Barbara and the Pacific Institute, is to identify the flows of both water and energy within California. This includes water for electricity generation (hydropower) and all of the electricity used for water – from initial diversion or extraction through conveyance, treatment, use, and disposal. This project will increase understanding of the electricity demand for different water uses within the residential, commercial, and industrial sectors. It will also further understanding of the energy intensity of the water cycle. The results of this study will help focus future water conservation programs where they will make the greatest impact on energy (PIER Environmental[64]).

[64] The names in parentheses at the end of the paragraphs identify the group within the Energy Commission that is responsible for the activity described in the paragraph.

Groundwater and Surface Water Management and Electricity Demand
Conjunctive use of surface and groundwater supplies is increasingly relied upon as a water management tool. Concern about a significant increase in conjunctive use and its associated electricity demand, particularly under drought conditions, is a major concern. Conducted by Lawrence Berkeley National Laboratory (LBNL), the aim of this project is to see how surface and groundwater supplies will be managed under different climatic conditions, and what the consequences would be for electricity demand and prices. It is important to consider not only the likely impact of new conjunctive use programs on regional electricity demands, but also how reservoir management will affect water supply for agriculture and municipal uses and electricity generation and demand. (PIER Environmental).

The U.S. Department of Energy's Energy-Water Nexus Team

In partial response to an identified gap in federal jurisdiction at the nexus of energy and water, the Energy Policy Act of 2003[65] directed the U.S. DOE to:

- Assess future water needs for energy, future energy for water purification and treatment, use of impaired water by energy, and technology for water use efficiency.

- Develop a program plan that incorporates scientific and technology requirements, decision tools, demonstration projects, and information transfer.

Eleven national laboratories and EPRI came together to form the federal Energy-Water Nexus Team (Team), which is charged with developing technology products that will help increase the nation's energy security. The scope of the Team's investigations is very broad:

- Energy versus water tradeoffs in optimizing hydropower and the implications of those tradeoffs on energy supply risk.

- Energy usage by water-related systems and processes (including municipal water, wastewater, and industry).

- Water used to produce energy, such as hydropower and water for cooling.

[65] Section 961, Subtitle (f) *Water and Energy Sustainability Program*.

- Development of tools, including benchmarking, and opportunities to improve efficiency both through more efficient energy consumption and redesigning processes, systems, and operations.

- Financial and economic analyses of markets and participants, including impacts on equipment manufacturers and utilities.

- Environmental impacts, including the economic impacts of hydrology and climate factors, relationships, impacts, and interdependencies.

Presently, the Team is undertaking a road-mapping process for the US DOE, viewed primarily from the perspective of water used for energy and energy used for water - particularly with respect to the research and development of new technologies to improve water and/or energy use and efficiency.

The Ernest Orlando Lawrence Berkeley National Laboratory and the Lawrence Livermore National Laboratory are participating in the Energy Commission's Water Energy Relationship Working Group and can help merge efforts undertaken by the state and the federal government.

The ***2005 Energy Policy Act*** (EPAct) expanded the scope of US DOE's studies on the water-energy nexus.

Water and Wastewater Facilities

Energy consumption is a significant cost component of providing water and wastewater services to the public. The Energy Commission is dedicated to providing resources to help water professionals reduce these costs through implementation of energy efficiency measures at their facilities.

AB 970 – Peak Load Reduction at Water and Wastewater Facilities
At the peak of the 2000-2001 energy crisis, AB 970 provided $4.5 million in grant funding to reduce 52.1 MW of peak electrical load at water and wastewater facilities in four categories: curtailment, efficiency, generation, and load shifting. The grants ranged from $9,000 to $486,000, with an average amount of roughly $110,000 per project, at a rate of $300 per peak kW reduction. This program has been completed (Energy Efficiency Division).

SB 5X – Water Agency Generation Retrofit Program
The program started in May 2001 and was completed in December 2003. Projects were funded in two categories - distributed generation and energy efficiency - with a total on-peak load reduction capacity of 17.7 MW. Of this capacity, distributed generation retrofits provided up to 9.2 MW of on-peak load reduction, while energy efficiency projects provided up to 8.5 MW of load reduction. Twenty-eight qualified applicants received $4.35 million from this

program. The program paid distributed generation participants an average of $259/kW for projects with a combined construction cost of $7,205,488. Energy efficiency participants received an average of $230/kW for their projects, which cost $6,598,108 to install. Overall, the program averaged $245/kW of electrical load reduction (Energy Efficiency Division).

Flex-Your-Power's Water and Wastewater Guide: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures

In response to the 2000-2001 energy crisis, the state's Flex-Your-Power program worked with hundreds of California water and wastewater agencies to develop measures to reduce energy consumption by 15 percent within their systems and facilities, for the purpose of both reducing power costs and alleviating the risk of rotating outages. A four-step process was developed to increase energy self-sufficiency through a combination of on-site power production, total energy consumption reductions through energy efficiency measures and retrofits, and peak shifting to partial- and off-peak periods wherever possible.

Energy Partnership Program

This program provides customized technical assistance to water and wastewater facilities to identify energy efficiency projects, project costs, and associated savings. Consultants are paid up to $20,000 for a detailed study of the facilities. Approximately $260,000 have been paid so far to consultants for feasibility studies, comprehensive energy audits, reviews of energy projects proposals, identifying cost-effective energy-saving measures, review of specifications for energy efficient equipment, and assistance in selecting contractors and design professionals for the water and wastewater facilities that have participated in this program (Energy Efficiency Division).

Energy Efficiency Financing Program

Energy Efficiency Financing Program: The Energy Commission provides low-interest rate loans to fund up to 100 percent of the cost of energy efficiency and self-generation projects. Loans are provided on a first-come, first-served basis. Eligible projects must have an average simple payback of less than 9.8 years. If projects have a greater simple payback, the Energy Commission can provide a loan equal to 9.8 times the annual energy cost savings. Eligible projects include pumps and motors, variable frequency drives, lighting, building insulation, HVAC modifications, automated energy management systems, automated energy management controls, energy generation, streetlights and light emitting diode (LED) signals. The Energy Commission has provided more than $11.2 million in loans for projects associated with both improving the energy efficiency of water and wastewater facilities and reducing the energy costs of these facilities. These projects have saved public facilities about $1.9 million annually in lower energy bills. This is equivalent to saving 23 million kWh annually, with billing demand savings of about 2.3 MW (Energy Efficiency Division).

Development of a Water and Wastewater Industry Energy Efficiency Roadmap

The Energy Commission collaborated with the American Water Works Association Research Foundation (AwwaRF) {Note: Thought I'd flag this since lower-case letters are so rare in acronyms – is this correct?] to develop a roadmap to fund the highest priority research and development energy needs of California's water and wastewater utilities. To achieve this, the Commission and AwwaRF in February 2003 conducted a workshop that was attended by water experts from water and wastewater facilities, electric utilities, academia, researchers, and consultants. More than 44 projects in eight research areas were developed and ranked according to their savings potential (in either kilowatts or dollars), likelihood of success, and timeliness. The Energy Commission and AwwaRF committed to more than $2 million in funding for the five highest-ranked projects. These projects are:

> **Development of a Utility Energy Index to Assist in Benchmarking of Energy Management for Water and Wastewater Utilities**
>
> The objective of this project is to produce industrywide energy performance metrics to describe the performance of water and wastewater utilities that will subsequently be incorporated within a comparison framework (benchmarking tool) to facilitate internal and external comparisons within and between utilities. The approach will be similar to the US EPA's **Energy Star®** program, which makes energy performance comparisons in commercial buildings (PIER Industry, Agriculture and Water).
>
> **Zero Liquid Discharge and Volume Minimization for Inland Desalination**
>
> This project is discussed in the section on desalination (PIER Industry, Agriculture and Water).
>
> **Assessing Risks and Benefits of Drinking Water Utility Energy Management Practices**
>
> The project will develop a decision framework based on risk management principles for water utilities implementing energy management strategies. The risks and benefits of a broad array of both supply-side and demand-side energy management options will be assessed. The decision framework will provide a management tool for water utilities to mitigate possible downsides to water quality and reliability when implementing energy management practices or technologies (PIER Industry, Agriculture and Water).

Water Consumption Forecasting to Improve Energy Efficiency of Pumping Operations

The purpose of this project is to provide the best options for short-term water consumption forecasting for water utilities. Short-term consumption forecasting (SCTF) is required for water utilities to proactively optimize both their pumping and treatment operations and water supply and treatment costs while maintaining a reliable and high-quality product for their customers. The project will provide information on various techniques, performance data, benchmarks, selection criteria, and functional requirements to help utilities evaluate and select the best forecasting techniques. The project will examine different forecasting methods currently used at public utilities. These forecasting methods will be tested at utilities that are not currently forecasting their water consumption, and the results will be documented. The SCTF performance data will be analyzed for all seasons of the year to provide peak, off-peak, and average-day consumption data (PIER Industry, Agriculture and Water).

Evaluation of the Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Technologies

The objectives of this project are to quantify the actual and theoretical energy consumption of selected water and wastewater advanced treatment unit operations, evaluate the factors that affect energy consumption, and identify energy optimization opportunities while still maintaining treatment performance (PIER Industry, Agriculture and Water).

Future Projects in Collaboration with AwwaRF

Five more projects from the roadmap are being considered for future funding by the Energy Commission and AwwaRF.

1. Review of international desalination research. The product would be a searchable CD ROM database similar to Desal Net, owned by AWWA (<u>not</u> AwwaRF). Desal Net is a searchable CD ROM database for the U.S.
2. Energy consumption of ultraviolet and chlorine/hypochlorite disinfection.
3. UV disinfection: Develop next generation of energy efficient UV disinfection systems for water and wastewater treatment.
4. Development of a guidance manual to design and operate desalination facilities for maximum energy efficiency.
5. Identification and evaluation of innovative water treatment processes.

Agricultural Water

Energy consumption is a significant cost component of providing water to the agricultural industry. State and IOU ratepayer funds, administered by the Energy Commission, CalPoly San Luis Obispo, and Fresno State University have delivered energy efficiency and water conservation programs aimed at conservation and peak load reduction in agriculture. Programs include:

SB 5X –Agricultural Peak Load Reduction Program

- The program started on June 1, 2001, and was completed on December 31, 2004. The program components related to electricity used for water purposes, include:
- 1. The development and implementation of a pump test and repair program to improve pumping plant efficiencies.
- 2. Funding projects with irrigation districts and large farming companies to participate in demand response and TOU schedules. Over 60 MW of on-peak load reduction was achieved. Thousands of pump tests were performed and many of the tested pumps were repaired to achieve even higher efficiencies (Nexant, M&V report for California Energy Commission Agricultural Peak Load Reduction Program, 2003). More than $7 million were dedicated to water-related energy projects.

CPUC- Public Goods Charge (PGC)-Third-Party Administrator for Pump Test and Repair Program

The program, administered by the Fresno State University Center for Irrigation Technology, delivers pump test services to customers in the PG&E and SDG&E service territories. The pump tests are conducted by private sector providers that have enhanced the quality and standards of properly conducted pump test results for several years. The program also provides pump repair incentive payments. The educational component is a valuable tool for communicating efficiency principles and water conservation practices to farmers. A $5 million annual appropriation from the CPUC has funded this effort to date.

Development of an Agricultural Water Energy Efficiency Roadmap

The Energy Commission's PIER Agricultural Program Technology Roadmap was accomplished in collaboration with CalPoly San Luis Obispo, Fresno State University, the University of California Cooperative Extension Program, industry associations, farmers, and irrigation district managers. The roadmap document calls for research and development efforts that improve irrigation efficiency, create flexible water delivery systems, and achieve peak load reduction. Possible research, development, and demonstration projects include reducing the total pressure required to operate drip irrigation technologies (including the filter system as well as the pipe and micro-sprayer technologies), advancing the use of longer-lasting materials for pump components, and working with the State Water Project, the Central Valley Project, and the irrigation districts to increase the flexibility of water deliveries to farms. Additional information is available at: [http://energy.ca.gov/2005publications/CEC-400-2005-002/CEC-400-2005-002.PDF].

PIER Agriculture Energy End Use Efficiency

The purpose of this contract is to improve the energy efficiency in the transportation, delivery, and utilization of agricultural water provided by irrigation districts. Proposed outcomes include:

1. Documenting the implementation of new technologies.
2. Developing a simple procedure for tuning controller constants for automatic upstream control of canal check structures.
3. Developing new devices resistant to plugging or tangling moss for volumetric metering of delivered water - trash shedding propeller meters.
4. Testing and evaluating new electronic technologies for the volumetric metering of delivered water such as magnetic meters, ultrasonic meters (Doppler), vortex shedding meters, and ultrasonic flow-measurement meters.
5. Developing strategies for energy-efficient transition from low-pressure non-reinforced concrete pipe.
6. Verifying power quality measurement and conditioning methods.
7. Assessing use of variable frequency drives on agricultural pumps.

National Programs

Development of a National Water-Wastewater Industry Energy Roadmap
In order to bring together the energy efficiency and water/wastewater communities to define avenues for increasing energy efficiency in the water and wastewater sectors, the American Council for an Energy Efficient Economy (ACEEE) organized a national road mapping workshop to further explore and plan next steps for greater energy efficiency in the water/wastewater sectors. A workshop was held in Washington, D.C., in July 2004, and a final report is being refined for publication. The Energy Commission was a member of the advisory committee. The advisory committee defined the scope of this effort, developed a mission statement for the project, and established a set of goals. It also assisted ACEEE staff in identifying key issues relating to energy use in the water and wastewater industries. These issues formed the basis for design of a survey instrument that was used to collect impressions of key issues from a wider group of

stakeholders identified by the advisory committee. Based on this research and the goals of the workshop, ACEEE staff and the advisory committee developed an agenda that addressed key topics (Energy Efficiency Division).

National Municipal Water and Wastewater Facility Initiative
In 2002, the Consortium for Energy Efficiency (CEE) formed the Water and Wastewater Exploratory Committee to:

- Serve as a platform for members to exchange program information and resources.
- Better understand the water and wastewater industry - its structure, energy use, decision-making, and regulatory environment.
- Begin outreach efforts to the water and wastewater industry and other industry stakeholders.
- Explore the merits of a national program initiative to improve the effectiveness of local programs serving this sector. This initiative is intended to maintain a sustained focus on facility energy-efficiency at the national and local levels by increasing demand for energy-efficiency products and services within the municipal water and wastewater sector, and by transforming the delivery of products and services to the municipal water and wastewater sector by encouraging industry stakeholders to incorporate energy-efficiency as a standard business practice. The Energy Commission is a founding member of this initiative (Energy Efficiency Division).

US EPA's ENERGY STAR Water and Wastewater Facilities Initiative
ENERGY STAR is a voluntary program that helps organizations, businesses, and individuals protect the environment through superior energy performance. The ENERGY STAR Water and Wastewater Facilities Initiative helps improve energy performance by creating momentum for the continued improvement of energy efficiency by identifying and tackling barriers to energy efficiency in the water and wastewater industry, providing tools and resources to enhance energy performance, uncovering new energy-saving opportunities, and encouraging information-sharing on efficiency in the water and wastewater industry. The Energy Commission is one of the founding members of this initiative. The first Web conference on the Energy Star Water and Wastewater Facilities Initiative was on May 12, 2005 (Energy Efficiency Division).

Water Supply

Desalination

Desalination is one of the sources of new water identified by the Department of Water Resources in the ***2005 Water Plan Update***. It is also the most energy intensive of these new sources. There are several efforts underway to assist in the development of low-cost, energy-efficient desalination technologies for various source waters using membrane and thermal processes.

Improving Energy Usage, Water Supply Reliability and Water Quality Using Advanced Water Treatment Processes
The Energy Commission and the Metropolitan Water District of Southern California are jointly funding the full-scale demonstration and refinement of newly developed electro-technologies for producing potable and non-potable water. These technologies remove salts and disinfect various source waters, including Colorado River water, brackish groundwater, municipal wastewater, and agricultural drainage water. There are 18 individual projects and eight research partners involved in this research program (PIER Industry, Agriculture and Water).

Zero Liquid Discharge (ZLD) Desalination of Inland Waters
At coastal facilities, concentrate is typically discharged to the ocean. This option is not available at inland facilities, and the need to protect surface water and groundwater sources may preclude disposal into the environment. The alternative is ZLD, in which the concentrate is further treated to produce desalinated water and essentially dry salts. In collaboration with AwwaRF, this research project will develop technologies that reduce the cost and energy consumption for inland desalination (PIER Industry, Agriculture and Water).

West Basin Municipal Water District – Demonstration of a Low Energy Sea Water Reverse Osmosis (SWRO) Desalination
Energy is the single largest cost component of operating seawater desalination systems. The purpose of this project is to demonstrate that SWRO desalination can be performed at 1.6 kWh/m^3 of permeate produced. The project will also establish the relationships between reverse osmosis recovery rate, membrane salt rejection, permeate quality, boron levels, feed pressure, and energy consumption. These relationships will help the SWRO desalination industry establish optimum recovery, flux, and salt rejection rates using today’s best-available technologies. This research is being conducted by the West Basin Municipal Water District, in collaboration with the DWR, several local water agencies, and the industry, in collaboration with the Naval Facilities Engineering Service Center’s Seawater Desalination Test Facility at Port Hueneme, California (PIER Industry, Agriculture and Water).

California Desalination Task Force
In September 2002, AB 2717 (Hertzberg) was signed into law, directing the DWR to convene a Desalination Task Force (Task Force) to “make recommendations related to potential opportunities for the use of seawater and brackish water desalination.” The work of the Task Force and its subsequent findings and recommendations provided a useful background to DWR in developing Proposition 50 guidelines for funding desalination

projects and for estimating the future potential and prospects of desalination in the ***2005 California Water Plan Update***. The Energy Commission served as one of the four co-chairs of the Task Force along with California Coastal Commission, State Water Resources Control Board, and State Department of Health Services (Energy Efficiency Division).

Salton Sea Desalination Demonstration Project Using Geothermal Heat
Energy Commission staff is serving on the advisory panel for U.S. Bureau of Reclamation's geothermal-driven vertical tube evaporation (VTE) desalination test project at the Salton Sea, to be conducted by Sephton Water Technology (SWT). The purpose of this project is to demonstrate the feasibility of controlling the salinity, nutrient, selenium, and other contaminant content of seawater by using geothermal waste steam to drive a VTE desalting system. The project satisfies one of the principal goals of the California Desalination Task Force, which is to identify potential opportunities for brackish water desalination, as well as the Energy Commission's need to improve the energy efficiency of water and wastewater treatment facilities in California. The project also addresses the problem of concentrate disposal. In this case, the plan calls for the concentrate to be pumped "down hole" to help recharge the geothermal aquifer, resulting in zero liquid discharge from the desalting plant (Energy Efficiency Division).

National Programs

Implementation of the U.S. Bureau of Reclamation's Desalination Roadmap
In 2001, Congress directed the Bureau of Reclamation to work with Sandia National Laboratories (SNL) to develop a desalination technology research plan for the United States. With the help of a multidisciplinary committee of representatives from academia and the public, private, and non-profit sectors***, The Desalination and Water Purification Technology Roadmap: A Report of the Executive Committee (Roadmap)*** was published in January 2003. The ***Roadmap*** presents a summary of water supply challenges facing our nation through 2020 and suggests areas of research that could lead to technological solutions for these challenges. The ***Roadmap*** may be used as a planning tool to facilitate science and technology investment decisions or as a management tool to help coordinate research efforts. To develop a mechanism to implement the recommendations of the Desalination Roadmap, the Joint Water Reuse and Desalination Task Force (JWR&DTF) was formed and is conducting workshops to establish a desalination research funding process. The Energy Commission was a member of the JWR&DTF planning committee that organized these workshops, and will participate in these workshops in the near future (Energy Efficiency Division).

Working Group on Concentrate Management Guidelines for Desalination and Water Reuse

Both the U.S. Bureau of Reclamation's ***Desalination and Water Purification Technology Roadmap,*** published in 2003*,* and the California Desalination Task Force identified concentrate management as a major area where research is needed to create next-generation desalination technologies. To help address the identified technical and environmental concerns associated with desalination and water reuse concentrate, Sandia National Laboratories initiated an effort, in cooperation with the Bureau of Reclamation, the American Water Works Association, the American Society of Civil Engineers, and the Water Reuse Foundation, to jointly develop guidelines for concentrate management. Energy Commission staff actively participate in the Concentrate Management Working Group, which is working on these guidelines (Energy Efficiency Division).

National Salinity Management Conference

This high-profile annual national conference is jointly sponsored by Multi-State Salinity Coalition, the US Desalination Coalition, the Northern California Salinity Coalition, the Water Reuse Association, the Southern California Salinity Coalition, and others in conjunction with the Nevada Water Reuse Association. It includes invaluable presentations, industry tours, and roundtable discussions on technical, policy, and program issues concerning energy issues in desalination. Energy Commission staff are regular members of the planning committee for this conference (Energy Efficiency Division).

Water Treatment

Developing and Validating an Energy Efficient Arsenic Removal Process

The current EPA standard for arsenic, a naturally occurring contaminant in groundwater, is 50 parts per billion (ppb). Effective January 2006, federal standard for arsenic in drinking water will be lowered to 10 ppb. The new arsenic standard will leave many public drinking water supply systems out of compliance, including several hundred systems in California. California has set a long-term public health goal for arsenic in drinking water at 4 parts per trillion (ppt) -- 2,500 times lower than the new federal standard of 10 ppb.

To attain this standard, the water systems in California will have to first meet the EPA standards in a cost-effective manner. Currently, the average cost of lowering arsenic from 50 ppb to 10 ppb from drinking water is in the range of $58 to $237 per household per year. Lawrence Berkeley National Laboratory is conducting research on an innovative medium, which, if successful, will lower the arsenic removal cost to $1 per household per year and have little or no incremental energy costs over current practices (PIER Industry, Agriculture and Water).

Wastewater Treatment

Development and Demonstration of a Digital System for Control and Mentoring of Oxygen Transfer Efficiency (OTE) Measurements
The majority of wastewater treatment plants nationwide uses an activated sludge secondary treatment process. Blowing air into the activated sludge aeration tanks accounts for 50 to 80 percent of a wastewater treatment plant's entire energy consumption. Over time, the diffusers through which this air blows become fouled by bacterial slime growth and scale buildup from hard water. One of the challenges of the wastewater industry is to monitor in real time the performance of wastewater treatment and how well aeration systems function.

Aeration system performance can be correlated with power consumption and calculated from material balances, but these results are not obtained in real time and can take weeks or months to obtain. A much better method is to measure OTE directly, using data collected from an instrument that measures oxygen in the gas released from the surface of the aeration basin. Currently, commercially available OTE instruments are large, heavy, and fragile, and require a crew of several people to operate. The purpose of this project is to design and demonstrate a new digital, fully-automated off-gas testing technology for purposes of evaluating and optimizing oxygen transfer efficiency, which would reduce energy demand (PIER Industry, Agriculture and Water).

Water-Related End Uses

Several projects underway are looking at ways to reduce the energy consumption of water-related end uses. Other efforts are focusing on increasing water use efficiency.

Waste Not, Want Not: The Potential for Urban Water Conservation in California
In 2003, the Pacific Institute published a report that quantified the unrealized potential for cost-effective water conservation in California. The report estimated that nearly 30 percent of potable water consumed in California – as much as 2 million acre-feet per year – could be cost-effectively conserved. In the context of the Pacific Institute's report, cost-effective is defined as "… the point where the marginal cost of the efficiency improvements is less than or equal to the marginal cost of developing new supplies."

Energy Down the Drain -The Hidden Costs of California's Water Supply
In the western United States there is a close connection between water and power resources. Water utilities use large amounts of energy to treat and deliver water, and even after utilities deliver water, consumers use even more

energy to heat, cool, and use it. This August 2004 report from the National Resources Defense Council (NRDC) and the Pacific Institute shows how water planners in California have largely failed to consider the energy implications of their decisions, and suggests a model for policymakers to calculate the amount of energy consumed during water use. Integrating energy use into water planning can save money, reduce waste, protect the environment, and strengthen the economy.

Water for Growth: California's New Frontier

According to the Public Policy Institute of California, which issued this report in July 2005, California’s population grew by over 10 million between 1980 and 2000. It is expected to increase by another 14 million by 2030, reaching a total of 48 million by that date. One of the most serious concerns of policymakers is whether the state will be able to supply enough water to support a population of this size. If per capita urban water use remains at its 2000 levels of 232 gallons per person per day, California will face an expansion of water demand of 40 percent, or 3.6 million acre-feet, by 2030. Policymakers and water planners have begun to consider several ways to bring supply and demand into balance over the years ahead. Options include expansion of nontraditional sources of supply (for example, underground storage, recycling, and desalination), reallocation through water marketing and conservation incentives and regulations.

California Water 2030: An Efficient Future

On September 13, 2005, the Pacific Institute released its newest report on the potential for saving water in California by 20 percent over the next 25 years while satisfying a growing population, maintaining a healthy agricultural sector, and supporting a vibrant economy. The report discusses how smart technology, strong management, and appropriate rates and incentives can allow the state to meet its needs well into the future, using less water.

The Irrigation Training and Research Center (ITRC)

The Irrigation Training and Research Center (ITRC) was established in 1989 at California Polytechnic State University, San Luis Obispo, as a center of excellence built upon a history of contributions to agriculture. The ITRC has a number of ongoing programs to develop and promulgate irrigation best practices in California. While ITRC’s research focuses on irrigation for agriculture, the tools, technologies, and techniques are often applicable to landscape irrigation as well (PIER Industry, Agriculture and Water).

California Urban Water Conservation Council (CUWCC)

The CUWCC is a non-profit organization created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The Council's goal is to integrate urban water conservation BMPs into the planning and management of California's water resources. Presently, more than 300 urban water agencies and environmental groups are signatories to a historic memorandum of understanding pledging to develop and implement 14 comprehensive water conservation BMPs. To the extent that the state adopts a policy allowing energy utilities to invest in water savings for their energy and environmental benefits, CUWCC's goals and activities are certainly in direct alignment.

Residential Hot Water Distribution System Research Project
The purpose of this project was to conduct a scoping study to establish the first-order estimate for the water and energy wasted in hot water distribution systems in California and the United States. This study found that the losses in residential hot water distribution systems total more than $1 billion per year in California and $10 billion per year in the United States, including the cost of energy, water, and wastewater treatment. A roadmap to identify future activities was part of the original project but has not been completed (PIER Buildings).

Testing of Hot Water Distribution Systems
The purpose of this project was to systematically test the performance of hot water distribution systems. Field work assessing the types of distribution systems in current construction practice was combined with laboratory testing. Test procedures were developed and used on ½- and ¾-inch copper piping and ¾-inch PEX-Aluminum-PEX piping. Tests were conducted in air on both uninsulated and insulated pipe. The results of this project will be combined with additional testing to support the 2008 Title 24 Residential Building Energy Efficiency Standards proceeding (PIER Buildings).

Water Heating R&D for the 2008 Residential Building Energy Efficiency Standards
This research will provide hot water distribution system data, analysis, and recommendations to the 2008 Title 24 Residential Building Energy Efficiency Standards proceedings. Specific efforts will inform the building standards proceeding in the areas of multi-family water heating, hot water pipe losses, single family water heating construction practices, and hot water distribution system modeling. This project will also study California housing's current hot water performance issues and cost-effective retrofit opportunities, and identify future research priorities for hot water distribution systems (PIER Buildings).

Super Efficient Gas Water Heating Appliance Initiative
This research will develop the foundation for a multi-year initiative to determine the best approach for achieving a 30 percent efficiency improvement in gas water heaters. Technical and market analysis will be conducted, along with stakeholder involvement, to implement a product development competition that develops and tests prototypes for safe, reliable, and cost-effective replacements for natural gas water heaters (PIER Buildings).

Market and Technical Considerations for a Next Generation Instantaneous Water Heater

Gas-fired instantaneous water heaters are highly efficient and can play an important role in reducing energy consumption. The barriers to the current generation of instantaneous water heaters include higher initial cost, installation cost adders, water waste associated with start-up, the inability to adjust to low flow rates or relatively warm incoming cold water, and the inability to meet large household or simultaneous demands. The goal of this research is to determine if current state-of-the art instantaneous water heaters can meet both current and projected California domestic hot water needs and to identify technology(ies) that can be incorporated into instantaneous water heaters to overcome current market and technical barriers (PIER Buildings).

Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment

The goal of this research is to establish representative gas loads for both the installed base and higher-efficiency hot water systems in commercial kitchens, based upon a review of current literature monitoring data for three commercial food service sites (a quick-service, full-service, and institutional facility). This field experience will form the basis for a design guide for hot water systems in commercial food service (PIER Buildings).

Water for Electricity Generation

Water is used to generate electricity, both directly in hydropower plants and indirectly as part of cooling systems in thermal electric facilities. The Energy Commission has funded several projects to evaluate ways to reduce the effects of electricity generation on California's freshwater supplies and on aquatic species and habitats.

The Ecological Effects of Pulsed Flows from Hydropower Plants

The Center for Aquatic Biology at the University of California, Davis, is conducting research addressing the ecological effects of ramping and other pulsed flows from hydropower plants. These discharges are results of load following, sediment and vegetation management, and recreational requirements. Seven different projects are evaluating a wide range of issues, from the effects of these flows on invertebrates residing in stream and river bed sediment to the effects on the potentially threatened foothill yellow-legged frog. The purpose of this research is to provide information that will prompt regulatory decision making that would not otherwise be accomplished within the regulatory process. The information from this research will be used by regulators to establish information needs for impact assessment, set impact thresholds, and establish suitable mitigation measures. Research partners include the State Department of Water Resources, California Department of Fish & Game, PG&E, EBMUD, and NOAA Fisheries (PIER Environmental).

Development of Bioassessment Criteria for Hydropower Operation
The California Department of Fish and Game is conducting research to develop environmental indicators, using benthic macroinvertebrates, to assess and monitor the effects of hydropower operation on rivers and streams. The purpose of this project is to establish a low-cost assessment and monitoring tool that will provide a direct indication of ecosystem health, as opposed to relying upon indirect factors such as water temperature or flow. Research partners include the California Department of Fish and Game, California State Water Resources Control Board and California State University, Chico (PIER Environmental).

Integrated Forecast and Reservoir Management Project
Runoff and stream flow forecasting has historically relied upon limited hydrologic records. With the development and refinement of global circulation models and an improved understanding of climate conditions and their ramifications for California, future runoff probabilities can be more accurately predicted. Using these forecasts on an hourly to seasonal basis can result in better planning and optimization of California's water resources. The Energy Commission is funding a demonstration of this approach for four Northern California reservoirs: Shasta, Trinity, Oroville, and Folsom. This effort uses global circulation model scenarios, downscaled to hydrologic models, that encompass the catchments of each of these reservoirs, as well as the entire Sacramento River. This information is used to create probabilistic forecasts on an hourly to month-long basis. Since these major reservoirs are all multi-purpose, the project includes the development of decision support models that will allow reservoir operators to make better decisions about the balance between flood control, water supply, hydropower generation, and instream flow requirements. Based upon a retrospective analysis of Folsom Reservoir using this methodology, the researchers showed that there could be a15 percent increase in hydropower generation. Research partners include the National Oceanic and Atmospheric Administration, CalFed, the Department of Water Resources, Sacramento Area Flood Control District, the U.S. Bureau of Reclamation and the Army Corps of Engineers (PIER Environmental).

Development of Seasonal Forecast of Hydropower Generation
Scripps Institute is developing seasonal forecasts of hydropower production in the Pacific Northwest and California. Since the amount of hydropower production in these two regions has a significant effect on the cost and availability of electricity within California, providing forecasts on a seasonal basis will improve energy planning, especially natural gas demand. Another aspect of this project is to develop seasonal temperature predictions for California based upon global circulation model simulations. This information will allow planners to predict whether an upcoming summer will be exceptionally severe and plan accordingly. Research Partners include the Western Electricity Coordinating Council (WECC), Pacific Northwest National Laboratory and the University of Washington (PIER Environmental).

Advanced Cooling Strategies and Technologies
This program is being managed by EPRI and addresses approaches for reducing freshwater consumption in the thermal generating sector. Specifically, the program addresses both the barriers to wider adoption of water conserving cooling technologies and alternative cooling technologies. These approaches, such as the use of air-cooled condensers, can substantially reduce the amount of water used within a power plant. There are, however, economic and performance issues to overcome before industry will adopt these approaches. Research partners include NETL, Reliant, AES and Crockett Cogeneration (PIER Environmental).

Ecological Effects of Cooling Water Intake Structures
Within California, a significant portion of in-state thermal electric generation is from coastal power plants that use once-through cooling, which uses millions of gallons of water per day. The intake of these vast amounts of cooling water, which is not evaporated, means that millions of the eggs, larvae, and other early life stages of fish, clams, and other aquatic species are destroyed by the heat transferred to the cooling water. The ecological effects of this once-through cooling are not known. In addition, there is a need to develop new assessment techniques and establish the suitability of innovative technology to reduce this impact. The Moss Landing Marine Laboratory, a part of California State University, San Jose, is managing the research program on this topic. Research partners include the California Costal Commission, the California Department of Fish and Game, NOAA Fisheries and the University of California, Santa Cruz (PIER Environmental).

RPS-Eligible Small Hydropower Resource Assessment
The purpose of this project is to assess the magnitude of in-conduit resources potentially available for greater small hydropower development in California. Specifically, the study focuses on irrigation and municipal water systems where no new appropriation or diversion is required, which retains RPS eligibility under the conditions of SB1078. This study does not cover new or incremental power at existing dams or other potential in-conduit resources such as industrial process water and municipal wastewater (PIER Renewables).

Use of a Down-Hole Pump as a Turbine-Generator
The purpose of this project is to demonstrate and assess the performance of a reverse operated down-hole pump commonly used in the oil and gas industry as a turbine-generator for power production. The unit will be demonstrated in a Northern California Power Agency injection well at the Geysers, where the feedstock will be treated wastewater used to replenish and extend the life of the region’s underground steam fields. If successful, this would provide a means of partially offsetting the cost of pumping wastewater to the injection site (PIER Renewables and GRDA).

APPENDIX B: 2001 CALIFORNIA ENERGY CONSUMPTION BY END USE

2001 California Energy Consumption by End Use

Sector	Description	Electricity (GWh)	Percent Related to Water	Natural Gas (million therms)	Percent Related to Water	Adjusted Electricity (GWh)	Adjusted Natural Gas (million therms)
AG & WP	Domestic Water Pumping	11,953	1.00	19	1.00	11,953	19
AG & WP	Crops	3,284	1.00	103	0.05	3,284	5
AG & WP	Irrigation Water Pumping	2,269	1.00	5	1.00	2,269	5
AG & WP	Livestock	1,216	0.50	15	0.50	608	8
RESIDENTIAL	Clothes Drying	5,769	1.00	145	1.00	5,769	145
RESIDENTIAL	Water Heating	2,352	1.00	1,079	1.00	2,352	1,079
RESIDENTIAL	Indirect Hot Water Heating for Clothes Washing	1,053	1.00	486	1.00	1,053	486
RESIDENTIAL	Washing Machine	726	1.00	0		726	0
RESIDENTIAL	Indirect Hot Water Heating for Dish Washing	686	1.00	316	1.00	686	316
COMMERCIAL	Water Heating	549	1.00	174	1.00	549	174
RESIDENTIAL	Evaporative Cooling	519	1.00	0		519	0
RESIDENTIAL	Solar Water Heating	18	1.00	7	1.00	18	7
COMMERCIAL	Cooling	12,916	0.50	66	0.50	6,458	33
MINING & CON	Oil and Gas Extraction	3,958	0.50	2,775	0.50	1,979	1,388
RESIDENTIAL	Dish Washing	2,008	0.50	0		1,004	0
INDUSTRY	Publishing and Broadcasting Industries	955	0.50	9		478	0
INDUSTRY	Printing and Related Support Activities	773	0.50	19		386	0
INDUSTRY	Nonmetallic Mineral Product Manufacturing	710	0.50	116		355	0
TCU	National Security and International Affairs	2,649	0.20	60	0.30	530	18
RESIDENTIAL	Residential Miscellaneous	24,419	0.05	168	0.05	1,221	8
COMMERCIAL	Commercial Miscellaneous	19,156	0.05	722	0.05	958	36
INDUSTRY	Petroleum Refining and Related Industries	7,194	0.05	1,464	0.05	360	73
COMMERCIAL	Refrigeration	6,771	0.05	5	0.05	339	0
INDUSTRY	Food Manufacturing, Beverage and Tobacco	4,939	0.05	390	0.50	247	195
INDUSTRY	Chemicals	3,674	0.05	226	0.05	184	11
RESIDENTIAL	Cooking	3,595	0.05	286	0.05	180	14
INDUSTRY	Electronic Components	3,261	0.05	39		163	0
INDUSTRY	Computer and Electronic Product Manufacturing	2,988	0.05	37	0.05	149	2
INDUSTRY	Plastics and Rubber Products Manufacturing	2,886	0.05	40		144	0
TCU	Telephone	2,289	0.05	3		114	0
INDUSTRY	Fabricated Metals	2,045	0.05	122	0.05	102	6
INDUSTRY	Transportation Equipment	1,960	0.05	84		98	0
INDUSTRY	Machinery Manufacturing	1,777	0.05	24		89	0
INDUSTRY	Miscellaneous Assembly Industry	1,300	0.05	14		65	0
INDUSTRY	Sugar and Canned, Dried, and Frozen Food	1,283	0.05	299	0.50	64	149
MINING & CON	Construction	1,213	0.05	22	0.05	61	1
INDUSTRY	Primary Metals	1,192	0.05	133	0.05	60	7
INDUSTRY	Pulp, Paper, and Paperboard Mills	1,149	0.05	110	0.50	57	55
TCU	Electric and Gas Services, Steam Supply	1,006	0.05	25	0.05	50	1
INDUSTRY	Lumber	951	0.05	56		48	0
INDUSTRY	Paper Products; Excludes SIC 261,262,263,266	895	0.05	51		45	0
INDUSTRY	Furniture and Fixtures	793	0.05	9		40	0

Sector	Description	Electricity (GWh)	Percent Related to Water	Natural Gas (million therms)	Percent Related to Water	Adjusted Electricity (GWh)	Adjusted Natural Gas (million therms)
TCU	Airports, Flying Field and Airport Terminal Service	771	0.05	5	0.05	39	0
COMMERCIAL	Cooking	758	0.05	141	0.05	38	7
INDUSTRY	Electrical Equipment, Appliance, and Component Manufacturing	646	0.05	7		32	0
MINING & CON	Mining (except Oil and Gas)	615	0.05	58	0.05	31	3
INDUSTRY	Textile Products	397	0.05	8	0.05	20	0
INDUSTRY	Textiles	386	0.05	65	0.05	19	3
INDUSTRY	Textile Products	183	0.05	14	0.05	9	1
RESIDENTIAL	Pool Heating	60		100		0	0
RESIDENTIAL	Hot Tub Fuel	168		93		0	0
RESIDENTIAL	Water Bed	2,150		0		0	0
INDUSTRY	Glass manufacturing	877		128		0	0
INDUSTRY	Cement, Hydraulic	1,636		38		0	0
RESIDENTIAL	Pool Pump	3,024		0		0	0
RESIDENTIAL	Solar Pool Heating	0		64		0	0
RESIDENTIAL	Refrigeration	13,282		0		0	0
RESIDENTIAL	Solar Heater Pump	97		0		0	0
RESIDENTIAL	Hot Tub Pump	901		0		0	0
TCU	Water Transportation	48		0		0	0
TCU	Pipeline	935		16		0	0
COMMERCIAL	Heating	2,625		670		0	0
COMMERCIAL	Indoor Lighting	31,568		0		0	0
COMMERCIAL	Office Equipment	1,405		0		0	0
COMMERCIAL	Outdoor Lighting	5,332		0		0	0
COMMERCIAL	Ventilation	9,325		0		0	0
STLT	Street lighting and Traffic Control	1,713		0		0	0
RESIDENTIAL	Central Air Conditioning	4,199		45		0	0
RESIDENTIAL	Color Television	3,425		0		0	0
RESIDENTIAL	Freezer	2,461		0		0	0
RESIDENTIAL	Furnace Fan	1,273		0		0	0
RESIDENTIAL	Room Air Conditioner	486		0		0	0
RESIDENTIAL	Central Space Heating	3,245		2,339		0	0
TCU	Other Local Transportation, Parking Garages	212		5		0	0
TCU	Trucking and Warehousing	545		2		0	0
TCU	Post Office	528		3		0	0
TCU	Shipping Terminals	262		1		0	0
TCU	Air Transportation, Carrier	121		2		0	0
TCU	Transportation Service	201		2		0	0
TCU	Telegraph Communication	6		0		0	0
TCU	Radio and Television	461		1		0	0
TCU	Cable TV	514		1		0	0
TCU	Railroad Transportation	143		3		0	0
TCU	Rapid Transit	400		5		0	0
TCU	Sanitary Service	2,012	1.00	27	1.00	2,012	27
	Totals	**250,494**		**13,571**		**48,012**	**4,284**
	Percent					**19%**	**32%**

This table comes from the California Energy Commission's Demand Analysis Office. The data are for 2001 and are based on energy utility reporting for that year. They also include self generation above 1 MW. The percent of the energy related to water was discussed by the WER Working Group on July 29, 2005. If we agreed that most of the energy was water related, we assigned it a 1. If we knew there was a relationship but didn't understand enough to know how big, we assigned it 0.05. If there was some intermediate relationship, we assigned it 0.5, except for National Security and International Affairs which we felt was typical of the overall energy relationship to water. We assigned zero to those categories where there did appear to be a relationship.

APPENDIX C: ENERGY IMPACT ANALYSIS OF EXISTING WATER MANAGEMENT PRACTICES

Introduction

This appendix examines various water management practices focused on water conservation and efficiency and estimates the effects of water efficiency activities on energy savings. The analysis in this appendix is intended to:

- ✓ Quantify energy requirements in water use cycle processes.
- ✓ Determine current water efficiency measure energy impacts.
- ✓ Compare water and energy efficiency program characteristics.
- ✓ Recommend policy changes to incorporate water efficiency in the energy efficiency portfolio.
- ✓ Identify areas of research to better understand water-energy interdependencies.

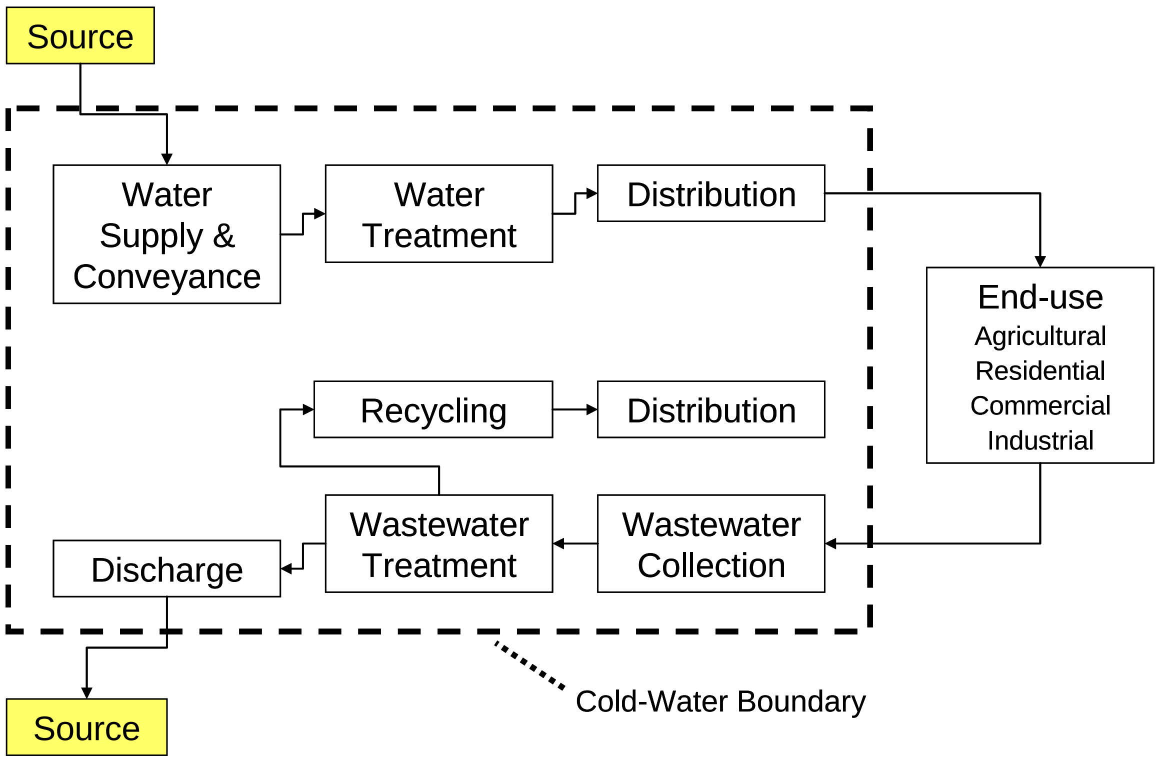
The Water Use Cycle

Electric and natural gas energy efficiency programs focus primarily on the application of energy consuming end-use technologies at utility customer facilities. In contrast to conservation, where usage is reduced through end-user behavioral changes, energy efficiency program planners target more permanent efficiency gains through known end-use technology or design applications. Likewise water use efficiency is achieved by implementing measures that result in reduced water consumption without customer behavioral changes.

In water systems, energy utilities target efficiency gains primarily by improving heating and pressurizing processes. For example, a low-flow showerhead saves energy because less hot water is used, thereby reducing the amount of energy needed to heat water. This is the case for water efficiency measures included in past energy efficiency programs such as faucet aerators, high-efficiency washing machines, and restaurant pre-rinse valves. Energy efficiency programs target efficiency gains in pressurizing applications by improving electric motor and/or pump efficiencies often at water and wastewater utility facilities. In each case the application is an end-use energy consuming technology located behind a customer meter.

When a unit of water is saved, so too is the energy required to convey, treat, deliver, perform wastewater treatment, and safely dispose of that unit of water. The energy intensity of the water use cycle must be examined on a systemic basis and varies widely by delivery location. Figure C-1 identifies the boundary of the water use cycle, showing the water processes that require energy, defined as cold water energy.

Figure C-1 Water Use Cycle



Significant customer-end use energy and water efficiencies have been, and are yet to be, achieved in the water sector[66]. These customer end-use efficiencies, while important, are excluded from this analysis to bring visibility to incremental cold-water energy savings.

When a water efficiency measure is implemented, the cold-water energy savings are achieved at multiple locations often transcending utility, city, and county jurisdictional boundaries. This analysis addresses the integration of water and energy demand-side management to increase cold water energy efficiency gains.

Water Use Cycle Energy Requirements

Electricity used to move or process water supplies (described above as cold water related energy) is quantified below in four primary stages or processes: conveyance, treatment, distribution, and wastewater treatment. The following table documents

[66] Even after accounting for expectations from existing efforts in this area, an additional 30-50 percent urban water (and associated energy) savings are possible with cost-effective existing technologies. (Waste Not, Want Not: The Potential for Urban Water Conservation in California, Pacific Institute, 2004.)

ranges of energy intensity for each process in terms of kilowatt-hours (kWh) per million gallons (MG):

Table C-1 Range of Energy Intensities for Water Use Cycle Processes (kWh/MG)

Water Cycle Segments	Low	High	Assumptions (Numbers in parentheses refer to sources listed below in this table)	
1. Water Supply & Conveyance	0	14,000	0:	(1) Assume total gravity feed;
			14,000:	(2) pg. 27 - SWP @ Pearblossom 4,444 kWh/AF or 13,638 kWh/MG (14,000 kWh/MG)
2. Water Treatment	100	16,000	100:	(3) Water treatment without raw water pumping (max. gravity feed) and distribution pumping (accounted for under Distribution) = 99.7 kWh/MG Table 2-1, page 2-3
			16,000:	(7) Sea Water Desalination
3. Water Distribution	700	1,200	700:	(6)
			1,200:	(3) High Service Pumps To Distribution - 12,055 kWh/day for a Typical 10 MGD Surface Water Treatment Plant - figure 2-1, page 2-2 equivalent to 1,205.5 kWh/MG
4. Waste Water Collection	-	-		This category has been incorporated into the next category.
5. Waste Water Collection & Treatment	1,100	4,600	1,100: 4,630:	(4) Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - Range from 1,073 kWh/MG to 4,630 kWh/MG
				(3) Influent wastewater pumping is included in wastewater treatment process; figures 3-2 and 3-3, pages 3-3 and 3-4, respectively
6. Waste Water Discharge	0	400	0:	(1) assumes gravity ocean outfall; 400 ground water recharge
			400:	(3) pg. 3-7
7. Recycled Water Treatment	-	-		(4)(5) Tertiary/Advanced Waste Water Treatment Included under range of Waste Water Collection & Treatment
8. Recycled Water Distribution	400	1,200	Range:	(5) Municipal Recycled Water Use in California 2002: 46% Ag. Irrigation; 21 % landscape irrigation; 10% ground water recharge; Industrial 5%. This accounts for 82% of all recycled water. Energy needed for these applications fall within the ranges of the energy needed for typical water distribution and ground water recharge 400 - 1200 kWh/MG.

Sources:
(1) - Water Energy Working Group Assumption
(2) - Methodology for Analysis of the Energy Intensity of California's Water Systems; LBL January 2000
(3) - Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment, EPRI March 2002
(4) - Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities, PG&E February 2002
(5) - DWR Water Facts No. 23
(6) - EBMUD 2003 Load Study by Navigant Consulting
(7) - California Water Plan Update 2005 Volume 2, Resource Management Strategies, Chapter 6 – Desalination. A 50 mgd seawater plant (approximately 50,000 acre-feet per year, or 16.25 billion gallons, assuming operations 90% of the time) would require about 33 MW of power. California Water Plan Update 2005 Volume 2, Resource Management Strategies, Chapter 6 – Desalination. This translates to about 5,200 kWh per acre-foot, or 16,000 kWh per million gallons

Regional Water-Energy Characteristics

The ranges of water use cycle energy requirements identified above vary significantly because of regional water system operating requirements. To project energy savings associated with unit volume reductions in water requires adoption of prototypical energy needs, incorporating the variability inherent in regional resource alternatives. Analysis in this appendix separates water energy regions broadly into the Northern and Southern California regions, but additional research to assess regional water-energy characteristics is needed (see Suggested Research Topics, below).

The Northern California Region: Contains the North Coast, San Francisco, Sacramento River, San Joaquin River, Tulare Lake and Central Coast[67] Hydrologic Regions as defined by the California Department of Water Resources. The Northern California region contains 42 percent of the state's population and 42 percent of urban residential and non-residential applied water[68]. The region is characterized overall by relatively higher annual precipitation than in Southern California and significant native ground and surface water resources.

The Southern California Region: Contains the South Coast Hydrologic Region; 53 percent of the state's population and 48 percent of urban residential and non-residential applied water[69]. The region is characterized by relatively low annual precipitation and limited native surface water resources and has historically relied heavily on groundwater and imported water to meet water demand.

Other Hydrologic Regions: Hydrologic regions not included in this analysis are the North Lahontan, South Lahontan and Colorado River Hydrologic Regions[70]. Future studies will need to refine analyses addressed herein and incorporate these regions.

For purposes of this analysis, the Northern and Southern California regions, as referred to in this appendix, include 95 percent of the state's population and 90 percent of urban residential and non-residential applied water.

Water Use Cycle Energy Intensity

Table C-2 reflects the variability between water use cycle energy requirements between Northern and Southern California.

[67] The Central Coast hydrologic region includes Santa Barbara and San Luis Obispo Counties that are served by the SWP Coastal Branch with transport energy intensity on-par with the SWP West Branch (water must be lifted over the coastal mountain range). For the purposes of this analysis, the Central Coast is included in the Northern California region because 80 percent of the population within the Central Coast Hydrologic region resides north and east of the mountain range in communities such as Salinas, Santa Maria, Santa Cruz, Lompoc, and Monterey.

[68] Department of Water Resources 2005 Water Plan Update, Volume 3, Chapter 1 Table 1-4. Year 2000 is referenced for all regional characteristics and is described (same reference Table 1-1, page 1-10) as the "Average Year" within the context of precipitation and Wet versus Dry Years.

[69] Ibid

[70] North Lahanton is the extreme northeast of the state; South Lahanton is the region east of the Sierra Nevada Mountains including Mono Lake, Owens Valley and Death Valley; Colorado River Hydrologic Region include eastern San Bernardino, Riverside and Imperial Counties.

Table C-2 Percent Electricity Use for Water System Components[71]

	Northern California	Southern California
Imported Water Supply	-	71%
Local Ground/Surface Water Supply	17%	6%
Local Distribution	26%	9%
Wastewater Treatment	56%	14%

As reflected in Table C-2, the majority of the water use cycle energy required for Southern California, due to imported water, is not present in Northern California. To define process energy savings from water unit volume reductions, representative applications have been adopted for each primary process type: conveyance, treatment, distribution, and wastewater treatment. Energy use scenarios adopted and supported here are based on prototypical values for each process type. For purposes of this analysis, north/south water conveyance energy requirements are addressed separately and water treatment, distribution, and wastewater treatment assumptions are constant.

Water Conveyance

Northern California: As described in Table C-1, the range of water energy intensity for supply and conveyance ranges from 0 to 14,000 kWh/MG. Zero is assumed for gravity-fed systems. Water supplies from native surface water and groundwater sources require much less energy per unit conveyed than in Southern California. Approximately 60 percent of Northern California's urban water requirements are met with surface water and 40 percent is met with groundwater[72]. Additionally, roughly 40 percent of the region's population is located in the San Francisco Hydrological Region, where much of the water is conveyed by gravity from higher elevation reservoirs.

In this analysis, a prototypical value for water conveyance for Northern California is taken from the raw water pumping requirements of surface water treatment, based

[71] Methodology for Analysis of Energy Intensity of California's Water Systems and An Assessment of Multiple Potentials Benefits through Integrated Water-Energy Efficiency Measures; Exploratory Research Project Supported by: Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency; Principle Investigator Robert Wilkinson, PhD. January 2000, pg-7.

[72] Surface water and groundwater supply percentages are calculated using Water Supply and Use information provided in the California Water Plan Update 2005, Volume 3 for the California Department of Water Resources' North Coast, San Francisco, Sacramento River, San Joaquin River, Tulare Lake, and Central Cost Hydrological Regions.

upon a survey of approximately 30,000 public water supply systems in the United States[73] (see Water Treatment, below) and is estimated at 150 kWh/MG[74].

Southern California: Groundwater meets 23 and 29 percent of Southern California's water demand in normal and dry years, respectively[75]. The Metropolitan Water District (MWD) of Southern California provides 85 percent of the region's water supply to 26 cities and water districts serving 18 million people[76]. MWD's *Integrated Resource Plan* cites goals to mitigate heavy dependence on imported water by balancing its supply portfolio between imports; storage and transfers; recycling; groundwater recovery; conservation; brackish and seawater desalination; and exchanges[77]. While the region's water agencies have compiled a wide array of water management tools and planning practices to bring local water resources on a more equal footing, the region remains dependent on imported water for at least 50 percent of its water supplies[78].

As water agencies develop and employ least-cost resources to meet regional water demands, imported water serves as the primary baseline or "marginal resource." The 2003 *Qualifying Settlement Agreement* enabled implementation of the "4.4 Plan," where California will reduce its use of Colorado River water from a high of 5.3 million acre-feet to its 4.4 million acre-feet annual apportionment, by year 2016[79]. For Southern California, State Water Project (SWP) water supplies from Northern California are treated as the marginal water resource. A brief description of SWP water delivery to Southern California follows:

> As the California Aqueduct moves water south along the west side of the San Joaquin Valley, four pumping plants raise it more than 1,000 feet before reaching the Tehachapi Mountains. Pumps situated at the foot of the mountains pump the water up 1,926 feet through tunnels, which take the water into the Antelope Valley. In the Antelope Valley, the aqueduct divides into two branches: the East Branch and the West Branch.

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[73] Water & Sustainability (Volume 4) U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century, EPRI 2002, Page 2-3

[74] Ibid, Figure 2-1, page 2-2, Raw Water Pumping 1,205 kWh per day for a treatment plant with 10 MGD capacity; equivalent to 120.5 per MG; assumption is raised to 150 kWh/MG as a minimum prototypical energy requirement.

[75] Ibid, Chapter 5, page 5-3

[76] Ibid, pages 5-2 and 3.

[77] MWD presentation to the Water Energy Working Group April 8, 2005.

[78] Ibid, page 5-5

[79] Department of Water Resources 2005 Water Plan Update, Volume 3, Chapter 5, page 5-8

The East branch carries water through the Antelope Valley into Silverwood Lake in the San Bernardino Mountains. From Silverwood Lake, the water flows through the San Bernardino Tunnel, through the Devil Canyon Power Plant before continuing on to the southernmost SWP reservoir, Lake Perris. East Branch water energy intensity, net of any SWP system generation, is 3,236 kWh per acre-foot, or 9,931 kWh per MG. Water in the West Branch flows through the Warne Power Plant into Pyramid Lake in Los Angeles County. From there it flows through the Angeles Tunnel and Castaic Power Plant into Castaic Lake, terminus of the West Branch. West Branch water energy intensity, net of any SWP system generation, is 2,580 kWh per acre-foot, or 7,918 kWh per MG[80].

For purposes of this analysis, the energy intensity of Southern California's dominant and marginal water source, averaged between the SWP East and West Branch, is 8,924 kWh/MG (rounded off to 8,900 kWh/MG).

Water Treatment

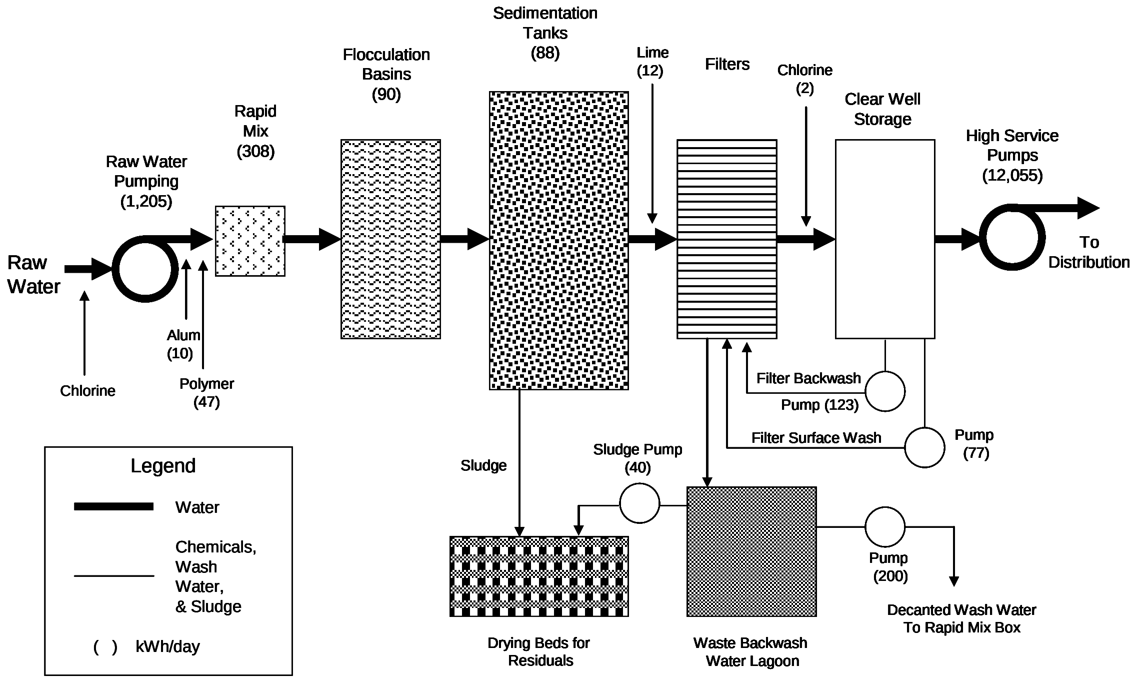
As explained above, for purposes of this analysis, water supply and conveyance energy requirements were addressed separately for Northern and Southern California. The remaining processes, water treatment, distribution, and wastewater treatment are considered similar enough between the two regions to assign the same prototypical water energy intensity. Due to the relative reliance on surface water supply in California, surface water treatment energy intensity has been adopted as prototypical.

In a typical sequence of operations for surface water treatment, the following steps are followed (see Figure C-2): Raw water is first screened and pre-oxidized, using chlorine or ozone to kill organisms; alum and/or polymeric materials are added to the water; flocculation and sedimentation remove finer particles; a second disinfection step kills remaining organisms with disinfectant residue carried into the distribution system to prevent organism growth; the clear well storage tank allows contact time for disinfection; and treated water is distributed to consumers by high-pressure pumps. Sludge and other impurities removed from the water are concentrated and disposed of.

[80] Methodology for Analysis of Energy Intensity of California's Water Systems and An Assessment of Multiple Potentials Benefits through Integrated Water-Energy Efficiency Measures; Exploratory Research Project Supported by: Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency; Principle Investigator Robert Wilkinson, PhD. January 2000, pages 24 through 27.

Figure C-2 Water Treatment Process Energy Requirements[81]

Representative Water Treatment Plant
Typical Daily Electricity Consumption for a 10 Million Gallon/Day Facility



Source: Electric Power Research Institute

[81] Water & Sustainability (Volume 4) U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century, EPRI 2002, Page 2-2, Figure 2-1.

Table C-3 Water Treatment Energy Intensity *(based on Figure C-2)*

		Surface Water Treatment Typical 10 mgd facility	kWh/MG
Public Supply	(Conveyance)	Raw Water Pumping	120.5
	(Treatment)	Alum	1.0
		Polymer	4.7
		Rapid Mix	30.8
		Flocculation Basins	9.0
		Sedimentation Tanks	8.8
		Lime	1.2
		Filters	0.0
		Chlorine	0.2
		Clear Well Storage	0.0
		Filter Backwash Pump	12.3
		Filter Surface Wash Pump	7.7
		Decanted Washwater to Rapid Mix	20.0
		Sludge Pump	4.0
		Treatment Subtotals	99.7
	(Distribution)	High Service Pumps	1,205.5
		Total	1,425.7

There is little variation in water energy intensity between plant sizes (shown in million gallons per day (MGD), as reflected in the following table:

Table C-4 Unit Electricity Consumption for Surface Water Treatment Plants[82]

Plant Size	**kWh/MG**
1 MGD	1,483
5 MGD	1,418
10 MGD	1,406
20 MGD	1,409
50 MGD	1,408
100 MGD	1,407

Referring back to Table C-3, in order to isolate the energy requirements for water treatment, the energy needed for raw water pumping and high service pumps to distribution have been removed. The remaining treatment processes total 997 kWh

[82] ibid, Page 2-3, Table 2-1. However, this study omitted the decanted wash water to rapid mix box pump rated at 20 kWh/MG from its totals. This amount was included in the numbers in the table.

per day for a typical 10 MGD capacity treatment plant or 99.7 kWh/MG. Actual energy requirements are driven by the site-specific characteristics of incoming raw water and water quality mandates. Industry standard practice, as well as process load metering, often doesn't differentiate raw water pumping, water treatment and distribution pumping loads adequately. Information provided in Table C-3 is drawn from large treatment plant populations and demonstrates this practice. Operational reporting of water treatment energy intensity is often driven more by the distance and elevation of the treatment plant in relation to water sources and the water distribution system than by the characteristics of raw water due to these vagaries. Typical water treatment processes are estimated at between 100 and 250 kWh/MG, and can be as high as 500 kWh/MG. In this analysis, 100 kWh/MG has been adopted as the prototypical and conservative water treatment energy intensity.

Water Distribution

Table C-4 shows there is little variation in the amount of energy required to treat and distribute a unit of water, regardless of plant size. As described above, Service Pumps to Distribution (for a typical 10 MGD water treatment plant) consume 12,055 kWh per day or 1,205.5 kWh per MG, or roughly 85 percent of total energy requirements (1,205 kWh/MG/1425 kWh/MG). For purposes of this analysis, a prototypical water distribution system energy intensity of 1,200 kWh/MG was adopted.

Wastewater Treatment

Unlike the water treatment and distribution systems, unit volume energy requirements for wastewater treatment plants vary greatly depending upon plant size. As would be expected, unit electricity consumption rises as the degree of treatment and complexity of the process increases. For example, advanced wastewater treatment with nitrification is three times as energy intensive (due to additional pumping requirements) as the relatively simple trickling filter plant[83]. Further complicating the assessment of prototypical wastewater treatment energy intensity are unique operational environments, discharge limitations, influent characteristics, and permitted effluent limitations as well as variations in plant permitting cycles. Table C-5 shows wastewater treatment plant energy intensities reflecting a range of energy intensity for facilities operating in California and cited in studies. Based on this range, 2,500 kWh per MG has been adopted as the prototypical wastewater treatment energy intensity.

[83] ibid, Pages 3-4 & 5 and Table 3-1.

Table C-5 Wastewater Treatment Energy Intensity

	kWh/MG
Inland Empire Utilities Agency [A]	2,971
City of Santa Rosa [B]	2,920
East Bay Municipal Utilities District [C]	2,001
Metropolitan Water District [D]	2655
Methodology for Analysis of Energy Intensity in California's Water Systems [E]	1,911
Energy Down The Drain, The Hidden Costs of California's Water Supply [F]	2,302
Energy Benchmarking Secondary Wastewater Treatment [G]	2,625

[A] Average of Five Wastewater Treatment Plants, CALeep Program Analysis May 2005
Program 1241-04, Conducted under the Auspices of the California Public Utilities Commission
[B] Laguna Wastewater Treatment
Sonoma County August 2002 Greenhouse Gas Emission Analysis, Page B-7
[C] EBMUD Load Studies Prepared by Navigant Consulting, December 2004
[D] The Metropolitan Water District of Southern California estimates that the wastewater facilities in its service territory consume between 1,470 to 3,840 kWh/MG
[E] Methodology for Analysis of Energy Intensity in California's Water Systems, January 2000, P. 43
Wastewater Treatment Plants with Nitrification
Ernest Orlando Lawrence Berkeley Laboratory
Principal Investigator: Robert Wilkinson, Ph.D.
Ref.: Burton, Franklin L. (Burton Engineering) , 1996 Water and Wastewater Industries
Electric Power Research Institute Report CR-106941, p. 2-45
[F] Wastewater Treatment with Nitrification (average 1-100 mgd plant capacities)
Energy Down The Drain, p. 26
[G] Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes
at Various (nine) Municipal Wastewater Treatment Facilities, PG&E February 2002
Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - 1,073 kWh/MG
Electric Use of Total Plant Operations Exec-1 and pg. 5, Table 3 - 4,630 kWh/MG

Summary of Water Energy Intensity for Northern and Southern California

The rest of this analysis is based on the following estimated energy intensities per million gallons of water (kWh/MG) delivered, treated, distributed, and disposed of in Northern and Southern California:[84]

[84] ibid (In this example NorCal system-wide Supply is estimated at 30 percent).

Table C-6 Prototypical Water Use Cycle Process Energy Intensity

	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	150	8,900
Water Treatment	100	100
Water Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700
Adopted	4,000	12,700

The Energy Efficiency of Water Use Efficiency

Energy savings associated with water savings provided in Table C-7 support the inclusion of water efficiency measures in energy efficiency program portfolios because of their relative low cost, long service life, and high resource value in terms of the avoided cost of energy. The following table reflects traditional water efficiency measures and their associated cold water energy savings resource values.

Table C-7 Water Efficiency Measure Cold Water Energy Savings

			Northern California			Southern California		
	Annual Savings Gallons/Year	Service Life	Annual kWh	Life-Cycle kWh	Resource Value	Annual kWh	Life-Cycle kWh	Resource Value
Residential								
Toilet Replacement 1.6 gpf (pre-1992)	2,250	25	9	225.0	$9	29	714	$32
Ultra Low-Flow Toilets	11,340	25	45	1,134.0	$44	144	3,600	$159
Energy Star Washing Machine	7,866	15	31	471.9	$27	100	1,498	$81
Commercial								
Ultra Low Flush Urinals	13,323	25	53	1,332	$52	169	4,230	$187
Waterless Urinals	25,568	25	102	2,557	$101	325	8,118	$359
Cooling Tower Condition Meter	729,906	10	2,920	29,196	$1,961	9,270	92,698	$5,609
Pre-Rinse Spray Head Installation	87,120	5	348	1,742	$136	1,106	5,532	$395
X-Ray Processor	1,042,723	5	4,171	20,854	$1,627	13,243	66,213	$4,733

Cost-effectiveness Assumptions

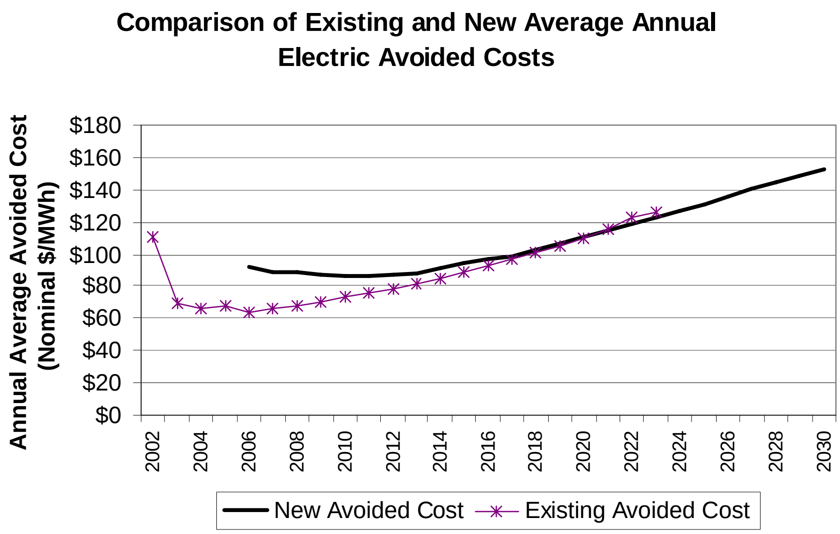
Resource values in this appendix were developed using the E3 Avoided Cost Methodology adopted by the California Public Utilities Commission (CPUC) in the April 7, 2005, Decision 05-04-024, Rulemaking (R.) 04-04-025. The CPUC adopted the E3 methodology for purposes of evaluating energy efficiency programs in R.01-08-028 and related energy efficiency proceedings.

The E3 model incorporates market price effects; the value of reliability through ancillary services; and the disaggregation of the avoided costs to time (hour, month, or time-of-use period) and to California climate zones. The E3 model forecasts the avoided costs of electric generation, transmission, and distribution that vary by hour, and the avoided costs of natural gas procurement, transportation, and delivery, which vary by month. Transmission and distribution (T&D) costs vary by utility service territory, planning division, and by the 16 Title-24 climate zones. Externality adders report environmental externalities: a T&D adder, which captures incremental demand-related capital expenditures, line losses and maintenance costs associated with increased energy use; a system reliability adder, which includes the cost of maintaining a reserve margin; and a price elasticity of demand adder, which recognizes that reduced demand results in a decrease in market-clearing price for electricity and therefore an increase in consumer surplus. The price elasticity of demand estimate varies by time-of-use period and month.

As currently utilized by the CPUC and energy utilities, the avoided cost projections in the E3 methodology extend to 2025. The calculations in this appendix include water use efficiency measures with 25-year service lives requiring that avoided cost projections be extended to 2030. The energy utilities submitted advice letter filings to the CPUC in April 2005 for purposes of updating their avoided cost projections. These filings projected utility avoided costs through 2030 for incorporation into the E3 methodology for valuing their energy efficiency resources. Figure C-3[85] compares the average utility avoided cost in place before and after the advice letter filings.

[85] Figure comes from E-3 published analysis of new and existing utility avoided costs.

Figure C-3



Source: E3

To calculate the resource value associated with the water use efficiency measures, the E3 methodology was modified to extend avoided cost projections to 2030. The adjustment from a 20-year to a 25-year measure results in less than a 7 percent change in the stated energy resource values. This means that the significant resource value potentials identified later in this appendix are not contingent upon modifying the avoided cost projections. E3 reviewed the adjustments and agreed the calculations were performed correctly.

Cold water energy savings are realized when one or more elements of the water use cycle - water conveyance, water treatment, water distribution systems and wastewater treatment facilities - process less water. They are also realized by avoiding incremental growth and requirements for plant expansions. In both cases the energy savings in the water use cycle result from the water use efficiency measures that were implemented. In this analysis water use cycle processes are assumed to operate 24 hours per day with an 85 percent load factor.

Energy Value of 2004 Best (Water) Management Practices

At a programmatic level, the California Urban Water Conservation Council (CUWCC) was created through the *Memorandum of Understanding (MOU) Regarding Urban Water Conservation in California* in 1991 to manage the process of implementing and updating the list of Best [water] Management Practices (BMP). To date 189 water agencies have pledged to implement the BMPs. CUWCC BMPs serve as a framework to quantify the energy resource value associated with water efficiency. The current lists of BMPs developed by the CUWCC follow.

Table C-8 CUWCC Best Management Practices[86]

BMP	Quantifiable Results
BMP 01: Water Survey Programs for Residential Customers	X
BMP 02: Residential Plumbing Retrofit	X
BMP 03: System Water Audits, Leak Detection and Repair	
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	X
BMP 05: Large Landscape Conservation Programs and Incentives	X
BMP 06: High-Efficiency Washing Machine Rebate Programs	X
BMP 07: Public Information Programs	
BMP 08: School Education Programs	
BMP 09: Conservation Programs for CII Accounts	X
BMP 09a: CII ULFT Water Savings	X
BMP 10: Wholesale Agency Assistance Programs	
BMP 11: Conservation Pricing	
BMP 12: Conservation Coordinator	
BMP 13: Water Waste Prohibition	
BMP 14: Residential ULFT Replacement Programs	X

Source: California Urban Water Conservation Council

[86] Quantifiable means annual reported BMP water use efficiency savings in acre feet per year, net of plumbing code compliance savings, reported pursuant to the 1991 Memorandum of Understanding Regarding Urban Water Conservation in California under protocol set forth by CUWCC. References: CUWCC (2005) *BMP Costs and Savings Study - A guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices* and (2003) *First Partial Revision*; M. Cubed (2003) *BMP Reporting Database Water Savings Calculations*; M. Cubed (1997) *California Urban water Agencies BMP Performance Evaluation, Final Report*; A&N Services (1996) *Guidelines to Conduct Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices*; U.S. EPA (1994) *Customer Incentives for Water Conservation, A Guide,* EPA/X820683-01-1, U.S. Environmental Protection Agency, Washington, DC. Measurement and evaluation is addressed by the CUWCC Measurement & Evaluation Committee.

To provide visibility to the potential impacts of integrated resource planning for water and energy efficiency programs, 2004 water sector BMP achievements were examined using the adopted energy efficiency avoided cost valuation methodology[87]. This analysis combines known planning criteria from each industry to assess the efficiency gain potential though programmatic integration.

Quantifiable water savings are available for eight of the BMPs, as shown in Table C-8. Each BMP includes several related water use efficiency measures. Assumptions for the water savings of each measure in gallons per day (GPD) and measure service life are reflected below in Table C-9.

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[87] Resource values are produced using the E3 Avoided Cost Methodology adopted by the CPUC in the April 7, 2005 Decision 05-04-024, Rulemaking (R.) 04-04-025. The Commission adopted the E3 Methodology for the purposes of evaluating energy efficiency programs in R.01-08-028 and related energy efficiency proceedings. Avoided cost bases are maintained at the website http://www.ethree.com/CPUC/cpucAvoided26.xls

Southern California Resource Values: The E3 calculator utilized is version "SCE Tool 1q" and incorporates SCE's update to the E3 Methodology as described in SCE Advice 1187-E (U-338-E) of April 25, 2005 specifically "extending the avoided cost forecast to 25 years from the base year of 2006" and applying "a linear trend based on the last five years of data contained in the E3 Methodology" as described in the referenced Advice Letter, page 3, Section A.

Northern California Resource Values; The E3 calculator utilized is version "CEE_Calc_Tool_Commercial_1d" and incorporates PG&E's update to the E3 Methodology as described in PG&E Advice 2626-G/2654-E (U-39-M) of April 25, 2205 and reflect ATTACHMENT A, Table 4: Adjustments Made to Extend Forecast through 2030.

Table C-9 BMP Water Use Efficiency Measure Service Life and Savings

	Service Life	Savings gpd	Reference
BMP 01:	4.5	26.6	Residential Surveys: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	5	21.0	Residential Surveys, Single Family: Metropolitan Water District of Southern California (MWD) program planning assumptions
	4	8.8	Residential Surveys, Multi-Family: MWD program planning assumptions
BMP 02:	5.1		Residential Plumbing Retrofits: BMP Costs & Savings Study (July 2000 ed.), page 2-13, mid-point range, equivalent useful life five years April 28 2003 M. Cubed Technical Memorandum to M&E Committee re; BMP Reporting Database Water Savings Calculations - Page 4 of 15
	5	5.5	Low Flow Showerheads: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	3.5	4.2	Toilet Displacement Devices: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	2	1.5	Faucet Aerators: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	8.5	0.64	Toilet Leak Detection: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	8.5	0.5	Other Household Leak Detection: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	4	12.2	Turf Audit: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	4	25.9	Turf Audit With Timer: BMP Costs & Savings Study, First Partial Revision December 2003, page 2-38, Table 1 Method 1 average
	25	24.2	Ultra Low-Flow Toilets (ULFT): BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	17.5		Hot Water on Demand: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
BMP 04:	10.5	Reported	Metering With Commodity Rates: BMP Costs & Savings Study, Draft Revision March 2005, page 2-29 (though should probable be 20+, as if and when a meter fails, it would be replaced see Section 2.5
BMP 05:	10	Reported	Large Landscape: Budgets and Surveys: MWD Planning Practices; BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range) see Section 2.16
			Evapotranspiration (Eto)-based budgets: BMP Costs & Savings Study (July 2000 ed.), Table 1, page 53
			Large Landscape Surveys: Urban Water Conservation Potential (August 2001)
BMP 06:	14	21.6	H/E Washing Machines: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	15	21.6	BMP Costs & Savings Study, First Partial Revision December 2003, page A-6
		13.8	BMP Costs & Savings Study, First Partial Revision December 2003, page A-8 range average
BMP 09:	12.4		CII Conservation Programs: Urban Water Conservation Potential (August 2001) (decay rate 10%)
		527.5	CII Surveys: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	5	2,856.8	X-Ray Processor: MWD Program Planning assumptions
	3	136.6	Water Broom: MWD Program Planning assumptions
	5	300.0	Pre-Rinse Spray Head: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range 100-500 gpd); expected life span see page 2-80
	3	200.0	MWD program planning assumptions
	5	240.0	PG&E Non-Residential Work Papers Supporting Application For Approval of 2006-2008 Energy Efficiency Programs and Budgets filed June 20 2005, R.01-08-028, pages 40 - 43 (electric) and 57 - 59 (gas) of 279, Non-Res Deemed Savings pages 14 or 20
	5	892.7	Industrial Process Improvement: MWD program planning assumptions
	8	103.6	High-Efficiency Washers: MWD program planning assumptions
	5	22.3	Flush Valve Kit: MWD program planning assumptions
	10	1,999.7	Cooling Tower Conditioning Meter: MWD program planning assumptions
BMP 09a:	25	36.5	CII ULFT Replacement: M. Cubed (2003) Technical Memorandum to the CUWCC M&E Committee re; BMP Reporting Database Water Savings Calculations - Page 10 of 15; BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range); BMP Costs & Savings Study, First Partial Revision December 2003, page A-12, Example 2A
	25	30.4	CII Dual Flush CII ULFT: MWD program planning assumptions
	30	30.1	Ultra Low-Flow Urinals: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
	25	70.1	Waterless Urinals: BMP Costs & Savings Study, Draft Revision March 2005, page 1-10 & 11, Table 1-3 (average of range)
BMP 14:	25	31.1	Res - ULFT: BMP Costs & Savings Study, First Partial Revision December 2003, page A-12, Example 2A; MWD program planning assumptions; BMP Costs & Savings Study (July 2000 ed.), page 2-29; April 2003 Technical Memorandum, page 15 of 15

Source: California Urban Water Conservation Council

The CUWCC reporting system for reductions in water used by member agencies reflects 2004 BMP achievements for BMPs with quantifiable results.[88] The energy savings for these measures, both annual and life cycle, are shown for each of these measures in Table C-10.

[88] Data was obtained from pubic access CUWCC website http://bmp.cuwcc.org/bmp/summaries/public/bmpsavings.lasso

Table C-10 Energy Resource Value in Water Use Efficiency (2006-2008 (E3) Avoided Cost)[89]

Northern California (PG&E/SMUD)	MG	Annual Savings kWh	Useful Life	Life-Cycle kWh Savings	NPV Electric Avoided Cost
BMP 1 Water Survey Programs MF/SF	802	3,208,000	5	16,040,000	1,251,113
BMP 2 Residential Plumbing Retrofit	132	528,000	5	2,640,000	205,919
BMP 4 Metering & Commodity Rates	671	2,684,000	11	29,524,000	1,929,737
BMP 5 Large Landscape Conservation Programs	2,249	3,261,050	10	32,610,500	2,190,009
BMP 6 High-Efficiency Washing Machine Rebate	134	536,000	15	8,040,000	474,057
BMP 9 Conservation Programs CII	2,035	8,140,000	12	97,680,000	6,217,380
BMP 9a CII ULFT	109	436,000	25	10,900,000	430,340
BMP 14 Residential ULFT	5,490	21,960,000	25	549,000,000	21,674,941
Total Northern California	11,621	40,753,050			$34,373,496
Southern California (SCE/LADWP/SDG&E)					
BMP 1 Water Survey Programs MF/SF	1,095	13,906,500	5	69,532,500	4,969,753
BMP 2 Residential Plumbing Retrofit	180	2,286,000	5	11,430,000	816,946
BMP 4 Metering & Commodity Rates	916	11,633,200	11	127,965,200	7,543,053
BMP 5 Large Landscape Conservation Programs	3,072	31,334,400	10	313,344,000	18,959,692
BMP 6 High-Efficiency Washing Machine Rebate Program	183	2,324,100	15	34,861,500	1,872,831
BMP 9 Conservation Programs CII	2,779	35,293,300	12	423,519,600	24,350,142
BMP 9a CII ULFT	149	1,892,300	25	47,307,500	2,092,023
BMP 14 Residential ULFT	7,498	95,224,600	25	2,380,615,000	105,275,069
Total Southern California	15,871	193,894,400			$165,879,509
Total Statewide Impacts	27,492	234,647,450			$200,253,005

Source: CUWCC Reporting Database, April 2005 with 86 of 269 Reporting Units (32%) reporting BMP expenditures in 2004 Reporting Units include: Water utility districts, water agencies, irrigation districts, city and county water departments and, water service companies implementing BMPs.

The numbers shown in Table C-10 reflect the variability in water conservation impacts on water related energy requirements, depending upon measure location.[90] The energy values have been obtained based on the multipliers for Northern and Southern California. The landscape numbers assume that the applied water is not treated as wastewater. In addition to the more than 27 million gallons saved from the 2004 BMPs, 234 million kWh were also saved that year, worth more than $200 million over their useful lives.

At this time it is reasonable to use the energy intensity values contained in this appendix as proxy values to support program planning. Future analyses of water energy intensity should be refined geographically by applying characteristics of hydrologic regions, planning areas or detailed analysis units as required, and finally

[89] See footnote 83.

[90] Water conservation activity is reported by CUWCC aggregated; to support disaggregating between SoCal and NorCal, electric service customer populations were used to establish approximately 60 percent - 40 percent shares for SoCal and NorCal, respectively.

applied to a structure that will align with energy efficiency planning climate zones[91] (See Suggested Research Topics).

The need to measure location-specific water-energy efficiency impact does not constitute a programmatic barrier for energy efficiency planners. This treatment is consistent with current energy efficiency program planning practices. For example, all current weather-dependent energy efficiency measure savings reflect location-specific savings across 16 climate zones - for example heating; ventilation and air-conditioning as well as building envelope measures; insulation; window glazing; and infiltration. Therefore, adopting savings for water-energy efficiency reflecting regional water energy intensity could be readily incorporated into current energy efficiency program planning protocols. The key point is that regional variability in water energy intensity should not defeat integrated planning. Energy efficiency planning already addresses many efficiency measures with varying degrees of savings in 16 geographic climate zones.

Statewide Water Use Efficiency (WUE) Potential

While the energy saving potential of 2004 BMP results are significant, they in no way indicate statewide potential. As related above, this appendix relied on the CUWCC's reporting database and used CUWCC's BMP reporting structure to provide visibility for associated energy benefits. CUWCC stresses that the reported savings are conservative and "the database does not include water efficiency for a whole series of BMPs for which CUWCC did not have a method to calculate water savings"[92].

The Pacific Institute, in its November 2003 report *Waste Not, Want Not: The Potential for Urban Water Conservation in California*, cites water savings potential, reflected in Table C-11. The 2004 BMP reported results in Table C-10 that represent approximately 4 percent of the minimum potential cost-effective savings identified here.

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[91] The California Department of Water Resources subdivides the state into 10 hydrological regions, 56 planning areas plus a more detailed breakdown into 278 detailed analysis units. Existing spatial analysis (GIS) readily supports integration of water measures into energy-efficiency program planning climate zones to ensure regional values align with energy-efficiency program planning protocols.

[92] Comments of Mary Ann Dickinson, Executive Director of the California Urban Water Conservation Council at the California Energy Commission Energy-Water Relationship Comment Workshop, Docket No. 04-IEP-01-H, June 21, 2005; Proceeding Minutes page 22.

Table C-11 California Urban Water Use in 2000

Potential to Improve Water Use Efficiency and Conservation

California Urban Water Use by Sector	Current (2000) Water Use (AF/year)	Best Estimate of Conservation (AF/year)	Potential to Reduce Use (%)	Minimum Cost-Effective Conservation (AF/year)
Residential Indoor	2,300,000	893,000	39	893,000
Residential Outdoor	983,000 to 1,900,000 (b)	360,000 to 580,000 (c)	25 to 40	470,000
Commercial/ Institutional	1,850,000	714,000	39	Combined CII: 658,000
Industrial	665,000	260,000	39	(e)
Unaccounted-for Water	695,000	(d)	(d)	(d)
Total	**6,960,000** (+/- 10%)	2,337,000	34	2,020,000

Source: The Pacific Institute

The question is really how much energy savings can actually be achieved through this much water use efficiency. The following calculations were performed to make this determination:

1. The average of *Best Estimate of [Water] Conservation* and *Minimum Cost-Effective Conservation* (Table C-11 above) is 2,178,500 acre feet per year, rounded to 2,150,000.
2. As shown in Table C-6 (and applied in Table C-11), the average energy intensity for Northern and Southern California is 4,000 and 12,700 kWh/MG, respectively; the weighted average based on customer populations is 9,220 kWh per MG[93].
3. 2,150,000 AF or 700,580 MG of California's achievable water conservation, multiplied by the 9,220 kWh per MG (the state's weight average water use cycle energy intensity), yields equivalent energy savings of 6,450 GWh, rounded to 6,500 GWh.

[93] The weight average of water use cycle energy intensity is based on year 2000 customer populations for Northern California of 5.167 million customers (PG&E and SMUD) and for Southern California of 7.057 million customers (SCE, LADWP and SDG&E) representing 92 percent of California's electric customers. This yields a customer allocation of 42.3 percent for Northern and 57.7 percent for Southern California. Applying the rounded allocation of 40 percent and 60 percent to respective energy intensities of 4,000 and 12,700 kWh per MG yields a population based weighted average of 9,220 kWh per MG.

4. 6,500 GWh and an 85 percent load factor yield a demand reduction of 873 MW, rounded to 850 MW.

   In Summary:

   - ✓ Annual water use efficiency water savings:
     - 700,580 MG
   - ✓ Water use cycle energy requirements:
     - 9,220 kWh/MG
   - ✓ Water use efficiency energy savings:
     700,580 (MG) X 9,220 (kWh/MG) = 6,459,344,373 kWh or 6,459 GWh
     Assumed Water Use Cycle Energy Savings = 6,500 GWh
   - ✓ Water use efficiency demand reduction:
     Peak Load (kW) = kWh / (Load Factor * 8760)
     Peak Load (kW) = 6,500,000,000 / (.85 * 8760) =
     873,000 kW or 873 MW
     Assumed Peak Load Reduction = 850 MW

5. Information from multiple sources shows that the cost of most water use efficiency measures ranges from about $58 to $710 per acre-foot or $178 to $2,179 per MG, depending upon the program. These costs include the full cost to manage the programs, capital investments, and required staffing[94]. Assuming an average of this range, or $384 per acre-foot ($1,178 per MG), the approximate cost in terms of energy efficiency is $0.13 per annualized kWh (700,580 MG X $1,178/MG = $825.6 million / 6,500,000,000 kWh = $0.127/kWh, rounded to $0.13/kWh).

Table C-12 presents the results of these calculations and compares them to the California's energy efficiency programs for 2004-2005 and those planned for 2006-2008.

[94] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-2, Potential Benefits of Urban Water Use Efficiency, and; Potential Costs of Urban Water Use Efficiency

Table C-12 Comparison of Water Use Efficiency to Energy Efficiency Resource Value

	2004-2005 [1]	2006-2008 [2]	WUE [3]
GWh (Annualized)	2,745	6,812	6,500
MW	690	1,417	850
Funding ($ million)	$762	$1,500	$826
Cost per Annual kWh	$0.28	$0.22	$0.13
WUE Relative Cost	46%	58%	

[1] CPUC Rulemaking R.01-08-028, Decision D.03-12-060
[2] CPUC Rulemaking R.-01-08-0228, Decision D.04-09-060
[3] California Water Plan Update 2005, Bulletin 160-05 California Department of Water Resources, page 22-2

The table shows that the estimated energy savings from statewide water use efficiency is more than double the energy savings from the 2004-2005 energy efficiency programs and almost as large as those planned for 2006-2008. The estimated peak reduction from water use efficiency falls between the values for these years. From a program cost standpoint, water use efficiency is roughly one-half the cost of energy efficiency programs.

These estimates are reasonably robust. If the energy savings were only half as much or if the costs were twice as much, water use efficiency would be as cost-effective as current and planned energy efficiency programs.

One of the questions that came up during the California Energy Commission's (Energy Commission) *Integrated Energy Policy Report (Energy Report)* proceedings was concerned with the different ways that water and energy programs address the useful life of the same measures. To evaluate the potential impact of this difference, Table C-13 compares several measures that are common to both energy efficiency and water use efficiency programs. The Estimated Useful Life (EUL) and energy savings from water heating and from savings in the water use cycle (cold water savings) are presented for four common measures:

Table C-13 Energy Efficiency – Water Use Efficiency Common Measures

	Energy - EUL	Water – EUL	Heating Annual Savings (kWh)	Cold Water Savings (kWh)
Low-Flow Showerhead[1]	10	5	202	16
Faucet Aerator[2]	10	2	78	4
Clothes Washer[3]	15	15	644	100
Pre-Rinse Spray Valve[4]	5	5	12,310	1,106

[1] Measure #504 California Statewide Residential Sector Energy Efficiency Potential Study #SW063
[2] Measure #506 ibid
[3] Measure #601 ibid
[4] PG&E CPUC Application for Approval of 2006-2008 Energy Efficiency Programs and Budget (U 39 M), Advice Letter 05-06-004 ATTACHMENT 4, ERRATA FOR PROGRAM DESCRIPTIONS, Workpapers

As shown above, water use efficiency planners apply estimated useful lives to the same measures that are either equal to or lower than those applied by energy efficiency planners. For purposes of consistency with the energy savings calculations shown later in this appendix, the EULs used by the energy planners were adopted.

Another concern was that these four measures represent the full potential for additional water use efficiency gains. However, the small set of overlapping measures represents less than 2 percent of the *known* energy savings and resource value that can be created through cold water savings. These additional savings – 98 percent - will come from measures that have been generally overlooked by energy efficiency planners.

At one time water use efficiency was narrowly viewed as a temporary source of water supply in response to drought or emergency water shortage situations. However, this analysis shows that water use efficiency is a viable long-term water and energy resource supply option. In short, significant, attainable energy savings can be realized in the form of water use efficiency.

Comparing Water and Energy Efficiency Programs

Comparing water and energy efficiency programs reveals differences in treatment in the following areas: program oversight, resource valuation, technical potential, budgets (trends), planning, implementation and evaluation, measurement, and verification. This section examines how both programs address these areas.

Program Oversight and Compliance

There is significant variability between water and energy efficiency program targets, regulatory oversight, and compliance. Targets for water conservation are referenced to a 10-year reporting period. Performance requirements for the BMPs with quantifiable results follow in Table C-14:

Table C-14 Best Management Practices

BMP	Requirements
BMP 01: Water Survey Programs for Single-Family and Multi-Family Residential Customers	Survey 15 percent of residential customers within 10 years
BMP 02: Residential Plumbing Retrofit	Retrofit 75 percent of residential housing constructed prior to 1992 with low-flow showerheads, toilet displacement devices, toilet flappers and faucet aerators
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	Install meters in 100 percent of existing un-metered accounts within 10 years; bill by volume of water use; assess feasibility of installing dedicated landscape meters
BMP 05: Large Landscape Conservation Programs and Incentives	Prepare water budgets for 90 percent of commercial and industrial accounts with dedicated meters; provide irrigation surveys to 15 percent of mixed-metered customers
BMP 06: High-Efficiency Washing Machine Rebate Programs	Provide cost-effective customer incentives, such as rebates, to encourage purchase of machines that use 40 percent less water per load
BMP 09: Conservation Programs for CII Accounts	Provide a water survey of 10 percent of these customers within 10 years and identify retrofitting options; OR reduce water use by an amount equal to 10 percent of the baseline use within 10 years
BMP 14: Residential ULFT Replacement Programs	Replace older toilets for residential customers at a rate equal to that of an ordinance requiring retrofit upon resale

Source: California Urban Water Conservation Council

A consistent and broadly acceptable method to evaluate (water use efficiency) cost-effectiveness and water savings is needed[95]. Documentation and evaluation of the achievements attributable to water use efficiency projects and programs, vital elements of successful water use efficiency efforts, need to be improved. The quantification of benefits for many projects lacks a necessary level of scientific

[95] Ibid

rigor[96]. Implementation of the BMPs by the water agencies is voluntary, and water efficiency program performance is self-reported, monitored by the CUWCC[97]. CUWCC is a non-profit agency with its governance administered by a committee comprising six representatives: three representatives from member water agencies and three representatives from public advocacy organizations[98]. Not all water agencies have signed onto the MOU agreement, and not all signatories are fully implementing the BMPs[99].

In contrast, the state's investor-owned utilities (IOU) energy efficiency programs are regulated by the CPUC[100]. The requirements include:

- ✓ Administrative structure for efficiency programs
- ✓ Program evaluation, measurement, and verification (EM&V)
- ✓ Separation between "those who do" and "those who evaluate" programs
- ✓ Protocols for measuring efficiency programs are defined in the *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs* [101]
- ✓ EM&V integration into the program planning process
- ✓ EM&V funding guidelines
- ✓ The type and frequency of EM&V studies conducted for each program and the major study parameters utilized for each study, including sample design, monitoring duration and schedule, and approaches undertaken to evaluate and minimize bias
- ✓ Cost-effectiveness tests used to evaluate program performance and proposed programs including:

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[96] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-4, WUE Challenges – Data Collection.

[97] CUWCC Governance Policies Section 10. Access to BMP Reporting Data: 10.1a.: "The Council will regard any data stored in the Council BMP Reporting Database that has been formally 'submitted as final" as public information', and; Section 10.1c.: "All publicly-released reports shall carry a disclaimer indicating that reports are based on self-reported data that has not been 100% validated by the Council."

[98] CUWCC Governance Policies Section 6.1, "The Council's Governance Committee shall be responsible for initiating the Executive Director's Annual Performance Review. The committee shall be responsible for oversight of Council governance, including review of bylaws, policies, membership development and training, communication (internal and external), strategic planning and meeting protocol." "The Governance Committee shall be composed of three Group 1 representatives (urban water supplier representatives) and three Group 2 representatives (public advocacy organizations) from the Steering Committee.

[99] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-3

[100] See CPUC Rulemaking 01-08-028, Decision 05-04-051 April 21, 2005

[101] As adopted by California Public Utilities Commission Decision 93-05-063 Revised March 1998 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021,95-12-054, 96-12-079, D.98-03-063, and D.99-06-052.

- program costs and participation levels
- number and type of measures
- environmental adders informed by and coordinated with the Climate Change Action Registry
- continuity of the input assumptions and calculations for the tests of cost-effectiveness (California Standard Practice Manual[102])
- *ex post* (after-installation) measurement of lifecycle savings inform and update *ex ante* (pre-installation) assumptions for future programs
- values for the weighted cost of capital (instead of using different values for each implementer). The current authorized cost of capital for the IOUs ranges between 7.6 percent and 8.7 percent, depending upon the IOU.

Program Funding

Variations in program oversight and compliance might reflect, in part, energy efficiency program ratepayer funding and funding levels. California electric industry deregulation legislation and other regulation established minimum levels of energy efficiency funding from 1998 through 2001, and are currently used by both IOUs and local publicly owned electric utilities[103].

Additionally, in 2003 the CPUC ordered IOUs to file plans to include energy efficiency as part of their long-term procurement supply portfolios for the first year, five years, and twenty years[104].

[102]http://www.cpuc.ca.gov/static/industry/electric/energy+efficiency/rulemaking/03eeproposalinfo.htm

[103] Electric Industry restructuring legislation Assembly Bill 1890 (Brulte, 1996) codified in Public Utilities Code (PU Code) under Division 1, Part 1, Chapter 2.3. Electrical Restructuring. Under Article 7 Research, Environmental, and Low-Income Funds, Section 381 directed the CPUC to require each IOU to identify a separate rate component to collect revenues used to fund cost-effective energy efficiency and conservation activities. Herein the IOUs were directed to fund not less than the following levels commencing January 1998 through 2001 ($ million dollars):

	1998	1999	2000	2001	Total
SDG&E	$32	$32	$32	$32	$128
SCE	$90	$90	$90	$50	$320
PG&E	$106	$106	$106	$106	$424
Total	$228	$228	$228	$188	$872

Article 8, Section 385 (a) directs each local publicly owned electric utility to establish a non-bypassable, usage based charge on local distribution service of not less than the lowest expenditure level of the three largest IOUs on a percent of revenue basis, calculated using the utility's total revenue requirement for the year ended December 31, 1994, and IOU total annual expenditures described above under section 381 (approximately 3 percent).

[104] CPUC Decision D.0312062 directs IOUs recover authorized procurement-related energy efficiency [costs] through its existing non-bypassable Public Purpose Programs Charge (PPPC), which applies to all IOU retail customers. Additionally, CPUC D.03-12-062 directs that incremental procurement

Table C-15 shows projected procurement costs for utility energy efficiency programs for the years 2004 through 2008 ($ millions):

Table C-15 IOU Supply Portfolio of Electric Energy Efficiency Procurement

Utility	2004	2005	2006	2007	2008	Total
PG&E	25	50	50	75	100	300
SCE	60	60	60	60	60	300
SDG&E	25	25	25	25	25	125
Total	**110**	**135**	**135**	**160**	**185**	**725**

Table C-16 shows the effect of combining the procurement budget with the budget for electric energy efficiency programs directed under the Public Goods Charge (PGC) funds for 2004 and 2005 ($ millions). This increases the total electric energy efficiency budget for 2004-2005 by $245 million, bringing the total to more than $760 million.

Table C-16 IOU Combined Electric Energy Efficiency Budgets 2004-2005

	PGC Budget	Procurement Budget	Total Budget
PG&E	258	75	333
SCE	183	120	303
SDG&E	77	50	127
Total	**518**	**245**	**763**

Current Energy Efficiency Program Funding

- $763 million was allocated to 2004-2005 electric energy efficiency programs, an increase of $245 million (43 percent) over statutory levels
- The 2006 – 2008 funding cycle was approved at just under $2 billion, of which approximately $1.5 billion is for electric energy efficiency, with the balance for natural gas.

Current Water Efficiency Program Funding

- In 2002 voters approved Proposition 50, which provides $180 million for water use efficiency programs in the years 2003 – 2007[105]. Proposition 50 annual

energy efficiency costs be subject to recovery though a non-bypassable charge to all customers and orders IOUs to establish the Procurement Energy Efficiency and Balancing Account (PEEBA) to track costs and revenues.

[105] Proposition 50 Chapter 7 provides $180 million for water use efficiency programs per year as follows: Urban water use efficiency $60 million; Agricultural water use efficiency $60 million; Water

funding for water efficiency is estimated at $36 million (actual program funds provided water agencies is reported to be an average of approximately $30 million per year[106]).

- Funding for water efficiency programs also comes from several other sources, including the implementing water agency, the state's General Fund, federal funds, and general obligation bonds. While these sources add to the available funds, the total is significantly less than that committed to energy efficiency programs.
- Funding has fallen below commitments made in 2000 through the CALFED Record of Decisions, Stage 1 2000-2007. By 2003 investments lagged by $235 million[107].

Integrated Resource Planning

Currently, water efficiency programs receive no credit for, and planners do not quantify, the large energy savings associated with water saving measures that are implemented. Additionally, until energy efficiency regulation and policy are changed, energy utilities cannot include or target these significant energy-efficiency gains. Neither water nor energy efficiency program planners address or target these potential efficiency gains, and a significant gap exists in statewide water and energy resource planning.

Water, wastewater, and energy efficiency program planners acknowledge the importance of comprehensive resource management. Water efficiency programs are based on the same cost-benefit methodology as energy efficiency programs and reference the Standard Practice Manual.[108] This common methodology recognizes the importance of clearly understanding the following four cost-effectiveness perspectives:

1. Water, wastewater or energy program participants
2. The water, wastewater or energy utility
3. The water, wastewater or energy supply system
4. Society

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recycling $60,000. The Bond law was passed in November 2002, and the funding will be allocated through 2007 (five years). Proposition 13 also had funding for water use efficiency but in form of loan. DWR Water Use Efficiency Office is funded partially through the general fund; annual budget less than $1 million. In addition to Statewide funding, local agencies also budget for water use efficiency programs.

[106] See footnote 72, Proceeding Minutes page 23.

[107] Department of Water Resources 2005 Water Plan Update, Volume 2, page 22-2.

[108] "A Guide to Customer Incentives for Water Conservation" Prepared by Barakat and Chamberlain for CUWA, CUWCC, and US EPA, February 1994 (EPA # 230R94001).

However, water, wastewater, and energy efficiency cost-benefit valuation is performed from the utility and, in the best cases, the electric supply system ***or*** the water supply system ***or*** the wastewater collection system perspective (See 2 or 3 above). Ultimately the suboptimal affects of this discrete or isolated water, wastewater, and energy resource management is borne by the consumer who must pay the water, the wastewater, and the energy utility bills.

Under the broader societal perspective, transfer payments between the water utility and participating customers are canceled out; also eliminated are transfer payments among the water utility and other utilities. The costs that are avoided by the electric, gas, water, or wastewater utilities are viewed as societal benefits, and any additional costs that are incurred by these utilities as a result of a water efficiency program are societal costs. Drawing the boundary around the entire water use cycle and including all end users and affected utilities facilitates this societal valuation.

Analysis contained in this appendix has demonstrated that the state's water, wastewater and energy resources are inextricably entwined. Incomplete accounting understates the resource value of water use efficiency. Integrated resource planning of water, wastewater and energy must be performed from *society's* perspective and answer the question, "What mix of water and energy efficiency measures will create the greatest return on the combined ratepayer investment?"

An integrated water-energy societal total resource cost valuation would include the avoided marginal cost of water and wastewater treatment, related environmental externalities, and the associated marginal cost of energy (kWh), capacity (kW), transmission, distribution (including line losses), and environmental externalities. Environmental externalities related to avoiding water and energy use need to be itemized (to remove potential double-counting) and combined to reflect composite environmental impacts.

With a more complete avoided cost-based justification, improved cost-benefit ratios and corollary increased program funding, water-efficiency program market penetration could significantly increase. Integrated water and energy demand-side management would increase both water and energy efficiency program impacts.

Suggested Research Topics

1. Regional Cold Water Energy Intensity (near-term):

    a. Research and develop regional cold water energy intensities. Adopt proxy values and establish linkage to forecasting climate zones. The information being developed by the University of California, Santa Barbara and the Pacific Institute will help develop a proxy that can be relied upon to develop pilot water-energy programs while more detailed studies are being conducted. In particular, while studies of urban water uses indicate that significant energy can be saved by reducing water consumption, the drivers for these opportunities are not well understood. A comprehensive inventory, characterization, and assessment of the primary types of water-related energy consumption by type of water source, system, function, and end use will eventually be needed to develop the detailed methodologies upon which cost-effective programs can be based. Water-related energy consumption can then be mapped from its source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the water supply chain, and the types of systems, processes, equipment, and measures that could reduce water and energy consumption at these points.

b. For existing cold ,water measures develop base case unit energy consumption (UEC), high-efficiency (HE) UEC, Base and HE Peak watt and demand savings, volume sensitive installed measure costs, and expected useful life values.
c. Identify opportunities for participating in demand response programs.
d. Identify and evaluate new cold water measures targeted to create resource value specifically suited to integrated water-energy resource planning not previously addressed under the discrete/isolated water/energy resource management regime.
e. For cold water measures found to be viable under item d., above, develop planning data identified for existing cold water measures.
f. Incorporate research elements (steps a. through d., above) into the Database for Energy Efficiency Resources (DEER) for use by energy efficiency program planners consistent with program planning protocols enunciated in CPUC Rulemaking 01-08-028, Decision 05-04-051.

2. Pilot Projects that Document and Quantify the State's Primary Water-Energy Interdependencies (longer-term):

    a. Select water utilities that collectively represent most of the primary types of water-energy interdependencies in California to include in the pilot. Several water utilities have already indicated interest in participating in such a pilot. These include the Metropolitan Water District (MWD), Inland Empire Utilities Agency (IEUA), the Los Angeles Department of Water and Power (LADWP), Palo Alto Utilities, and Sonoma County Water Agency.
    b. Conduct pilot projects to document the specific relationships.
    c. Inform and adjust proxy values developed above.

3. Seasonal Demand Shifting

    a. In Southern California, groundwater pumping uses approximately 30 percent of the energy required to import water from Northern

California. Groundwater aquifer source production and recharge requirements are fixed and finite. During periods of seasonal peak energy demand water agencies might rely on groundwater sources and recharge the aquifers using imported water months later in the off-peak season. In this manner ground water storage capacities could be used to encourage large-scale and long-term seasonal peak demand shifting.

b. Identify groundwater aquifers where groundwater pumping and recharge is being performed by water agencies.
c. Identify groundwater aquifers that are not currently being tapped for groundwater pumping.
d. Assess the operational feasibility and associated costs and benefits to encourage the seasonal demand shifting described above (item a.).

4. Conveyance-Related Peak Demand Reduction (State Water Project and other systems)

    a. Water agencies undertake projects to increase pumping and storage capacities based upon the given agency's operational cost-benefit perspective. Assess and report incremental cost-effective measures that can be implemented to increase pumping capacities and storage to reduce peak energy demands that are cost-effective, based upon a more comprehensive societal cost-benefit evaluation.
    b. Evaluate opportunities to reduce peak demand through the coordinated operation of federal and state water projects.

APPENDIX D: EXCERPT FROM CALIFORNIA WATER PLAN UPDATE 2005

VOLUME 1, STRATEGIC PLAN, CHAPTER 2, A FRAMEWORK FOR ACTION

Sustaining Our Water Resources

Fundamental Lessons

The Framework for Action embodies the following fundamental lessons, learned by California's water community through the experience of recent decades.

- The practice of water conservation and recycling in California has grown dramatically and must continue as a fundamental strategy for all regions and individual water users in California. The cumulative effect of each decision to use water more efficiently has an enormous impact on future water supplies and water quality.
- California must protect the quality of its water and use available supplies with great efficiency because water will always be a precious resource.
- Science and technology are providing new insights into threats to our watersheds, including our waterways and groundwater basins. California must use this knowledge to take protective actions and manage water in ways that protect and restore the environment.
- Sustainable development and water use foster a strong economy, protect public health and the environment, and enhance our quality of life. Sustainable development relies on the full consideration of social, economic, and environmental issues in policy- and decision-making. Sustainable water use assures that we develop and manage our water and related resources in a way that meets the needs of the present while protecting our environment and assuring the ability to meet the needs of the future.
- Solutions to California's water management issues are best planned and carried out on a regional basis. Hydrological, demographic, geopolitical, socioeconomic, and other differences among California's regions demand that the mix of water management strategies be suited to meet each region's needs for the long term.
- California needs additional groundwater and surface water storage capacity. Storage gives water managers tremendous flexibility to meet multiple needs and provide vital reserves in drier years.

Foundational Actions

To ensure that our water resource use is sustainable, water management at all levels – State, federal, regional, and local - must achieve these three foundational actions:

1. Use water efficiently.
2. Protect water quality.
3. Support environmental stewardship.

A number of resource management strategies that can be used to accomplish the foundational actions are listed in the following sections and described in more detail in Volume 2 Resource Management Strategies.

Use Water Efficiently

To minimize the impacts of water management on California's natural environment and ensure that our state continues to have the water supplies it needs, Californians must use water efficiently to get maximum utility from existing supplies. Californians are already leaders in water use efficiency measures such as conservation and recycling. Because competition for California's limited water resources is growing, we must continue these efforts and be innovative in our pursuit of efficiency. Water use efficiency will continue to be a primary way that we meet increased demand.
In the future, we must broaden our definition of efficient water use to include other ways of getting the most utility out of our groundwater and surface water resources and water management systems:

- Increase levels of urban and agricultural water use efficiency.
- Increase recycled municipal water and expand its uses.
- Reoperate water facilities to improve their operation and efficiency.
- Facilitate environmentally, economically, and socially sound transfers.
- Reduce and eliminate groundwater overdraft.

As California's population grows from 36.5 million to a projected 48 million in 2030, there is bound to be an effect on California's environment. By wringing every bit of utility from every drop of water, Californians can stretch water supplies and help ensure continued economic and environmental health.

Protect Water Quality

California must also protect and improve water quality to safeguard public and environmental health and secure the state's water supplies for their intended uses. Water supply and water quality are inseparable in water management. While implementing projects to reduce water demand or to augment supply, water managers must employ methods and strategies that protect and improve water quality:

- Protect surface waters and aquifers from contamination.
- Explore new treatment technologies for drinking water and groundwater remediation.

- Match water quality to its intended uses.
- Improve management of urban and agricultural runoff.
- Improve watershed management.

Support Environmental Stewardship

To ensure sustainability, California must also manage water in ways that protect and restore the environment. Water is a vital natural resource for people and the environment, so water management activities must occur in the context of resource management and environmental protection. Water development in California has a rich history of conflict, at times pitting water supply projects against ecosystem protection. Water supplies and the environment must both be considered together. Water managers must support environmental stewardship as part of their management responsibilities. As managers develop and deliver reliable water supplies, environmental stewardship can be incorporated in many ways:

- Integrate ecosystem restoration with water planning and land use planning.
- Restore and maintain the structure and function of aquatic ecosystems.
- Minimize the alteration of ecosystems by water management actions.
- Improve watershed management.
- Protect public trust resources.
- Integrate flood management with water supply management.

Recommendations

California Water Plan Update 2005 provides recommendations for the next 25 years. These recommendations are directed at decision-makers throughout the state (referred to as California), the executive and legislative branches of State government, and DWR and other State agencies. (See Chapter 5 Implementation Plan for details.)

1. California needs to invest in reliable, high quality, sustainable, and affordable water conservation, efficient water management, and development of water supplies to protect public health, and to maintain and improve California's economy, environment, and standard of living.

2. State government must provide incentives and assist regional and local agencies and governments and private utilities to prepare integrated resource and drought contingency plans on a watershed basis; to diversify their regional resource management strategies; and to empower them to implement their plans.

3. State government must lead an effort with local agencies and governments to inventory, evaluate, and propose management strategies to remediate the causes and effects of contaminants on surface and groundwater quality.

4. California needs to rehabilitate and maintain its aging water infrastructure, especially drinking water and sewage treatment facilities, operated by State, federal, and local entities.

5. State government must continue to provide leadership for the CALFED Bay-Delta Program to ensure continued and balanced progress on greater water supply reliability, water quality, ecosystem restoration, and levee system integrity.

6. State government needs to take the lead in water planning and management activities that: (a) regions cannot accomplish on their own, (b) the State can do more efficiently, (c) involve interregional, interstate, or international issues, or (d) have broad public benefits.

7. California needs to define and articulate the respective roles, authorities, and responsibilities of State, federal, and local agencies and governments responsible for water.

8. California needs to develop broad and realistic funding strategies that define the role of public investments for water and other water-related resource needs over the next quarter century.

9. State government should invest in research and development to help local agencies and governments implement promising water technologies more cost effectively.

APPENDIX E: A WATER-ENERGY ROADMAP

Recommendations of the Water-Energy Relationship Working Group

Presently, water and energy utilities seek to separately optimize their respective resource portfolios. Since energy is typically their second largest cost,[109] water utilities already proactively seek opportunities to reduce energy consumption and increase energy production to reduce the net cost of their water supplies. However, the search for opportunities typically does not extend beyond their own systems and facilities. This is more a significant opportunity than a problem.

Stakeholder input for this staff paper indicates that the greatest potential for positively affecting the state's energy circumstance is beyond current best practices. Specifically, the primary opportunity is in the integrated value of water, energy, and externalities - like societal value - embedded in a unit of saved water. The incremental benefit of these integrated values can be realized by arranging the systems and operations of both the state's water and energy utilities around this holistic valuation approach.

For example, the state's single largest consumer of energy, the State Water Project (SWP), already strives to maximize off-peak and minimize on-peak pumping. However, if the goal were instead to minimize total and peak water-related energy consumption throughout the state, what options might be considered that would otherwise remain unconsidered? Below is a sample of the types of opportunities that could be possible if the planning perspective were broadened to include the optimization of water and energy resources statewide.

- <u>Shift water pumping to off- and partial-peak time periods</u>. Both DWR and the State Water Contractors (SWC) – 29 water agencies that purchase water from the SWP -- note that the SWP is designed to deliver water 24 hours a day, 365 days a year. Purchasers of SWP water need to take delivery when it comes down the aqueduct. Additional storage at strategic points along the aqueduct, whether owned by SWP or any of its customers, could increase operating flexibility and allow additional shifting of both SWP and SWC pumping loads to partial-and off-peak periods.[110]

- <u>Shift water pumping to non-summer periods</u>. Some water agencies in Southern California already rely heavily on groundwater pumping during the

[109] Salaries are usually first.
[110] Any increase in storage increases operational flexibility. This can be accomplished by oversizing aqueducts and canals, off-stream storage, and pipelines. SWP agricultural customers' systems are presently optimized for 24-hour deliveries. With proper incentives, it may be possible to modify these agricultural customers' systems to increase flexibility in SWP deliveries.

summer, and recharge their wells with imported SWP water during other times of the year. This groundwater production and recharge could be coordinated to create seasonal load-shifting.[111]

- Increase use of recycled water. While use of recycled water has nearly tripled since 1970, it still accounts for a very small percentage of the state's water supplies.[112] At a minimum, recycled water should be used wherever possible for landscape irrigation, though the high cost of dual distribution networks has been a major barrier.[113] When viewed from a societal perspective, significant investment in programs to reduce landscape irrigation is warranted on the basis of their energy benefits alone.

- Capture energy in water systems. Water utilities purchase significant amounts of energy to transport water though their systems. There are opportunities to recapture some of this energy through in-conduit turbines. The effect of this in-conduit hydropower production would be to decrease a water utility's net energy requirements. While opportunities exist to capture this energy, there are few incentives (and many disincentives) for development. Viewed on a holistic basis, the efficient utilization of energy within an existing pipeline or conduit would be viewed as an efficiency retrofit that qualifies for funding support by energy utilities.[114]

- Reduce energy for water pumping. Oversizing and/or lining pipelines can reduce friction and the amount of energy needed to transport water.

- Reduce energy for treatment. Both potable and wastewater systems could be reconfigured to incorporate storage, allowing treatment to be deferred to off-peak periods.

In addition to opportunities for reducing and shifting water utilities' energy consumption, stakeholders identified an important new opportunity – saving energy by saving water. When a unit of water is saved, so too is the energy required to convey, treat, deliver, and safely dispose of that unit of water.

In order to employ this value in designing cost-effective programs, this water ***energy intensity*** must take into account all of the steps in the water cycle. The energy

[111] The state's highest electric demand is on hot summer days. If significant water activities could be shifted to other months, the state may need to build less generation and transmission capacity. In addition, electric reliability would be increased, and the adverse public health, safety, and economic impacts of rotating outages avoided.
[112] *California Water Plan Update* 2005, public review draft, April 2005.
[113] During summer months, as much as 50-70 percent of residential water use in Central and Southern California is for landscape irrigation.
[114]In-conduit hydropower does not presently qualify as an energy efficiency retrofit for purposes of energy utilities' programs. While in-conduit hydropower is RPS-eligible and could qualify for supplemental energy payments (SEPs), it would not be feasible to develop mini- and micro-hydro under the same rules as utility-scale generation.

intensity of cold-water energy savings is presently not considered in water or energy efficiency program planning. When a saved unit of water is valued from a societal cost perspective, significant energy-efficiency, embedded in water efficiency, is clear. The following example shows the electric energy resource value of just one water efficiency measure, BMP14[115]:

> An ultra-low-flow toilet saves 11,340 gallons of water per year and has a service life of 25 years. This results in potable cold-water energy savings of 91 kilowatt hours (kWh) per year, or 2,275 kWh over its useful life. The present value of electricity's avoided cost is $141. In 2004, water utility programs installed 1.8 million ultra-low-flow toilets in California residences, resulting in cold water savings of 60 million kWh per year, or 1.5 billion kWh over the program's life. The present avoided cost value through this single BMP is $119 million[116].

This simple analysis shows how energy can be saved by saving water. However, energy utilities are not currently authorized to invest in cold water savings. This raises some important questions:

- How much water or energy could be saved with existing technology, without basing their cost-effectiveness upon a single resource like the avoided cost of water or electricity, natural gas, or diesel?

- What incremental energy benefits would be realized if saved water were valued on a societal basis, and energy utilities were allowed to participate in programs that save energy by saving water?

Regarding a comprehensive statewide water and energy program:

- How can programs and incentives be structured to both encourage collaboration across utility systems and boundaries and allow energy utilities to share the costs of water conservation and efficiency programs (to access water savings not deemed cost-effective on a single utility resource cost test)?

The following table describes some actions that could facilitate a statewide shift toward integrating the water and energy resource planning and management needed to achieve incremental societal benefits.

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[115] See discussion of water conservation and efficiency "best management practices" (BMPs) in Appendix C.
[116] See Appendix C for full discussion of this issue and information source references.

ENERGY OBJECTIVE	APPROACH	OPTIONS
Optimize the state's water and energy resources & assets on an integrated basis	Build policy framework & infrastructure	1. Identify synergistic benefits that make business sense to both water & energy stakeholders. 2. Revise both water & energy utilities' investment criteria to incorporate a societal perspective. 3. Adjust resource pricing methodologies to reflect total societal values. 4. Authorize energy utilities to invest in programs for cold water savings. 5. Structure funding & incentives to attain targeted responses. 6. Provide low-interest loans & grants for incremental water infrastructure that produce benefits to the electric grid. 7. Create a joint agency task force to establish protocols for sharing costs, benefits and responsibilities among multiple stakeholders subject to different jurisdictional rules and regulations. 8. Coordinate water and energy capital programs to maximize infrastructure investments for benefit of both resources.
Increase energy supplies	Support development of additional hydropower capacity	1. Resolve conflicts with FERC relicensing process. 2. Modify Renewable Portfolio Standards to include all new and increased hydropower capacity. 3. Provide access to Supplemental Energy Payments. 4. Establish incentives for re-powering for incremental pumped storage capacity.[117] 5. Allow in-conduit hydropower to qualify for funding as an energy recovery facility, qualified as an energy efficiency retrofit.
	Remove disincentives to energy self-sufficiency	1. Allow water utilities to wheel self-produced power to themselves, anywhere on their systems. 2. Streamline the interconnection process and reduce costs. 3. Remove net metering caps.
	Encourage production of excess power	1. Provide technical & funding support for development of renewable resources & distributed generation. 2. Encourage partnering between water & energy utilities in power development. 3. Establish long-term power purchase agreement for such excess production that exceeds bulk wholesale markets and

[117] Hetch Hetchy implemented system improvements that increased peak hydropower capacity by 48 MW at a capital cost of $8 million, 83 percent less than the cost of installing a new unit of comparable capacity.

ENERGY OBJECTIVE	APPROACH	OPTIONS
		assures payments that support project financing. 4. Provide a ready market for purchasing any over-production of power (e.g., require investor-owned utilities to include in their energy supply portfolios).
Increase energy efficiency and demand side management	Help water utilities develop & implement comprehensive energy management	Provide technical, funding & other support.
	Reduce peak energy consumption (seasonal & time-of-use)	Increase system & operating flexibility (e.g., increase capacity for pumping groundwater during summer, deferring water imports to fall and winter).
	Establish incentives for shifting seasonal use	Compensate water utilities for deferring water imports from summer to fall.[118]
Increase operating flexibility	Maximize ancillary services benefits of the state's hydropower resources	1. Increase pump storage capacity. 2. Use hydro to shape wind & other intermittent resources (e.g., solar).
	Increase storage	Support development of new and incremental storage wherever possible.[119]
Increase water conservation & efficiency	Increase investments that attain statewide energy benefits	1. Incorporate a societal perspective into water utilities' investment criteria. 2. Allow energy utilities to invest in water system improvements that attain benefits for energy ratepayers. 3 Create a Public Goods Charge equivalent for water utilities.

A Conceptual Road Map

Following is a conceptual road map for a five-year program structured to achieve the above objectives. The plan considers a three-phase approach:

Phase 1 – Policy Framework and Infrastructure
Phase 2 – Pilot Programs
Phase 3 – Implementation

The process of building the policy framework and infrastructure needed to support a major policy shift of this kind would begin in *Phase 1*. *Phase 2* would be triggered by adoption of interim policies and pilot programs by energy utilities, and their regulator(s), in recognition of the energy value of saved water. *Phase 3* would begin with adoption of permanent policies and programs by energy utilities and their regulator(s) that will invest in saving water to save energy.

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[118] Incentives already exist to encourage shifting loads from on-peak to partial- and off-peak periods.
[119] Water remains the most effective means of storing energy.

The work in each phase is generally described below.

Phase 1 – Policy Framework and Infrastructure [8-12 months]

During the initial phase, three distinct activities would proceed concurrently:

- Task 1: Increase access to existing energy programs and resources by water and wastewater utilities.
- Task 2: Develop a policy roadmap for statewide integrated water and energy planning and management.
- Task 3: Conduct studies of California's water-energy relationships.

Activities included in each task could include, but are not limited to, the following:

Task 1: Increase access by water and wastewater utilities to existing energy programs and resources. Energy utilities already offer programs where water utilities can participate. These include traditional energy efficiency programs such as retrofits of lighting and HVAC and programs for increasing the efficiency of pumps and motors. In addition, the state's investor-owned utilities (IOU) offer energy-performance contracts (EPCs) that provide customized cash incentives for projects that demonstrate real energy savings.

The following tasks are designed to increase access to existing programs and resources, identify additional resources, and facilitate identification of opportunities for attaining incremental benefits through increased collaboration, and, potentially, the joint operation of multi-utilities' systems, resources, and assets.

1.1 Develop a clearinghouse of water-related energy information for water professionals and others concerned about energy and water use in California. The clearinghouse should include the leading references and studies that highlight energy best practices for water utilities; creative approaches to system design and operations that provide operating flexibility to moderate peak energy consumption; opportunities to become energy self-sufficient; and sources of technical, funding and other types of support.

1.2 Develop a pilot assistance program for water utilities to help individual water agencies integrate comprehensive energy planning and management into their activities.

1.2.1 Establish the baseline of current practices. Provide direct and active technical assistance for best practices for reducing energy consumption by water systems and processes. Encode these best practices into benchmarking tools and make them available to practitioners, enabling them to compare their current practices with what is possible. Develop a clearinghouse of information on a range from current to best practices. Establish measurement and evaluation protocols to verify savings and share lessons learned.

1.2.2 Provide incentives for incremental and/or joint infrastructure improvements that reduce total and peak energy requirements for water transport and processing. These incremental facilities would likely include storage (reservoirs, groundwater wells, and oversized pipelines) that both increases system flexibility and facilitates time-of-use (TOU) and/or seasonal load shifting.

1.2.3 Identify long-term funding opportunities for both ongoing existing programs and for funding retrofits that exceed single utility resource cost-effectiveness tests.[120]

1.2.4 Assist in identifying opportunities for peak-load reductions and seasonal load shifting.

1.2.5 Provide technical and funding assistance in identifying and implementing self-generation opportunities, especially renewable resources and emerging technologies.

1.2.6 Facilitate opportunities for collaborating with local energy distribution companies on all aspects of energy management and energy self-sufficiency, including strategies to meet projected load growth.

Depending upon the results of the pilot, successful programs could be quickly ramped up to provide assistance to water agencies statewide.

<u>Task 2: Develop a policy roadmap for statewide integrated water and energy planning and management</u>. A policy shift of this magnitude requires thoughtful consideration of the barriers and hurdles that need to be overcome before successful implementation. A policy roadmap identifying key changes to laws and regulations that would help facilitate the shift would be very beneficial when embarking upon this effort. The types of activities within this task could include:

2.1 <u>Establish a statewide multi-agency Water-Energy Task Force</u>. This task force would provide consistent, long-term leadership, policy direction, and technical and resource support for a comprehensive statewide water-energy program. The Water-Energy Task Force would include staff from the Energy Commission, Department of Water Resources, California Public Utilities Commission, Air Resources Board, State Water Resources Control Board, and the California Department of Health Services.

The goal of the task force would be to achieve the benefits of *statewide integrated planning and management of the state's water and energy resources*. Specific tasks include the following:

[120] Long-term funding was identified as an important factor in gaining support from water utilities.

- Collaboratively build a knowledge base of water and energy interdependencies. Investigate beneficial statewide integrated water and energy planning and management practices and recommend policies, programs, and funding for successful programs.

- Expand the Water-Energy Relationship (WER) Working Group created through this process to include strong participation by all key stakeholder groups needed for successful implementation of the program. The WER Working Group will provide technical advice to the Water-Energy Task Force.

- Designate a Water-Energy Liaison at the Energy Commission. This person or group would be responsible for coordinating policy, research, and programmatic efforts within the Energy Commission and act as liaison to the Water-Energy Task Force, other state agencies, local jurisdictions, and water, wastewater, and energy utilities. Similar people or groups should be identified at other agencies on the Task Force.

- Collaborate with other parties and entities with compatible goals. These include DWR's Office of Water Use Efficiency, the Recycling Task Force, and the Desalination Task Force.

- Develop a roadmap that establishes goals for increasing water efficiency and demand-side management. Among other things, the roadmap should prioritize investments in programs and measures that have the highest resource value and impact. In recognizing that every unit of water saved allows displacement of higher-energy intensity water supplies, high priority should be assigned to reductions in agricultural water use and urban landscape irrigation, both residential and commercial.

- Charge the Water-Energy Task Force with monitoring technology changes that affect the energy intensity of the water cycle, and identify potentially feasible and cost-effective applications.[121] A mechanism should be established to continually identify and incorporate new technologies wherever beneficial and feasible.

2.2 *Build the policy framework and infrastructure.* The concept that there are statewide benefits from "saving water to save energy" needs to be emphasized and regularly underscored. *Energy Report* findings and recommendations should be presented to the CPUC, water and energy utilities, key water and energy

[121] For example, new tunneling equipment and techniques may one day make it possible to drill through mountains instead of transporting water over mountains, significantly reducing energy used for water pumping. In addition, improvements in desalination and other water supply development techniques may become more cost-effective than transporting water from Northern California to Southern California. Further, technologies such as cloud seeding may become more successful in producing local supplies that could reduce Southern California's need for water imports.

policymakers, and other key stakeholders. The bases for computing potential benefits needs to be widely and clearly understood.

Policies, procedures, business processes, analytical methods, investment criteria, and decision making tools all need to be adjusted to support a policy and planning shift of this magnitude. To support this shift, the importance of the state's water-energy relationship needs to be better understood. Preliminary studies show the complexities of the water supply balance and cycle, and geographic, source, end user and other diversities – all of which must be documented, quantified, and modeled to assure that programs and strategies achieve their intended results. Thereafter, policies, rules, regulations, protocols, methodologies, programs, and funding need to be brought into alignment.

- Establish a valuation methodology for the societal value of water. We are just beginning to understand the water-energy relationship. Preliminary studies of the water supply-use-disposal cycle and overall water supply balance show distinctly different energy intensities of water in various regions of the state, depending upon climate, topography, and water storage/recovery/delivery options and methods. In addition, different uses have different energy intensities. A valuation methodology is needed to capture these diversities in a manner that will help planners prioritize their investments.[122]

- Leverage developmental work already in progress by others, including the U.S. Department of Energy National Laboratories' Water-Energy Nexus Program, Pacific Institute, California Urban Water Conservation Council, and the Irrigation Training and Research Center. Collaborate with these (and other) entities, to:

    - Inventory, characterize, and measure California's types of water and energy interdependencies.

    - Develop pilot programs to test tools and methodologies for evaluating tradeoffs among these interdependencies.

    - Develop analytical models for policymakers, regulators, utilities, and other key stakeholders in developing cost effective joint water and energy programs.

- Facilitate joint investment to attain societal benefits. As opportunities are identified that could produce incremental energy benefits but are not deemed

[122] For example, while it may be possible to increase total groundwater capacity in Southern California, unique geological characteristics create uncertainties as to both ultimate capacity (groundwater doesn't behave predictably) and impacts on production capacity of other wells in the vicinity. Similarly, displacing SWP imports with increased seawater desalination in Southern California may not produce a net benefit; nor would over-pumping of groundwater supplies and reducing drought reserves be desirable. All of the interdependencies – water to energy, energy to water, and water to water -- need to be evaluated to determine how best to attain positive net benefits.

cost-effective on a single utility resource cost test, mechanisms are needed that facilitate joint investment to attain those incremental benefits.

- Incorporate a societal valuation approach in both water and energy utilities' resource pricing methodologies, water and energy efficiency program portfolios, and investment criteria.

- To facilitate early results, establish a proxy for the societal value while a detailed methodology is developed.

- Establish a water resource loading order that incorporates the societal value of an avoided unit of water consumption and that mirrors the preferred energy resource loading order in the Joint Agency Energy Action Plan for energy.[123]

- Establish a public goods charge equivalent for public purpose water conservation and efficiency programs.

- Provide incentives for water, wastewater, and energy utilities to optimize their joint resources beyond traditional discrete single utility service boundaries (water or energy).[124]

- Require the state's energy and water planners to collaborate on plans and strategies to reduce net water sector energy consumption and to meet projected energy load growth.

2.3 <u>Identify changes to existing laws and regulations</u>. Examples of some proposed changes are provided in the table of potential actions on pp. 4-5.

2.4 <u>Request that DWR provide input to the IEPR with respect to projected energy load growth in the water sector and potential energy impacts of drought risk mitigation measures</u>. Similarly, request Energy Commission's participation in DWR's Water Plan Update process to provide assumptions as to energy supply availability and price forecasts.[125] Energy Commission and DWR should also synchronize planning assumptions for dry, wet and average hydrology years, as well as

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[123] The California Water Plan Update 2005 already identifies a prioritized resource strategy. In order to attain results that optimize the state's water and energy resources on a joint basis, societal values should also be considered in the resource loading order. For example, least-cost water supply options at low electricity prices (e.g., desalination and water transfers) may become expensive when electricity prices are high. Since high electricity prices typically coincide with electricity supply shortages, water resource planning that does not consider energy impacts during times of shortage can create electric reliability risks that affect all California ratepayers. Integrated planning of water and energy resources provides the policy perspective needed to develop contingency plans and strategies for mitigating these types of risks.

[124] For example, the SWP could work with the water agencies that take water from the aqueduct to identify incremental infrastructure and changes to operations that can shift more water pumping to off-peak periods and/or non-summer months.

[125] This could result in a water supply equivalent of the state Energy Action Plan's resource load order.

assumptions as to the duration and magnitude of a multi-year drought for contingency planning purposes.

2.5 Expand the 14 water conservation best management practices (BMPs) to include new measures that meet the broader goals of statewide integrated water and energy planning and management.[126] Prioritize investments in BMPs in accordance with cost-effectiveness from a societal perspective.

2.6 Resurrect long-term purchase commitments (e.g., "standard offer contracts") that provide a ready market for excess power produced by water agencies after meeting all of their own energy requirements. One option might be to merely include such default purchase mechanisms in investor-owned utilities' procurement baselines.

2.7 Increase collaboration among state agencies to assure a consistent policy perspective. Unintended consequences result when multiple regulators seek to discharge their separate responsibilities in absence of a consistent policy framework. For example, while the state is encouraging increased energy production, the Department of Fish and Game restricted operational flows at Silverwood, a man-made reservoir, to protect non-native fish. The WER Working Group identified a need for consistent policy in which state agencies collaborate regularly to assure that energy, water and environmental benefits are continually balanced.

Task 3: Conduct studies of California's water-energy relationships. There is a near-term opportunity to access California ratepayer funds to support the policy shift to statewide integrated water and energy planning and management. Specifically, the state's investor-owned utilities are challenged to attain the targeted energy efficiency goals established by the CPUC for the 2006-2008 round of ratepayer investments. The opportunity to save water to save energy has significant promise to deliver, and potentially to exceed, system benefits targeted by the CPUC. In fact, water-energy programs may well represent the most promising opportunity for "second generation" energy efficiency measures.

The purpose of this task is to establish the foundation for an interim water-energy program that will demonstrate the expected benefits of statewide integrated water and energy resource management, prior to establishing permanent programs. The following work will need to be accomplished to support design of one or more interim programs.

3.1 Establish an interim methodology and proxy for the societal value of a unit of water saved. Design of cost effective programs requires computation of the societal value of a saved unit of water. The computation needs to be performed over the

[126] See Appendix C for a discussion about water conservation BMPs.

entire water use cycle (i.e., the total costs of water, externalities and energy incurred during the entire life of a unit of water[127]).

Ultimately, a comprehensive methodology is needed that recognizes the diversity of water supplies, treatment processes, types of end use, and other factors. The number and complexity of variables will need to be analyzed to determine which are most significant in computing the societal value. In the meantime, a proxy can be employed to allow interim water-energy programs to go forward while detailed studies of the water-energy relationship continue in parallel. There is precedent at the CPUC for utilizing proxies while formal methodologies are being debated and refined.[128]

[<u>Note</u>: The "triple bottom line" concept captures the full spectrum of economic and societal values that today's organizations must address. In developing the proxy, it may be desirable to consider aligning the components of the societal value of water with this evolving concept that is gaining increased acceptance.]

3.2 <u>Inventory needs</u>. Prior to designing the studies, a needs assessment should be conducted to inventory the spectrum of primary water-energy relationships in California, and the current body of data, models, tools, policies, programs, practices, funding, legislation and regulations. Water-related energy consumption will be benchmarked by type of water system, function, and end use. Water-related energy consumption will then be mapped from source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the supply chain, and the types of systems, processes, equipment and measures that could reduce energy consumption at these points.

3.3 <u>Conduct detailed studies</u>. The final task under Phase 1 is to conduct detailed studies of California's water-energy interdependencies and to integrate these data into analytical models and tools that can help both water and energy utilities develop cost-effective joint water-energy programs. The scope of these studies will include establishing baseline water use by all sectors and then linking this to the energy baseline. In addition, technologies will be researched for their water and energy savings potential, and the associated environmental benefits.

Studies will proceed in parallel with commencement of Phase 2 – Pilot Programs. The Pilot Programs will employ a proxy until more detailed data and methods become available to support adoption of a formal methodology for valuing the energy and societal value of an avoided unit of water. The types of studies needed are described more fully at the end of this appendix.

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[127] Water collection, transmission, treatment, distribution, wastewater treatment, and ultimate disposal or recycling.
[128] In recent years, for example, proxies were established and relied upon by the CPUC for both the market price referent and avoided costs of energy.

Phase 2 – Pilot Programs [12-24 months]
During Phase 2, a proxy will be adopted and applied to develop pilot water-energy programs in which the projected incremental benefits of joint water and energy planning and management can be verified. Concurrently, Phase 1 studies to perfect the data, methods, and tools needed to establish a reliable methodology for supporting development of cost effective programs on an ongoing basis will continue in parallel.

Several water-energy pilot programs are recommended:

- A pilot for investor-owned and municipal utilities that targets specific types of water use reduction to demonstrate and measure the expected economic and reliability benefits to energy ratepayers and the California electric grid. The pilot would employ a proxy for the societal value of each type of water use reduction based on a preliminary methodology, pending completion of further studies and analyses. The scope of such a pilot could include:

    - Direct co-investment by energy utilities in water conservation and efficiency programs with high potential for energy savings. (The Pacific Institute, in its November 2003 study "Waste Not, Want Not: The Potential for Urban Water Conservation in California", estimated a remaining annual potential for cost effective urban water conservation as high as 2 million acre feet (651.7 billion gallons). Assuming a conservative estimate of 5,000 kWhrs/mg[129], this quantity of saved water could reduce energy consumption by 3,258 Gwh per year. This is about 1.8% of the state's total energy consumption.)

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[129] Refer Appendix C, Energy Impact Analysis of Existing Water Management Practices. For the sole purpose of illustrating the potential magnitude of impacts, we have assumed a statewide average value of 5,000 kWhrs/mg.

California Urban Water Use in 2000
and the Potential to Improve Efficiency and Conservation

California Urban Water Use by Sector	Current (2000) Water Use (AF/year)	Best Estimate of Conservation (AF/year)	Potential to Reduce Use (%)	Minimum Cost-Effective Conservation (AF/year)
Residential Indoor	2,300,000	893,000	39	893,000
Residential Outdoor	983,000 to 1,900,000 (b)	360,000 to 580,000 (c)	25 to 40	470,000
Commercial/ Institutional	1,850,000	714,000	39	Combined CII: 658,000
Industrial	665,000	260,000	39	(e)
Unaccounted-for Water	695,000	(d)	(d)	(d)
Total	**6,960,000** (+/- 10%)	2,337,000	34	2,020,000

Source: "Waste Not, Want Not: The Potential for Urban Water Conservation in California", The Pacific Institute, November 2003.

- Subsidized investments in incremental water infrastructure that are expected to attain significant energy benefits (e.g., increasing capacity of, or adding new reservoirs, pipelines, and groundwater wells).

- A pilot that investigates the potential incremental benefits attainable by optimizing joint water and energy resource management of the state's largest water utilities on a combined basis. For example, the pilot could investigate incremental water and/or energy infrastructure (water storage, delivery, power production, etc.) that could increase the operating flexibility of combined large water systems (SWP, SWC, CVP and/or the Colorado River System, as well as other large water systems that are now or could become interconnected).

Phase 3 – Implementation
Phase 3 will be defined by completion of most of the detailed studies of the state's water-energy interdependencies, and of the analytical models and tools that employ these data to design cost effective joint water-energy efficiency programs. During Phase 3, proxies for the societal value of saved water will be replaced with permanent methodologies, and long-lived (5-10 years) water-energy programs will be established and funded.

Implementation Challenges

While some opportunities could be accessed now for early results, there are some challenges to implementation of joint investments that attain the incremental energy resource and reliability benefits of fully integrated water and energy resource planning and management.

1. Water and energy utilities are regulated, operated and managed separately. Short of a few programs in which end users can earn energy incentives for reducing consumption of hot water, there presently is little incentive for water, wastewater, and energy utilities to even coordinate their resource planning activities and much less to share investments in programs and infrastructure.

2. Program goals and incentives will need to be aligned. Societal values are derived from reducing or avoiding the buildup of costs along the water cycle. In this case, water and wastewater utilities and their ratepayers will need to make the investments that attain energy resource and reliability values that benefit other ratepayers and the state overall. This presents challenges with respect to equitable sharing of joint program costs. For example:

    - Increasing use of recycled water in Southern California to reduce high-energy water imports from Northern California may well provide a benefit to all water and energy ratepayers.[130] However, the incremental investment in recycled water distribution facilities needs to be made by a local government or wastewater utility that must then seek recovery of its investment. If the costs of such incremental facilities are allocated only to users of that recycled water, the cost of recycled water may far exceed the cost of potable water.

    - During summer months, as much as 50 to 70 percent of residential water use in central and Southern California is for landscape irrigation. When viewed from a societal perspective, significant investments in programs to reduce landscape irrigation are warranted on the basis of the energy benefits alone. However, water utilities' investments are limited to those that benefit their own ratepayers (i.e., not on the basis of benefits that may accrue to the entire water supply chain or to other stakeholders). Further, there presently is no mechanism that allows energy utilities to invest in programs that reduce water use to save energy.

Allocating incentives to the stakeholder(s) who need to make the investment on behalf of all California ratepayers, both water and energy, is not a trivial task.

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[130]Water ratepayers benefit by avoiding investments in higher cost water supplies and increasing water supply reliability. Energy ratepayers benefit from associated reductions in energy procurement, as well as by avoiding investments in additional electric infrastructure and by increased electric system reliability.

Additional Needs for Research and Assistance

Integrating water and energy resource management will require additional knowledge in a number of key areas to develop the analytical methods, tools, and data needed to develop and implement cost effective water-energy projects and programs.

Building on Present Knowledge

Considerable work is already being performed in this area. Some current efforts are described in Appendix A.

Additional information is needed to facilitate a statewide policy shift to comprehensive planning and management of the state's water and energy resources. In particular, more accurate information about the nature and magnitude of the state's water and energy relationships -- including the spectrum of opportunities for realizing the synergies of integrated water and energy resource management, the amount of needed investments, and the relative costs vs. benefits of each type of measure – is needed to prioritize investments and develop methods, models, and tools that support cost-effective program design.

The following ***conceptual*** research and development plan describes the primary research activities needed to support the program objectives identified in the table in the first section of this appendix. The plan is structured to allow near- and long-term initiatives to proceed in parallel to provide opportunities for early benefits.

CONCEPTUAL Research and Development Plan

R+D Program Objectives	Near-Term Strategies	Long-Term Strategies
1. Proactively manage water-related energy consumption	Synchronize the state's water & energy planning assumptions and strategies to meet projected energy load growth	Develop comprehensive programs for technical & resource assistance that attain water utilities' energy management best practices
2. Increase understanding of the state's water-energy relationship	Demonstrate primary water-energy interdependencies; develop prototypical values by Forecasting Climate Zones	Inventory, document & quantify the state's primary water-energy interdependencies for input to detailed models & tools
3. Implement statewide integrated water and energy resource management	Develop proxy for interim societal valuation methodology for cold water savings for discussion with CPUC[131], policymakers, other interested stakeholders	Develop data, analytical tools and methodology for computing the societal value of saved water for different water sources, end uses, climate zones, etc. for valuation of societal costs in long-term cold water savings programs
4. Increase water utilities' energy self-sufficiency	Investigate potential for revising existing programs, policies, methods & practices to reduce water utilities' net energy consumption ('net' of power production)	Develop studies, methods, tools & techniques to assist water utilities in becoming energy self-sufficient, and potentially becoming net exporters of power
5. Increase water efficiency and demand-side management	Develop preliminary valuation of existing cold-water efficiency measures	Identify & evaluate new cold-water measures; develop cost-effective programs

Primary research and assistance needs identified to-date are described in more detail below by program objective.

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Objective 1: Proactively manage water-related energy consumption.

1. Establish baseline of current practices. Research "best practices" for reducing energy consumption by water systems and processes. Encode "best practices" into benchmarking tools and make them available to practitioners, enabling them to compare their current practices to what is possible. Populate the "Clearinghouse" with information on the range from current to best practices. Establish measurement and evaluation protocols to verify savings and provide lessons learned.

2. Conduct an assessment of the penetration and adoption of "best energy practices" by water and wastewater utilities, and barriers and hurdles that prevent or restrict adoption, to support development of targeted assistance programs that incorporate workarounds to identified barriers and hurdles.

3. Track and evaluate energy use by function to enable development of targeted measures and retrofits with high benefit potential. For example, a better

[131] CPUC could adopt a proxy for the societal value of cold water savings that would allow pilot programs to go forward in the 2006-2008 energy efficiency funding cycle.

understanding is needed as to how recycled water fits into the water supply portfolio and water balance. While increasingly stringent federal discharge rules are pressing water utilities to upgrade secondary treatment to higher energy intensive tertiary treatment, incremental energy consumption attributable to the higher level of treatment should be offset (at least in part) by using recycled water to displace higher energy intensity water supplies.

4. Continue to monitor and plan for projected changes in energy usage by water systems and treatment processes. Continue to study the projected energy requirements of changed federal water treatment and discharge regulations as these evolve, and develop approaches to help energy and water utilities manage the energy impacts of these changes.

5. Continue to identify and evaluate opportunities to reduce energy consumption in targeted high-use sectors, such as agriculture. Work with interested stakeholders to identify and evaluate opportunities to reduce energy use by the agricultural sector and to conduct various studies. Potential projects might, for example, include tracking energy-use trends associated with changes in crop-planting and harvesting patterns; evaluating impacts of pressurized irrigation systems (drip and spray) on fields now irrigated by gravity; and converting diesel-engine pumps to motor-driven pumps.

6. Evaluate the potential energy impacts of increased water transfer transactions. Little is known about whether changes in conveyance patterns will have a noticeable impact on water-related energy consumption. The Energy Commission could work with water utilities involved in contracting for or providing conveyance services, to first determine the likely extent of such transactions, and make a rough estimate of the magnitude of change in electricity use patterns. If warranted, staff could recommend further study of methods to track such transactions, and determine and prepare for their expected energy impact.

7. Continue studies with AwwaRF and others to reduce energy consumption by desalination technologies, and to coordinate water and energy planning for dry years. Though the WER Staff Paper identified only fairly modest impacts on the electric system from known planned desalination plant development, the number of planned facilities could increase quickly if one or both of two things occur: an extended drought or other scenario that significantly curtails surface water deliveries, and/or a significant decrease in the cost of operating such facilities.

8. Develop a comprehensive program to study groundwater-related energy use. Groundwater is a particularly significant area of study, since use of groundwater storage has potentially significant impacts, both positive and negative, on water-related energy consumption. On one hand, increased groundwater storage provides significant operating flexibility that could allow

more SWP water deliveries to be shifted from summer to fall. On the other hand, over-pumping groundwater basins could increase energy consumption at undesirable times and also reduce critical drought supplies.

Less is known about groundwater than any other water source. This is due to the fact that each groundwater basin is unique, and production characteristics of wells are often interlinked. Further, since use of groundwater is largely unregulated, the actual quantity of energy used for groundwater pumping statewide is undeterminable. The complexities of groundwater warrants a comprehensive monitoring approach that tracks groundwater levels, pump production, electricity use, and other data over multiple years.[132]

9. Assist water utilities in developing less energy intensive water supplies. For example, increased reliance on recycled water to displace need for desalted water.

10. Continue to build on PIER/AwwaRF's Water and Wastewater Technology Roadmap.

Objective 2: Increase understanding of the state's water-energy relationship.

1. Conduct pilots and studies that document and quantify the state's primary water-energy interdependencies. The information being developed by UCSB and Pacific Institute will help develop a proxy that can be relied upon to develop pilot water-energy programs while more detailed studies are being conducted. In particular, while studies of urban water uses indicate significant energy can be saved by reducing water consumption, the drivers for such opportunities are not well understood. A comprehensive inventory, characterization, and assessment of the primary types of water-related energy consumption by type of water

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[132] The Irrigation Training and Research Center (ITRC) study on agricultural energy requirements perhaps goes farther than any other, and bases much of its information on real-world geographical information system (GIS) data; but it must make many assumptions concerning average pump lift (groundwater levels), distribution uniformity, surface water availability (timing factor), irrigation type, average drawdown, discharge pressure, and so forth. It uses the real-world results of the pump efficiency tests conducted for the Agricultural Peak Load Reduction Program by the Center for Irrigation Technology, but those data did not include static or pumping water levels and primarily covered only wells in PG&E's territory.

Considerable additional study is needed in order to facilitate detailed modeling of groundwater supplies. The ITRC study also is the result of at least two levels of computer modeling: that by Department of Water Resources to estimate groundwater levels in Northern California and ITRC's own crop water model, which produced the energy use estimates in its groundbreaking study. Much of ITRC's results are based on what can only be described as rough calculated estimates by DWR for Central and Southern California groundwater volumes, which is especially critical in the Kings and Kern River Basins, where more than 50 percent of the energy used for agriculture-related groundwater pumping occurs. (A detailed discussion of ITRC's model can be found in their report No. 02-001, available on their Web site at www.itrc.org) source, system, function, and end use will eventually be needed to develop the detailed methodologies on which cost-effective programs can be based.

Water-related energy consumption can then be mapped from the source through various categories of end use to develop a comprehensive understanding of the points and relative magnitudes of energy consumption along the water supply chain, and the types of systems, processes, equipment, and measures that could reduce water and energy consumption at these points. Ideally, a sampling of water utilities that collectively represent most of the primary types of water-energy interdependencies in California would be included in such a pilot. Several water utilities have already indicated interest in participating in such a pilot. These include MWD, IEUA, LADWP, Palo Alto Utilities, Sonoma County Water Agency, and Semitropic Water District.

2. <u>Construct a valuation methodology that accounts for the societal cost (water, energy and externalities) of avoided water consumption for various types of water sources and end uses</u>. Relying upon the data and knowledge gained from detailed studies, quantify the water-energy tradeoffs of various resource decisions through computation of the "Regional Cold-Water Energy Intensity".

    - Research and develop regional cold-water energy intensities (or co-opt existing research), adopt prototypical values, and establish linkage to Forecasting Climate Zones;

    - For existing "cold-water measures" develop base case Unit Energy Consumption (UEC), High-Efficiency (HE) UEC, Base and HE Peak watt and demand savings, volume-sensitive installed measure costs and expected useful life values;

    - Identify and evaluate new cold-water measures targeted to create resource value specifically suited to integrated water/energy resource planning not previously addressed under the discrete/isolated water/energy resource management regime;

    - For new cold-water measures deemed viable, develop planning data identified for existing cold-water measures, and;

    - Incorporate research elements into the Database for Energy Efficiency Resources (DEER) for use by energy-efficiency program planners consistent with program planning protocols enunciated in CPUC Rulemaking 01-08-028, Decision 05-04-051.

The above described methodology is consistent with that employed by the CPUC in its regulation of investor-owned utilities' energy efficiency programs, thus allowing proposed investments in water saving measures to be considered on an equivalent basis.

Objective 3: Implement statewide integrated water and energy resource management.

1. Develop tools and techniques for identifying potential infrastructure upgrades that extend beyond a single utility's service boundaries. The goal of implementing statewide integrated water and energy resource planning and management opens up new opportunities that heretofore have not been considered. Specifically, water and energy utilities presently attempt to optimize their separate resources and systems. Many of these utilities have calibrated their models and tools to simulate their own systems' operations. New analytical models, tools, and methods will be needed to help water and energy utilities look beyond their system boundaries, looking for opportunities to optimize their systems and resources on a joint basis with other water and energy utilities with which they may now be interconnected (or potentially could be interconnected). The underlying premise of joint optimization is that it is at this level of fully integrated planning – i.e., the "nexus" – that the most beneficial incremental benefits will be found.

   Potential opportunities include optimizing the systems and operations of the SWP and the 29 member agencies that comprise its sole customer, the SWC, as well as the CVP, the Colorado River system, and any other points of interconnection along the way.

2. Develop analytical models and tools that:

   - Assist both water and energy utilities in developing joint programs that are cost-effective from a societal point of view;

   - Assist wholesale water utilities in evaluating the net benefits of system reconfigurations or retrofits that exceed their own boundaries[133];

   - Assist both water and energy utilities in assessing the net water supply and associated energy and externalities benefits of proposed measures and retrofits (e.g., assessing the net impact on the water supply balance);l

   - Other analytical models and tools needed to support development and implementation of cost-effective joint water-energy programs.

[133] These may include those that assist the State Water Project operator in making determinations as to how to optimize energy consumption for itself and its customer, the SWC, (and potentially other interconnected systems such as CVP and the Colorado River system) on a combined basis.

Objective 4: Increase water utilities' energy self-sufficiency.

Reduce Energy Consumption:

1. Identify opportunities to reduce conveyance-related peak demand reduction (State Water Project and other large water systems). The State Water Contractors and DWR observed that it might be possible to increase off-peak pumping at Edmonston Pumping Station; however, additional pumping capacity would be needed. In addition, they noted that while there may be opportunities to further increase operational flexibility, additional storage would be needed at points along the aqueduct.[134] In order to assess the statewide opportunity to support such incremental capital expenditures that may be beneficial to the state overall, but are not deemed cost-effective from the perspective of a single entity, the Energy Commission could:

    - Assess and report incremental cost-effective measures that can be implemented to increase pumping capacities and storage to reduce peak energy demands that are cost effective based upon a more comprehensive societal cost-benefit evaluation.

    - Evaluate opportunities to reduce peak demands through coordinated operation of federal and state water projects.

2. Assist water utilities in identifying methods to increase operational flexibility such that energy intensive pumping and water treatment processes could be shifted from on-peak periods, to partial- and off-peak periods.

    - According to ACWA, installation of sensors and other equipment could substantially increase water utilities' flexibility in operating their systems. This flexibility could allow water utilities to maintain minimal pumping loads during peak periods, either by delaying such use into the evening hours or at least by cycling such loads sequentially to minimize peak use.

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[134] Reservoirs, depending on location and size, including intake and discharge capacities, provide opportunities for pumping load and generation time-shifting -- hourly/daily shifts for small reservoirs, and sometimes monthly/seasonal shifts for larger reservoirs. For large river reservoirs, like Lake Mead, a downstream re-regulation reservoir such as Lake Mojave could support optimum water deliveries and peak generation. However, Lakes Mead and Mojave increase evaporative losses and incur greater costs and environmental concerns.

Urban hillside tank storage reservoirs that provide system pressure for urban retail water users can be oversized to emphasize off-peak pumping to fill the reservoirs if the pumping capacity in the supply system (say, groundwater wells) is simultaneously increased to produce needed water yield in the less-than-24-hours window. (Note: the pumps can wear out sooner and incur increased operations and maintenance costs if the frequency stop/starts increase to match daily Flex-Your-Power objectives.)

- IEUA has designed its systems to allow water to be “detained” during critical peak periods and held for processing during partial- and off-peak periods.

3. Explore increased use of groundwater storage to allow shifting of summer SWP deliveries to fall. In Southern California, groundwater pumping uses approximately 30 percent of the energy required to import water from Northern California. Groundwater aquifer source production and recharge requirements are fixed and finite. During periods of seasonal peak energy demand, water agencies might rely on groundwater sources and recharge the aquifers using imported water months later in the off-peak season. As noted previously, some Southern California water utilities already choose to pump groundwater during summer and recharge groundwater wells during fall. In this manner groundwater storage capacities could be employed to affect large-scale and long-term seasonal peak demand shifting.

   The potential of increasing groundwater storage capacity to further defer seasonal deliveries should be studied. These studies are complicated, due to unique hydrogeology of groundwater basins and potential linkages among wells. The scope would include:

   - Identification of groundwater aquifers where groundwater pumping and recharge is being performed by water utilities;

   - Identification of groundwater aquifers that are not currently being tapped for groundwater pumping that could be used to affect the aforementioned, and;

   - Assessment of the operational feasibility and associated costs and benefits of potential incremental seasonal demand shifting.

   Analytical tools and techniques will be needed to help determine the efficacy and relative costs vs. benefits of this approach. The study should include consideration of who should develop, fund, own, and operate such assets, which potentially may be constructed primarily for energy benefits (i.e., the value of shifting summer demand to other months).

Increase Power Production:

1. Conduct studies of potential for incremental power production through in-conduit hydropower, pumped storage, and repowering. In-conduit hydropower is a very attractive option since it produces energy as a by-product of water operations. Pumped storage has unique capabilities to produce power during peak periods. The Hetchy Hetchy example illustrated a potential for increasing the state’s hydropower capacity by as much as 10 percent at a fraction of the cost of installing new units and much more quickly.

There are multiple barriers to water utilities' energy self-sufficiency. The statewide potential for increased hydropower and pumped storage capacity should be assessed, and a roadmap developed for attaining this potential that includes potential work-arounds to the policy, regulatory, economic, technical, and other barriers that will need to be overcome.

2. Develop mitigation strategies to reduce lost hydropower capacity during FERC relicensing. As discussed previously, the National Hydropower Association reported that an average of 8 percent of the nation's total hydropower capacity is being lost through relicensing. The Energy Commission could evaluate causes and identify potential mitigation strategies that consider the societal value of associated hydropower capacity.

3. Develop models and tools to evaluate the energy water tradeoff for reservoir storage. Detailed modeling studies of reservoir operations should be performed to evaluate the additional hydropower generated by changing average year reservoir releases. Similarly, conduct studies detailing the decrease in groundwater pump electricity demand associated with a change in average and dry-year reservoir releases.

4. Develop analytical models and tools that assist both water and energy utilities in assessing power production potential by water utilities including, but not limited to:

   - Self-generation utilizing local renewable resources (digester gas[135], agricultural wastes and other biomass, solar,[136] and hydropower).

   - Renewable resource potential for utility scale generation facilities on watershed lands and rights-of-way.[137]

5. Conduct demonstration projects that allow testing of workarounds to barriers and hurdles and verification of net energy and other benefits of water projects that produce energy. In particular, demonstrate means for water utilities to produce energy as a by-product of water delivery and treatment processes (e.g., in-line conduit applications for water and wastewater utilities), and extrapolate statewide potential for these types of opportunities.

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[135]Biogas potential need not be restricted to that produced by sewage digesters. Studies are underway to test the energy potential of blending sewage sludge with other biosolids, such as dairy animal waste and food refuse. In addition to increasing power production, this process provides an attractive means for disposing of other types of waste products. In addition, some parties are investigating development of a sludge-derived solid fuel that could be burned in power plants.
[136] Solar power is well suited to meeting small pumping loads in water distribution systems.
[137] Water utilities' extensive watershed land holdings could provide good opportunities for utility-scale wind and concentrating solar power development.

6. Conduct a comprehensive resource assessment of the renewable resource potential of watershed lands and rights-of-way and determine the barriers and hurdles that would need to be overcome.

Objective 5: Increase water efficiency and demand-side management.

1. Develop a pilot program that evaluates societal benefits of water conservation and efficiency programs presently deemed non-cost-effective under traditional water utility planning criteria. Potential items include: new balanced irrigation systems, weather based-irrigation systems, drought tolerant plant/low runoff landscape retrofits, synthetic turf retrofits, free water brooms for every school, connectionless water steamers, digital x-ray machines or x-ray water recirculation systems for doctors and hospitals, free cooling tower conductivity controllers for all public schools and buildings (may be commercial uses too), small scale water recycling projects for communities and golf courses, incentives for new home owners to buy water/energy efficient new homes, large-scale irrigation controllers and landscape retrofits for parks and greenbelts, water softeners[138], etc.

2. Expand the 14 BMPs to include other water conservation measures that meet the more comprehensive "societal" resource test. Building on the important work by CUWCC and its members, Pacific Institute, and other key stakeholders, identify and value incremental measures that can help meet the goals for a comprehensive statewide water-energy program. These measures should then be ranked alongside other feasible water and energy efficiency options on the basis of highest benefit:cost ratio, and then incorporated into joint water-energy programs.

3. Continually improve agricultural water use efficiency.
   - Continue to implement the PIER Agricultural Irrigation Technology Roadmap calling for research and development efforts improve irrigation efficiency. Possible studies include:
     - Reduce the total pressure required to operate drip irrigation technologies; this includes the filter system as well as the pipe and micro-sprayer technologies.
     - Advance the use of longer lasting materials for pump components.
     - Work with the SWP, the CVP and the irrigation districts to increase the flexibility of water deliveries to farms.

[138] One California water agency performed an analysis of retrofits of water softeners. The program did not meet the cost-effectiveness threshold on water alone, but the societal benefits are potentially large.

- Learn more about the increasing trend to adopt drip/micro systems, the implications to energy consumption, and the energy management benefits the systems provide.

- Work with irrigation districts to understand the ramifications increased reliance on groundwater.

- Work with the CPUC to ensure appropriate implementation of Critical Peak Pricing and other TOU rates.

- Work with the CPUC, the utilities, the irrigation districts, and the farmers to ensure widespread use of available energy efficiency programs.

4. <u>Reduce outdoor water consumption</u>. In the context of greatest near-term benefit, there is no dispute among stakeholders: The single largest opportunity for saving a lot of water quickly is through reductions of outdoor water use, both in agricultural and landscape irrigation.

    - ➢ Pacific Institute stated that more than 75 percent of the state's total water consumption is used by agriculture.

    - ➢ IEUA stated that during summer, outdoor water use for landscape irrigation accounts for 50 to 70 percent of all water consumed by the residential sector. Regions along the coast tend to use less; hotter interior uses more. Seasonal factor translates into even bigger impacts. Overall, reducing residential usage from 200 gal per capita daily down to 80 gal per capita daily (SF/LA numbers).

    - ➢ MWD stated that the biggest opportunity for outdoor water savings is in landscape replacement with native plants and synthetic turf.

5. <u>Reduce industrial water use</u>. Pacific Institute estimates that as much as 658,000 AF/year could be saved by the commercial and industrial sectors. Opportunities include joint investment in existing water savings programs, as well as potential joint investment in new technologies. MWD, for example, suggests joint investigation of innovative conservation program investments in industrial process water improvements, such as optimal approaches to industrial recirculation. In addition, this program could include investigation of new water efficiency technologies for various types of industrial processes.

6. <u>Explore a "Golden Carrot" equivalent for water conservation programs</u>. Develop joint investment opportunities in use funds to conduct innovative conservation program investigations into new technology and to kick start methods of obtaining water customer responses to these opportunities. One or more cash and other prizes could be awarded through a competitive innovation program that includes, for example, a call for water and energy-efficient home water heating systems and improvements.

Glossary

acre-foot (AF) - a quantity or volume of water covering one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

active storage capacity - the total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

adjudication - the act of judging or deciding by law. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party to the decision.

afterbay - a reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

alluvium - a stratified bed of sand, gravel, silt, and clay deposited by flowing water.

aquifer - a geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

artificial recharge - the addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

average annual runoff - the average value of annual runoff amounts for a specified area calculated for a selected period of record that represents average hydrologic conditions.

brackish water - water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

conjunctive use - the coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant - any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant.)

conveyance - provides for the movement of water and includes the use of natural and constructed facilities including open channels, pipelines, diversions, fish screens distribution systems, and pumplifts.

cost-effective - means that the benefit-to-cost ratio of a proposed program or measure exceeds 1.0. As applied to this test, both costs and benefits are measured either over the life of the program or in terms of societal cost. Water and energy utilities currently include only costs and benefits that affect their respective ratepayers in their cost-effectiveness computations. The conclusion of this staff paper is that a cost-effectiveness test should expand to include all economic, environmental, and societal costs and benefits over the entire water use cycle - even those extending beyond the boundaries of a utility's service territory, resources, and assets - in order to identify opportunities to benefit the state as a whole.[139]

desalination - water treatment process for the removal of salt from water for beneficial use. Source water can be brackish (low salinity) or seawater.

drainage basin - the area of land from which water drains into a river; for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called, "catchment area," "watershed," or "river basin."

drip irrigation - a method of microirrigation wherein water is applied to the soil surface as drops or small streams through emitters. Discharge rates are generally less than 8 L/h (2 gal/h) for a single outlet emitters and 12 L/h (3 gal/h) per meter for line-source emitters.

drought - the magnitude and probability of economic, social or environmental consequences that would occur as a result of a sustained drought under a given study plan. Measures the "drought tolerance" of study plans.

energy consumption - the energy consumption required to facilitate water management-related actions such as desalting, pump-storage, groundwater extraction, conveyance, or treatment. This criterion pertains to the economic feasibility of a proposed action in terms of O&M costs.

energy costs - refers to the cost of energy use related to producing, conveying and applying water. It also refers to the cost of energy use for processes and inputs not directly related to water, but which can affect the demand for water (e.g., the cost of nitrogen fertilizer, tractor manufacturing, etc.).

energy production - both instantaneous capacity (megawatt) and energy produced (kilowatt hours).

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[139] Eventually, the issue as to who pays for such incremental statewide benefits will also need to be addressed.

energy self-sufficiency – Refers to an entity that self-supplies its own energy requirements. This would typically be done through a combination of energy efficiency and self-provision of power, whether purchased or produced. Current regulatory barriers prevent water and wastewater utilities from becoming energy self-sufficient.[140]

effluent - wastewater or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

end use – the use of energy or water for specific activities such as heating, cooling, toilets, or irrigation.

end users – the consumers of energy or water.

estuary - the lower course of a river entering the sea influenced by tidal action where the tide meets the river current.

evapotranspiration (ET) - the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time.

forebay - a reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into ground water basins.

gigawatt (GW) - one thousand megawatts (1,000 MW) or one million kilowatts (1,000,000 kW) or one billion watts (1,000,000,000 watts) of electricity. One gigawatt is enough to supply the electric demand of about one million average California homes.

gigawatt-hour (GWh) - one million kilowatt-hours of electric power. California's electric utilities generated a total of about 250,000 gigawatt-hours in 2001.

gross reservoir capacity - the total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes

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[140] Barriers to energy self-sufficiency include:
(a) Long lead-time, complicated and costly interconnections;
(b) Prohibitive stand-by charges for grid-connected self-generation facilities:
(c) Net metering caps that discourage self-production of power at any site in an amount greater than 1MW (or the then current cap);
(d) Inability to "wheel" self-produced and/or purchased power to themselves anywhere on their own system (causing excess power to be either "lost" or sold at uneconomic wholesale prices that do not recover costs;
(e) Lack of standardized contracts, rates and terms for purchasing self-produced power that exceeds water and wastewater utilities' needs at prices that at least recover costs; and
(f) Prohibitive exit fees assessed to entities departing from bundled electric utility service.

dead (or inactive) storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

groundwater - water that occurs beneath the land surface and completely fills all pore spaces of the alluvium, soil or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

groundwater basin - a groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir.

groundwater overdraft - the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average.

groundwater recharge - increases in groundwater storage by natural conditions or by human activity.

groundwater table - the upper surface of the zone of saturation, except where the surface is formed by an impermeable body.

hydraulic barrier - a barrier developed in the estuary by release of fresh water from upstream reservoirs to prevent intrusion of sea water into the body of fresh water.

hydrologic balance - an accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

hydrologic basin - the complete drainage area upstream from a given point on a stream.

hydrologic region - a study area, consisting of one or more planning subareas.

infiltration - the flow of water downward from the land surface into and through the upper soil layers.

irrigation efficiency (IE) - the efficiency of water application and use, calculated by dividing a portion of applied water that is beneficially used by the total applied water, expressed as a percentage The two main beneficial uses are crop water use (evapotranspiration, etc.) and leaching to maintain a salt balance.

kilovolt (kV) - one-thousand volts (1,000). Distribution lines in residential areas usually are 12 kv (12,000 volts).

kilowatt (kW) - one thousand (1,000) watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon a typical home, with central air conditioning and other equipment in use, might have a demand of 4 kW each hour.

kilowatt-hour (kWh) - the most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

land subsidence - the lowering of the natural land surface due to groundwater (or oil and gas) extraction.

maximum contaminant level (MCL) - the highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

megawatt (MW) - one thousand kilowatts (1,000 kW) or one million (1,000,000) watts. One megawatt is enough energy to power 1,000 average California homes.

methane (CH4) - the simplest of hydrocarbons and the principal constituent of natural gas. Pure methane has a heating value of 1,1012 Btu per standard cubic foot.

methanol (also known as Methyl Alcohol, Wood Alcohol, CH3OH) - a liquid formed by catalytically combining carbon monoxide (CO) with hydrogen (H2) in a 1:2 ratio, under high temperature and pressure. Commercially it is typically made by steam reforming natural gas. Also formed in the destructive distillation of wood.

microirrigation - the frequent application of small quantities of water as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line. Microirrigation encompasses a number of methods or concepts such as bubbler, drip, trickle, mist, or spray.

minimum pool - the reservoir or lake level at which water can no longer flow into any conveyance system connected to it.

natural recharge - natural replenishment of an aquifer generally from snowmelt and runoff; through seepage from the surface.

percolation - process in which water moves through a porous material, usually surface water migrating through soil toward a groundwater aquifer.

photovoltaic cell - a semiconductor that converts light directly into electricity.

public water system - a system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

recharge - water added to an aquifer or the process of adding water to an aquifer. Groundwater recharge occurs either naturally as the net gain from precipitation or artificially as the result of human influence.

recycled water - the process of treating municipal, industrial, and agricultural wastewater to produce water that can be productively reused.

riparian right - a right to use surface water, such right derived from the fact that the land in question abuts the banks of streams.

runoff - the volume of surface flow from an area.

salinity - generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water.

seawater intrusion barrier - a system designed to retard, cease or repel the advancement of seawater intrusion into potable groundwater supplies along coastal portions of California. The system may be a series of specifically placed injection wells where water is injected to form a hydraulic barrier.

single utility resource cost test - refers to resource optimization from the perspective of a single utility - for example, a water utility already seeking optimization of its own water resources. Energy costs embedded in delivered wholesale water are included when considering cost-effectiveness. However, the single utility resource cost test does not evaluate the impact of these water resource decisions on either water or energy utilities, or on statewide water and energy resources and infrastructure. Similarly, neither water nor energy utilities consider the energy intensity embedded in a unit of avoided water over the entire water use cycle.

societal cost or societal value - refers to the total resource cost, including water and energy and externalities, embedded in a unit of water. For purposes of this staff paper, this term is consistent with that used by the California Public Utilities Commission when determining the cost-effectiveness of energy efficiency programs and measures, and by water utilities when determining the cost-effectiveness of their water conservation incentive programs.[141]

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[141] The CPUC's Energy Efficiency Policy Manual, Chapter 4 Cost-Effectiveness Methodology, relies upon a "Total Resource Cost (TRC) test - Societal Version" as "articulated [in] the California Standard Practices Manual: Economic Analysis of Demand-Side Management Programs." The California Standard Practices Manual states that "The Total Resource Cost Test measures the net costs of a demand-side management program as a resource option based on the total cost of the program, including both the participant's and the utility's costs." "A variant on the TRC test is the Societal Test. The Societal Test differs from the TRC test in that it includes the effects of externalities, excludes tax credit benefits, and uses a different (societal) discount rate." Water conservation incentives are typically valued in accordance with the February 1994 EPA manual, "A Guide to Customer Incentives

surface supply - water supply obtained from streams, lakes, and reservoirs.

surplus water - water that is not being used directly or indirectly to benefit the environmental, agricultural or urban use sectors.

tailwater – the excess water that was applied for agricultural irrigation water. This water is either returned to the environment or reused for irrigation.

transpiration - an essential physiological process in which plant tissues give off water vapor to the atmosphere.

Urban Water Management Planning Act – Sections 10610 through 10657 of the California Water Code. The Act requires urban water suppliers to prepare urban water management plans which describe and evaluate sources of water supplies, efficient uses of water, demand management measures, implementation strategies and schedules, and other relevant information and programs within their water service areas. Urban water suppliers (CWC Section 10617) are either publicly or privately owned and provide water for municipal purposes, either directly or indirectly, to more than 3,000 customers or supply more than 3,000 acre-feet of water annually.

volt - a unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes and office have 120 volts.

water balance - an analysis of the total developed/dedicated supplies, uses, and operational characteristics for a region.

water quality - description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

watershed - the land area from which water drains into a stream, river, or reservoir.

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for Water Conservation" which incorporates by reference the societal valuation approach adopted in the California Standard Practice Manual.