Arnold Schwarzenegger
Governor

REFINING ESTIMATES OF WATER-RELATED ENERGY USE IN CALIFORNIA

PIER FINAL PROJECT REPORT

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Prepared By:
Navigant Consulting, Inc.

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Prepared By:
Navigant Consulting, Inc.
Sacramento, CA 95670

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Prepared For:
Public Interest Energy Research (PIER) Program
California Energy Commission

Richard Sapudar
Contract Manager

Pramod Kulkarni
Program Area Lead
Industrial/Agricultural/Water End-Use

Nancy Jenkins
Office Manger
Energy Efficiency Research Office Manager

Martha Krebs
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION
B.B. Blevins
Executive Director

Jackalyne Pfannenstiel
Chair

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Refining Estimates of Water-Related Energy Use in California is the final report for the Refining Estimates of Energy-Related Energy Use in California project (contract number 500-01-008, work authorization number 49-P-05) conducted by Navigant Consulting, Inc. The information from this project contributes to PIER's Industrial/Agricultural/Water End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

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Abstract

In 2005, the California Energy Commission published a report, *California's Water-Energy Relationship* (CEC-700-2005-011-SF), that estimates the magnitude and intensity of water-related energy consumption by segment of the water-use cycle. Because water-energy is a new area of study, and data were not readily available, this report relied on a number of different data sources and methods to develop the magnitude and intensity estimates.

The current study reviewed and updated these estimates for the magnitude and intensity of water-related energy consumption by segment of the water-use cycle. This review indicates that while the data and methods used to prepare the Energy Commission's 2005 report were not perfect, they offered a reasonable starting place for prioritizing water-energy research and development, as outlined in the Energy Commission's *Integrated Energy Policy Report*. Further, this study provided adjusted water-energy proxies that are sufficient for informing policy and prioritization of research and development investments. The study also describes important data gaps and includes the collection of primary data from water utilities and the disaggregation of data geographically and within water-use cycle segments. A greater understanding of the sub-segments of the water-use cycle offers an opportunity to more effectively target research and development decisions at the technology level, and a phased approach is recommended to continually refine water-related energy intensity estimates on an ongoing basis.

Keywords: water-use cycle, water-related energy, research and development, California's water-energy relationship, embedded energy, water, wastewater, water-energy, water supply, water conveyance, water treatment, water energy intensity, agricultural water use, urban water use, industrial water use, residential water use, commercial water

Executive Summary

Introduction

In 2005, the California Energy Commission published a report *California's Water-Energy Relationship* (WER) (publication # CEC-700-2005-011-SF), that estimated the magnitude and intensity of water-related energy consumption by segment of the water-use cycle. These estimates were used to develop a proxy, or representative, valuation of the amount of energy deemed embedded in a unit of water, by virtue of the amount of energy consumed in collecting, extracting, conveying, treating, and distributing the water to end users (upstream embedded energy) and then by treating and disposing of the wastewater (downstream embedded energy). The Energy Commission's *Integrated Energy Policy Report* (IEPR) report relied on these estimates and the proxy. However, Energy Commission recognized that the data used to prepare the estimates and the proxy were limited, given that investigation of the water-energy relationship is a relatively new field.

Purpose

Looking to ensure that the data used in the 2005 reports were a good basis for informing research and development (R&D) decisions, the California Energy Commission's Public Interest Energy Research (PIER) division retained Navigant Consulting, Inc. to assist in reviewing the data, estimates, and proxy in the initial reports.

Project Objectives

- To review and document the bases for the Energy Commission's 2005 *Integrated Energy Policy Report* estimates of water-related energy magnitudes and intensities
- To determine whether the data and methodologies employed to develop these estimates were reasonable and can be used by PIER to prioritize its investments in water-energy research and development
- To identify beneficial adjustments to the data, methodologies, estimates and/or structure of the proxies
- To evaluate the relative merits of applying these estimates to different purposes
- To identify additional work needed to remedy critical gaps in data and methods that may otherwise impair PIER's ability to make informed R&D investment decisions

Project Approach

The distinct differences in the regional characteristics of the state's water supply and conveyance systems suggested that two separate proxies be established—one for Southern California and one for Northern California. To establish a consistent benchmark for evaluating the relative values of these proxies, the study team estimated the amount of energy needed for each segment of the water-use cycle in terms of the number of kilowatt-hours (kWh) needed to collect, extract, convey, treat, and distribute one million gallons

(MG) of water, and the number of kWh needed to treat and dispose of the same quantity of wastewater.

Inasmuch as water-energy is a new area of study, data were not readily available that directly related energy use to portions of the water-use cycle. Consequently, the team adjusted the existing data sets to prepare refined estimates.

Project Outcomes

Through detailed reviews of work papers and interviews with stakeholders, the study team identified a number of recommended adjustments to the water-energy relationship proxies for energy embedded in water for Northern and Southern California. Some of the recommended adjustments addressed a number of minor errors and inconsistencies in allocations made during the preparation of the WER. Others addressed adjustments needed to ensure consistency. In addition, the team recommends adjusting the estimates by segment of the water-use cycle for losses.

The type of water use determines whether wastewater treatment and disposal will be required. In general, outdoor water use, such as landscape irrigation, typically either flows into storm drains or recharges groundwater or natural waterways, bypassing need for wastewater treatment and disposal. Indoor water use typically discharges to sanitary sewers, consuming energy for wastewater treatment and disposal. To simplify application of the proxies, we recommend further breaking down the northern and southern proxies into indoor and outdoor use.

Table ES-1. Recommended revised water-energy proxies

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

The bases for the recommended adjustments are provided in Section 2 and the appendices to this report.

Conclusions

This review indicates that while the WER data and methods were not perfect, the results were not unreasonable.

While some of the adjustments recommended in this report are arithmetically significant, these are not deemed to impair the viability of the WER's general approach and proposed structure for valuing embedded energy upstream and downstream of water end use. The primary purpose of the proxy from PIER's perspective is to help make informed investment decisions. In this context, the following is clear:

- In general, indoor water uses have a higher energy intensity than outdoor water uses, and Southern California water has a higher energy intensity than Northern California water.
- Energy applied in the consumption of water by agricultural and urban end uses—typically, pumping, and heating—accounts for more than 50 percent of the water-related energy consumption identified in the WER.
- Other water-related energy is consumed by water industry operations. The magnitude and intensity of energy consumption by water operations determines the amount of energy that can be saved by saving water.
- The segments of the water-use cycle outside of the retail water meter with highest variability in energy intensity and magnitude of energy use are supply and conveyance. Therefore, these segments offer the highest potential for significant energy savings.
- Energy magnitude and intensity are not the sole determinants of energy savings potential. The ability to influence that magnitude or intensity, whether through changed systems and operations or new technologies, must also be considered in targeting R&D investments.
- Further disaggregation of energy magnitudes and intensities by sub-segments of the water-use cycle can facilitate better targeting of R&D investments. It can also help to inform the design of incentives for reducing water-related energy consumption.

Recommendations

- The adjusted WER proxies in Table ES-1 (repeated as Table 7) are sufficient for informing policy and prioritization of research and development investments.
- Drilling down into sub-segments of the water-use cycle offers an opportunity to more effectively target R&D decisions at the technology level.
- Supply and conveyance have both the highest energy magnitude and the greatest variability in energy intensity of options. These segments of the water-use cycle need further study to better understand the key drivers of energy intensity and the magnitude of potential benefits for various supply options.

- Data gaps that should be addressed are described in Table 14 and include the collection of primary data from water utilities and the disaggregation of data geographically and within water-use cycle segments.
- A phased approach should be undertaken to continually refine water-related energy intensity estimates on a going forward basis.

Benefits to California

This study has helped confirm the validity of using existing estimates and proxies (as adjusted in this report) for making decisions about water and energy R&D in California--despite any imperfections in the data or methods used to create these estimates and proxies. In fact, as this study has underscored, the decision making process is inherently iterative: decisions often lead to the development and improvement of data, which in turn inform the refinement of decisions.

Further, the recommendations in this report can improve existing data—and related decisions—in a very short timeframe. The report also suggests a consistent and cost-effective method for improving and augmenting data over time, recommending logical steps to take in the near-, mid-, and long-term. Following the recommendations and findings in this report can help California continue to make sound, effective, and beneficial decisions concerning water and energy R&D, both now and in the future.

1.0 Introduction

In 2005, Energy Commission staff conducted a comprehensive multi-stakeholder process that resulted in a study entitled *California's Water-Energy Relationship* (California Energy Commission 2005a) (also called the Water-Energy Report or WER). The WER concluded that the water sector is the largest user of energy in the state, accounting for 19% of all electricity consumed in the state and 30% of nonpower plant–related natural gas use[1].

This compelling finding triggered a number of recommended actions intended to alleviate water sector impacts on the state's stressed energy supplies and infrastructure. These recommendations included developing mitigation measures to reduce both the magnitude and intensity of water-related energy demand and consumption and increasing production of water-related renewable energy resources. Conventional and new systems, processes, and technologies were deemed to play important roles.

These recommendations were included in the Energy Commission's *2005 Integrated Energy Policy Report* (IEPR) to the Governor and the Legislature. The Energy Commission's Public Interest Energy Research (PIER) division was charged with increasing knowledge about the state's water-energy interdependencies and applying that knowledge to advance technologies with the potential to significantly reduce both current and projected water-related energy impacts. This new area of study is referred to as water-energy.

In response to the IEPR's recommendations, PIER is preparing to develop a five-year strategic plan and roadmap that will increase the state's understanding of this new area of opportunity and undertake a diversified portfolio of water-energy research and development (R&D) activities. One of PIER's initial tasks is to review the energy estimates developed by the WER and relied upon by the IEPR. PIER retained Navigant Consulting, Inc. to assist in conducting this study, with the following primary objectives:

- To review and document the bases for the IEPR estimates of water-related energy magnitudes and intensities
- To determine whether the data and methodologies employed to develop these estimates were reasonable and can be relied upon by PIER to prioritize its initial investments in water-energy research and development

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[1] Water-related energy included that amount of energy directly consumed by water agencies in the collection, extraction, conveyance, treatment, and distribution of water to end users, and the treatment and disposal of wastewater. In addition, the WER included the amount of energy used to consume water, e.g., to heat water for a shower or to pump it through a cooling tower. Energy consumed during the consumption of water consists primarily of pumping and water heating.

- To identify beneficial adjustments to the data, methodologies, estimates, and structure of the proxies
- To evaluate the risks and benefits of applying these estimates to different purpose
- To identify additional work that may be needed to remedy critical gaps in data and methods that could impair PIER's ability to make informed R&D investment decisions

The primary purpose of this study is to revisit the WER estimates of energy magnitude and intensity by segments of the water-use cycle to determine whether any adjustments should be made before relying upon these numbers for purposes of prioritizing PIER's R&D investments in its first Five-Year Water-Energy Strategic Plan and Roadmap. In addition, this report identifies significant data gaps and provides recommendations about additional work that should be undertaken to fill these gaps.

A secondary purpose of this study is to inform concurrent deliberations by policymakers and stakeholders as to whether existing data are sufficient to support proceeding now with preliminary proxies of the water-energy intensity of various portions of the water-use cycle to compute embedded energy in water saving measures. To the extent that the needs of policymakers and stakeholders for assurance of the reliability of these estimates may be reasonably in alignment with PIER's needs for informed R&D investments, this study may serve both purposes.

1.1. Overview

This project leverages the body of work conducted to date on water-related energy use in California and represents ideas and concepts from numerous stakeholders and state agencies. In developing this report, Navigant Consulting, Inc. reviewed a wide variety of research and policy documents and held discussions with representatives of state agencies, water agencies, electric utilities, consultants, universities, and research organizations. Input was solicited from interested parties, and this input has been taken into consideration in this final document.

This study adopted the definitions of water-related energy magnitude and energy intensity established by the WER and relied upon by the IEPR. The study then identified alternative approaches to structuring proxies for the embedded energy values within segments and sub-segments of the water-use cycle, upstream and downstream of water end use. The study team focused on validating the relative energy intensities by portions of the water-use cycle outside the retail water meter. This focus facilitates identification of opportunities with high potential to reduce both direct (e.g., energy consumed by water and wastewater operations) and indirect (e.g., energy saved by avoided water consumption) water-related energy. The team also identified appropriate applications of energy intensities for average versus marginal water supplies.

1.1.1. Water-Related Energy Magnitude and Energy Intensity

This study adopts the same definitions for water-related energy magnitude and energy intensity as those used in the WER and the IEPR:

- Energy magnitude is the total energy consumption by a particular segment of the water-use cycle, customer class, or market sector. Energy magnitude is an important indicator of the total amount of energy used and potentially saved.
- Energy intensity is 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 treatment. Benchmarking energy intensity enables comparing the relative energy efficiency of different systems, processes, and technologies.

Both of these concepts are applied to water supplies, to water functions (e.g., components of the water-use cycle), and to water end use by various customer and market sectors. (California Energy Commission 2005a, p.4)

In the WER, energy intensity values by portion of the water-use cycle were summed separately for Northern and Southern California to construct estimates, or proxies, for the value of energy embedded in water upstream (prior to the customer's water meter) and downstream of water end use. The structure of the recommended proxies for the energy value of water in Northern and Southern California and the estimated values employed to represent the energy intensity of each portion of the water-use cycle are at the heart of the proxy review.

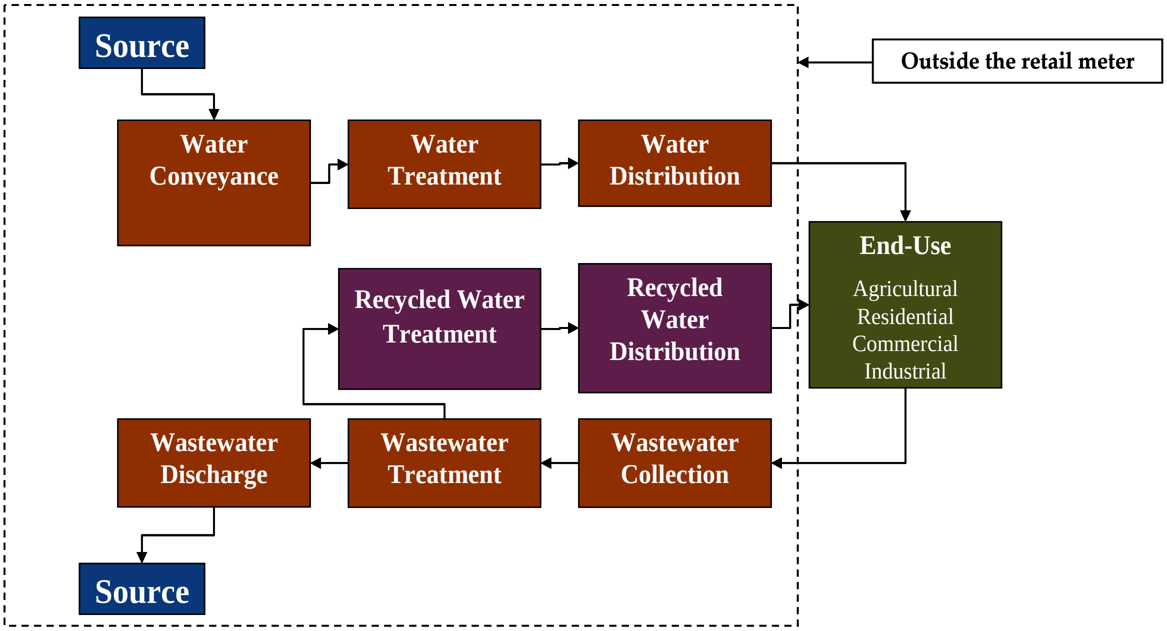
For purpose of R&D, it is important to break out the energy intensity of different types of water supplies and water systems and processes to a more granular level than the water-use cycle segments. To this end, the study team identified a number of sub-segments within the water-use cycle segments that reflect intensities that vary by specified characteristics or technology type. In this manner, supply and technology options can be ranked relative to each other, and the potential costs and benefits of different options can be better understood. An illustration of a more targeted proxy structure is provided in Section 4 of this report.

1.1.2. The Water-Use Cycle

In addition to reviewing the magnitude of water-related energy use, this study focused on water-related energy intensities outside of the retail meter as a key framing concept because understanding energy consumption by water systems and operations highlights where the most significant energy savings can be attained.

Figure 1 illustrates the water-use cycle and identifies portions of the water-use cycle outside the retail meter, including supply, conveyance, treatment and distribution, and wastewater collection, treatment, and disposal.

Figure 1. The water-use cycle



The WER identified significant ranges of relative energy intensities for various portions of the water-use cycle, shown in Table 1.

Table 1. Range of energy intensities for water-use cycle segments[2]

	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

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[2] WER Table 1-2, p. 9

The WER found that water operations consume large amounts of energy. The amount of energy consumed varies significantly by portion of the water-use cycle. Understanding these relationships provides California opportunities to attain significant energy benefits through two primary strategies:

- Saving water saves the energy that would have been used to convey, treat, and distribute the water (upstream embedded energy), and energy that may have been needed to treat and dispose of the wastewater (downstream embedded energy).
- Reducing the energy intensity of water operations reduces the total amount of energy consumed by the water sector and ultimately reduces the value of energy embedded in saved water.

A significant amount of information is available about direct water and energy efficiencies that can be realized through end uses of water (e.g., toilets, showers, dishwashers, clothes washers, other potable and sanitary uses, and landscape irrigation). Much less is known about indirect benefits, such as the embedded energy values in saved water in different geographic regions and water and energy utility service territories. For example, changes in groundwater supplies are not well understood. In addition, while considerable research has studied energy consumption by different types of water and wastewater treatment systems, processes, and technologies, there is considerable variability among the different systems and sources of supply.

This study focuses on understanding the key drivers of energy intensity values outside of retail water meters—primarily, the energy consumption and intensities of water and wastewater operations. This focus will help refine the proxies for energy intensities of segments of the water-use cycle that form the basis for valuing the amount of energy that can be saved by saving water. The concept of saving energy by saving water—i.e., avoiding water consumption to avoid the energy embedded in water—is the primary finding of the WER.

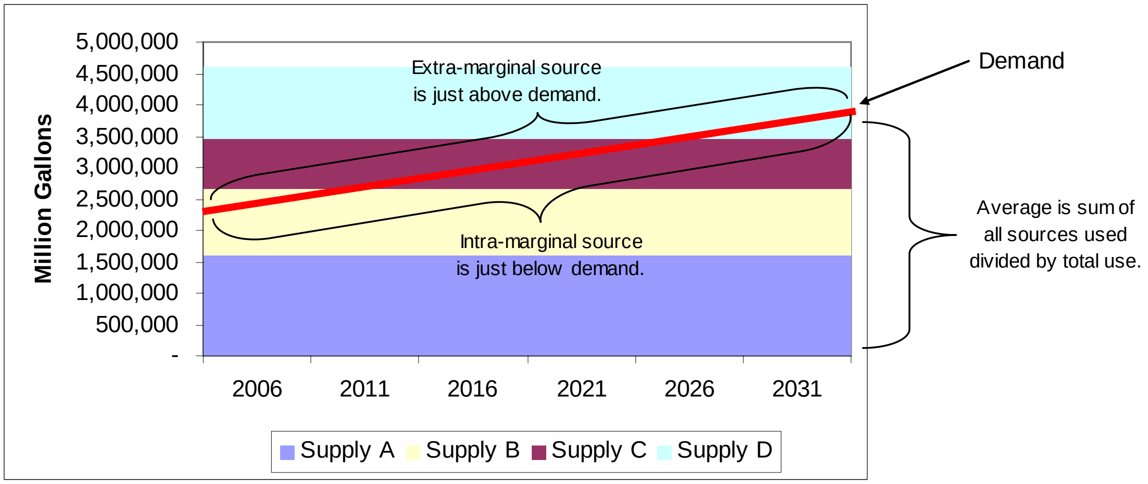
1.2. Average and Marginal Water Supplies

Another key concept that runs through this report is the difference between average water supplies and marginal water supplies—a concept used in resource planning for both energy and water.

- Average water supply reflects the mix of water supplies currently being used by the water supplier or group of water suppliers in the area being examined.
- Marginal water supply is the water source at the economic margin for the water supplier or group of water suppliers in the area being examined. In addition, the marginal water supply can be considered the last water source used (intra-marginal) or the next water source that will be used (extra-marginal).

Figure 2 illustrates the difference between average and marginal water sources.

Figure 2. Average and marginal water sources



It is important to note that average and marginal water supplies change over time, due to a combination of load growth and changes in the water resource mix.

When water-related energy intensity is determined for a jurisdictional or geographic area, the appropriate water source will vary depending upon the intended use of the energy intensity estimate. Energy efficiency via water-related energy use can occur from decreased water use or from increased energy efficiency of water-related energy use technologies. The type of energy efficiency measured may have an impact on the use of marginal or average water sources.

When considering potential energy efficiency due to decreased water use, energy intensities related to the marginal water source are most appropriate. This is because decreased water use should result in a decrease in the last water source employed—generally the most expensive water source. Most analyses to date, including the WER, have tended to consider this intra-marginal source of water as the marginal source of water.

It is correct to consider the intra-marginal source as marginal if current demand conditions are sustained. Water demand, however, is rarely static or decreasing. Urban water demand, for example, is often directly related to population. If populations are increasing, which is the case in California, it is likely that water demand is also increasing. In this instance, gains in water efficiency are more likely to result in the ability to forestall implementation of the next available, or extra-marginal, water source.

Examination of average supply is appropriate for certain uses and examination of marginal supply is appropriate for others. Marginal supply analysis, however, holds a particularly important place in the regulatory arena as it relates to providing incentives to act in a particular way. California regulators have traditionally applied the concept of marginal supplies as the basis for calculating avoided costs from energy efficiency by valuing the avoided cost as the cost of the marginal unit of energy, not the average of the energy portfolio. This strategy is appropriate when the regulatory body is attempting to provide a true price signal to create a market-based incentive for energy efficiency, because the value of saved energy is equal to the value of the most expensive source of energy used, assuming that an economically rational utility would first decrease use of the most expensive supply source.

For this study, the team considered marginal supplies as the appropriate basis for the energy intensity proxy. The team's approach to estimating the value of the proxy is discussed in Section 2 and the appendices to this report.

2.0 Baseline Estimates of the Magnitude and Intensity of Water-Related Energy Use in California

During preparation of the WER, Energy Commission staff relied upon existing data sources to estimate both the magnitude and the intensity of the state's water-related energy consumption. Magnitude refers to total energy consumption, and intensity to the relative amount of energy needed to perform certain functions. Both magnitude and intensity impact investment decisions.

Since water-energy is a new area of study, data were not readily available in the form needed to definitively determine the extent of the water-energy relationship for various customer and market segments or for types of uses and end uses. As a result, staff needed to develop approaches to adjusting existing data to develop reasonable estimates.

To identify a reasonable basis for prioritizing PIER R&D investments, the study team sought to understand the quality and characteristics of data relied upon by staff to produce the WER estimates by interviewing Energy Commission staff and other stakeholders that participated in the development of the WER. Wherever possible, the team also reviewed any available work papers that documented the data sources and bases for adjustments made. Through this effort, the team reviewed and documented the methodologies employed to develop these preliminary estimates.

This investigation indicated that, particularly given the lack of data about water-energy interdependencies, the WER estimates of water-related energy magnitudes and intensities generally employ reasonable assumptions. However, some adjustments are recommended.

Following is a summary of the study's primary findings. The detailed findings and bases for recommended adjustments are provided in Appendix C.

2.1. Baseline Estimates of Magnitude

The baseline estimates of water-related energy magnitude were computed by Energy Commission staff and reported in WER Appendix B. Since "perfect" data were not available, staff relied on existing sources with adjustments, using two primary types of adjustments:

- For sectors other than residential and commercial (industrial, agricultural, water pumping, mining, streetlights, and transportation-communications-utilities), the figures in WER Appendix B for total electricity usage by customer type (chemicals, lumber, crops, airports, etc., before the adjustment to estimate the "water-related" portion, described below) are taken from SIC-code based data provided by the state's electric utilities to the Energy Commission.

- For the residential and commercial sectors, the Energy Commission used demand forecasting modeling to estimate electricity usage by end use in each sector (e.g., water heating, cooling, cooking, refrigeration, etc), by electric utility service area. These figures were then calibrated so that the total electric estimate for a customer sector in a utility service area matched that reflected in the historical SIC-code based data provided to the Energy Commission by the electric utility.[3]

The end use (or customer type) category energy totals, by sector, were then adjusted by application of a *percent-related-to-water* factor to the energy total for each end use (or customer type) category in each sector[4]. Table 2 outlines the WER approach to estimates and adjustments. The end-use energy figures (adjusted for percent related to water) were then totaled across all sectors and end uses. The total unadjusted energy across all sectors and end-use categories sums to an amount that ties to the total statewide energy usage reflected in Energy Commission data.[5] These figures are presented in WER Appendix B.

Table 2. WER Appendix B approach to computing water-related energy use

Sectors	Baseline Estimate	Adjustments
Residential & Commercial	Demand forecasting modeling for electric consumption by end use sector by electric utility service area, calibrated so sector totals match historical SIC code data	Percent-related-to-water factor (used limited set of potential factors: 0%, 5%, 50%, 100%)
Industrial, Agricultural & Other	Energy consumption data by SIC code	

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[3] Historical SIC code–based data were used directly for the other sectors because those sectors' models do not incorporate sufficient end-use level demand forecasting. Conversation with Andrea Gough, Energy Commission.

[4] E.g., 50% of residential dish washing energy was deemed to be related to water.

[5] 250,494 gigawatt-hours (GWh) for California 2001 energy consumption in WER Appendix B versus 250,241 GWh in data published on the Energy Commissions website: http://www.energy.ca.gov/electricity/consumption_by_sector.html.

The "percent related to water factor" was developed through a combination of professional judgment and vetting with some WER stakeholders. Some very broad assumptions were employed.

- An end-use or customer type was first evaluated to determine whether water-related energy consumption was either 0% or 100%. If such determination could reasonably be made, the assignment was made. Approximately 65% of total water-related energy was attributable to end uses or customer types in which 100% of the energy use was deemed water-related.
- Approximately 35% of total water-related energy was attributable to end uses or customer types in which some portion of the energy use was deemed water-related. For end uses or customer types for which a partial assignment was deemed appropriate, a determination was then made as to the significance of water-related energy use. If deemed not significant, water-related energy consumption was assigned a modest allocation of 5%. If deemed significant, it was assigned a value of 50%.

Absent better data, it is impossible to determine whether the WER estimate for the magnitude of water-related energy is reasonable. It's possible, however, to bound the question. For example, an estimate that water-related energy use represents 19% of total energy use in California suggests that water-related energy use is significant in the state. At least 65% of the magnitude is based on a strong correlation of SIC codes to water-related energy consumption. If, after more data are obtained, estimated water-related energy consumption dropped to 15% of total energy use, water-energy consumption would still be deemed a very significant portion of the state's energy consumption. Therefore, policies and decision making would likely not be affected by more perfect data about the magnitude of water-related energy consumption.

The magnitude of water-related energy is not significant in context of constructing the proxy for energy embedded in segments of the water-use cycle outside of the retail water meter—the primary objective of the proxy for the value of energy embedded in saved water.

2.1.1. Recommended Adjustments to Baseline Energy Magnitudes

During the course of investigation, the study team identified modest reallocations of energy among the various water use sectors (see Table 3). None of these adjustments were material and they would not affect any decision making that relies upon these data. The identified adjustments also did not change the WER estimate for statewide water-related energy consumption (approximately 19.2%).[6]

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[6] This does not mean that the WER estimate is necessarily correct. As discussed above, the arbitrariness of the "% related to water" factor leaves this number subject to challenge. However, given that 65% of total water-related energy consumption was based on end uses or customer types

Table 3. Recommended adjustments to WER Table 1-1, Water-related energy use in California in 2001

	Electricity (GWh)	
	WER Table 1-1	**Adjusted***
Water Supply and Treatment		
Urban	7,554	7,583
Agricultural	3,188	2,788
Water End Uses		
Agricultural	7,372	7,372
Residential	27,887	28,258
Commercial		
Industrial		
Wastewater Treatment	2,012	2,012
Total Water-Related Energy Use[7]	**48,013**	
Total California Energy Use	**250,494**	
Percent	**19.2%**	

* Please see Appendix C for detailed explanations of these recommended adjustments.

Energy consumption for agricultural and urban water end uses accounts for 73% of total water-related energy consumption. End-use energy consumption includes water pumping and heating. End uses are excluded from the scope of this study, since they do not impact the proxy for energy embedded in saved water.

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that appear to be directly related to water, the percentage of statewide water-related energy consumption would still be a very high number and worthy of detailed study and investigation.

[7] Estimates of magnitude of water-related energy use do not consider energy that is produced as a by-product of water supply and conveyance. Magnitude estimates include only energy use. Conversely, many of the water-related energy intensity estimates shown later are net of generation associated with water supply and conveyance.

2.1.2. Opportunities for Improving Data

This review indicated several areas for improving knowledge about the magnitude (quantity) of water-related electric and gas consumption by sector:

- No direct relationship exists between energy reported by SIC codes and water-related energy consumption. Further, some types of energy reported within a single SIC code contain information about multiple types of energy use or span multiple customer or market sectors.
- The percent-related-to-water factors applied by the WER to estimate energy magnitudes are subject to challenge. To the extent that more accurate data are desired, water-related energy consumption may need to be captured and reported separately. In many cases, this would probably require installing additional meters to separately capture energy consumption for water-related systems and processes. Whether or not the incremental expense of changing in the current means of capturing and reporting energy consumption data is merited depends on PIER's goals and objectives. If PIER determines that a more accurate read of water-related energy consumption is needed, a sampling approach could be implemented to minimize costs.

In addition, the WER relied on 2001 data. Two important factors that may skew these data:

- Water year 2001 (October 2000 to September 2001) was a dry year. Present data are insufficient to determine whether the magnitude of water-related energy consumption would need to be adjusted upwards or downwards, especially when including the net impacts of hydropower production directly related to water deliveries.[8]
- About half of calendar year 2001 also coincided with the worst of the California power crisis. During this period, unusual amounts of energy conservation were required by all customer sectors to "keep the lights on".[9]

For both of these reasons, calendar year 2001 is not a particularly reliable benchmark for baseline magnitudes of water-related energy consumption. PIER may wish to select another year to reflect "baseline", or to select several years for further comparison and analysis.

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8 Contrary to popular belief, neither water deliveries nor hydropower production necessarily decrease in a dry year. The amount of water delivered or hydropower produced depends on a number of factors, including carryover storage from prior years; water and power contracts, commitments, and transactions; and risk management decisions. The assessment of actual net energy impacts of a dry year is a complex analysis that exceeds the scope of this study.

9 Some responses did not reduce overall energy consumption, but merely shifted the time of use to reduce peak demands. Other responses resulted in true energy savings. The actual net effect of these actions is not known.

2.2. Baseline Estimates of Intensity

The relative magnitude of water-related energy consumption, both for the state overall and by end-use sectors, is useful to understanding where the potential for significant energy savings may reside. However, total energy consumption is only one indicator. If the magnitude of energy consumption is high but there is little opportunity for achieving savings, investments should probably be directed elsewhere. In that context, an understanding of energy intensity—i.e., the relative amount of energy needed to perform work for a unit of water—provides an important dimension for qualifying and characterizing energy savings opportunities. This concept and an approach to a recommended proxy for valuing energy embedded in water were provided in WER Appendix C.

Again, recognizing that there are no perfect data, the WER relied on multiple sources to estimate the relative energy intensity for various purposes. Since there are a variety of different sources of supplies, systems, processes, and technologies, each with its own unique energy characteristics and ranges of energy intensities, some simplifying assumptions were applied to develop conservative estimates of the average energy intensity within each segment of the water-use cycle.

The WER recommended the following build-up of values to estimate the value of energy upstream and downstream (i.e., embedded) in water end use. Because of the significant differences in sources of supply and conveyance identified by the WER for northern versus southern California, the WER suggested two separate proxies (California Energy Commission 2005a, p. 11). Table 4 below replicates WER Table 1-3 to indicate an estimate of 4000 kWh/MG in Northern California, and 12,700 kWh/MG for Southern California. The WER did not identify a basis for assuming significant geographic differences in other portions of the water-use cycle (e.g., water and wastewater treatment and distribution).

Table 4. Electricity use in typical urban water systems (as shown in WER Table 1-3)

	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**

2.2.1. Recommended Adjustments to Baseline Estimates of Energy Intensity

Based on discussions with staff and key stakeholders, and review of data sources and methodologies, the team identified three primary adjustments to the WER estimates of energy intensity by segment of the water-use cycle:

- Supply and conveyance. The WER very conservatively estimated the energy intensity of water supply and conveyance in Northern California as an estimated representative average raw water pumping requirement for public water supply systems.[10] The study team recommends adjusting the estimated energy intensity for water supply and conveyance in Northern California to a basis that is consistent with that applied to Southern California. Specifically, the WER based the estimate for Southern California on the average of the energy intensities for the East and West Branches of the State Water Project (SWP) on the basis that SWP is "Southern California's dominant and marginal water resource."[11]

  The study team agrees that marginal water supplies are the appropriate basis for a proxy for upstream embedded energy. Consequently, the team recommends adjusting the Northern California estimate for energy embedded in supply and conveyance to a comparable basis, using the SWP as a proxy marginal resource. The WER's Northern California supply and conveyance proxy was based in part on the population concentrations located in the San Francisco Bay Area that are served by gravity-dominated systems (e.g., Hetch Hetchy and Mokelumne aqueducts). However, while these populations are significant, data indicate that these gravity-dominated systems account for less than 19% of the Northern California urban water supply, and less than 2% of Northern California urban plus agricultural water supply. Groundwater makes up more than 23% of Northern California's water supplies, and deliveries from the SWP and the Central Valley Project (and other federal deliveries) make up more than 38% of urban plus agricultural water supply (California Department of Water Resources 2005a, Vol. 3).

  In addition, four times as much water was delivered to Northern California in 2000 (a "normal year") from the SWP than from the gravity-dominated systems above. Given the diversity of water supplies used in Northern California and the range of intensities for supply and conveyance above the gravity-dominated proxy figure, the study team deemed a reasonable proxy to be a weighted average of SWP deliveries to the San Francisco Bay Area, Central Coast, and San Joaquin Valley, recognizing that some geographic or jurisdictional areas may have lower or higher intensity

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[10] WER pp. 111–112, citing *Water & Sustainability (Volume 4) U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century*, EPRI 2002, pp. 2-3. Intensity estimates based on engineering estimates.

[11] WER, p.113. Note, the study team also recommends using a weighted average of 55% East Branch and 45% West Branch for the Southern California supply and conveyance proxy and netting out generation on the MWD system.

marginal water sources.[12] That adjustment increases the energy intensity for supply and conveyance in Northern California from 150 kWh/MG to 1,811 kWh/MG.

- Wastewater treatment. The other primary change recommended to the WER proxy relates the estimated value for wastewater treatment. The WER used a figure of 2,500 kWh/MG, reflecting a rough average of results indicated by several studies. In reviewing these assumptions, the team selected the low end of the range (1,911 kWh/MG)—the estimated value for plants using "advanced wastewater treatment with nitrification," as the appropriate basis. This recommendation is consistent with projections for the numbers of treatment plants by varying sizes by the U.S. Environmental Protection Agency and related energy intensity estimates.
- Adjustment for system losses. All water systems have losses. Some of these are physical, due to a number of factors, including leaks, evaporation, and seepage. Some of these are due to such issues as unapproved water connections. The actual loss experienced varies widely by water system age and other characteristics. Recognizing the wide variability, the team relied upon estimates cited or employed by the Natural Resources Defense Council (NRDC) in its 2004 study, *Energy Down the Drain.* Note that losses are cumulative along segments of the water-use cycle. The effects of these cumulative losses are consistent with actual experience reported by the California Department of Water Resources' (DWR's) Office of Water Use Efficiency.[13] The energy and water sectors both include estimates for losses in their resource plans.

Table 5 shows adjustments recommended to account for estimated system losses.

Table 5. Recommended loss adjustment factors

Segment of the Water-use cycle	Segment Loss Factor	Cumulative Losses
Water Conveyance	5%	16.9%
Water Treatment	5%	11.3%
Water Distribution	6%	6%

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[12] For example, Santa Clara Valley Water District indicated its water energy study assumptions were 3070 kWh/MG for imports (47% of supply, from both SWP and CVP) and 1996 kWh/MG for groundwater (39% of supply).

[13] The California Department of Water Resources reported that "A detailed water audit and leak detection program of 47 California water utilities found an average loss of 10 percent and a range of 30 percent to less than 5 percent of the total water supplied by the utilities. The July 1997 Journal American Water Works Association cites examples of more than 45 percent leakage." These figures did not include other types of water system losses, such as seepage and evaporation. [DWR's Office of Water Use Efficiency, http://www.owue.water.ca.gov/leak/faq/faq.cfm]

The above loss factors are deemed conservative. The Federal Energy Management Program reported average U.S. water distribution system losses of 10% and cumulative system losses of up to 25%. (Federal Energy Management Program 2001).

The above findings resulted in recommended adjustments to the WER estimates for energy intensity by segment of the water-use cycle. These adjustments are shown in Table 6.

Table 6. Recommended adjustments to WER Table 1-3, Electricity use in typical urban water systems

Segment of Water-use cycle	Northern California (kWh/MG)			Southern California (kWh/MG)		
	WER	Adjusted	w/Losses	WER	Adjusted	w/Losses
Water Supply and Conveyance	150	1,811[1]	2,117[2]	8,899	8,324[3]	9,727[2]
Water Treatment	100	n/a[4]	111[2]	100	n/a[4]	111[2]
Water Distribution	1,200	n/a[4]	1,272[2]	1,200	n/a[4]	1,272[2]
Wastewater	2,500	1,911[5]	1,911	2,500	1,911[5]	1,911
Total	**3,950**	**5,022**	**5,411**	**12,700**	**11,535**	**13,022**

Bases for Adjustments:

[1] Adjusted estimate is based on a representative weighted average of SWP deliveries to the San Francisco Bay Area, Central Coast, and San Joaquin Valley.

[2] Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.

[3] Adjusted estimate is based on a weighted average intensity of the two SWP branches, net of hydro generation on the conveyance system of the Metropolitan Water District of Southern California.

[4] No change from WER estimate, other than adjustment for losses (note [2]).

[5] Adjusted estimate is based on a representative proxy for plants using "advanced wastewater treatment with nitrification," based on U.S. Environmental Protection Agency (EPA) projections for the number of treatment plants by varying sizes and the Electric Power Research Institute's (EPRI's) related energy intensity estimates.

Recommended Revised Proxies

The final adjustment needed is to adjust the proxies for energy intensity for indoor versus outdoor water uses.

The type of water use determines whether wastewater treatment and disposal will be required. In general, outdoor water use such as landscape irrigation typically flows into either storm drains or recharges groundwater or natural waterways, bypassing need for wastewater treatment and disposal. Indoor water use typically discharges to sanitary sewers, consuming energy for wastewater treatment and disposal. To simplify application of the proxies, the study team recommends further breaking down the Northern and Southern California proxies into indoor and outdoor use.

This further refinement yields the revised proxies in Table 7 for indoor versus outdoor water uses in Northern California and Southern California.

Table 7. Recommended revised water-energy proxies

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	**5,411**	**13,022**	**3,500**	**11,111**

3.0 Critical Variables

To refine energy intensity estimates of segments of the water-use cycle and prioritize efforts undertaken to effect those refinements, it is essential to identify the variables within the water-use cycle that are most critical in terms of opportunity for significant energy savings.

Critical variables are those that can significantly impact decision making. In context of this study, critical is determined by potential for significant energy savings. A variable becomes critical, in varying degrees, in the following cases:

- The variable offers the potential to impact a significant magnitude of water-related energy use.
- The variable creates known potential options for increasing energy efficiency (and, therefore, realizing energy savings).
- The variable appears to have the potential to increase efficiency via new technological developments.

In determining how to design a proxy that meets current and future planning needs and objectives, the team looked to the critical variables.

- Which variables impact a high magnitude of energy use?
- Which variables present significant opportunities for energy savings?
- Which supply, process, and technology options offer high variability of energy intensity?
- Which supply, process, and technology options offer significant potential to reduce energy demand and consumption?

Magnitude and intensity alone is not sufficient; there is also a need to identify options that have ability for significant improvement.

3.1. High Magnitude Variables

Within the water-use cycle, certain segments comprise a significantly larger proportion of water-related energy use. Further, within the highest-use segments (e.g., supply and conveyance), there is significant variability in the magnitude and intensity of energy use. Table 8 illustrates both the magnitude and variability of energy intensities within segments of the water-use cycle.

Table 8. Updated 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[14]	0	13,800
Water Treatment[15]	100	100
Water Distribution[16]	1,200	1,200
Wastewater Collection and Treatment	1,100	2,050
Wastewater Discharge	0	400
Recycled Water Distribution[17]	1,200	3,000

Table 9 presents a matrix of energy intensities by sub-segment of the water-use cycle. This can be examined to drill down farther in identifying areas of potential focus for future

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[14] Supply and conveyance are considered together in estimating a range of intensities because the high end of the supply intensity range typically does not coincide with the high end of the conveyance intensity range.

[15] Treatment is currently only represented by one data point. New water quality regulations may increase the energy intensity of treatment as higher levels of disinfection are required.

[16] Distribution is currently only represented by one data point. This report suggests that further disaggregation of distribution systems is warranted due to variance in energy use and intensity, primarily due to pumping requirements. (See Section 4 of this report.)

[17] Recycled water generally requires no additional energy for supply, conveyance, or treatment since recycled water is often usable for some purposes after discharge from a wastewater treatment plant. In some cases, a lower level of wastewater treatment (requiring less energy) may require additional treatment for recycled water use. In those cases, however, it is likely that the additional required treatment, along with the lower level of wastewater treatment, will require no more energy than a higher level of wastewater treatment. Therefore, with a few exceptions, the only additional energy requirement for recycled water is typically pumping for distribution from the wastewater treatment plant to retail users. For purposes of the proxies, we assumed that distribution of recycled water is at least as high as, and generally higher than, distribution of potable water, since wastewater facilities are often sited at lower elevations to take advantage of gravity. Consequently, recycled water often needs to be pumped to higher elevations for reuse.

research. The intensity estimates provided in the matrix are indicative estimates only and are subject to future refinement as additional or updated data become available.

Table 9. Urban water intensity matrix (kWh/MG)

Supply	Conveyance	Treatment	Distribution	Wastewater Collection	Wastewater Treatment	Wastewater Disposal
Surface Water (0)	SWP-L.A. Basin (8,325)	EPRI Avg. (100)	EPRI Avg. (1,200)	Average of 140 is aggregated within treatment	Trickling Filter (955)	Gravity Discharge (0)
Groundwater (4.45/MG/Foot)	SWP-Bay Area (3,150)		Flat Topography (proposed)		Activated Sludge (1,322)	Pump Discharge (400)
Ocean Desalination (13,800)	SWP-Central Coast (3,150)		Moderate Topography (proposed)		Advanced (1,541)	
Brackish Water Desal (1,240-5,220)	SWP-San Joaquin Valley (1,510)		Hilly Topography (proposed)		Advanced w/Nitrification (1,911)	
Recycled Water (0)	CRA-L.A. Basin (6,140)		Recycled Water (1,200-3,000)			
	Hetch Hetchy-Bay Area (0)					
	Mokelumne Aqueduct (160)					
	Local/Intrabasin (120)					

Within the supply segment of the water-use cycle, energy use for desalination (either ocean or brackish water) is a high-energy use sub-segment. At deeper well depths (greater than 250 feet), groundwater pumping can also be a high-energy use sub-segment, perhaps exceeding the energy use required to de-salt certain levels of brackish water.

Within the conveyance segment of the water-use cycle, energy use for importing water from one area to another can be a high-energy use sub-segment, depending upon the distance and lift required to convey the water. Taken together, supply and conveyance will almost always be a high-energy use (the exception being local surface water supplies or shallow groundwater). Even though there is no energy component to surface water supply, in many cases surface water supplies are linked to high-energy use conveyance (e.g., State Water Project and Colorado River imports). Conversely, some of the high-energy use supply sources (e.g., desalination, recycling, and deep groundwater pumping) have relatively low conveyance-related energy use because the source is located near the end use area.

The distribution and wastewater treatment segments of the water-use cycle are relatively high-energy use segments and may justify further examination based on the intensity of energy use, without consideration of other factors. Distribution of recycled water, in particular, can require substantial amounts of energy to pump treated wastewater to end uses. The nature of wastewater collection and disposal has some similarities to distribution systems in the potential need for pumping in areas with a hilly topography[18]. In addition,

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[18] However, similarities are not direct since wastewater treatment plants will almost always be built in low-lying areas, allowing the majority of collection to occur via gravity.

changes in regulatory rules related to the quality of drinking water and effluent discharge will likely increase the energy intensity of these sub-segments for the foreseeable future. (California Energy Commission 2005a, p. 69)

3.2. Ability to Increase Energy Efficiency

Regardless of the magnitude of water-related energy use within a particular segment of the water-use cycle, some segments (or sub-segments) are simply better suited to realize energy efficiencies and water-related energy use savings. Absent technological advancements that are discussed later, a number of activities that can be undertaken to increase the energy efficiency of water-related energy use. These activities include, but are not limited to, implementation of revised management practices and operations engineering, coordinated operations of facilities, and conjunctive use among water agencies and the sources of water supply they have available.

Water supply and conveyance are water-use cycle segments that lend themselves to potential efficiency gains from revised operational and management practices because there are many possible permutations in developing a water supply and delivery plan for many water agencies, particularly if consideration is given to planning on a wider basis that encompasses more than one water agency.

Conveyance, treatment, and distribution all can benefit from management practices that limit the amount of losses incurred. Reducing the amount of water lost in traveling from the source of supply to the retail customer in turn reduces the amount of water that needs to be moved and treated to meet end-use requirements, resulting in energy savings equal to the amount of energy required to move and treat the reduced amount of lost water. In many instances, the impediment to reducing losses is simply economic. As an example, a municipal water supplier in a metropolitan area with high building density and expensive repair costs may have significant losses in their distribution system and still not be (at least financially) better off repairing the system because it costs less to replace the lost water with additional water supplies and to treat and convey that additional water than to repair the distribution system.

3.3. Potential to Increase Energy Efficiency via Technological Developments

Activities that consume energy within a water use segment or sub-segment and are driven by a technology that could be improved or developed to increase energy efficiency are also considered critical and help pinpoint potential areas of R&D investment. Examples of activities that might fit this profile include desalination treatment, recycled water treatment, and wastewater treatment. Potential technology advancements include high-efficiency pumps and improved renewable or low-cost distributed energy sources. In the case of distributed energy sources, the actual energy efficiency may not improve, but the implementation of the energy sources may efficiently displace other, centralized energy sources and may also allow for increased electric reliability by shifting pumping loads off-peak.

3.4. Research and Development Implications

As noted previously, outside of the retail water meter, supply and conveyance are the segments of the water-use cycle with the highest energy magnitude. In addition, sub-segments of supply and conveyance have very high variability.

- Supply ranges from a low of 0 kWh/MG for surface water supplies to a high of 13,800 kWh/MG for ocean desalination.
- Conveyance ranges from a low of virtually nil for Hetch Hetchy's largely gravity-fed system to a high of about 8,325 kWh/MG for State Water Project deliveries to the Los Angeles Basin.[19]

Assessing these types of critical variables helps identify opportunities for significantly reducing water-related energy magnitudes and intensities. Below are some strategies that were identified by WER stakeholders and refined through this study.

- Displace high energy–intensity water supplies with low energy–intensity supplies through a variety of approaches. Each of these approaches has an R&D component. Examples include:
    - Increase development and use of local supplies to reduce reliance on high energy intensity imports
    - Increase use of reclaimed water
    - Reduce use of potable water for non-potable uses
    - Reduce outdoor water use (i.e., landscape irrigation)
    - Increase recapture and reuse of storm water
    - Develop technologies that reduce the energy intensity of membrane treatment and other high energy intensity water supply processes

  While particularly true in Southern California, the overarching strategy of displacing high energy–intensity water supplies with low energy–intensity water supplies has wide applicability throughout the state.

- Reduce system losses. As discussed previously, significant amounts of water are lost throughout the water cycle due to a variety of causes. Conservative planning estimates suggested by NRDC result in a hefty 19.6% factor on wholesale water supplies to account for these cumulative system losses. Avoided losses in local systems result directly in increased local water supplies, thereby reducing high energy–intensity water imports.[20]

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[19] Conveyance intensity on a point-specific basis is even higher. Deliveries to the East Branch of the SWP display an energy intensity of 9391 kWh/MG, net of generation on the SWP and MWD’s conveyance system.

[20] The California Department of Water Resources estimates that about 81 billion gallons of water leak from municipal systems in California each year: http://www.epa.gov/ow/you/leaks.html

The relative costs and benefits of R&D investments for each of these strategies need to be evaluated in context of both the range of potential reductions in energy intensities for each strategy, and the level of R&D investment needed to attain these benefits. Characterizing and qualifying drivers of energy consumption by segment of the water-use cycle helps determine the level of detail needed in an effective proxy for prioritizing R&D investments. Table 10 below provides a partial description of areas of research that might be considered for priority funding.

Table 10. Illustrative and partial list of opportunities for improving the energy efficiency of the water-use cycle

Water-Use Cycle Segment	Range of Energy Intensities (kWh/MG)	R&D Opportunities
Supply and Conveyance	0–13,800	Reduce system losses to increase local supplies. Reduce outdoor use to increase local supplies. Reduce storm water diversions to increase local groundwater recharge. Increased water recycling to displace more energy intense marginal water supplies. Pursue technological advancement in desalination processes to decrease energy requirements and cost. Revise operations and systems to reduce total energy and peak energy use. Analyze coordinated operations and foster conjunctive use of supplies to decrease use of more energy intense marginal water supplies decrease peak energy use.
Water Treatment	100	Pursue technological advancements in response to more stringent water quality regulations. Reduce losses to increase local supplies.
Water Distribution	1,200	Reduce system losses to increase local supplies. Optimize pumping.
Wastewater Treatment[21]	1,100–2,450	Increase biogas production.

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[21] Includes wastewater collection and discharge.

It is also critical to update proxies periodically to reflect new information and changed conditions. For example, the current proxies indicate relatively low energy intensities for water treatment. However, increasingly stringent disinfection rules for potable water is expected to result in significant increases in energy intensity as water agencies upgrade their treatment systems and strategies to multi-stage disinfection processes that use energy hungry technologies, such as ozonation and ultraviolet treatment. Similarly, wastewater treatment requirements are increasing due to more stringent effluent discharge rules. (California Energy Commission 2005a p.69)

Changes in policies, rules, regulations, systems, processes, technologies, and other factors need to be monitored regularly to identify potential impacts on current and future energy magnitudes and intensities, and the proxies updated to reflect those changes.

4.0 Incremental Refinement of Energy Intensity Estimates

Estimates of water-related energy intensity are still in the early stages of data collection, review, and analysis. As with any research topic, early efforts to develop estimates help to frame the discussion and lead to additional research and analyses that build upon the relatively sparse body of work available. Such efforts have been undertaken, and documented herein, by (among others) EPRI, Irrigation and Training Resource Center (ITRC), Wilkinson and Wolff.[22] Most of these efforts have been undertaken in the last six years. Building upon a body of research and refining the findings and methodologies within previous research is the cornerstone of any analytical process.

Water-related energy intensity proxies have been developed (most recently in the WER) that build upon—and look to improve—the information available. This report serves the same purpose by refining the energy intensity proxies presented in the WER, based on additional information or refined methodologies (see Section 2). It is expected that energy intensity proxies will continue to be refined and modified over time.

While it is the nature of these estimates to be changed and improved, the team does not imply that current proxy information is not adequate for use. To the contrary, planning decisions are made on the basis of the best available information. Choosing a start-point from which to grow the body of knowledge provides the opportunity for a continuous loop of learning and growth.

This section of the report focuses on opportunities for further refinement of water-related energy intensity estimates. There are four key points that guide the development of a plan to refine energy intensity estimates:

- The existing information available is sufficient to use for resource planning, regulatory review, R&D planning, and other analytical purposes.
- Energy intensity estimates or proxies will modify and improve over time.
- Improvement can, and should, be made in incremental steps to continually improve the body of knowledge and the ability of users of the information to make the most informed decisions possible in a timely fashion.
- The applicability of energy intensity estimates can be broadened by the following:
    - Improving primary data collection of water-related energy use
    - Increasing the granularity of geographic or jurisdictional disaggregation
    - Increasing the granularity of data within segments of the water-use cycle
    - Refining intensity estimates for enhanced technological developments

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[22] See bibliography for full listing of sources.

4.1. Validity and Usefulness of Current Energy Intensity Estimates

The energy intensity estimates identified in the WER provide a useful construct for considering energy intensity at different segments of the water-use cycle. Energy intensity estimates may be developed for several purposes including policy development, policy and program implementation, and targeted efforts for research and development related to water and energy efficiency. Depending on the intended use, the level of aggregation within the water-use cycle segments and the geographic and jurisdictional areas to be considered can and should vary.

The energy intensity estimates identified in the WER are segregated by geography, providing one set of estimates for Northern California and another for Southern California. The only segments of the water-use cycle for which differing energy intensities were identified were supply and conveyance. As noted earlier, those estimates (particularly as adjusted in this report) are valid and useful for planning and analytical purposes. The refinements discussed below attempt to improve understanding of the estimates of sub-segment energy intensity that underlies the recommended values in the proxies.

4.2. Long-Term Goals in Refining Energy Intensity Estimates

Because there are various potential uses for energy intensity estimates, the value of these estimates will increase over the long-term by disaggregating water use segments and further disaggregating geographic and jurisdictional data. In particular, opportunities to reduce energy intensity through technological change are more easily identified by better understanding the relative energy intensities of sub-segments of the water-use cycle. In addition, data deficiencies can be substantially resolved by collecting data at the primary-source level under a construct that minimizes variation in the type and quality of data collected.

4.2.1. Disaggregation of Water Use Segment Components

Significant variability of energy use intensities can be found within each primary water use segment identified and described in Figure 1—supply, conveyance, treatment, distribution, and wastewater collection, treatment and discharge. This variability can occur because very different technologies or applications are used within a segment (e.g., surface water, groundwater, and desalination within the supply segment) and because those technologies or applications will vary depending on the geographic or jurisdictional area they are applied to (e.g., state, city, IOU service area, water district).

The level of disaggregation needed depends on a number of factors and will vary by segment. The most important factor in determining the level of disaggregation required is the level of energy use intensity variance within a particular segment of the water-use cycle.

- **Supply:** Energy intensities within the supply segment will generally not vary significantly from one geographic area to another, but they will vary significantly between sources of supplies and the technologies that are applied to extract those supplies. Energy intensity within the supply segment should therefore be broken out in sufficient detail to capture that variance by developing valid and reliable estimates of energy intensity for pumping groundwater, for ocean desalination, and for various levels of brackish water desalination.

- **Conveyance:** Energy intensities within the conveyance segment will generally not vary significantly between technologies (in almost every case, the energy use is for pumping water from one area to another), but rather from one geographic area to another. Energy intensity in conveyance is directly related to the distance and lift involved in transporting water from the source to the location it will be used. Energy intensity within the conveyance segment should be broken out in sufficient detail to capture that variance by developing valid and reliable estimates of energy intensity for pumping water from major sources (e.g., State Water Project, Colorado River, Hetch Hetchy) to major use areas (e.g., Los Angeles, San Francisco, San Joaquin Valley). In particular, SWP keeps very good records that support development of credible estimates of the amount of energy needed to transport water to various points along the project. This information has been relied upon in previous studies and in this report.
- **Water Treatment:** Energy intensities within the treatment segment can vary for processes and technologies on a relative basis. However, the relatively low intensity within this segment (e.g., compared to supply and conveyance) means that energy intensities of sub-segments will likely not vary significantly in absolute terms. Consequently, absent a special need, disaggregation of energy intensities within the treatment segment does not appear to be a high priority.
- **Distribution:** Energy intensities within the distribution segment are similar to those of the conveyance segment: they will generally not vary significantly between technologies (in almost every case, the energy use is for pumping water from one area to another), but rather from one geographic area to another. Energy intensity in distribution is directly related to the distance and lift involved to transporting water from the conveyance terminus to the retail customers. Energy intensity within the distribution segment should be broken out in sufficient detail to capture that variance by developing valid and reliable estimates of energy intensity for different topographies (accounting for lift and distance).

  Distribution of recycled water is typically more energy-intensive than standard distribution systems because wastewater treatment facilities are often sited in low-lying areas to take advantage of gravity for wastewater collection and disposal of effluent. Distribution of recycled water from the wastewater treatment facility, therefore, requires additional pumping (often, to higher elevations) to deliver recycled water to end uses.

  While some case studies have been performed in areas that have varying topographies, few data are available that would allow easy transference of representative energy intensities to various types of topographies. Equally important, there appear to have been no efforts to define types of topographies and catalogue geographic or jurisdictional areas by defined topographies.

- **Wastewater collection:** Energy intensities within the wastewater collection segment are similar to those of the distribution segment in that they will generally vary significantly from one geographic area to another. As with distribution, energy intensity in wastewater collection is directly related to the distance and lift involved to transport water—in this case, from the retail customers to the wastewater treatment plant. Energy intensity within the wastewater collection segment should be broken out in sufficient detail to capture that variance by developing valid and reliable estimates of energy intensity for different system topographies (accounting for lift and distance). Very little appears to have been done in developing estimates of energy intensity for wastewater collection. In fact, the one data source that identified wastewater collection included the estimate for this segment within the estimates for wastewater treatment. However, the wastewater collection segment may not provide a significant enough absolute level of energy intensity to warrant intensive efforts to disaggregate data within the segment.
- **Wastewater treatment:** Energy intensities within the wastewater treatment segment are similar to those in the supply segment in that they will generally not vary significantly from one geographic area to another, but rather between technologies. Energy intensity within the wastewater treatment segment should be broken out in sufficient detail to capture that variance by developing valid and reliable estimates of energy intensity for those technologies primarily employed in California. Additional research should be performed to define the primary technologies in California, the level to which each is employed, and the technologies being employed at the margin. One geographic or jurisdictional element is that technological implementation may vary by region and, depending on the area being considered; a specific technology may be more prevalent in one area than another.
- **Wastewater disposal:** Energy intensities within the wastewater disposal segment also depend upon the level of pumping required—in this case, from the wastewater treatment plant to the place of final discharge. Often times, no pumping is required, and a gravity-only discharge is in place. Average pump discharge energy intensity estimates have been identified, but the data are limited and it is perhaps more important to determine how much applicability pumped wastewater disposal has in California prior to making further disaggregation within this segment a priority.

4.2.2. Applicability of Geographic and Jurisdictional Disaggregation

Variance in energy intensities by geography was briefly discussed in the previous paragraphs, but warrants further discussion on its own due to the potential implications of disaggregating intensities by geographic or jurisdictional area. Disaggregating energy intensity estimates by geography is always necessary—some geographic or jurisdictional area must be defined to place any context on information presented. Starting at the state level, a number of geographic or jurisdictional areas can be defined. Any one may be most appropriate, depending upon the intended use of the data.

A few examples of how data might be disaggregated for various purposes are presented in Table 11 below.

Table 11. Potential geographic and/or jurisdictional disaggregation levels

Geographic/Jurisdictional Area	Potential Applicability
State	May be applicable for statewide planning and consideration of resource management by state agencies.
Northern California versus Southern California	Variation between marginal energy intensities suggests that areas are sufficiently different to warrant separation. North versus South separation maintains a large geographic area for applying generalized information.
Climate Zone	Consistent with DEER database for applicability to current regulatory framework.
Water Basin	Allows consideration of consistency of water supply sources. Surface water, groundwater, and imports will be relatively consistent within a specific water basin.
Retail Water Supplier	May allow consideration of the ability of the retail supplier to realize savings via customer-specific incentives. Generally more useful for end-use water consumption.
Wholesale Water District	May allow consideration of the ability of the wholesale supplier to realize savings via incentives.
Electric Utility Service Area	May allow consideration of the ability of the utility to realize savings via incentives and, in the case of regulated utilities, for tracking of public benefits.

The appropriate level of geographic or jurisdictional disaggregation depends on the planning goals and objectives being considered. The use of energy intensities at the statewide level may be appropriate if the intended application is to consider resource allocation from the perspective of a state agency. If, however, regulated electric utilities are interested in tracking water-related energy efficiency for the purpose of allocating public benefits charges, then the appropriate jurisdictional level may be the utility's service area. Water districts and other water planners may disaggregate data at the water supplier level to formulate future water plans and consider which water sources may warrant additional consideration for development. At the retail water supplier level or the water district level, the application of energy intensity estimates can allow consideration of programs that could effectuate water or energy savings via incentives or technological or management improvements.

For R&D purposes, since PIER's focus is statewide, disaggregation at the sub-segment of the water-use cycle (and potentially, by specific processes and technologies within each) is most useful. Cross-referencing the relative magnitude of statewide energy use by different segments and sub-segments of the water-use cycle with the relative energy intensities of the systems, processes, and technology options within each, provides a useful framework for prioritizing R&D investments.

4.2.3. A Menu or Matrix Approach to Estimating Energy Intensity

One way to clarify data needs and to structure future analytical efforts to identify water-related energy intensities is to use disaggregated data to develop intensities through additive segment intensities via an intensity matrix or menu. The Energy Intensity Matrix provides a framework for examining water-related energy intensity at any geographic or jurisdictional level. The matrices shown in Tables 12 and 13 and provide current information on what appears to be the best available data and potential refinements in levels of disaggregation for urban water use and agricultural water use, respectively. The intensity estimates provided in the matrices are indicative estimates only and are subject to future refinement as additional or updated data becomes available.

Sub-segments such as brackish water desalination show significant variability, primarily due to the quality of the water treated to a supply level. These data could benefit from further research that further disaggregated treatment levels by water quality, perhaps in terms of total dissolved solids (TDS). Sub-segments within distribution (with the exception of recycled water distribution) have no data associated with them at all. These are sub-segments that could benefit from research that disaggregates the basic information currently available in distribution by various levels because of the wide variation in energy intensity likely to exist between different distribution systems depending upon the topography and corresponding pumping requirements.

Table 12. Urban water intensity matrix (kWh/MG)

Supply	Conveyance	Treatment	Distribution	Wastewater Collection	Wastewater Treatment	Wastewater Disposal
Surface Water (0)	SWP-L.A. Basin (8,325)	EPRI Avg. (100)	EPRI Avg. (1,200)	Average of 140 is aggregated within treatment	Trickling Filter (955)	Gravity Discharge (0)
Groundwater (4.45/MG/Foot)	SWP-Bay Area (3,150)		Flat Topography (proposed)		Activated Sludge (1,322)	Pump Discharge (400)
Ocean Desalination (13,800)	SWP-Central Coast (3,150)		Moderate Topography (proposed)		Advanced (1,541)	
Brackish Water Desal (1,240-5,220)	SWP-San Joaquin Valley (1,510)		Hilly Topography (proposed)		Advanced w/Nitrification (1,911)	
Recycled Water (0)	CRA-L.A. Basin (6,140)		Recycled Water (1,200-3,000)			
	Hetch Hetchy-Bay Area (0)					
	Mokelumne Aqueduct (160)					
	Local/Intrabasin (120)					

Table 13 . Agricultural water intensity matrix (kWh/MG)

Supply	Conveyance	Treatment	Distribution	Wastewater Collection	Wastewater Treatment	Wastewater Disposal
Ag Surface Water (0)	Ag Surface Water (0-1,150)	N/A (0)	N/A (0)	N/A (0)	N/A (0)	N/A (0)
Ag Groundwater (600-1,200)	Ag Groundwater (0)					

Information in each column of the matrices is summarized below.

Supply

The energy intensity of supply sources relates to the energy required to provide a usable water supply above ground and at the point where it is able to be moved. Even though supply and conveyance are often dependent on one another, the conveyance of supplies is not considered in the supply column.

Because surface water is, by definition, water that is already a treatable, above-ground water source ready to be conveyed, it requires no energy to become a supply source. Therefore, the energy intensity of surface water supply is zero.

Energy intensity for pumping treatable groundwater varies based on two primary factors, pump efficiency and the depth of the well. Based on an estimated average pump efficiency of 70%, a set of energy intensity estimates based on average well depths in significant groundwater pumping areas in California has been estimated by DWR (Woolf et al. 2004)[23]. Using those estimates, and maintaining the assumption of 70% pump efficiency, a calculated standard groundwater pumping energy intensity per foot of lift can be obtained. The estimate of 4.45 kWh/MG/foot of lift provides a standard that can be applied across various groundwater basins, regardless of average well depth.

Energy intensity estimates of desalination of ocean water are based on those reported in a February 2005 PIER report prepared by the Pacific Institute (Wolff 2005). This estimate of 13,800 kWh/MG is based on estimates from the author's communications with operators and developers of newer desalination plants. Ocean desalination is an important resource to consider because it does not face many of the availability barriers that other potential supply sources may. In many instances, it may be, or soon become, the next resource developed. In addition, the abundance of ocean water provides reliability value because it should always be available, even in drought conditions.

The range of energy intensity estimates of desalination of brackish water are based on those reported in an August 2004 report prepared by NRDC (Wolff et al. 2004, p. 12-13). The energy intensity for desalination of brackish water can vary significantly based on the quality of the water source. Brackish water treatment is generally performed on brackish groundwater, which may be brackish in part because the aquifer is somewhat depleted. The availability of this resource may be limited, depending on location and the stability of the aquifer.

The use of recycled water to displace potable water supplies allows the consideration of recycled water as a supply source. Energy intensity for recycled water as a supply source, however, is negligible since the manner in which recycled water becomes a supply source is through treatment of wastewater, for which energy use is already accounted. In some cases, a lower level of wastewater treatment (requiring less energy) may require additional treatment for recycled water use. In those cases, however, it is likely that the additional required treatment, along with the lower level of wastewater treatment, will require no more energy than a higher level (e.g., advanced treatment with nitrification) of wastewater treatment. Therefore, the only additional energy use associated with recycled water is typically distribution from the wastewater treatment facility to the end user. Recycled water is generally used to recharge groundwater aquifers and for landscape and agricultural irrigation and certain industrial uses. While it is not directly used as a potable water source, its use in these other applications allow it to displace the need for potable water to irrigate or recharge aquifers, effectively providing potable water savings equal to the potable water need displaced.

The level of energy intensity for recycled water will generally be lower than that for most forms of desalination for potable water use and, in many cases, less than energy intensity for

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[23] Page 11, citing *Energy Use in the Supply, Use and Disposal of Water in California*, Carrie Anderson, California Energy Commission , p. 4 (referring to DWR analyses).

other supply and conveyance requirements. While this suggests that recycled water is a very strong candidate for increased use over other water supplies, there are some other potential barriers to its application.

In many cases, recycled water may not be physically located in an area where aquifer recharge is practical, because either a nearby aquifer may not require recharge or, more likely, no aquifer is nearby. Therefore, pumping energy is required to move the recycled water to an area for aquifer recharge—negating a potentially significant portion of the efficiencies that might be gained.

The highest value of recycled water lies with its ability to directly displace potable water requirements. The use of recycled water for irrigation or industrial end use, however, requires a parallel distribution system since the recycled water can not be mingled with the potable water supply. The potential high capital cost of installing a parallel system may limit the applicability of recycled water use, particularly for residential applications. In addition, the public's concerns about recycled water used in residential areas, even when limited to residential irrigation, may present a significant barrier. Cost and acceptability barriers may be less significant when considering the provision of recycled water to certain large industrial users or for agricultural irrigation.

The potential recapture through recycled water systems of water lost via storm drains may also be significant. Water, whether from precipitation or irrigation, that would traditionally be captured via percolation into the groundwater system may now be diverted away from the area via storm drains as urban sprawl and hardscapes expand.[24]

Due to its potential and the need for more focused analysis, the use of recycled water appears to present fertile ground for additional research.

As with urban water supplies, agricultural surface water has no associated energy use. Also as with urban water supplies, agricultural groundwater pumping energy intensities vary based on pump efficiency and the depth of the well. The standard urban groundwater supply estimate of 4.45 kWh/MG/foot of lift should also be applicable to agricultural groundwater supplies. The estimated range of agricultural groundwater supply is based on a 2003 study by ITRC and varies by region of the state. The statewide average energy intensity in California is estimated at 1030 kWh/MG.[25]

Conveyance

The energy intensity of conveyance relates to energy required to move a usable water supply and is heavily dependent upon the supply source. That is, certain conveyance

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[24] Martha Davis, Executive Manager of Policy Development for the Inland Empire Utilities Agency reported that approximately 40,000 acre foot per year of water that would otherwise have recharged the Chino basin is now being diverted out of the Basin via storm drains.

[25] The 1,030 kWh/MG figure relates to groundwater pumping by irrigation districts; on-farm groundwater pumping ("after the meter") is estimated to require an average of 1140 kWh/MG.

energy use is limited to specific water supply sources (e.g., all of the SWP conveyance estimates are only applicable to the SWP, a surface water supply).

All of the SWP energy intensity estimates are based on weighted averages of DWR estimates to specific delivery points on the SWP system. The energy intensity of Colorado River imports to the L.A. Basin is based on estimates provided by Metropolitan Water District of Southern California. Other major areas for surface water conveyance include Hetch Hetchy water to the San Francisco Bay area, Mokelumne Aqueduct deliveries to the east San Francisco Bay area, and Owens Valley water to the Los Angeles metropolitan area. In addition, some energy use is required for moving water locally or within a smaller water basin. The energy intensity estimate of 120 kWh/MG for local and intrabasin conveyance shown in Table 12 is based on an average raw water pumping component identified in a 2002 study by EPRI (Goldstein and Smith 2002, Figure 2-1).

Most agricultural surface water receives only local conveyance. The bulk of conveyance energy, however, is due to movement of about 10–15% of the surface water volumes among several agricultural zones. The range presented in Table 12 is based on a 2003 study by ITRC (Burt et al. 2003, Tables 1 and 2) and includes both local and inter-zonal conveyance energy. The statewide average based on data in the same study is 330 kWh/MG, about two-thirds of which is for conveyance energy to move the 10–15% of surface water volumes that move between several agricultural zones.

Treatment

Energy intensity estimates for water treatment are generally smaller in absolute terms than for other water-use cycle segments. While estimated data points for treatment energy intensity can vary greatly by facility in terms of percentage, those estimates do not exhibit a great deal of absolute variance. The estimated average energy intensity presented in Table12 is based on information presented in a 2002 study by EPRI (Goldstein and Smith 2002, Figure 2-1). No energy use is estimated for treatment for agricultural use.

Distribution

Energy intensity estimates for distribution are also generally smaller in absolute terms than for other water-use cycle segments. Distribution energy intensity estimates could vary a great deal depending on topography and total area of the system, but very little disaggregated information appears to exist. The estimated average energy intensity presented in Table 12 is based on information presented in a 2002 study by EPRI (Goldstein and Smith 2002, Figure 2-1). No energy use is estimated to be required for distribution for agricultural use.

Energy intensity estimates for distribution of recycled water are generally larger than for primary (potable) water systems, because wastewater treatment facilities are generally sited in low-lying areas and distribution from the wastewater treatment facility will require additional pumping to move recycled water to end users. The energy intensity range presented in Table 12 for recycled water distribution is based on very few data points—the intensity estimated for potable water systems, a telephone conversation with staff of Santa

Clara Valley Water District (Appendix B, Index #67) and an NRDC document (Woolf et al. 2004, p. 17).

Few data are available that would allow easy transference of representative energy intensities to various types of topographies. Equally important, few data are available to help estimate the relative energy intensities of distribution systems by types of topographies of catalogue geographic or jurisdictional areas by defined topographies. Efforts to develop more area- or topography-specific data could be very beneficial in identifying areas of potential research for policy and technological development to increase distribution efficiency.

Wastewater Collection

Energy intensity estimates of wastewater collection appear to have been addressed only as a component of wastewater treatment. The single point average estimate of 140 kWh/MG shown in Table 12 is provided by EPRI in its estimates of wastewater treatment energy intensity (Goldstein and Smith 2002, Figure 3-3). No energy use was estimated for wastewater collection, treatment, or disposal for agricultural use.

As noted earlier, energy intensities within the wastewater collection segment are extremely similar to those of the distribution segment in that they will vary by the type of system and the topography of the collection area.

Wastewater Treatment

Energy intensity estimates of wastewater treatment vary by type of treatment facility and size of facility. The estimates shown in Table 12 for various types of treatment facilities are representative proxies across all sizes of facilities as estimated by EPRI (Goldstein and Smith 2002, pp. 3–6, 7).

Wastewater Disposal

Energy intensity estimates of wastewater disposal are shown in Table 12 for gravity discharge from treatment facilities and for no discharge treatment (e.g., dispersal to ponds, etc.). Gravity discharge will have no energy use associated with wastewater disposal. No discharge treatment has an estimated average energy intensity of 400 kWh/MG, according to by EPRI. This energy intensity may vary, but the absolute value is likely to be relatively small and may not warrant significant efforts to disaggregate information.

4.3. Resolution of Data Deficiencies

As noted earlier, while existing information is sufficient for resource planning, regulatory review, R&D planning, and other analytical purposes, improvement can, and should, be made in incremental steps to continually improve the body of knowledge and enable the most informed decisions possible in a timely fashion. Table 14 provides a listing of specific data gaps that exist, the timing for potentially closing these gaps, and the relative importance for purposes of informed R&D investment decisions.

Table 14: Existing data gaps in refining water-related energy intensity estimates

State of Current Data	Gap to be Filled	Timing	Importance of Closing the Gap
Significant reliance on case study data for data points.	Collect primary data on water-related energy use from a wide range of water utilities.	Near-term	Very important
Application of data to large geographic areas and little specificity of data to geographic areas.	Disaggregate data by more applicable geographic areas.	Mid-term	Important
Application of data to broad segments of the water-use cycle.	Disaggregate data by more applicable sub-segments.	Mid-term	Important
Applicability of recycled water as a substitute for use of potable water supplies for groundwater recharge, irrigation, and industrial uses.	Consider studies that examine the financial and social impediments to recycled water systems. Consider energy intensity of re-distribution.	Long-term	Very important
Wide variation of estimates within brackish water desalination sub-segment of supply segment.	Identify energy intensity by level of treatment required. Consider studies that examine the operational impediments to brackish water desalination.	Long-term	Less important
No disaggregation within distribution segment.	Develop energy intensities for various topographical sub-segments.	Long-term	Less important

4.4. Proposed Incremental Actions for Refining Energy Intensity Estimates

The identification of long-term goals in refining energy intensity estimates should not preclude the use of reasonable current estimates or suggest that further refinements be made only when all desired data are available. Certain refinements can be made quickly, and there is no reason not to make these changes now.

Within this report, the study team identified general and specific actions that can be taken to bridge the gap between what currently exists and a long-term vision for developing and maintaining estimates of energy intensity. First-order actions are those that can be taken now, or very quickly, to provide some level of additional clarity, precision, or accuracy to existing estimates or that can set the stage for intermediate- and long-term refinements. Second-order actions are those that should be considered after first-order actions have been undertaken. These actions will generally lay a foundation for long-term actions to be taken later. They will include the initiation of key studies or data collection efforts. Third-order actions are those that can create a sustainable method for collecting and applying additional information in the study of complex issues.

Table 15 summarizes a set of incremental actions that can be taken to refine energy intensity estimates. The actions proposed are intended to improve current and future data, methodologies and estimates for use in prioritizing research and development efforts and to inform policy related to water and energy efficiency.

Table 15. Potential approach to refining water-related energy intensity estimates

	Objectives	Recommended Actions
1st Order Actions	Implement refinements that are: - Quickly achievable within existing construct and data - Provide immediate important and timely value	Adopt adjustments proposed in Section 2 for Supply & Conveyance, Wastewater Treatment, Losses, and Indoor vs. Outdoor End Uses (see revised proxies in Table 7) Reconvene WER stakeholders to continue to refine estimates and help identify near-term opportunities for significant water-related energy savings
2nd Order Actions	Establish framework and foundation for high potential near- to mid-term opportunities Provide bridge for long-term actions	Integrate more granularity into proxy structure to improve the ability to assess and rank R&D opportunities Identify data and methodologies needed to support PIER water-energy R&D near- and long-term efforts Collaborate with entities likely to have access to these data and methods
3rd Order Actions	Implement sustainable mechanism for addressing ongoing issues and analytical needs Address more challenging and complex issues	Implement sustainable data collection and analytical method for continued refinements of water-related energy intensity estimates Define roles and responsibilities for various stakeholders in maintaining and building upon the body of existing data, methods, and tools

5.0 Conclusions and Recommendations

Previous studies have estimated water-related energy intensity for portions of the water-use cycle and certain geographic areas. The appropriate energy intensity estimates to apply depend upon the use for which the estimates are needed. In addition, many of the water-related energy intensity estimates that have been developed can be further refined through improved methodology, improved data collection, and appropriate application.

The purposes of this report were defined earlier as follows:

- To review and document the bases for the Energy Commission's 2005 *Integrated Energy Policy Report* estimates of water-related energy magnitudes and intensities
- To determine whether the data and methodologies employed to develop these estimates were reasonable and can be relied upon by PIER to prioritize its investments in water-energy research and development
- To identify beneficial adjustments to the data, methodologies, estimates and structure of the proxies
- To evaluate the relative merits of applying these estimates to different purposes
- To identify additional work needed to remedy critical gaps in data and methods that may otherwise impair PIER's ability to make informed R&D investment decisions

The sections below discuss the conclusions reached in carrying out actions to meet those purposes.

5.1. Conclusions

- In general, indoor water uses have a higher energy intensity than outdoor water uses, and Southern California water has a higher energy intensity than Northern California water.
- Energy applied in the consumption of water by agricultural and urban end uses—typically pumping and heating—accounts for more than 50% of the water-related energy consumption identified in the WER.
- Other water-related energy is consumed by water industry operations. The magnitude and intensity of energy consumption by water operations determines the amount of energy that can be saved by saving water.
- Supply and conveyance are the segments of the water-use cycle outside of the retail water meter with highest variability in energy intensity and highest magnitude of energy use. Therefore, these segments offer the highest potential for significant energy savings.
- Energy magnitude and intensity are not the sole determinants of energy savings potential. The ability or changed systems and operations or new technologies to

influence energy magnitude and intensity must also be considered in targeting R&D investments.

- Further disaggregation of energy magnitudes and intensities by sub-segments of the water-use cycle can facilitate better targeting of R&D investments. It can also help to inform the design of incentives for reducing water-related energy consumption.

5.2. Recommendations

- The adjusted WER proxies in Table 7 is sufficient for informing policy and prioritization of research and development investments.
- Drilling down into sub-segments of the water-use cycle offers an opportunity to more effectively target R&D decisions at the technology level.
- Supply and conveyance have both the highest energy magnitude and the greatest variability in energy intensity of options. These segments of the water-use cycle need further study to better understand the key drivers of energy intensity, and the magnitude of potential benefits for various supply options.
- Data gaps that should be addressed are described in Table 14 and include the collection of primary data from water utilities and the disaggregation of data geographically and within water-use cycle segments.
- A phased approach should be undertaken to continually refine water-related energy intensity estimates on a going forward basis.

By establishing a coordinated policy that is oriented toward actions that enhance energy efficiency in California, the State can move forward immediately to include water-related energy use as part of the efficiency target for utilities in the state, while refining the ability to identify, quantify and accurately track water-related energy use and the associated efficiency that is achieved with decreased water use or increased energy efficiency of water use.

In any case, the recommended revised proxies provided in this report are sufficient for PIER's purposes in prioritizing its R&D investments in this important new area of opportunity.

5.3. Benefits to California

This study has helped confirm the validity of using existing estimates and proxies (as adjusted in this report) for making decisions about water and energy R&D in California--despite any imperfections in the data or methods used to create these estimates and proxies. In fact, as this study has underscored, the decision making process is inherently iterative: decisions often lead to the development and improvement of data, which in turn inform the refinement of decisions.

Further, the recommendations in this report can improve existing data—and related decisions—in a very short timeframe. The report also suggests a consistent and cost-effective method for improving and augmenting data over time, recommending logical steps to take in the near-, mid-, and long-term. Following the recommendations and findings in this report can help California continue to make sound, effective, and beneficial decisions concerning water and energy R&D, both now and in the future.

6.0 References

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7.0 Glossary

EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
DWR	California Department of Water Resources
Energy Commission	California Energy Commission
GWh	gigawatt-hours
kWh	kilowatt-hours
IEPR	Integrated Energy Policy Report
ITRC	Irrigation and Training Resource Center
MG	million gallons
NRDC	Natural Resources Defense Council
PIER	Public Interest Energy Research
R&D	research and development
SWP	State Water Project
TDS	total dissolved solids
WER	The Energy Commission 2005 report, *California's Water Energy Relationship*, CEC-700-2005-011-SF

Appendix A.

Contacts and Communication

Person	**Entity**
Lon House	Association of California Water Agencies (consultant)
Robert Wilkinson	Bren School of Environmental Science and Management, University of California, Santa Barbara
Frank Burton	Burton Environmental Engineering (re: EPRI)
Catherine Smith	California Association of Sanitation Agencies
Bupender Sandhu	California Department of Water Resources
Chris Fakunding	California Department of Water Resources
Dave Todd	California Department of Water Resources
Do Nguyen	California Department of Water Resources
Mike Nalasko	California Department of Water Resources
Peter Brostrum	California Department of Water Resources
Simon Eching	California Department of Water Resources
Andrea Gough	California Energy Commission
Gary Klein	California Energy Commission
Gina Barkalow	California Energy Commission
Glen Sharp	California Energy Commission
Joe O’Hagan	California Energy Commission
Mark Ciminelli	California Energy Commission
Ricardo Amon	California Energy Commission
Katie Shulte Joung	California Urban Water Conservation Council
Mary Ann Dickinson	California Urban Water Conservation Council
Gregg Baatrup	Delta Diablo Sanitation District
Robert Goldstein	Electric Power Research Institute
Keith Carns	Global Energy Partners
Marjorie Stein	Green Building Studio
Dan Howes	Irrigation Training and Research Center, Cal Poly, San Luis Obispo
Steve Giampaoli	KEMA
Don Marquez	Kern County Water Agency

Person	**Entity**
Gary Gero	Los Angeles Department of Water and Power
Glenn Singley	Los Angeles Department of Water and Power
Mike Grahek	Los Angeles Department of Water and Power
Tom Crooks	MCR
Andy Sienkiewich	Metropolitan Water District of Southern California
Ann Finley	Metropolitan Water District of Southern California
John Lambeck	Metropolitan Water District of Southern California
Ken Kules	Metropolitan Water District of Southern California
Timothy Blair	Metropolitan Water District of Southern California
Bob Ghirelli	Orange County Sanitation District
Gerry Hamilton	Pacific Gas and Electric Company
Oliver Kesting	Pacific Gas and Electric Company
Matthew Gass	San Francisco Public Utilities Commission (Hetch Hetchy)
Hossein Ashktorab	Santa Clara Valley Water District
Jeannine Larabee	Santa Clara Valley Water District
Craig Jones	State Water Contractors
Dee Dillon	State Water Contractors
Gary Wolff	State Water Resources Control Board
Meena Westford	United States Bureau of Reclamation

Appendix B.

Energy Intensity Data Points From Studies Reviewed or Discussed

Energy Intensity Data Points From Studies Reviewed or Discussed

Note: Conversion factor is 1.0 kWh/MG = 3.07 * kWh/ac-ft.

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
				Water Supply: Surface/Import	
1	DWR	Bulletin 132-03 support	October 2002	3,236 kWh/ac-ft (9,935 kWh/MG) for SWP East Branch from Delta	DWR schematic, dated 10/1/02
2	DWR	Bulletin 132-03 support	October 2002	2,580 kWh/ac-ft (7,921 kWh/MG) for SWP West Branch from Delta	DWR schematic, dated 10/1/02
3	MWDSC	"Small Customer Plan…"	October 2001	2,000 kWh/ac-ft (6,140 kWh/MG) for CRA to Southern California	Pg. 5
4	SCVWD	N/A	Forthcoming	1,000 kWh/ac-ft (3,070 kWh/MG) for imports	Per telephone conversation
5	Wilkinson	"Methodology for Analysis…"	January 2000	3,000 kWh/ac-ft (9,210 kWh/MG) for SWP to Southern California	Pg. 6; "on average"
6	Wilkinson	"Methodology for Analysis…"	January 2000	2,000 kWh/ac-ft (6,140 kWh/MG) for CRA to Southern California	Pg. 6; "on average"
7	Wilkinson	"Methodology for Analysis…"	January 2000	3,519 kWh/ac-ft (10,803 kWh/MG) for marginal (e.g., imported) supplies to Southern California	Pg. 6; "average figure for marginal supplies", citing 1992 QEI, Inc. Report for SCE
8	Wolff (NRDC)	"Energy Down the Drain"	August 2004	2,947 kWh/ac-ft (9,047 kWh/MG) weighted average for SWP to Southern California	Pg. 10; Citing 2003 Larry Dale report for NRDC
9	Wolff (PIER)	"Quantifying the Potential…"	July 2005	1,000 kWh/ac-ft (3,070 kWh/MG) for urban	Pg. 28; "generic import"

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
10	Wolff (PIER)	“Quantifying the Potential…”	July 2005	500 kWh/ac-ft (1,535 kWh/MG) for agricultural	Pg. 28; “generic import”
				Water Supply—Ocean Desalination	
11	MWDSC	N/A	October 2006	4,200 kWh/ac-ft (12,894 kWh/MG)	Third-party data, via e-mail (Including pumping)
12	Wilkinson	“Methodology for Analysis…”	January 2000	6,759 kWh/ac-ft (20,750 kWh/MG) for City of Santa Barbara municipal facility	Pg. 44; Projected long-term requirements, including distribution pumping
13	Wolff (NRDC)	“Energy Down the Drain”	August 2004	5,500 kWh/ac-ft (16,885 kWh/MG) for Orange County MWD study	Pg. 12
14	Wolff (NRDC)	“Energy Down the Drain”	August 2004	5,400 kWh/ac-ft (16,578 kWh/MG) for Carlsbad project	Pg. 12
15	Wolff (NRDC)	“Energy Down the Drain”	August 2004	4,800 kWh/ac-ft (14,736 kWh/MG) for Trinidad plant	Pg. 12
16	Wolff (NRDC)	“Energy Down the Drain”	August 2004	4,400 kWh/ac-ft (13,508 kWh/MG) for IEUA study	Pg. 12
17	Wolff (NRDC)	“Energy Down the Drain”	August 2004	4,200 kWh/ac-ft (12,894 kWh/MG) for Encina study	Pg. 34
18	Wolff (PIER)	“Quantifying the Potential…”	July 2005	4,500 kWh/ac-ft (13,815 kWh/MG) study assumption	Pg. 28; Based on Trinidad, Carlsbad, and SDCWA input
				Water Supply—Brackish Desalination	

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
19	MWDSC	N/A	October 2006	1,400 kWh/ac-ft (4,298 kWh/MG)	Third-party data, via e-mail
20	Wolff (NRDC)	“Energy Down the Drain”	August 2004	1,700 kWh/ac-ft (5,219 kWh/MG) for Chino Desalter Facility	Pg. 12
21	Wolff (NRDC)	“Energy Down the Drain”	August 2004	405 kWh/ac-ft (1,243 kWh/MG) for Reynolds treatment plant in San Diego County	Pg. 13
				Water Supply—Groundwater	
22	Anderson	“Energy Use in the …”	1999	175 kWh/ac-ft (537 kWh/MG) for Tulare Lake	Pg. 4; Citing DWR; equals 1.45 kWh/ac-ft per foot of depth for cited depth of 120 feet
23	Anderson	“Energy Use in the …”	1999	292 kWh/ac-ft (896 kWh/MG) for San Joaquin River and Central Coast	Pg. 4; Citing DWR; equals 1.45 kWh/ac-ft per foot of depth for cited depth of 200 feet
24	Burt (ITRC)	“California Agricultural…”	December 2003	335 kWh/ac-ft (1,028 kWh/MG) for irrigation district pumping	Calculated from statewide energy and water total estimates, Table 1 (Pg. vii) and Table 2 (Pg. xi)
25	Goldstein (EPRI)	“Water & Sustainability…”	March 2002	197 kWh/ac-ft (605 kWh/MG) average for municipal groundwater wells	Pg. 4-5
26	SCVWD	N/A	Forthcoming	650 kWh/ac-ft (1,996 kWh/MG)	Per telephone conversation

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
27	Wolff (NRDC)	"Energy Down the Drain"	August 2004	570 kWh/ac-ft (1,750 kWh/MG) assumption for San Diego County case study	Pg. 34
28	Wolff (NRDC)	"Energy Down the Drain"	August 2004	580 kWh/ac-ft (1,781 kWh/MG) for Los Angeles	Pg. 11; citing 2003 Larry Dale report for NRDC
29	Wolff (NRDC)	"Energy Down the Drain"	August 2004	740 kWh/ac-ft (2,272 kWh/MG) for Westlands Water District case study	Pg. 11
30	Wolff (PIER)	"Quantifying the Potential…"	July 2005	650 kWh/ac-ft (1,996 kWh/MG) study assumption	Pg. 28; Based on pump depths for San Diego County and Westlands Water District
				Water Supply—Other/Misc.	
31	MWDSC	N/A	October 2006	175 kWh/ac-ft (537 kWh/MG) estimated generation on MWD system for East Branch SWP deliveries	Raw data provided, via e-mail
32	MWDSC	N/A	October 2006	295 kWh/ac-ft (906 kWh/MG) estimated generation on MWD system for West Branch SWP deliveries	Raw data provided, via e-mail
				Local Conveyance	
33	Goldstein (EPRI)	"Water & Sustainability…"	March 2002	39 kWh/ac-ft (120 kWh/MG)	Figure 2-1; "raw water pumping" requirement for generic treatment plant
34	WER	work papers	2005	52 kWh/ac-ft (161 kWh/MG)	Based on EBMUD data

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
35	Wolff (NRDC)	“Energy Down the Drain”	August 2004	80 kWh/ac-ft (246 kWh/MG) for study assumption	Pg. 34; “raw water lift to treatment plants”
				Water Treatment	
36	Goldstein (EPRI)	“Water & Sustainability…”	March 2002	33 kWh/ac-ft (100 kWh/MG)	Figure 2-1; Based on generic water treatment plant
37	MWDSC	N/A	October 2006	30 kWh/ac-ft (92 kWh/MG)	Per e-mail
38	SCVWD	N/A	Forthcoming	100 kWh/ac-ft (307 kWh/MG)	Per telephone conversation
39	WER	work papers	2005	95 kWh/ac-ft (293 kWh/MG)	Based on EBMUD data
40	Wolff (NRDC)	“Energy Down the Drain”	August 2004	41 kWh/ac-ft (126 kWh/MG) for Perdue Treatment Plant (S.D.)	Pg. 16
41	Wolff (NRDC)	“Energy Down the Drain”	August 2004	48 kWh/ac-ft (147 kWh/MG) for Escondido-Vista plant (S.D.)	Pg. 16
42	Wolff (NRDC)	“Energy Down the Drain”	August 2004	68 kWh/ac-ft (209 kWh/MG) for Levy plant (S.D.)	Pg. 16
				Water Distribution	
43	Goldstein (EPRI)	“Water & Sustainability…”	March 2002	391 kWh/ac-ft (1,200 kWh/MG) average	Figure 2-1

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
44	SCVWD	N/A	Forthcoming	320 kWh/ac-ft (982 kWh/MG)	Per telephone conversation
45	WER	work papers	2005	223 kWh/ac-ft (686 kWh/MG)	Based on EBMUD data
46	Wilkinson	“Methodology for Analysis…”	January 2000	219 kWh/ac-ft (672 kWh/MG) average for Southern California	Pg. 8; Citing 1992 QEI, Inc. Report for SCE
47	Wolff (NRDC)	“Energy Down the Drain”	August 2004	170 kWh/ac-ft (522 kWh/MG)	Pg. 17; Statewide average estimated in study
48	Wolff (NRDC)	“Energy Down the Drain”	August 2004	215 kWh/ac-ft (660 kWh/MG) for Levy-Helix Water District in S.D. County; 430 kWh/ac-ft (1320 kWh/MG) in pressurized portion	Pg. 17
49	Wolff (PIER)	“Quantifying the Potential…”	July 2005	395 kWh/ac-ft (1,213 kWh/MG) study assumption	Pg. 28
				Wastewater Collection	
50	Goldstein (EPRI)	“Water & Sustainability…”	March 2002	46 kWh/ac-ft (140 kWh/MG) average for influent pumping	Figure 3-3
				Wastewater Treatment	
51	Quantec	“Energy Efficient Local…”	January 2005	506 kWh/ac-ft (1,554 kWh/MG)	Weighted average calculated over 4 plants from study data

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
52	Rosenblum Environmental Engineering (IEUA)	“Potential Energy Efficiency…”	August 2005	877 kWh/ac-ft (2,691 kWh/MG)	Weighted average calculated over five plants from study data
53	SBW Consulting (PG&E)	“Energy Benchmarking…”	February 2002	697 kWh/ac-ft (2,140 kWh/MG)	Weighted average calculated over nine plants from study data (adjusted plant “f” for UV process)
54	SCVWD	N/A	Forthcoming	440 kWh/ac-ft (1,351 kWh/MG)	Per telephone conversation
55	WER	work papers	2005	652 kWh/ac-ft (2,001 kWh/MG)	Based on EBMUD data
56	Wilkinson	“Methodology for Analysis…”	January 2000	652 kWh/ac-ft (2,002 kWh/MG) average for Southern California	Pg. 8; Citing 1992 QEI, Inc. report for SCE
57	Wilkinson	“Methodology for Analysis…”	January 2000	311 kWh/ac-ft (955 kWh/MG) for trickling filter	Pg. 43; Citing Burton (1996 EPRI)
58	Wilkinson	“Methodology for Analysis…”	January 2000	431 kWh/ac-ft (1,322 kWh/MG) for activated sludge	Pg. 43; Citing Burton (1996 EPRI)
59	Wilkinson	“Methodology for Analysis…”	January 2000	502 kWh/ac-ft (1,541 kWh/MG) for advanced treatment	Pg. 43; Citing Burton (1996 EPRI)
60	Wilkinson	“Methodology for Analysis…”	January 2000	622 kWh/ac-ft (1,911 kWh/MG) for advanced treatment with nitrification	Pg. 43; Citing Burton (1996 EPRI)
61	Wolff (NRDC)	“Energy Down the Drain”	August 2004	816 kWh/ac-ft (2,505 kWh/MG) for Santee Basin plant	Pg. 26

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
62	Wolff (NRDC)	“Energy Down the Drain”	August 2004	1272 kWh/ac-ft (3,905 kWh/MG) for North City (San Diego) plant	Pg. 26
63	Wolff (PIER)	“Quantifying the Potential…”	July 2005	440 kWh/ac-ft (1,351 kWh/MG) study assumption	Pg. 28; Citing Burton (1996 EPRI) for activated sludge
				Wastewater Discharge	
64	Goldstein (EPRI)	“Water & Sustainability…”	March 2002	130 kWh/ac-ft (400 kWh/MG) for “no discharge” plants	Pg. 3-7; For pumping to ponds or hillsides
				Recycling	
65	Dale	Document provided by NRDC	2003	1500 kWh/ac-ft (4,605 kWh/MG) for San Diego project	Page 13
66	Dale	Document provided by NRDC	2003	2300 kWh/ac-ft (7,061 kWh/MG) for Orange County plant	Page 13
67	SCVWD	N/A	Forthcoming	900 kWh/ac-ft (2,763 kWh/MG)	Per telephone conversation
68	Wolff (NRDC)	“Energy Down the Drain”	August 2004	940 kWh/ac-ft (2,886 kWh/MG) for North City recycling plant distribution	Pg. 17

Appendix C.

Recommended Adjustments to Baseline Estimates of the Magnitude and Intensity of Water-Related Energy Use in California

Last year, Energy Commission staff conducted a comprehensive multi-stakeholder process that resulted in a study entitled "California's Water-Energy Relationship" (the "Water-Energy Report" or "WER") (California Energy Commission 2005) During the preparation of the WER, Energy Commission staff relied upon existing data sources to estimate both the magnitude and the intensity of the state's water-related energy consumption. Since water-energy is a new area of study, data were not readily available in the form needed to definitively determine the extent of the water-energy relationship for various customer and market segments, or for types of uses and end uses. As a result, staff needed to develop approaches to adjusting existing data to develop reasonable estimates.

In order to identify a reasonable basis for allocating PIER R&D investments, the team needed first to understand the quality and characteristics of data relied upon by staff to produce the WER estimates. The study team interviewed Energy Commission staff and other stakeholders that participated in the development of the WER. Wherever possible, the team also reviewed any available work papers that documented the data sources and bases for adjustments that were made. Through this effort, the team identified and documented the methodologies that were employed to develop these preliminary estimates of both the magnitude of water-related energy consumption and the relative energy intensities within various portions of the water-use cycle.

Bases for Current Estimates

Chapter 1 of the WER summarized estimates of the magnitude (California Energy Commission 2005, p. 8) and the relative intensity of water-related energy use in California (California Energy Commission 2005, p. 11). The derivations of these estimates were reported in WER Appendix B, relative to magnitude, and WER Appendix C, relative to intensity

The following discussion documents the study's findings as to the methodologies that were employed by Energy Commission staff and WER stakeholders to derive the Baseline Estimates of Magnitude and Baseline Estimates of Intensity that were used to develop the WER estimated energy intensities of 4,000 kWh/MG for water in Northern California, and 12,700 kWh/MG for water consumed in Southern California (California Energy Commission 2005).

Baseline Estimates of Magnitude

The WER calculated and reported estimates of the magnitude of water-related energy use in California a combination of two ways:

- For sectors other than residential and commercial (i.e., industrial, agricultural and water pumping, mining, streetlights, and transportation-communications-utilities), the figures in Appendix B for total electricity usage by customer type (e.g., chemicals, lumber, crops, airports, etc., before the adjustment to estimate the "water-related" portion, described below) are taken from SIC-code based data provided by the state's electric utilities to the Energy Commission.
- For the residential and commercial sectors, the Energy Commission used demand forecasting modeling to estimate electricity usage by end use in each sector (e.g., water

heating, cooling, cooking, refrigeration, etc), by electric utility service area. These figures were then calibrated so that the total electric estimate for a customer sector in a utility service area matched that reflected in the historical SIC-code based data provided to the Energy Commission by the electric utility. (A conversation with Andrea Gough, CEC, noted that historical SIC-code based data were used directly for the other sectors because those sectors' models do not incorporate sufficient end use level demand forecasting.).

The end-use (or customer type) category energy totals, by sector, were then adjusted by application of a "percent related to water" factor to the energy total for each end use (or customer type) category in each sector (e.g., 50% of residential dish washing energy was deemed to be related to water).

Table C-1: WER Appendix B Approach to Computing, Water-Related Energy Use

Sectors	Baseline Estimate	Adjustments
Residential & Commercial	Demand forecasting modeling for electric consumption by end use sector by electric utility service area, calibrated so sector totals match historical SIC code data	"% related to water" factor (used limited set of potential factors: 0%, 5%, 50%, 100%)
Industrial, Agricultural & Other	Energy consumption data by SIC code	

The end-use energy figures (adjusted for percent related to water) were then totaled across all sectors and end uses. The total unadjusted energy across all sectors and end-use categories sums to an amount that ties to the total statewide energy usage reflected in Energy Commission data. (250,494 GWh for California 2001 energy consumption in WER Appendix B vs. 250,241 GWh in CEC internet data found at: http://www.energy.ca.gov/electricity/consumption_by_sector.html).) These figures are presented in WER Appendix B.

Energy Commission staff indicated that they encountered the following issues during the compilation of the energy magnitudes reported in WER Appendix B that were then used to prepare WER Table 1-1, "Water-Related Energy Use in California in 2001".

- The classification methodology used by the utilities is not transparent. Energy Commission staff requested utilities to assign customer-related industry codes to particular accounts to increase consistency. However, staff does not know what assumptions were applied in making these assignments.

- The “percent related to water” factors for various customer types or end uses were based on a combination of professional judgment and input from water and energy utilities and industry stakeholders, but in some instances still are only rough estimates.

To alleviate potential uncertainties associated with SIC-code reporting, Energy Commission demand modeling output was used where available (residential and commercial sectors), but calibrated to the total energy reported by utility by sector. For other sectors, utility data were used as reported by customer type. With respect to estimating the percent of energy that is “water related”, a consensus approach among stakeholders was employed to come up with estimates by customer type and/or end use, but did not involve detailed analysis due to limitations in time and data. A limited set of assumed factors were used (0%, 5%, 50%, 100%).

Another area of concern related to the categories that reflect agricultural uses and water pumping. The primary issue is that energy consumption attributable to agricultural use and supply and urban water pumping are reported on a combined basis(California Energy Commission 2005, Appendix B, p. 105, sector AG & WP) While the combined total appeared reasonable, the data in WER Appendix B relative to agriculture (i.e., “crops”, “irrigation water pumping”, and “livestock”) may be understated. (Following conversations with Gary Klein of the Energy Commission and Dan Howes of the Irrigation Training and Research Center [ITRC], “crops” and “irrigation water pumping” were both given percent related to water factors of 1.0, and “livestock” was given a factor of 0.50. The total agricultural water-related energy in Appendix B came to 6,161 GWh. Data used from the ITRC put total agricultural water-related energy at 10,560 GWh; see WER, Table 1-4, citing Burt et al. 2003. See also the discussion on page 5 of this Appendix C, related to a necessary 400 GWh adjustment in CEC’s use of ITRC data.)

In order to estimate the allocation of energy among agricultural vs. urban water pumping for this one category, staff worked with the ITRC to estimate agricultural uses, and then netted that number from the total reported energy to estimate energy attributable to urban water pumping. (The 10,560 GWh total for agricultural water pumping shown in WER Table 1-4 [4,499 GWh for on-farm groundwater pumping, plus 2,873 GWh for on-farm booster pumping, plus 3,188 GWh for four items composing agricultural water supply and treatment, such as irrigation district conveyance and pumping] was netted from the 18,114 GWh reported for “AG & WP” in Appendix B, leaving a balance of 7,554 GWh that was deemed attributable to “urban water supply and treatment” as shown in WER Table 1-1.) This methodology for determining that allocation was deemed the “best available” at the time.

Potential Refinement of WER Estimates

Discussions with Energy Commission staff and WER stakeholders and review of the WER methodology indicated potential improvements in data collection and reporting.

Data Reporting and Analysis

1. Disaggregate SIC-Code Categories. For the industrial sector customer types, apply the “percent related to water” method to individual SIC-code categories rather than aggregated

SIC-code categories (e.g., analyze separately the constituents of the "chemicals" category, such as pigments, plastics, fertilizers, etc.).

2. Review assignment of "percent water related" factors with Energy Commission demand forecasting staff. Potential adjustments to the "percent water related" factors could be warranted, but would require further coordination with demand modelers. It should be noted that detailed review of the components of end-use categories (e.g., dishwashers vs. ovens within the commercial "cooking" end use category) does not appear possible due to data limitations. In addition, revisit certain end uses to consider removing from "water-related" items those that may not "consume" water, such as clothes drying.

3. Obtain Detailed Descriptions from Utilities of Procedures for Account Segregation by SIC-Code. Further understanding of the utility process for assigning accounts to specific SIC codes could be helpful in understanding the nature of the energy use by SIC code, and in estimating "percent water related" factors. In addition, any "mislabeling" (e.g., small accounts for irrigation potentially being considered to be commercial rather than agricultural) could be addressed or understood.

In addition, some adjustments to WER estimates of electricity magnitudes by market sector were indicated. Following is the result of these adjustments.

Table C-2: Potential Adjustments to WER Table 1-1, Water-Related Energy Use in California in 2001

	Electricity (GWh)	
	WER Table 1-1	Adjusted
Water Supply and Treatment		
Urban	7,554	7,583[1], [2]
Agricultural	3,188	2,788[1]
End Uses		
Agricultural	7,372	7,372[2]
Residential	27,887	28,258[2]
Commercial		
Industrial		
Wastewater Treatment	2,012	2,012
Total Water-Related Energy Use	**48,013**	**48,013**

	Electricity (GWh)	
	WER Table 1-1	Adjusted
Total California Energy Use	**250,494**	**250,494**
Percent	**19.2%**	**19.2%**

The above reallocations resulted in modest changes to the relative magnitudes by segment of the water-use cycle. However, the total magnitude of water-related energy did not change.

Bases for Adjustments

[1] Agriculture/Water Pumping Breakdown. Because of the process by which energy requirements for urban water supply and treatment were determined (i.e., as a residual after subtracting agricultural water-related energy from a total), certain adjustments to the agricultural energy figures could require related changes in the urban water supply energy figure. One such adjustment relates to the 400 GWh shown in WER Table 1-4 for "conveyance to irrigation districts by the Western Area Power Administration". It appears that this information category was provided by ITRC for a purpose other than to be rolled into the ITRC totals reflected in its December 2003 report (i.e., 10,160 GWh),.as the 400 GWh was already included in the 10,160 GWh (Burt et al. 2003, Table 1, page vii and conversation Dan Howes of the ITRC). Thus, the 10,560 GWh figure in WER Table 1-4 should be 10,160 GWh. (Note that the 400 GWh is within the "confidence interval" of +/- 10% for the 10,160 GWh specified in the ITRC Report [Burt et al. 2003, pg. vii]). Correspondingly, the 3,188 GWh figure in Table 1-1 for agricultural "water supply and treatment" should be 2,788 GWh, and the residual-calculated figure in Table 1-1 for urban "water supply and treatment" should be 7,954 GWh rather than 7,554 GWh (subject to further adjustment as described in the next paragraph).

[2] Livestock/Commercial Breakdown. The livestock figure of 608 GWh in WER Appendix B is likely composed of some "agricultural" (water pumping for crops, per ITRC definition) and some "commercial" (other water pumping, e.g., for cleaning) components. The ITRC agriculture figure (10,160 GWh, per prior adjustment) would contain only the "agricultural" component of the livestock energy figure. (A conversation with Dan Howes of ITRC noted that the footnote 1 to WER Table 1-4 should have said that excluded uses were those that <u>are</u> considered to be commercial.) Thus, any "commercial" water-related energy relative to livestock would not be included in the ITRC "agriculture" water-related energy figure. To the extent of such "commercial" water-related livestock energy, an adjustment would need to be made to WER Table 1-1 to deduct that amount from urban "water supply and treatment" (since it would be included there by implication due to the calculation of the urban number as a residual), and added to the commercial end-use category. There is no definitive way to estimate the components within the livestock industry code, but assuming that 50% of the "dairy farms" category (making up 404 of the 608 GWh), of the "beef except feedlot" category (making up 59

of the 608 GWh), and of the horses category (making up 10 of the 608 GWh), totaling 237 GWh, and no other categories, are related to water pumping for crops, then the remaining 371 GWh of "commercial" water-related energy for livestock would need to be deducted from urban "water supply and treatment" and added to commercial end-use. The adjusted figures would be 7,583 GWh for urban "water supply and treatment" (also including the prior 400 GWh adjustment), and 28,258 GWh for "residential, commercial, industrial" end use.

Typographical Error. The reference to 58% of all water-related electricity being for combined agricultural, residential, commercial and industrial end uses on page 12 of the WER should be 73%; the 58% figure did not include agricultural end uses, per WER, page 9.

Review of Magnitude Estimates for Water-Related Natural Gas and Diesel Energy Use

The same potential refinements related to data reporting and analysis for electric energy use, i.e., disaggregation of SIC-code categories, review of "percent water related" factors, and utility account segregation process clarity, also are relevant to the estimation of the water-related natural gas usage amounts.

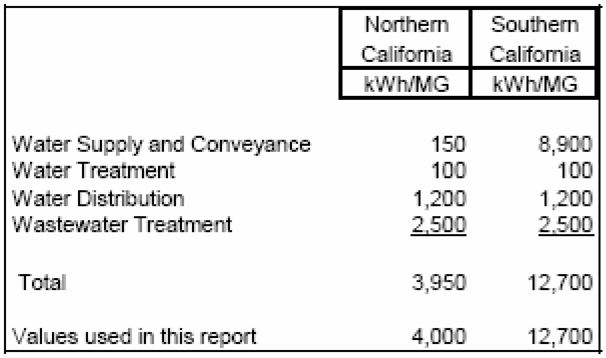
In addition, an area of worthwhile future review relates to the estimation of the electricity equivalent for the water-related natural gas and diesel fuel usage amounts as currently reflected in WER Table 1-5, "Estimates for Diesel and Natural Gas Engine Driven Water Pumping in California Agriculture" (California Energy Commission 2005 p. 14). At present, there is a significant unexplained deviation between the 1,231 GWh of equivalent electricity shown in Table 1-5 for natural gas and diesel fuel driven agricultural pumps, and a figure of 2,344 GWh that appears to be a reasonably derived theoretically equivalent amount based on the ITRC 2003 Report (Burt et al. 2003). The 2,344 GWh reflects the sum of the non-electric on-farm groundwater pumping in Table B-11 of the ITRC 2003 Report and the non-electric on-farm booster pumping in Table B-15 of that report.

Baseline Estimates of Intensity

The WER used the following data to provide the proxy estimates of energy intensity for the major segments of the water-use cycle as contained in WER Table 1-3 (California Energy Commission 2005 p. 11):

Table C-3: WER Table 1-3

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

Supply/Conveyance

For Southern California, the WER uses 8,900 kWh/MG, approximately the average of the energy intensities for the termini of the East Branch (Lake Perris, just beyond Devil Canyon Powerplant, about 9,931 kWh/MG) and the West Branch (Castaic Lake, about 7,918 kWh/MG) of the State Water Project, as the proxy energy intensity of "Southern California's dominant and marginal water source" (California Energy Commission 2005 p. 113).

For Northern California, the WER uses 150 kWh/MG, deemed the raw water pumping requirements for surface water treatment (California Energy Commission 2005, pg 111-112, citing Goldstein and Smith 2002, Figure 2-1).

Water Treatment

The WER uses a figure of 100 kWh/MG for treating surface water contained in the 2002 EPRI report (California Energy Commission 2005, pg 116, and Figure C-2 and Table C-3, citing Goldstein and Smith 2002, which cites Burton 1996).

Water Distribution

The Report uses a figure of 1,200 kWh/MG for distribution contained in the 2002 EPRI report (California Energy Commission 2005, pg 116, and Figure C-2 and Table C-3, citing Goldstein and Smith 2002, which cites Burton 1996).

Wastewater Treatment

The Report uses a figure of 2,500 kWh/MG for wastewater treatment, reflecting the rough average of seven figures summarizing various studies analyzing treatment plant energy intensities or estimates of intensities (California Energy Commission 2005 p. 116 and Table C-5).

Limitations of Current Estimates

The main limitation cited in the WER relative to specifying proxies for energy intensities for portions of the water-use cycle is the inherent variability in intensities, depending on factors often tied to geography, such as varying sources of water for water treatment, varying levels of gravity-fed vs. pumping dependent water distribution systems and wastewater collection and discharge systems, and varying levels of treatment type and plant size for wastewater treatment systems. The WER recognized that additional research would be needed to assess regional water-energy characteristics (California Energy Commission 2005 p. 109). Section 4 outlines a plan to incorporate such regional distinctions into a refined proxy structure.

Adjustments Made in the WER to Account for Limitations of Current Estimates

For simplicity, the WER used single data points for the estimated energy intensities for the four major portions of the water-use cycle (supply/conveyance, water treatment, distribution, and wastewater treatment), though with different figures used for Northern and Southern California for the supply/conveyance intensity.

Supply/Conveyance. The WER focused on import conveyance as the sole marginal supply option for Southern California (excluding, for example, a proxy for groundwater pumping), referring to data limitations as well as the primacy of surface water. For Northern California supply, the WER used surface water plus modest conveyance pumping as the sole marginal supply source (excluding, for example, a proxy for import conveyance in Northern California).

Treatment, Distribution and Wastewater. The WER assumed low variability and no significant regional differentiation for these segments (California Energy Commission 2005 p.12). However, the estimates for these segments are still single data points as opposed to a breakdown of values to correspond to different possible characteristics (e.g., different systems, processes and/or technologies) for these segments. The WER also provides proxies only relative to "urban" water systems (California Energy Commission 2005, Table 1-3), excluding water used for agricultural end uses. These issues of multiple potential proxies to account for different geographic or jurisdictional bases for proxy use will be discussed later in this report relative to a plan for further refinement of the structure of the intensity proxies. The remaining review in this section will focus on methodological issues and potential refinements with respect to the WER proxies as they are currently structured.

Potential Refinement of Current Estimates

Based on discussions with staff and key stakeholders, as well as review of data sources and methodologies, the following adjustments to the WER estimates of energy intensity by segment of the water-use cycle are recommended for consideration:

Table C-4: Potential Adjustments to WER Table 1-3, Electricity Use in Typical Urban Water Systems

	Northern California (kWh/MG)			Southern California (kWh/MG)		
	WER	Adjusted	w/Losses	WER	Adjusted	w/Losses
Water Supply and Conveyance	150	1,811[2]	2,117[5]	8,900	8,324[1]	9,727[5]
Water Treatment	100	n/a[3]	111[5]	100	n/a[3]	111[5]
Water Distribution	1,200	n/a[3]	1,272[5]	1,200	n/a[3]	1,272[5]
Wastewater	2,500	1,911[4]	1,911	2,500	1,911[4]	1,911
Total	3,950	5,022	5,411	12,700	11,535	13,022

Bases for Adjustments:

[1] Supply and Conveyance—Southern California. The Southern California supply and conveyance proxy in the WER is based on the simple average of East Branch and West Branch State Water Project energy intensity (approximately the average of 9,900 kWh/MG East and 7,900 kWh/MG West, or 8,900 kWh/MG). By accounting for the different water volumes on the two SWP branches (estimated at 55% East and 45% West, based on a review of historical distributions and DWR forecasts), a weighted average figure would be 9,028 kWh/MG. An additional adjustment to the Southern California supply and conveyance proxy is warranted due to the existence of hydro generation on the conveyance system of the Metropolitan Water District of Southern California. Such generation contributes about 906 kWh/MG on the West Branch and about 540 kWh/MG on the East Brach (based on 2005 SWP water flow and generation data provided by MWD), reducing the net energy intensities and yielding a revised weighted average intensity of 8,324 kWh/MG. An additional refinement to this figure will be discussed below, regarding “losses in water cycle segments”.

[2] Supply and Conveyance—Northern California. The Northern California supply and conveyance proxy could be refined by looking at SWP imported water as the marginal supply source rather than surface water with modest conveyance; this change would recognize that for many suppliers, the marginal water supply would be more energy intensive than local or gravity-fed surface water, and would be more consistent with the approach for Southern California. An indicative proxy using this approach would be about 1,811 kWh/MG (or 590 kWh/ac-ft), based on a representative weighted average of San Francisco Bay Area, Central Coast and San Joaquin Valley deliveries.(Based on SWP energy intensities for North Bay [615 kWh/ac-ft, average for Napa, Benicia and Vallejo pumping from Cordelia], South Bay [1,093 kWh/ac-ft for South Bay Aqueduct pumping], Central Coast [1,027 kWh/ac-ft], the weighted average of pumping for deliveries at Las Perillas [511 kWh/ac-ft] and Polonio [2,826 kWh/ac-ft], and San Joaquin Valley [492 kWh/ac-ft], the weighted average for deliveries at Check 21 [434 kWh/ac-ft], Buena Vista [676 kWh/ac-ft], Teerink [971 kWh/ac-ft] and Chrisman [1,610 kWh/ac-ft], weighted by 2000 delivery volumes to these points.)

An additional refinement to this figure will be discussed below, regarding “losses in water cycle segments”.

[3] Water Treatment and Distribution. The figures of 100 kWh/MG for water treatment and 1,200 kWh//MG for distribution appear to be reasonable proxies in the current structure, but subject to refinements to be discussed below, regarding “losses in water cycle segments”.

[4] Wastewater Treatment. The 2,500 kWh/MG figure used in the WER was based on seven figures that were used to present a range of wastewater treatment energy intensities. The average of the seven figures was about 2,483 kWh/MG, and the range was from 1,911 to 2,971 kWh/MG. Because of certain refinements that could be appropriate for the calculation of certain of the seven figures (or simply uncertainties), it appears appropriate to instead rely on the 1,911 kWh/MG figure (California Energy Commission 2005, Table C-5, note E, citing Wilkinson 2000,

citing Burton 1996. Goldstein 2002 also contains the 1,911 kWh/MG figure, as well as a table (Table 3-1, pg 3-5) summarizing data from Burton 1996 showing a range of energy intensities by treatment plant size (6 sizes) for four levels of treatment) as the proxy for wastewater treatment within the existing proxy structure, but subject to refinement to be discussed below, regarding "losses in water cycle segments". The 1,911 kWh/MG figure was intended to be a representative proxy for plants using "advanced wastewater treatment with nitrification", based on EPA projections for the number of treatment plants by varying sizes, and the related energy intensity estimates. (Conversation with Frank Burton). The issues with some of the other figures contained in WER Table C-5 are summarized below.

a. Inland Empire Utilities Agency. Examination of the data work papers indicates that a downward adjustment of the 2,971 kWh/MG figure may be appropriate. Data in a report provided by IEUA in August, 2005 relative to the California Local Energy Efficiency Program (CaLEEP) indicates that the energy intensity for the five subject treatment plants would be approximately 2,690 kWh/MG. (See Table 1, pg 14 of August 30, 2005 report on "Potential Energy-Efficiency Opportunities at IEUA Wastewater Treatment Plants RP-1, RP-2, RP-5, and CCWRF" (http://www.caleep.com/docs/pilots/ieua/WWTP%20EE%20Analysis.pdf)

b. City of Santa Rosa. As referenced in note B of WER Table C-5, the 2,920 kWh/MG figure for the City of Santa Rosa is based on a study of the Laguna Wastewater Treatment Plant. The 2,920 kWh/MG figure was the weighed average of flows with minimal outflow pumping requirements (1,794 kWh/MG) and flows for irrigation use that required significant outflow pumping requirements (3,654 kWh/MG); exclusion of such a significant site-specific factor seems warranted. Further, the study results were based on an assumed average power price that appears to have been understated relative to reviewed data; in that study's methodology, understatement of the power price would overstate the amount of electricity consumed, and therefore overstate the energy intensity. (Table B-7 of the Sonoma County August 2002 Greenhouse Gas Emission Analysis cited in note B of WER Table C-5 assumes an average power price for consumed electricity of 6.02 cents/kWh; work paper data indicates an average power price, 2003-2004, of 9.22 cents/kWh. Study results, therefore, could potentially be overstated.)

c. Metropolitan Water District. The figure of 2,655 kWh/MG shown relative to Metropolitan Water District service area wastewater treatment plants appears to be the simple average of the high (3,840 kWh/MG) and low (1,470 kWh/MG) figures shown in note D to WER Table C-5. The distribution of plants and plant flow volumes for these plants was not available for review at this time, but it is plausible that a weighted average of the set of plants by flow volumes would be less than the simple average of the high and low plants, since more volumes presumably flow through larger, less energy intensive plants.

d. Energy Down the Drain. The 2,302 kWh/MG figure shown in WER Table C-5 is the average of the 1 MG/day plant and the 100 MG/day plant data as shown in NRDC's "Energy Down the Drain" (Wolff et al. 2004). (The table referenced on page 26 of Wolff et al. 2004 basically restates a portion of Goldstein and Smith 2002 Table 3-1 in kWh/ac-ft rather than kWh/MG.)

As noted in footnote 39, the 2002 EPRI report includes data for six wastewater treatment plant sizes, ranging from 1 MG/day to 100 MG/day; the 1,911 kWh/MG figure used in the 2002 EPRI report as the unit electricity requirement for advanced treatment plants with nitrification was a representative proxy over the six plant size estimates (Wolff et al. 2004, p. 17) and should be superior to the 2,302 kWh/MG figure which would not address the higher level of overall flow volumes that would be associated with the larger plant size.

e. Energy Benchmarking Secondary Wastewater Treatment (PG&E). This study of nine municipal wastewater treatment plants produced a range of energy intensity estimates, from 1,073 to 4,630 kWh/MG. The simple average of the nine data points comes to 2,600 kWh/MG (the WER figure summarizing this study was 2,625 kWh/MG). The 4,630 kWh/MG figure, however, relates to a plant that has ultraviolet disinfection added, and the study notes the particularly high energy consumption of this plant; removing that component of energy would lower that plant's energy intensity to 3,354 kWh/MG (see SBW Consulting 2002, Table 3, pg 5, indicating that 23% of plant "f" energy is for UV processes). A recalculated simple average would then come to 2,480 kWh/MG. In addition, because the plants have different volume flows, a weighted average by flow volume would be an appropriate alternative, and that weighted average (after the removal of the ultraviolet process energy) would come to 2,140 kWh/MG.

[5] Losses in Water Cycle Segments. Since the purpose of the energy intensity proxies for the different segments of the water-use cycle is to enable an estimation of the effect of conserving water at the customer meter, the proxies should be adjusted to account for any changes in water volume over the course of the water-use cycle relative to a given volume at the customer meter. For example, losses due to evaporation, seepage, and leakage that may occur during the conveyance, water treatment, and distribution segments will have the effect of increasing the effective volume of water supply needed to deliver a given water volume to the end user. In addition, because not all water delivered to an end user will ultimately end up as inflow to a wastewater treatment plant, "losses" during end use (e.g., for landscape irrigation) will have the effect of decreasing the effective volume of water needing wastewater treatment for a given water volume delivered to the end user.

While the data are somewhat slim, it appears that the following loss factor estimates are reasonable:

- Conveyance on SWP: 5% (See Wolff et al. 2004, pg 11, citing unofficial SWP estimates and Central Valley Project modeling assumptions at 5%)
- Water Treatment: 5% (See Wolff et al. 2004, pg 71, specifying a 5% treatment loss factor for its San Diego County Water Authority case study
- Water Distribution: 6% (See Wolff et al. 2004, pg 71, specifying a 7% distribution loss factor for its San Diego County Water Authority case study. Also, see pg 17, urban distribution system losses typically range from 6% to 15%).

These factors would be applied additively backwards from end use delivery (to effectively account for increased water volumes to cover downstream losses), so that the distribution intensity would be increased by 6%, the treatment intensity would be increased by approximately 11.3% (for the additional 5% on treatment), and the conveyance intensity would be increased by approximately 16.9% (for the additional 5% on conveyance).

Adjusted Proxies for Energy Intensity by Segment of the Water-use cycle

Applying these factors to the proxies as adjusted in refinements described above yields the following adjusted proxies:

Supply and Conveyance

Northern California: 2,117 kWh/MG

Southern California: 9,727 kWh/MG

Water Treatment: 111 kWh/MG

Distribution: 1,272 kWh/MG

With respect to wastewater treatment, the most direct adjustment to account for the portion of water delivered to end users that would not require wastewater treatment would be to simply segregate the wastewater proxy into two categories, either applicable or non-applicable. Thus, water for "indoor" use (that which requires wastewater treatment) would be subject to the wastewater treatment energy intensity proxy, while water for "outdoor" use (that which does not require wastewater treatment) would not be subject to the wastewater treatment energy intensity proxy. If an average applicable wastewater treatment energy intensity proxy were desired, a 50% factor could be used to approximate the indoor/outdoor split (this would be considered a general average, since actual values would vary with geography) (The San Diego County Water Authority case study in Wolff et al. 2004 incorporated a 46% factor for end use water entering the wastewater system. The 1999 American Water Works Foundation Research Foundation "Residential End Uses of Water" study found that approximately 60 percent of residential water comes from outdoor uses [cited in California Department of Water Resources 2005 Vol 2, p. 22-2]. Also, 50% could be an average "rule of thumb", per conversation with Robert Wilkinson.), yielding an adjusted wastewater treatment energy intensity proxy of 955 kWh/MG.)

<u>Total Effect of Potential Refinements</u>. Incorporating the above potential refinements would yield the following revised proxies for indoor vs. outdoor water uses in Northern California vs. Southern California:

Table C-5: Potential Refined Energy Intensity Proxies

	Northern California (indoor) kWh/MG	Southern California (indoor) kWh/MG	Northern California (outdoor) kWh/MG	Southern California (outdoor) kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	**5,411**	**13,022**	**3,500**	**11,111**

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