

**CALMAC STUDY ID CPU0050
VOLUME 2 OF 6
APPENDIX A**

**Embedded Energy in Water Studies
Study 2: Water Agency and Function Component Study and Embedded
Energy-Water Load Profiles**

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**Prepared for the
California Public Utilities Commission
Energy Division**

**Managed by
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Appendix A Literature Review – Annotated Bibliography

A.1 References

A.1.1 General References on California's Water-Energy Intensity

AWWA, 2008

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

Published by: AWWA Research Foundation

Source Type: Report

2008

<http://www.waterresearchfoundation.org/research/topicsandprojects/>

This research project, performed by a collaborative team, and sponsored by the AWWA Research Foundation and the California Energy Commission, is a joint effort to evaluate factors that affect energy consumption by water/wastewater treatment technologies and to identify energy optimization opportunities while maintaining treatment performance. This research project consisted of five major activities:

Identification of advanced treatment technologies for inclusion in the study.

Development of a standard framework for evaluation energy consumption and efficiency of advanced treatment technologies.

Performing energy audits of selected advanced treatment technologies installations.

Analyzing data and identifying energy optimization opportunities.

Developing general guidelines for energy consumption analysis and optimization.

The study team identified fourteen water and wastewater treatment utilities located in the United States and Canada, three of which are in California, that used one or more of the selected advanced treatment technologies to be studied and developed case histories and conducted energy audits. Ten of the fourteen identified utilities participated in the study. The Contra Costa Water District in Contra Costa, the Water Replenishment District of Southern California in Torrance, and the West Basin Municipal Water District in El Segundo were the California participating utility partners. The City of Pooler, GA was the only participating wastewater treatment facility. The West Basin Municipal Water District in El Segundo, CA was the only participating municipal and industrial water reuse facility. The remaining facilities treated drinking water from surface and/or groundwater sources. The results of the study yielded energy consumption values that were determined for the targeted advanced treatment technologies and based on the case studies.

This study found that UV and ozone disinfection processes had the lowest specific energy consumption values in the range of 0.02 to 0.16 kWh per 1000 gal, whereas pressure driven processes (ultra-filtration, reverse osmosis, membrane bioreactors, and electrodialysis reversal) had higher specific energy consumption values ranging from 0.5 to 7.5 kWh per 1000 gallons. The study also found that for most processes (not including UV disinfection), the case study results indicated that by decreasing specific energy consumption with increasing flowrate, energy efficiency could be optimized by operating near design capacity.

Appendix A includes monthly reports and facility energy consumption data associated with each ATT and associated equipment from each participating treatment facility.

The study will provide typical information on water and wastewater energy use with respect to advanced treatment technology equipment to help guide and check information developed in Study 2.

California Sustainability Alliance, 2008

The Role of Recycled Water in Energy Efficiency and Greenhouse Gas Reduction

California Sustainability Alliance

Source type: Report

May 2008

<http://www.sustainca.org/files/FINAL%20RECYCLED%20WATER%20MAY%202%202008a.pdf>

The California Sustainability Alliance gathered senior water and wastewater agency managers throughout the state to brainstorm about opportunities for significantly reducing the water sector's energy and carbon footprint. The purpose of this study is to compute the energy value and associated GHG reduction by accelerating and increasing development and use of recycled water in California.

Recycled water was selected as a high potential area that is becoming increasingly important as a means of reserving limited potable water supplies for potable uses. This study developed an approach for attributing energy and carbon values to recycled water; estimated the magnitude of energy and carbon values achievable by accelerating and increasing use of recycled water in Southern California; and recommended remedies to primary barriers. The authors selected four agencies for detailed study: the Inland Empire Utilities Agency (IEUA); its customer, the City of Ontario; the Los Angeles Department of Water and Power (LADWP); and the City of San Diego. The authors point out that recycled water is resource that is available now in significant quantities, but is largely being discharged without being applied to beneficial uses. The study also concludes the energy and carbon benefits achievable by increasing use of recycled water instead of developing more energy intensive options such as seawater desalination are significant.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions:

Appendix B: Water Agency Profile: Inland Empire Utilities Agency (IEUA). This section documents detailed availability of recycled water in the IEUA region. Data on water supply makeup are summarized from the IEUA's 2005 Urban Water Management plan and other sources authored by the utility. Summary data on water energy intensity calculated jointly by the IEUA and Dr. Robert Wilkinson (author of *Methodology for Analysis of the Energy Intensity of California's Water Systems*) is presented.

Appendix C: Water Agency Profile: The City of Ontario. This section documents detailed availability of recycled water in Ontario. Data on water supply makeup and projected demand are summarized from Ontario's 2005 *Urban Water Management Plan*. Summary data on water energy intensity are presented sourced from a compilation of sources including the City of Ontario, IEUA, personal communications with the city staff, and other sources.

Appendix D: Water Agency Profile: The City of San Diego. This section documents detailed availability of recycled water in San Diego. Data on water supply makeup and projected demand are summarized from the 2005 *City of San Diego Urban Water Management Plan* and

City of San Diego Water Reuse Study. Summary data on water energy intensity are presented from data provided by these two reports. Energy required to pump recycled water is estimated in this appendix.

Appendix D: Water Agency Profile: The City of Los Angeles. This section documents detailed availability of recycled water and current use in Los Angeles. Data on water supply makeup and projected demand are summarized from the LADWP's *2005 Urban Water Management Plan*. Summary on water energy intensity are calculated from data provided by the LADWP and the MWD.

This study collected and compiled data from the water and wastewater agencies being studied, although not necessarily in the exact form needed for Study 2. Some of these data may be used for Study 2, if better sources are not located.

CEC, 2005

California's Water-Energy Relationship

California Energy Commission

Source type: Report

CEC-700-2005-011

November 2005

<http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF>

This report, prepared by California Energy Commission (CEC) staff in support of the 2005 Integrated Energy Policy Report, integrates input from multiple public and private stakeholders, including water and wastewater agencies, about the interdependencies of California's water and energy resources and infrastructure. The report includes information about the amount of water that can be saved by certain types of water conservation measures, and then estimates the amount of energy embedded in avoided water consumption by computing a proxy for the amount of energy used in various parts of the water use cycle. The numbers used in this report were obtained from other sources and were not documented in detail. The values of embedded energy by type of water measure were provided to illustrate a conceptual methodology. Different assumptions were used for water saved in northern California vs. southern California, to account for the significantly different mixes of water resources and energy embedded in those resources.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions.

Appendix B: 2001 California Energy Consumption by End Use was based on information provided by the state's energy utilities to the CEC for use in demand forecasting. Assumptions were made by members of the study group as to whether that end use sector was related to water consumption. If the group agreed that most of the energy was water related, it was assigned a factor of 1. If it was believed that there might be a relationship but the magnitude was not readily determinable, the group assigned it a factor of 0.05. Presumed "intermediate" relationships became 0.5. Categories where there did not appear to be a relationship were assigned a zero value.

Appendix C: Energy Impact Analysis of Existing Water Management Practices presented estimated ranges of energy intensities for various portions of the water use cycle in kWh/MG. Wide varieties of sources were used to develop this table and are cited in this appendix. The data used to prepare this table are based on compilations by other individual's and organization's reports from 2000 through 2005. These sources include: LBNL, EPRI, PG&E, DWR, and Navigant Consulting.

Appendix C then provides information about the amount of water savings achievable through various "BMPs" (Best Management Practices, a term used by the California Urban Water Conservation Council (CUWCC) for water savings measures) and proposes a methodology for computing the energy intensity of water saved by type of measure and by region (northern vs. southern California). All data about the amount of water savings attributable to each measure were provided by the CUWCC or its member water agencies from 2004.

Appendix C then provides a comparison of the cost-effectiveness of energy savings achievable by saving water (i.e., to avoid the amount of energy embedded in that unit of saved water). The data used for comparing these data with California's energy efficiency programs were obtained from regulatory filings at the California Public Utilities Commission for the 2004-2005 program period.

While this study was very important to helping frame water-energy issues and opportunities for consideration by California policymakers, data were very lean at the time and order of magnitude estimates were employed. Consequently, Study 2 will not be relying upon this report for any data.

CEC, 2005

Quantifying the Potential Air Quality Impacts from Electric Demand Embedded in Water Management Choices

California Energy Commission, 2005

CEC-500-2005-031

Document Type: Report

Data Range: 2000 through 2005

<http://www.energy.ca.gov/2005publications/CEC-500-2005-031/CEC-500-2005-031.PDF>

This report, prepared by the Pacific Institute in support of the CEC's Public Interest Energy Research Program (PIER), presents a model that quantifies the air pollutants generated from various methods of energy production used to acquire, treat, store, and transport water. This model was developed for both agricultural and urban settings and allows water managers to assess the energy and air pollutants generated from their water management decisions. The model and user manual are free to download and are available at

www.pacinst.org/resources/water_to_air_models

The data upon which this report relied comes from another report that the Pacific Institute recently worked with the National Resource Defense Council (NRDC) to evaluate the energy used in water management based on methods pioneered by Bob Wilkinson of the University of California, Santa Barbara. The 2004 NRDC/PI report *Energy Down the Drain: The Hidden Costs of California's Water Supply* includes case studies of San Diego County, the Westlands Water District in Central California, and the Columbia Basin Project in the Pacific Northwest. This report is available at no charge from www.pacinst.org. This report shows the potential energy savings associated with various water management practices which in turn would also yield a net benefit to air quality as energy production and use are a significant source of air pollution.

This source includes the user manual for the above mentioned model as an appendix, but otherwise is a summary of the model and a reference to previous work. Consequently, Study 2 will not rely on this study for any source data.

CEC, 2005-2006

Refining Estimates of Water-Related Energy Use in California
California Energy Commission, 2006

CEC-500-2006-118

Document Type: Report

Data Range: 2005 through 2006

<http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF>

This report, prepared by Navigant Consulting on behalf of the California Energy Commission's Public Interest Energy Research (PIER) division revisits and documents some of the original data sources and assumptions used in the CEC's 2005 white paper, "California's Water-Energy Relationship." The study reviews the estimation methodologies that were developed and used in the CEC's white paper and recommends three important modifications:

1. Differentiate energy intensity values for indoor vs. outdoor use to account for the difference in embedded downstream energy. Specifically, wastewater from indoor uses incur energy for treatment and disposal; outdoor uses such as landscape irrigation are deemed to typically flow into groundwater, thereby avoiding embedded downstream energy associated with wastewater treatment.
2. Energy intensity values should include a factor for system water losses.
3. There is wide variability in the range of energy intensities for certain types of water and wastewater systems and functions. Examples of key drivers of differences in energy intensity were identified and ranges of energy intensity for certain types of systems and functions were illustrated.

This report relies heavily on the original case study data, so any assumptions made during that study has significant influence on these values. The majority of the information for the update comes from a study published in 2002 by EPRI that documented the energy intensity of water and wastewater systems and functions on a national basis.

This study will not be relied upon as a source of data for Study 2. However, the key differentiators of energy intensity provide a start point for development of the Study 2 matrix of primary energy drivers and energy intensity characteristics of California water and wastewater systems. In addition, the guidance with respect to maintaining awareness of the contribution of system losses may be considered in the development of Study 2 energy use profiles and intensities. The issue with respect to differences between energy intensity of indoor vs. outdoor water uses is not included in the scope of Study 2.

CEC, 2007

Water Supply-Related Electricity Demand in California

Prepared for the CEC by: Water and Energy Consulting and the Demand Response Research Center

Source type: Report

CEC 500-2007-114, November 2007

<http://drrc.lbl.gov/pubs/62041.pdf>

This report documents the relationship between existing water agency electrical demands and customer water use to understand how this water use relates to the associated electrical energy consumed by the water agency. Estimates are produced for the load curve of the entire water treatment system on the peak demand day for three electric utility service areas: Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E). Furthermore, the authors investigate the amount of electrical load that water agencies can reduce or shift from on peak to off peak as a result of time of use (TOU) changes by customers.

Limited data exists on the subject of peak electricity consumption for water treatment. Thus, the authors developed a methodology for determining demand from secondary sources. Data on peak day hourly demand were collected from the three electric utilities by SIC and NAISC code. The authors filtered the data to find those facilities that treat water and wastewater. This set of data revealed the total peak demand of water and wastewater treatment in each of the three electric utility service areas. These data were compared to the California Energy Commission's Energy Demand Forecasts for water systems in 2004 and 2005. When discrepancies arose, the CEC data were selected as the best source. The resulting data presented are the hourly electricity demand on the peak demand day for water treatment, sewer systems, agricultural pumping, and the total for each of the three utility service areas. Demand related intensity (kW/mgal) is also calculated.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions:

Water demand profiles: Water demand profiles are summarized from secondary sources for residential homes and several commercial building types. Residential demand profile exhibits a diurnal pattern that is corroborated by several studies. The authors cited Oak Ridge National Lab (1997), the American Water Works Association Research Foundation (1999), and the Florida Solar Energy Center (2004).

Peak demand consumption by all water and wastewater facilities in each utility service region is calculated from customer data provided by the electric utilities between 2004 and 2005. The primary data collected that make up this figure are not provided. Peak demand is broken out into urban, agricultural, and sewer systems.

This study collected and compiled data from water and wastewater agencies. Some of these data could potentially be used for Study 2, if the agencies selected for study are the same and provided no better source of data is located. As noted previously, the Study Team strongly prefers identifying unadjusted agency source data wherever possible.

CDH Energy Corporation, 2007

Energy Index Development for Benchmarking Water and Wastewater Utilities #3009

CDH Energy Corporation

Source Type: Report

2007

<http://www.waterresearchfoundation.org/research/TopicsAndProjects/Resources/ResearchPlan/EmergingTrends/index.aspx#EnergyMgt>

The CDH Energy Corporation in cooperation with the California Energy Commission developed a process to allow normalized comparison of energy use among wastewater treatment plants and among water utilities. Factors that previously made comparisons challenging, such as plant configurations or loading were normalized through a scoring method that facilitated energy use comparisons among facilities.

The report defined the following research objectives:

Review literature for existing energy use data and methods of characterizing a utility.

Develop a statistically representative sample of utility energy use and characteristics.

Relate characteristics to energy use.

Apply and evaluate a multi-parameter benchmark score method similar to the EPA's ENERGY STAR rating system for buildings.

Review the resulting metric application at sample utilities.

The results of this project are a representative data set and a normalized metric tool (an Excel spreadsheet available for purchase) that can be used to rate the energy performance of a facility and compare it to others. This report recommends utilizing the performance score as an implementation tool within a management practice to set targets, make improvements and assess feedback to increase effective energy management.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions.

Appendix A: Literature Review – Water

Background information was obtained and reviewed to identify existing data sets and identify energy intensive processes and issues requiring energy intensive treatment methods to create energy benchmark metrics for water utilities.

Appendix B: Literature Review – Wastewater

Background information was obtained and reviewed to identify existing data sets and energy intensive processes and issues that require energy intensive treatment methods to create energy benchmark metrics for wastewater utilities.

Appendix C: Water Utility Survey Instrument

A Water Utility Energy Use Survey was utilized to gather information for the study from select utilities.

Appendix D: Wastewater Treatment Plant Survey Instrument

A Wastewater Utility Energy Use Survey was utilized to gather information for the study from select utilities.

This study does not provide any source data that can be relied upon for Study 2. The ranges of energy intensity estimates developed through this study may, however, provide information about “typical” energy use for wastewater treatment that may be used for comparison with Study 2 results.

CDWR, 2008
Complete Urban Water Management Plans
California Department of Water Resources
Source type: Reports
Updated November 2008
<http://www.owue.water.ca.gov/urbanplan/uwmp/uwmp.cfm>

The California Urban Water Management Planning Act requires that each urban water supplier, providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually, shall prepare, update, and adopt its urban water management plan at least once every five years. These plans are required to be filed with DWR.

This website contains links to folders for various agencies who have submitted completed Urban Water Management Plans (UWMPs) to the DWR. These data constitute the best available information about current, historical, and projected water demand and water supplies at the individual water agency level. UWMPs will be used in Study 2 to evaluate long-term marginal supplies and current and historical water operations for water agencies.

CDWR, 2009
Bulletin 160 California Water Plan Update 2009
California Department of Water Resources
Source type: Report and Data Report
January 2009
<http://www.waterplan.water.ca.gov/cwpu2009/index.cfm>

The California Department of Water Resources updates the state's water plan every five years. The California Water Plan Update 2009 is currently available for public comment and review, with a deadline of June 5, 2009 to submit comments. The California Water Plan Update 2009 is organized into five volumes:

- Volume 1 – Strategic Plan
- Volume 2 – Resource Management Strategies
- Volume 3 – Regional Reports
- Volume 4 – Reference Guide
- Volume 5 – Technical Guide

Due to the large size of the document, each volume has sub-sections that are available for individual download from the CDWR website. There is a Highlights document that summarizes the content of the five volumes and directs the reader to where more detailed information can be found within the larger text. The Draft Assumptions and Estimates Report and CD are available on the same web page and will be finalized in February 2009.

In summary, Update 2009:

- Provides an investment guide for state, federal, Tribal, and regional strategies to reduce water demand, improve operation efficiency, increase water supply, improve water quality, advance environmental stewardship, and improve flood management;
- Integrates objectives and strategies from numerous state agencies and initiatives and offers more than 90 near- and longer-term actions to achieve them;
- Describes 27 resource management strategies that each region can select from to develop a unique and diverse water portfolio suitable for managing an uncertain future; and
- Outlines new analytical methods and tools to help plan for future effects of climate change, population growth and development patterns, economic change, and other factors outside the water community's control.

Draft Assumptions and Estimates Report

The Draft Assumptions and Estimates Report (A&E) for the California Water Plan Update 2009 provides background on the measures the State is taking to improve data, the analytical tools used to develop the Water Plan, descriptions of the most significant data, and the data sources used to prepare the Water Plan Update 2009 (pg. 3).

The data used to prepare the Water Plan Update 2009 are available on CD and for download from the internet. The data are presented geographically, in a drill down fashion, according to

the major quantitative deliverables such as water portfolios, future scenarios, and response packages that were developed for the Water Plan (pg. 3). Data are provided for the following areas: the entire state, each of 10 hydrologic regions, the Sacramento-San Joaquin Delta including Suisun Bay and Marsh, and the Mountain Counties Area, which includes foothills and mountains of the western slope of the Sierra Nevada and a portion of the Cascade Range.

Multiple scenarios of California's future water conditions were developed to evaluate various resource management strategies for a range of water demand and supply assumptions, including climate change. Scenarios were developed using 2050 as the planning horizon with 2005 as the initial condition. A joint study by DWR with Montgomery-Watson-Harza, the Stockholm Environment Institute, the national Center for Atmospheric Research, and the RAND Corporation to quantify scenarios and evaluate potential future water management responses has been conducted. The Water Evaluation and Planning (WEAP) model was used for the study.

The two primary sources of data for climate change to the Water Plan are the California Climate Change Center studies from 2006 and 2008 Biennial Climate Science Reports required by Executive Order #S-3-05, signed by Governor Schwarzenegger on June 1, 2005. (pg. 7)

The Water Plan contains 12 regional reports summarizing California's hydrologic regions. These reports provide information on the water supplies and uses in each region or area, discussion of water issues, accomplishments, and challenges specific to each region. The information in these reports is based on Integrated Regional Management and local water and flood planning efforts. (pg. 8)

Twenty-five resource management strategies are outlined in the Water Plan. The data used to develop these strategies are available on the CD.

The Water Plan employs water portfolios to estimate and present actual water uses, supplies, and quality. Water portfolios for water years 1998 through 2005 were used for the Water Plan and are available on the CD. Data are presented in tables, flow charts, and in illustrations.

This is a comprehensive data report for the state of California. However, the purpose of this document is to provide a basis for long-term statewide planning. Consequently, data presented in this Plan are summarized from other sources and will not be relied upon for Study 2 unless original unadjusted source data from water and wastewater agencies selected for study cannot be obtained. In that case, some data from the Plan may need to be used.

EPRI, 2002

Water and Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply and Treatment - The Next Half Century

Electric Power Research Institute (EPRI)

Source type: Report

March 2002

<http://my.epri.com/portal/server.pt>

This report attempt to answer the question, “Will there be enough electricity to satisfy the United State’s need for fresh water?” In analyzing this question, this report estimates unit electricity requirements for the supply of freshwater and the treatment of wastewater. The authors used these unit electricity values to calculate the total energy required for different sectors of the economy. Results show electricity demand associated with urban water demand will increase proportional to population increase while demand associated with agriculture and industry water use will triple. The report identifies key factors that could increase the energy intensity of water delivery over time including (among other things) increased flow resistance from aging systems and increased standards and requirements for water treatment.

Energy intensities are presented from a previous EPRI report for surface water treatment and groundwater treatment sources. Waste systems analyzed include: trickle filter, activated sludge, advanced wastewater treatment, and advanced wastewater treatment with nitrification.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions:

Energy intensity of water treatment: This report references a previous study by EPRI titled *Water and Wastewater Industries: Characteristics and Energy Management Opportunities* (1996). A schematic view of a typical surface water treatment facility including energy intensity of specific components is included in this report. Survey data also show how total plant energy intensity is independent of plant capacity. An estimate of groundwater treatment energy intensity is also presented, though not on a system component basis. Data presented represents a national average. Regionalized and state specific figures are not available.

Energy intensity of wastewater treatment: This report also references EPRI (1996) for wastewater energy intensities. A schematic view of a typical activated sludge, advanced wastewater treatment including energy intensity of specific components is included. Survey data also show how total plant energy intensity is dependent on plant capacity for all facility types discussed. Despite this dependence on capacity, the report suggests the typical energy intensity for each plant.

Water source and energy intensity by end users: 1995 data are summarized from the USGS on the distribution of supply source to end users (self supplied ground or surface water vs. publicly supplied) by sector (residential, commercial, industrial, and mining). These data are available on a regional basis, but not state specific. The authors also estimate the energy intensity of self supply for both sources across all sectors. Finally, water requirements for thermal cooling of

power plants are summarized from a secondary source for 9 different power plant cooling system combinations.

This study collected and compiled national data for various treatment technologies to estimate average experience. These data will not be relied upon for Study 2, although the average national experience can be referred to as an additional data point, but only for purposes of comparison.

EPRI, 2002

Water and Sustainability (Volume 2): An Assessment of Water Demand, Supply, and Quality in the U.S. - The Next Half Century

Electric Power Research Institute (EPRI)

Source type: Report

March 2002

<http://my.epri.com/portal/server.pt>

EPRI developed this report to aid in its research and development activities in sustainable development. The report largely focuses on a discussion of issues pertaining to sustainable water resources. The report concludes sustainable development and water quality quantity require a balancing of technology use and management and policy, unlike past developments. Given this need, EPRI researchers were able to identify several R&D focus areas including: advanced water technology, monitoring, integration of economic and meteorological information, and various types of model development.

One section of the report presents a case study on the California water system. However, this section mostly summarized data from past California Water Plan Updates. More recent data are available to the study team from other sources.

Following are the primary types of data that were either provided or relied upon in the report:

California water supply is summarized for average and drought conditions in 1995 and projected in 2020 from the *1998 California Water Plan Update*.

The California water budget is summarized for average and drought conditions in 1995 and projected in 2020. This information was obtained from the *1998 California Water Plan Update*. It shows the net out-flow of water from California's storage indicating an unsustainable use of resources. The table also highlights how actions such as conservation and local sourcing, can reduce this net outflow in 2020, though further action is still need to achieve a sustainable level.

While this study was very important to helping frame sustainable water issues and opportunities, the results of this report will not be relied upon in Study 2. This study collected and compiled data for two hydrological scenarios in California; however, more detailed data are available from primary sources.

Green Buildings Studio, 2007

Supply and Demand Side Water-Energy Efficiency Opportunities

Green Buildings Studio

Source type: Report

February 2007

<http://docs.cpuc.ca.gov/energy/electric/energy+efficiency/pgewaterenergyfinalreport21607.pdf>

This report was commissioned by Pacific Gas and Electric Company (PG&E) to investigate the embodied energy required to deliver water to end-users and to treat wastewater for multiple water utilities within PG&E's service territory. The first part of the report provides detailed estimates of the energy intensity of water for select agencies; the second part presents the potential energy savings associated with demand side water conservation.

To determine energy intensities, the authors conducted detailed surveys of 11 water agencies to collect data (the report does not indicate the year the survey was conducted). Because this report only examines water agencies in the PG&E territory, the energy intensity of water use in other parts of the state are not reflected in any of the data presented.

The region studied has a high proportion of urban water use compared to the statewide average. Intensity calculations are compared to reports from the NRDC and the California Department of Water Resources. The authors do not present the total water-use energy intensity; they discuss how this figure can be misleading because the fresh water flow volumes do not correspond one-to-one with the wastewater volumes.

The report provides detailed estimates of energy intensity for each stage based on primary data collection and several secondary sources:

Supply and Conveyance (p. 18): Data on volume and energy consumption of supplied water was collected from five agencies and used to calculate the intensity of surface water supply. Groundwater pumping data were also collected from four agencies; some provided aggregate data while others gave data on specific wells. Data on the distribution of water supply (groundwater vs. surface) are also presented.

Water Treatment and Distribution (p. 22): Data on energy use for water treatment and distribution are presented separately in this section. Disaggregated data were only available for seven of the water authorities. However, total energy used from extraction through distribution was available from all utilities. The total energy intensity from extraction through distribution is presented in this section for all agencies in addition to any disaggregated data.

Wastewater Treatment (p. 24): Detailed data were obtained from seven wastewater treatment systems to calculate energy intensity. When primary data were not available, the authors cited the CEC's *Refining Estimates of Water-Related Energy Use in California* presentation.

Wastewater Discharge (p. 25): Only three agencies in the study use energy to discharge wastewater. The authors summarize primary data for their energy use in this section. Total wastewater cycle energy was calculated in this section and shown to exceed estimates used in Pacific Institute's Water to Air Model.

Recycled Water Distribution (p. 27): The authors collected primary data on the distribution of recycled water and present their energy intensities. These estimates did not include the energy required for treatment as that energy use is included in the wastewater treatment calculations.

This study collected and compiled data from water and wastewater agencies. Some of these data may be relied upon for Study 2, if the agencies selected for study are the same and provided no better source of data is located.

NRDC and the Pacific Institute, 2004
Energy Down the Drain: The Hidden Costs of California's Water Supply
Natural Resources Defense Council and the Pacific Institute
Source type: Report
August 2004
<http://www.nrdc.org/water/conservation/edrain/contents.asp>

The NRDC and Pacific Institute report presents a model to show policy makers how to calculate the amount of energy consumed in water use. The model is applied to three case studies in the western United States, two of which are in California. The authors suggest that integrating energy use into water planning can save money, reduce waste, protect the environment, and strengthen the economy. This report utilizes the Pacific Institute's Water to Air Model. See our review of the Water to Air Model in the Literature Review for Study 1 for more details.

In examining San Diego County's urban water use, the authors estimate the energy intensity of water use broken down by the amount of energy consumed at five different steps (source and conveyance, treatment, distribution, end use, wastewater treatment). The authors then calculate the energy intensity of available options to satisfy an incremental demand of 100,000 af/yr including: conservation, recycling, desalination, and various water transfer options. While the study finds conservation is the best option, other options are ordered in the energy intensity from low to high.

The report also examines agricultural water use in the Westlands Water District in California specifically focusing on land retirement. In this case study, the authors evaluate three alternatives for the disposition of the water formerly used to irrigate retired lands in the district: enhance environmental flows in the delta, use on other land within the district, or transfer to other agricultural or urban uses.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions.

Appendix A: Description of model used for San Diego urban water case study. This model was derived from the methodology described in the CIEE report *Methodology for Analysis of the Energy Intensity of California's Water Systems*. Although no data lie in this section, model documentation and explanation is present.

Appendix B: Sources for San Diego urban water case study. The authors rely on the CIEE report *Methodology for Analysis of the Energy Intensity of California's Water Systems* as a source for pumping energy used by the State Water Project and the Colorado River Aqueduct. Another primary source for data was personal communication in 2003 with the SDCWA for information on: energy intensity of desalination plants, groundwater pumping data, energy used for recycling, energy used in water treatment, and several demographic data sets. Other data sources are also referenced in Appendix B.

Appendix C: Description of model used for agricultural water use analysis. This model was derived from the methodology described in the CIEE report *Methodology for Analysis of the*

Energy Intensity of California's Water Systems. Although no data lie in this section, model documentation and explanation is present.

This study relied upon other studies for data. Consequently, this study will not be relied upon as an authoritative data source for Study 2.

Santa Clara Valley Water District, 2008

From Watts to Water

Santa Clara Valley Water District

Source type: Report

June 2008

<http://www.valleywater.org/conservation/media/Documents/WUE%20Water%20Energy%20Report.pdf>

In this report the Santa Clara Valley Water District (District) quantified the energy savings and air pollutant emissions reductions attributable to the District's water conservation and water recycling programs. The District used the Water to Air Model developed by the Pacific Institute to evaluate the performance of water reduction efforts between 1993 and 2006. The authors calculated energy savings by comparing two scenarios. The first scenario modeled conservation and recycling efforts at their actual levels over the study period. Historic data of the supply breakdown were used by the District. The second scenario modeled the total volume of water supplied by water conservation and water recycling over the study period as instead being supplied by imported water. This scenario removes the effects of conservation and recycling to calculate a "business as usual" case. The District concluded that significant energy and emissions savings have occurred due to the district's efforts to conserve and recycle water.

The District modified several assumptions in the Water to Air Model to more accurately reflect their service area. The District updated assumptions regarding end use efficiency levels for urban customers based on their historic conservation programs. The assumed emissions factors from electricity use were changed from the state average electricity mix to PG&E's electricity mix. Finally, energy intensities were tailored using various sources described below.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions:

California Energy Commission, *California Water-Energy Relationship* (2005): This report supplied the energy intensity for wastewater treatment and serves as a comparison for total energy intensity of source and conveyance.

Dr. Robert Wilkinson, *Methodology for Analysis of the Energy Intensity of California's Water Systems* (2000): This report supplied the energy intensity for importing water to the region from the California State Water Project to South Bay Aqueduct.

Santa Clara Valley Water District: Primary data were gathered from within the District pertaining to groundwater pumping, treatment, distribution, and recycling. This information was used to calculate the energy intensities of these activities. The final intensities calculated are listed in Appendix A.

This document relied upon data and methods developed by other studies. However, this document also includes primary agency data about its water operations. These agency-specific may be relied upon as a potential source of data for Study 2, in the event that the district is selected for detailed analysis.

UTSF, 2006
San Mateo County Energy – Water Snapshot
Utilities & Sustainability Task Force (USTF)
Source type: Report
August 2006
<http://www.recycleworks.org/co2/USTFwaterenergyreport.pdf>

This short report provides a snapshot on water and the energy-water connection. It is meant to brief the readers with a general overview of water usage in San Mateo County, the concept of energy intensity, and opportunities for reducing energy and water consumption. This report also provides water use statistics specific to San Mateo County.

The report's explanation of energy intensity cites the CEC and NRDC studies, and points out that the intensity of water supplied to San Mateo County is lower than the state average because the majority of water is transported to the region by gravity. However, there is little data to support this statement and no actual value provided for the energy intensity of local water supplies and systems.

Following are the primary types of data that were either provided or relied upon in the report to develop its conclusions:

Distribution of water use in the Bay Area (p. 2): The authors cite the Bay Area Water Supply Conservation Agency to present the distribution of water use by sector. The residential sector is the biggest consumer making up 59 percent of water use. Water use for agriculture is insignificant.

Per capita residential water use (p. 3): The authors present data on per capita water use in the residential sector among different communities. The report points out that higher- income communities clearly consume more water per capita than lower income communities. The data ranges over 50-325 gallons per person per day.

This study frames the local water supply circumstance and may be used to help capture a sense of the range of embedded energy in the state. However, since it does not provide actual energy data about the local water systems and resources, it will not be relied upon as a data source for Study 2.

Water-Energy Measure Calculator

Prepared for the CPUC by: James J. Hirsh & Associates

Source type: Excel model and report documentation

June 2007

<http://www.doe2.com/download/Water-Energy/>

This model was commissioned by the CPUC to examine the details of water-saving measures as they apply to gas and electricity savings. The calculator determines the following for individual water conservation measures as well as utility programs: water savings, energy savings, energy savings avoided cost, and the Total Resource Cost (TRC). The model is publicly available online. While the model is useful in calculating energy savings and cost savings from water related measures, it does not calculate energy intensity or resulting drops in energy intensity as a result of water conservation. Energy intensity is a user defined input. Instructions for use of the model are well documented by the authors. In addition, the model provides several default water saving measures to get users started; however, source for some default values are absent from documentation.

The model's cost calculations take into account demand savings based on the time of day water demand can be reduced by each agency. If water demand reduces electricity consumption during peak times, the cost savings are significant. Although the effect of electricity demand reduction shows up in cost calculations, demand reduction is not an output of the model.

Users may input detailed measure data for up to 50 technologies including: water savings, cost, rebates, savings profile (savings at different times of the day), and net-to-gross ratio. Up to 20 water agencies may be identified and characterized by: electric utility provider, energy intensity of water treatment, energy intensity of wastewater treatment, energy savings profile (savings at different times of the day), and emissions factors. Furthermore, up to 5 programs may be simulated using any combination of the 50 water-saving technologies.

Following are the primary types of data that are provided in the model as default assumptions:

Avoided cost for gas and electricity: To calculate the TRC for water-saving measures the model quantifies the avoided cost of reducing electricity use. These costs are the CPUC adopted values from the E3 calculator and include levelized hourly avoided cost data for electricity and natural gas utilities across the state.

This model is not intended to provide data for Study 2 – Study 2 will provide data to the model.

Wilkinson, 2000

Methodology for Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures

Ernest Orlando Lawrence Berkeley Laboratory

California Institute for Energy Efficiency

Agreement No. 4910110

Source type: Report

January 2000

http://www.es.ucsb.edu/faculty/Wilkinson.pdfs/Wilkinson_EWRPT01%20DOC.pdf

This exploratory study report, prepared by Dr. Robert Wilkinson of the Environmental Studies Program at University of California, Santa Barbara for the California Institute for Energy Efficiency examines the energy intensity of water used in specific geographic areas of the state and estimates the potential energy benefits of efficiency improvements of water use. The study developed a methodology to account for total energy requirements for water used within a specific service area, created a spreadsheet tool to apply the methodology, and incorporated a geographic information system (GIS) application to present the data geographically.

The analysis was focused on the two most energy-intensive water conveyance systems in the state, the State Water Project (SWP) and the Colorado River Aqueduct, with the focus on the municipal and industrial (M&I) sector as the users. The M&I sector has both greater energy intensity and availability of data than the agricultural sector. The study found that the energy intensity of water varies considerably by geographic location of both end-users and sources. Water use in certain parts of the state is highly energy intensive due to the combined requirements of conveyance over long distances with significant elevation lifts, local treatment and distribution, and wastewater collection and treatment processes. The analysis also indicates that significant potential *energy* efficiency gains are possible through implementation of cost-effective *water* efficiency improvements. This study also identifies potential cost-effective energy efficiency benefits from integrated energy, water, and wastewater efficiency programs and acknowledges work undertaken by others in the realm of combined end-use strategies.

This exploratory research project includes a well-documented review of previous work addressing energy elements of water and wastewater processes and systems, the goal of which is to provide a platform and to facilitate further research. Further research priorities were identified and form the basis of the recommendations from this study.

Energy inputs included (and excluded) in the analysis:

Energy inputs for extractions from natural systems through end-uses to ultimate disposal or re-use are included. Power generated by water systems separate from the delivery and conveyance systems is not included. Power generated as a part of conveyance systems is counted because it relates directly to the volume of water pumped through the system. The data used for this analysis were provided by MWD.

Data for Specific Geographic Locations

Geographic factors such as the sources of water and the location of end-use are usually used to determine the energy intensity. However, due to overlaps or inconsistencies in jurisdictional boundaries, the geographic boundaries must be accounted for and the appropriate energy factor for each element of the system must be attributed to the area. The author suggests the use of geographic information systems (GIS) to delineate the boundaries and record energy and other data is as a next step in this research project. (pg. 17)

Energy Inputs to Water Systems

State Water Project Energy Inputs to Water Systems

SWP energy requirements for the MWD region were obtained from MWD. (pg. 25)

The figure illustrating names, locations, and generating capacity of primary power facilities includes data provided by MWD (pg. 26).

The kilowatt-hours per acre foot pumped (including transmission losses) for each facility on the SWP shown on a flowchart, was based on data obtained from the California DWR, State Water Project Analysis Office, Division of Operations and Maintenance, Bulletin 132-97, 4/25/97. (pg. 27)

Water delivered in calendar year 1995 and delivery locations was shown geographically, with data obtained from MWD.

The Colorado River Aqueduct

Water volumes and energy required to import water to Southern California from the Colorado River Aqueduct were provided by the MWD. (pg. 30)

Local Sources (surface and groundwater)

Water Processes

A national average for estimates of electricity use in wastewater treatment was obtained from Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-45. (pg. 43)

Water Reuse

Trends in water reuse were identified in a 1999 case study for the Pacific Institute titled, "Use of Reclaimed Water in Urban Settings: West Basin Recycling Project and South Bay Water Recycling Program" for the years of 1987, 1989, and 1993 by Arlene Wong in Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., *Sustainable Use of Water: California Success Stories*, Pacific Institute, January 1999, based on data from: The 1987 and 1989 data are from *Water Recycling 2000*, 1991. The 1993 data are from *Survey of Future Water Reclamation Potential*, 1993. (pg. 43)

Energy Analysis

A spreadsheet tool was developed as a part of this exploratory project to assist in analyzing the energy intensity of water used at a given location.

Groundwater, surface water, and reclaimed water data inputs are provided by the agency in the form of total volume of water pumped and total amounts of energy (kWh of electricity and/or therms of gas) used. (pg. 47)

The imported supply energy is calculated based on a stated kWh/acre-ft factor, from DWR, MWD, or other source (available input choice), and the total amount imported for each source. (pg. 47)

The spreadsheet tool does not provide a refined methodology for calculating the marginal difference between wastewater treatments required under applicable standards and the level of treatment required for reuse. This is an area in which the author recommends further research. (pg. 48)

The regional distribution energy inputs are reportedly difficult to secure and according to the author, further research is needed to quantify the appropriate energy figures. Real-time data on MWD pumping facilities throughout its service area were provided by MWD. The user also inputs the sources of water delivered to each member agency including the associated energy intensities. (pg. 49)

Energy inputs for potable treatment and the energy required to pressurize and deliver supplies to customers is obtained from the individual agencies.

End-use factors may be included, however this study did not attempt to place values on these energy uses.

This spreadsheet applies a percentage factor to total water inputs for wastewater collection and treatment that can be adjusted and customized based on a specific facility, or it can be averaged for a service area.

The results can be viewed at each stage of the process, and a summary table of total energy and energy intensity is the final product.

This study provides a fundamental framework for calculating the energy intensity of water at specific locations and this methodology may be used as a starting point for the embedded energy study. This report may be used to help develop wholesale water scenarios for analysis under Study 1. However, it does not provide source data for use in Study 2.