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Main Report

Embedded Energy in Water Studies
Study 3: End-use Water Demand Profiles

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ABSTRACT

"Embedded energy in water"refers to the amount of energy that is used to collect, convey, treat, and distribute a unit of water to end-users, and the amount of energy that is used to collect and transport used water for treatment prior to safe discharge of the effluent in accordance with regulatory rules. In Decision 07-12-050, issued December 20, 2007, the California Public Utilities Commission (CPUC) authorized water-energy pilot projects and three studies designed to (a) validate claims that saving water can save energy, and (b) explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. The results from this research are intended to provide a better understanding of how energy is used in California. As part of this effort, The *End-use Water Demand Profile Study* was conducted to provide more accurate hourly water use profile data than have previously been available. The study examined cold-water use for six end-user (customer) categories, plus urban irrigation. Flow trace analysis (a process for determining the end-uses of water based on its flow through a meter) was conducted in order to provide precise information about water use patterns: where, when, and how much water is used by a variety of devices at the sites that were studied in the analysis. The results ofthe study include 24-hour end use water demand profiles for each category.

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Key Terms

STUDY UTILITIES (ENERGY)	
PG&E	Pacific Gas and Electric Company, a California IOU
SDG&E	San Diego Gas & Electric Company (a Sempra Energy subsidiary), a California IOU
SCE	Southern California Edison, a California IOU
SoCalGas	Southern California Gas Company (a Sempra Energy subsidiary), a California IOU
STUDY 3 AGENCIES (WATER)	
Cal Water	California Water Service Company
City of Lodi	City of Lodi Public Works
City of Petaluma	City of Petaluma Water Resources and Conservation Department
City of San Diego	City of San Diego Water Department
City of Santa Rosa	City of Santa Rosa Utilities Department
CVWD	Cucamonga Valley Water District
EBMUD	East Bay Municipal Utility District
IRWD	Irvine Ranch Water District
STUDY END-USER CATEGORIES	
Residential Single-family	Retail water customer residential unit with a single water meter. Usually detached, but can also be attached (e.g., duplex).
Residential Low-income Single-family	Retail water customer residential unit with a single water meter, and the inhabitants of which meet (or for Study 3 purposes, approximate per the best available data) the criteria established by the CPUC for the low-income energy efficiency programs. Usually detached, but can also be attached (e.g., duplex).
Residential Low-income Multi-family	Retail water customer residential units in a property in which multiple separate housing units are contained within one building, such as an apartment building, the inhabitants of which meet (or, for purposes of Study 3, approximate per the best available data) the income criteria established by the CPUC for the low income energy efficiency programs.
Commercial	Retail water customer non-residential facilities used to distribute a product or service, and which are not public buildings.
Urban Irrigation	Commercial or industrial retail water customer accounts (including public buildings) for which water meters measure irrigation uses either solely or predominantly.

Public Building	Retail water customer facilities operated and/or owned by federal, state and local governments. (Note that the term "public building" is used in Study 3 per CPUC D.07-12-050, however, in other contexts the term "institutional" is used to describe facilities with similar characteristics, e.g., schools and government buildings.)
Industrial	Retail water customer non-residential facilities used to manufacture or process non-agricultural goods.
Agricultural	Retail water customer facilities using potable and/or recycled water delivered by the water agency for either irrigation or post-harvest processing/cold storage. Study 3 did not address agricultural uses for non-potable water and/or water that is not delivered from an agency (e.g., well water).
ABBREVIATIONS/ACRONYMS	
AF	Acre-Foot - the volume of water required to cover 1 acre of area
BOR	Bureau of Reclamation (U.S. Department of the Interior)
CCF	Centum cubic feet (1CCF or water is equivalent to 748 gallons)
CEC	California Energy Commission
CIMIS	California Irrigation Management Information System - a network of 120 weather stations found throughout California managed by the California Department of Water Resources
CPUC	California Public Utilities Commission
DWR	Department of Water Resources
ET	Evapotranspiration
gpdc	Gallons per day per customer
kgal	Kilogallon (1,000 gallons)
IOU	Investor-Owned Utility (in California: Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Southern California Gas Company (SCG))
UWMP	Urban Water Management Plan
MISC. DEFINED TERMS	
Applied Water	Water applied for irrigation purposes (inches or gallons per square foot).
California Irrigation Management Information System (CIMIS)	A network of 120 weather stations found throughout California managed by the California Department of Water Resources.
Concentration Ratio	The ratio of the salinity in the circulating water to that in the make-up water in a cooling system.

CPUC Water-Energy Measure Calculator	An energy efficiency program cost effectiveness calculation tool used to estimate the embedded electricity and natural gas savings and resultant avoided costs derived from the installation of water saving measures. Developed for the CPUC.
Cycles of Concentration	The term cycles of concentration compares the level of solids of the recirculating cooling tower to the level of solids of the original raw make up water.(See Concentration Ratio)
Data Logging	Practice of installing data loggers on customer water meters in order to obtain a continuous record of water use.
Embedded Energy in Water	The amount of energy that is used to collect, convey, treat, and distribute a unit of water to end-users, and the amount of energy that is used to collect and transport used water for treatment prior to safe discharge of the effluent in accordance with regulatory rules. Note that "embedded energy" refers to cold, that is, unheated water. The energy it takes to heat water for purposes such as cooking or to generate steam is considered a separate category of activity. That is, energy used to heat water is not considered "embedded."
Embedded Energy in Water Studies	A collection of research efforts authorized by the CPUC in D. 07-12-050, December 20, 2007, designed to validate claims that saving water can save energy, and explore whether embedded energy savings associated with water use efficiency are measurable and verifiable.
End-use	As used in energy efficiency program analysis, refers to a category describing the specific activity or application for which energy is used. Examples of end-uses include refrigeration, HVAC, appliances, domestic hot water and lighting. As used in Study 3, refers to a specific activity for which water is used in residences or non-residential buildings, both indoor and outdoor. Examples include dishwashing, showers, outdoor irrigation, and processing. Such uses are also referred to as "water demand profile categories" in the report.
End-user	Customer or customer category using water (e.g., commercial and single-family low-income).
Evapotranspiration	A measurement of the water requirement of plants. According to CIMIS, ET is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water is needed by crops, lawn, garden, trees, etc. for healthy growth and productivity.The change in ET during the year mirrors the change in outdoor water use. For example, the peak ET observed during 2008-2009 occurred during July

Flow Trace	The record of continuous water use through a water meter provided by a data logger file.
Flow Trace Analysis	Process of disaggregating end-uses of water from a specific flow trace file.
HOBO Data Logger	A battery-powered logger that measures and records temperature, humidity, light, energy and a variety of other parameters. Commercial product produced by Onset Computer Corporation.
Low-income	Low-income criteria used during the study period by CPUC for its low-income energy efficiency programs. The CPUC requirements are derived the Health and Human Services poverty guidelines for the lower 48 states which are updated periodically in the Federal Register(U.S. Department of Health and Human Services under the authority of 42 U.S.C. 9902(2) 2008) Two criteria determine this characterization: the number of persons per household and whole-household income level, as shown below: Poverty Level = (number of persons per household * $3600) + $6800 Low-income Threshold = 200% of Poverty Level
Meter Master 100 Flow Recorder	A battery powered portable flow recording instrument that converts a water meter's magnetic drive signal to a digital output that is stored for downloading. Commercial product produced by F.S. Brainard& Co.
Omega Paddlewheel Flow Sensors	A flow measurement sensor with functionality of various output options including flow switch, multi-functional pulse divider or 4 to 20 mA. Commercial product produced by OMEGA.
Peak Energy Demand Period	Per CPUC decision R.06-06-063, June 29, 2006 the definition for peak for purposes of evaluating energy efficiency programs is the average grid-level impact for a measure between 2:00 PM. and 5:00 PM during the three consecutive weekday periods containing the weekday with the hottest temperature of the year. For purposes of Study 3, the peak energy demand period was defined as the three-hour period starting at 2:00 PM and ending at 5:00 PM during weekdayswithout additional criteria.
Post-harvest Processing Water	Water used for processing (cleaning, packing and canning) of fruits, nuts, vegetables, meat and dairy food products immediately following harvest.
Reclaimed Water	Former wastewater that has been treated to remove solids and certain impurities, and then used in sustainable landscaping irrigation or to recharge groundwater aquifers (also known as recycled water)

Scaled Water Use	The amount of water used per account in a given commercial/industrial group times the percentage of total water used by the group.
Sub-metering	A method of water use data collection that includes logging the flow of water through a water meter for to a water using fixture.
Trace Wizard©	A proprietary software package that analyzes flow trace data. Developed by Aquacraft, Inc.
Water Demand Profile	A measure of average hourly water use throughout a 24-hour period.
Water Demand Profile Category	The specific purpose for which water is used (e.g., showers and outdoor irrigation).

1 Executive Summary

1.1 Background and Introduction

In Decision 07-12-050[1], issued December 20, 2007, the California Public Utilities Commission (CPUC) authorized water-energy pilot projects and three studies designed to (a) validate claims that saving water can save energy, and (b) explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. "Embedded energy in water"refers to the amount of energy that is used to collect, convey, treat, and distribute a unit of water to end-users, and the amount of energy that is used to collect and transport used water for treatment prior to safe discharge of the effluent in accordance with regulatory rules. The authorized research is designed to characterize and quantify the relationships between water and energy use by water and wastewater agencies, and to determine the range of magnitudes and key drivers of embedded energy in water. The results from this research are intended to provide a better understanding of how energy is used in the California water industry, and will be used by the CPUC to help determine whether future programs to conserve water, thereby reducing the amount of energy "embedded" in the water, should be added to investor-owned utility (IOU) energy efficiency portfolios.

As part of this effort, Aquacraft conducted the third of these authorized studies, the *End-use Water Demand Profile Study* (hereinafter Study 3), which was designed to provide more accurate hourly water use profile data than are currently available. D.07-12-050 describes the need forinformation to be used to translate water conservation measure installation "into a change in the water demand profile that can then be compared with the water demand profile at the water agency to derive the effect a measure would have on the agency's energy load," and authorized Study 3 "to conduct in-line metering on selected customer samples and determine the water use shapes for these uses."[2]Data collected for Study 3 may be used to update the CPUC Water-Energy Measure Calculator,[3] a tool used to estimate the embedded electricity and natural gas savings and resultant avoided costs derived from the installation of water savings measures in residential and non-residential retail water customer categories.

The primary goal of Study 3 is to provide accurate current California end-user water demand profiles in order to better understand the opportunities for linking water-efficiency and energy-efficiency programs. A related objective is to quantify the percent of total daily water demands that occurred during the peak daily electric demand period from 2:00 PM to 5:00 PMfor end-user (customer) categories.In D.07-12-050, the CPUC notes that there are two sources of energy savings associated with water use efficiency: cold-water savings related to water agency activities (both upstream and downstream of the end-user), and hot-water savings related to energy used to heat water for water demand profile category purposes. The Decision states that "it is the former … that comprises the embedded savings opportunities that are the focus of these applications."[4]Therefore, Study 3 examined cold-water use for six end-user categories, plus

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[1] CPUC D. 12-07-050, December 20, 2007. http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/76926.htm
[2] Ibid, 77.
[3] For more on the Calculator see http://www.doe2.com/download/Water-Energy/WaterSavingMeasures-Calculator-v3.pdf
[4] CPUC D. 12-07-050, 8.

urban irrigation. This report documents the water demand profiles of these categories, and elaborates on the methodologies used to determine them.

1.2 Methodology

Flow trace analysis was used to generate hourly demand profiles as a percent of total daily use. Flow trace analysis, described in more detail in Section 4.6, obtains precise information about water use patterns: Where, when, and how much water is used by a variety of devices. On small meters, which give many pulses per gallon, it is generally possible to identify devices such as toilets, showers, baths, faucets, clothes washers, dishwashers, hand-held and automatic irrigation systems, evaporative coolers, home water treatment systems, leaks, and others. On large meters, which include most of the commercial, public building[5] and industrial sites, the analysis can identify indoor, outdoor and continuous uses, but, due to a lack of precision from the meter, the analysis cannot differentiate individual fixtures and appliances.

Much of the data required for Study 3 had already been collected in earlier water demand profiling studies conducted by the author.[6] As a result, it was possible to generate much of the information needed for Study 3 without having to undertake additional field work in the residential single-family and commercial end-user categories. To supplement existing data, new flow traces were collected from customers in water agencies located in PG&E, SCE and SDG&E service territories. Table 1 summarizes the water demand profiles that were measured, the sample size, and type of data collected for each end-user category.

[5] Study 3 uses the term "public building" for facilities owned and/or operated by federal, state and local governmental agencies. . In other contexts the term "institutional" is used to describe such facilities.

[6] For example, Aquacraft maintains a detailed end-use hourly demand profile database from a sample of more than 700 single-family homes sampled from 15 geographically distributed water utilities in California as part of the *California Single Family Water Use Efficiency Study* (*CSFWUES*). See Section 4.2, Appendix A: Sites in Existing Database and Appendix B: California Single Family Water Use Efficiency Study Information for more information.

Table 1: End-user Category, Water Demand Profile Category, Sample Size and Data Source

End-user Category	Water Demand Profile Category	Sample Size	Source of Hourly Demand Profile Data
Residential: -Single-family -Low-income Single-family	-Baths -Showers -Toilets -Clothes Washers -Dishwashers -Faucets -Leaks -Other -Irrigation	Existing: 361 single-family homes Existing: 54 low-income single-family homes	Existing database
Residential: -Low-income Multi-family		New: 159 individually-metered units	EBMUD, IRWD and City of San Diego customer flow traces
Commercial: -General Retail -Hotels and Motels -Offices -Supermarkets -Restaurants -Large Retail[7] -Laundromats -Car Washes -Automotive Service[8]	-Continuous -Indoor/Process -Outdoor/Irrigation	Existing: 35 sites New: 14 sites Total: 49 sites	EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Urban Irrigation	-Continuous -Indoor/Domestic -Outdoor/Irrigation	Existing: 7 sites New: 12 sites Total: 19 sites	EBMUD, City of Santa Rosa, IRWD, CVWD and City of San Diego customer flow traces, and existing database
Public Buildings: -Public Buildings -Schools -Hospitals	-Continuous -Indoor/Domestic -Outdoor/Irrigation	Existing: 65 sites New: 16 sites Total: 81 sites	EBMUD, City of Santa Rosa, CVWD, IRWD and City of San Diego customer flow traces, and existing database
Industrial	-Continuous -Process -Outdoor/Irrigation	Existing: 5 sites New: 12 sites Total: 17 sites	EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Agricultural	-Continuous -Process -Outdoor/Irrigation	New: 10 sites	EBMUD, City of Petaluma, City of Lodi, Cal Water, CVWD and City of San Diego customer flow traces

[7] Large retail was defined for this study as comprising regional shopping centers or large retail outlet "superstores."
[8] This sub-category includes gas stations with convenience marts, drive-through and self-car washes, and auto shops.

1.3 Key Findings

In general, there were four patterns of use observed: morning and evening, night-time, daytime, and continuous. Residential end-users tended to demand water during morning and evening periods. Irrigation tended to occur during night-time hours. While many commercial and public building facilities were daytime users, those in the industrial category were the most likely to be continuous users.Results of Study 3 show that while all of the water demand profile categories showed some use during peak energy demand hours, none could be singled out has having a key relationship with peak energy demand. Thus, at least from the perspective of embedded energy in water (that is, leaving aside issues related to heating water for its intended use), many water demand profile categories may not be a good target for peak reduction programs. However, energy efficiency and demand response programs might successfully target those usesthat exhibit the strongest link to the peak energy period (e.g., toilets and showers in the residential sector, car washes and agricultural irrigators). Table 3summarizes related Study 3 findings.

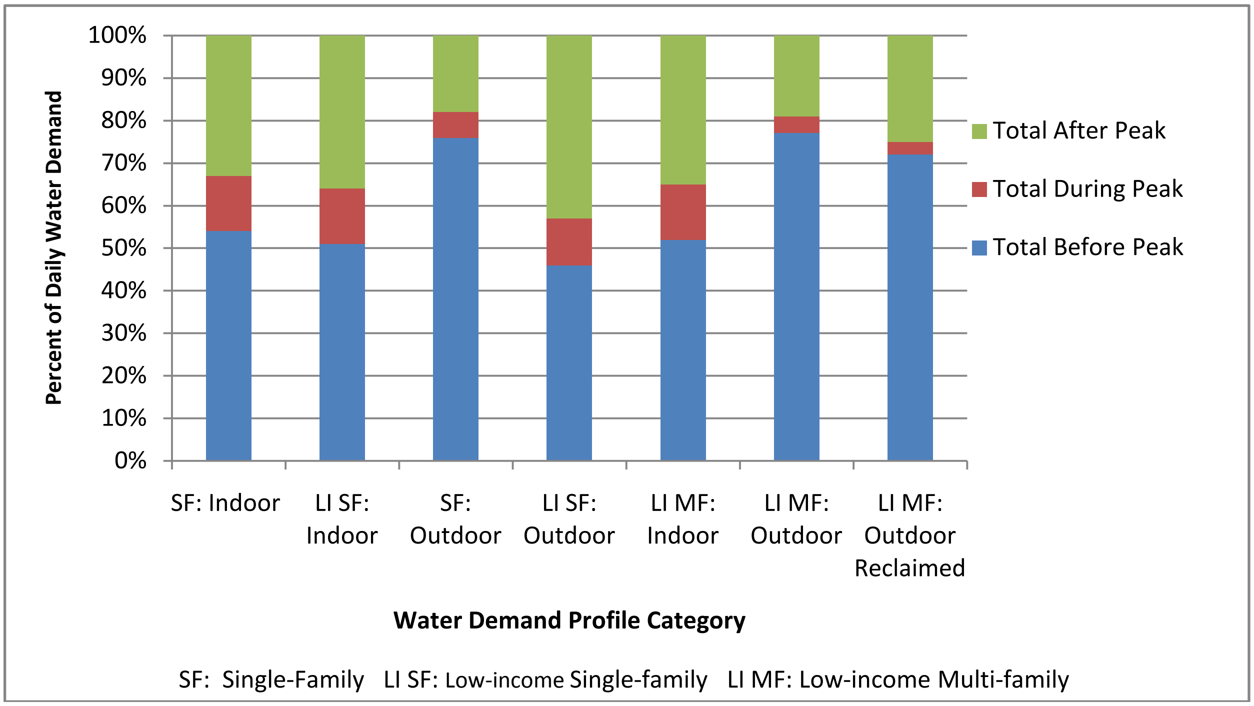
Table 2: Daily Water Use Coincident with Peak Energy Demand Period by End-user Category

End-user Category	Percent of Total Daily Water Use Coincident with Peak Energy Demand Period
Residential	
Single-family - Indoor	13%
Single-family - Outdoor	6%
Low-income Single-family - Indoor	13%
Low-income Single-family - Outdoor	11%
Low-income Multi-family - Indoor	13%
Low-income Multi-family - Outdoor	4%
Low-income Multi-family - Reclaimed	3%
Commercial	
General Retail	18%
Hotels/Motels	14%
Offices	9%
Supermarkets	14%
Restaurants	15%
Large Retail	21%
Laundromats	21%
Car Washes	29%
Automotive Service	17%
Urban Irrigation	
Urban Irrigation	4%
Public Buildings	
Public Buildings (excluding Schools and Hospitals)	13%
Primary and Secondary Schools	12%
Hospitals	18%
Industrial	
Industrial	14%
Cooling Towers	10%
Agricultural	
Agricultural Irrigator	33%
Agricultural Processor	14%
Cooling Towers	8%

Key findings by end-user category follow.

1.3.1 Residential

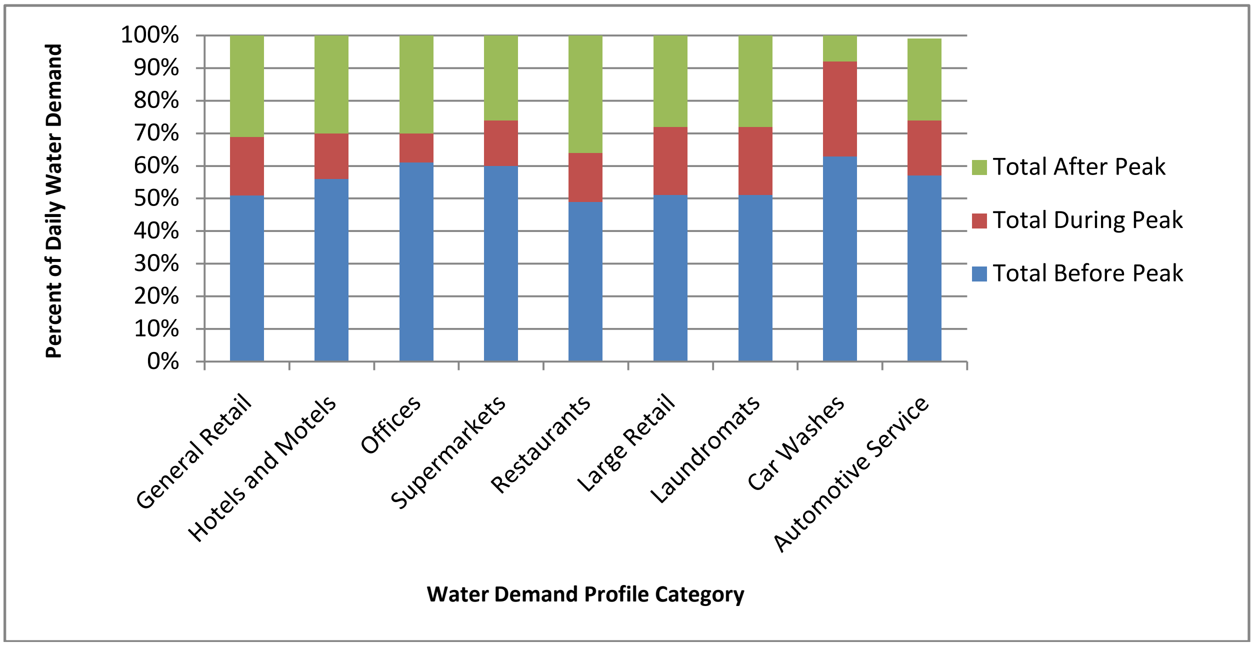
Figure 1: Aggregated Daily Water Demand – Residential



- The hourly water demands for indoor water use by single-family end-user categories show little variation by income group.
- Total outdoor water use in the single-family group was significantly higher than that in the low-income single-family group.
- The peak total indoor water use periods did not overlap with the peak energy demand period for any of the residential categories (single-family, low-income single-family and low-income multi-family.)
- Single-family, low-income single-family and low-income multi-family categories all had a similar percent of total daily indoor water use coincident with peak energy demand (13 percent.)

1.3.2 Commercial

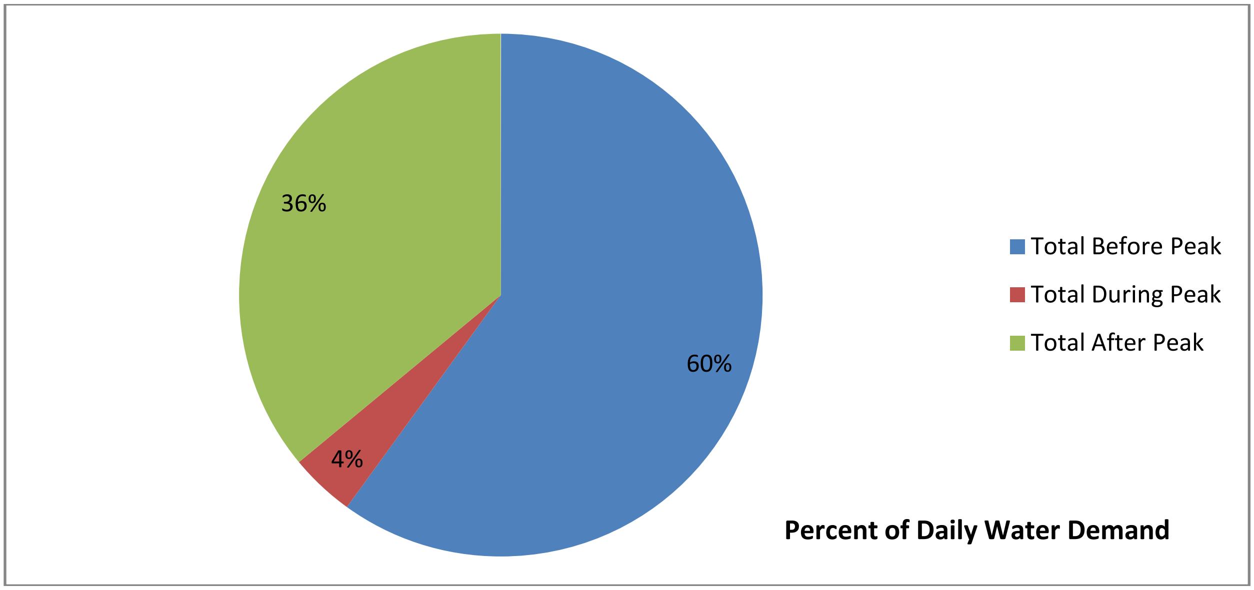
Figure 2: Aggregated Daily Water Demand – Commercial



- Commercial sites' daytime water use tended to include domestic, process and continuous applications. Irrigation tended to occur during the late night and early morning hours.
- Commercial sub-categories varied in the percentage of daily water use occurring during the peak energy demand period from 9 to 29 percent.

1.3.3 Urban Irrigation

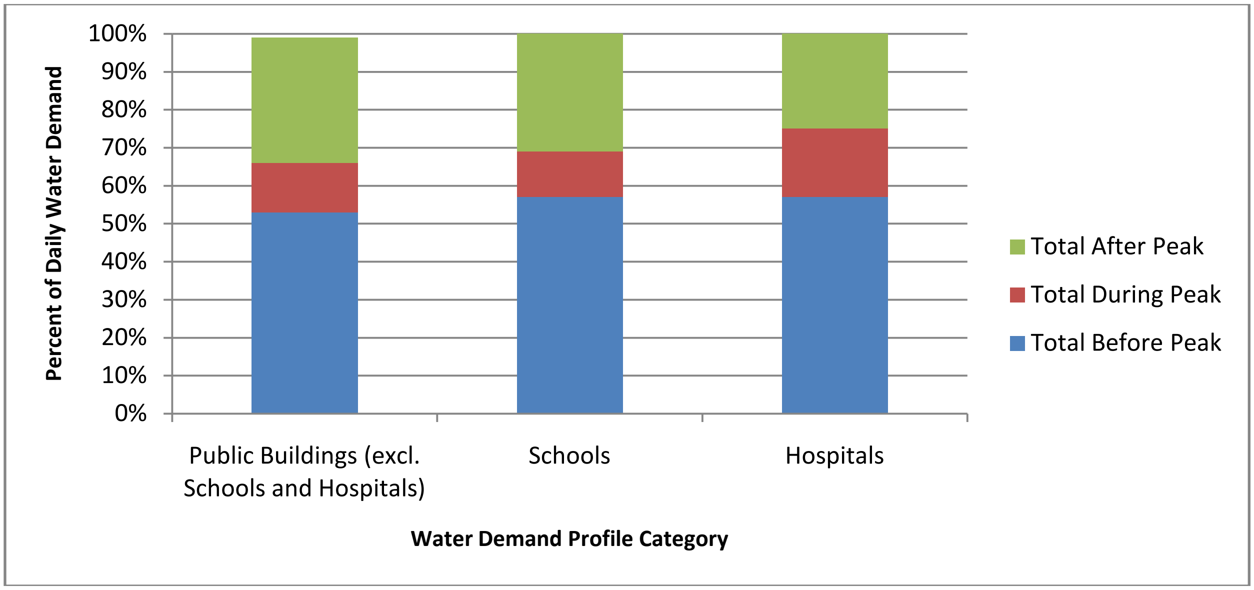
Figure 3: Aggregated Daily Water Demand - Urban Irrigation



- The water demand profile for urban irrigation is a mirror image of other end-user categories. The peaks occur during the night, and day-time irrigation use is relatively minor. The afternoon peaks occur after the energy peak demand period.
- Urban irrigation end-users showed only about four percent of their daily use occurring during the peak energy demand period.

1.3.4 Public Buildings

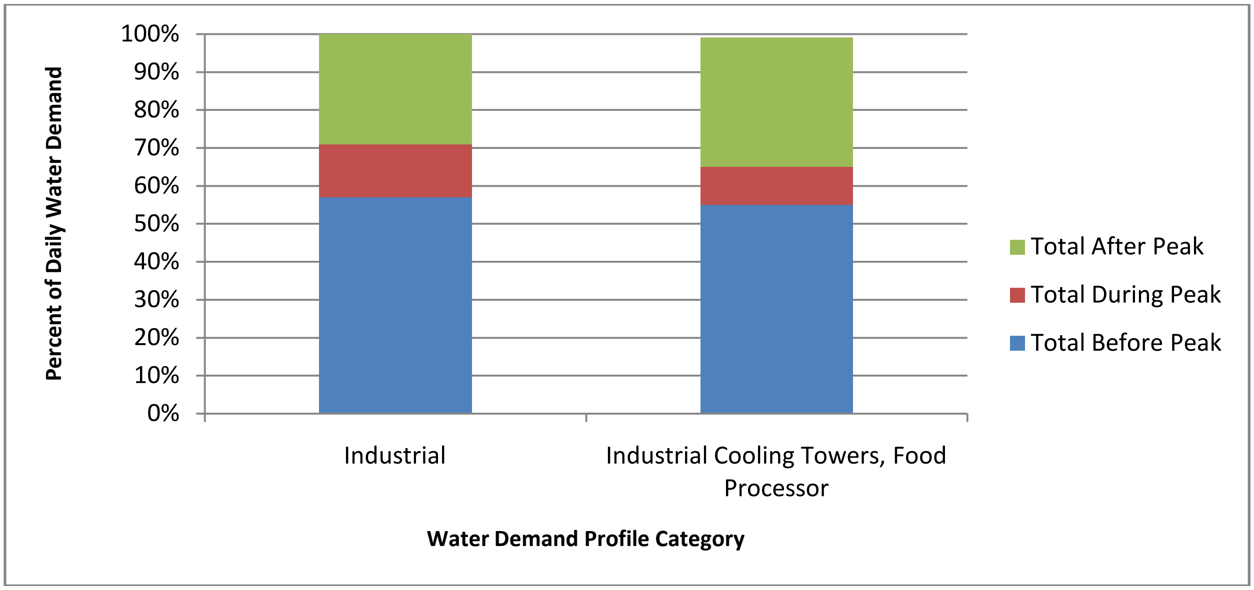
Figure 4: Aggregated Daily Water Demand - Public Buildings



- Public Building sub-categories varied in daily indoor water use patterns. Where outdoor irrigation was measured, it tended to occur during the late night and early morning hours.
- Water demand coincident with the peak energy demand period varied across the Public Building groups from 12 to 18 percent.

1.3.5 Industrial

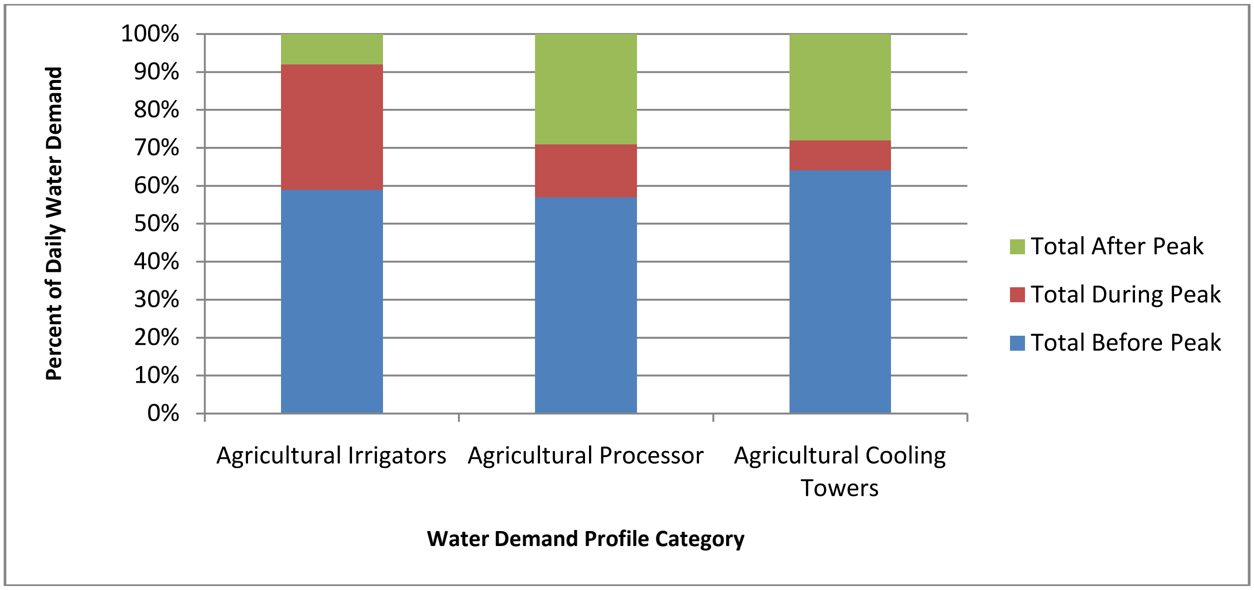
Figure 5: Aggregated Daily Water Demand - Industrial



- Industrial sites' daytime water use tended to include process and continuous applications. Irrigation tended to occur during the midnight hour.
- Industrial end-users use nearly 14 percent of their total daily water during the peak energy demand period.

1.3.6 Agricultural

Figure 6: Aggregated Daily Water Demand - Agricultural



- Agricultural sites' varied rather dramatically depending on the type of facility being considered. Daytime water use tended to be dominated by irrigation for agricultural irrigators and split between process and continuous uses for agricultural processors. Nighttime use was similar to daytime use for agricultural processors and almost non-existent for agricultural irrigators.
- Agricultural sub-categories varied in the percentage of daily water use occurring during the peak energy demand period from 8 to 33 percent.

1.4 Conclusion

The *End-use Water Demand Profile Study* (Study 3) supports the analysis of embedded energy in water by providing more accurate hourly water use profile data than were previously available. This will facilitate estimating the embedded electricity and natural gas savings and resultant avoided costs derived from the installation of water savings measures in residential and non-residential retail water customer categories. California end-user water demand profiles provided by Study 3 contribute to a better understanding of the opportunities for linking water-efficiency and energy-efficiency programs. Findings can be used to help target water conservation efforts that also lead to energy savings.

Hourly demand patterns determined in Study 3 can be used to model overall water agency demands in a way that show how changes in use by one category affect the hourly demand patterns for the system as a whole, and in wastewater load generation. The results from the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*[9] study

[9] G.E.I. Consulting and Navigant Consulting, Inc., *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*.

can then be used to determine how changes in the hourly water and wastewater load profiled affect the energy requirements at the water agency level. In that way, Study 3 results complement those of the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles* study to show the energy relationships in water treatment systems. This earlier study confirmed just how variable water agency configurations can be, depending on factors such as the size of their distribution system, topology of their service areas, and technologies used to treat water.

While this study, by itself, does not lead to any conclusions about whether changes in hourly water demand patterns may affect utility energy requirements, its results can be used as inputs to the models of water system operations developed to investigate relationships between retail water demand patterns and utility energy demands. With the right combination of water agency treatment and delivery capacity, treated water storage and hourly end-user water demand patterns, it should be possible to significantly reduce water agency energy demands during the peak energy demand periods. Note that even with this understanding of water agency operations, additional information will be necessary to link the timing of the effect of water conservation at a customer site with energy use at the water agency site.

2 Background and Introduction

In Decision 07-12-050[10], issued December 20, 2007, the California Public Utilities Commission (CPUC) authorized water-energy pilot projects and three studies designed to (a) validate claims that saving water can save energy, and (b) explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. "Embedded energy in water" refers to the amount of energy that is used to collect, convey, treat, and distribute a unit of water to end-users, and the amount of energy that is used to collect and transport used water for treatment prior to safe discharge of the effluent in accordance with regulatory rules. The authorized research is designed to characterize and quantify the relationships between water and energy use by water and wastewater agencies, and to determine the range of magnitudes and key drivers of embedded energy in water. The results from this research are intended to provide a better understanding of how energy is used in the California water industry, and will be used by the CPUC to help determine whether future programs to conserve water, thereby reducing the amount of energy "embedded" in the water, should be added to IOU energy efficiency portfolios.

As part of this effort, Aquacraft conducted the third of these authorized studies, the *End-use Water Demand Profile Study* (hereinafter "Study 3"), which was designed to supplement existing data and, in so doing, provide a variety of accurate hourly water use profiles. D.07-12-050 describes the need forinformation to be used to translate water conservation measure installation "into a change in the water demand profile that can then be compared with the water demand profile at the water agency to derive the effect a measure would have on the agency's energy load," and authorized Study 3 "to conduct in-line metering on selected customer samples and determine the water use shapes for these uses."[11]Data collected for this research may be used to update the CPUC Water-Energy Measure Calculator,[12]a tool used to estimate the embedded electricity and natural gas savings and resultant avoided costs derived from the installation of water savings measures in residential and non-residential retail water customer categories.

The earlier two studies funded as part of this overall research include the*Statewide and Regional Water-Energy Relationship*,[13]which developed a predictive model of the functional relationship between wholesale water deliveries in California and the energy used to deliver that water, and the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles Study*,[14] which characterized and quantified the relationships between water and energy use by water and wastewater agencies. This latter study confirmed just how variable water agency configurations can be, depending on factors such as the size of their distribution systems, topology of their service areas, and technologies used to treat water. Note that even with this understanding of water agency operations, additional information will be necessary to link the timing of the effect of water conservation at a customer site with energy use at the water agency

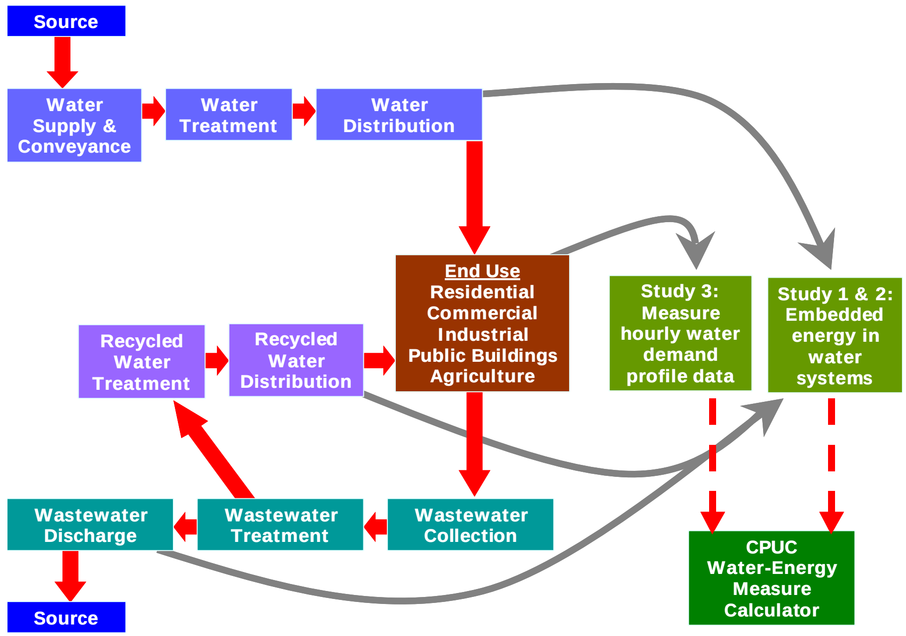
[10] CPUC D. 12-07-050, December 20, 2007. http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/76926.htm
[11] Ibid, 77.
[12] For more on the Calculator see http://www.doe2.com/download/Water-Energy/WaterSavingMeasures-Calculator-v3.pdf
[13] G.E.I. Consulting and Navigant Consulting, Inc., managed by California Institute for Energy and Environment, *Statewide Regional Water-Energy Relationship* (San Francisco: California Public Utilities Commission, 2010).
[14] G.E.I. Consulting and Navigant Consulting, Inc., managed by California Institute for Energy and Environment, *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles* (San Francisco: California Public Utilities Commission, 2010).

site. Table 5 outlines the pilot program evaluations and studies authorized in D.07-12-050. Figure 7 provides a simple picture of the linkages between the information developed in the three embedded energy in water studies.

Table 3: Embedded Energy in Water Studies

Study Name	Report Date	Objective/Topic	Conducted By/Author	Available for Download
Embedded Energy in Water Pilot Programs Process Evaluation ("Pilot Evaluation")	2010	Assess pilot program implementation and customer satisfaction.	ECONorthwest, et al.	• Report
Embedded Energy in Water Pilot Programs Impact Evaluation ("Pilot Evaluation")	2011	Evaluate the impacts of pilot programs offered by the IOUs to save water/energy.	ECONorthwest, et al.	• Report
Statewide Regional Water-Energy Relationship ("Study 1")	2010	Develop a predictive model of the functional relationship between wholesale water deliveries in California and the energy used to deliver that water	GEI Consultants, Inc. and Navigant Consulting, Inc.	• Statewide and Regional Water-Energy Relationship Model • Report
Water Agency and Function Component Study and Embedded Energy-Water Load Profiles ("Study 2")	2010	Characterize and quantify the relationships between water and energy use by water and wastewater agencies	GEI Consultants, Inc. and Navigant Consulting, Inc.	• Access database, program and meter data • Water Energy Load Profile (WELP) database • Report
End-use Water Demand Profiles ("Study 3")	2011	Develop 24-hourly demand profiles for water end uses	Aquacraft, Inc.	• Preliminary Information

Figure 7: California Water Use Cycle and Linkages



Fresh water	Recycled Water	End Uses	EEW Studies	Wastewater	W-E Calculator

2.1 Relationship between End-user Water Demand Profiles and Energy Use by Water Agencies

The following pro-forma demonstration illustrates the relationship between end-user water demand profiles and energy use by water agencies, and how an understanding of the timing of water demands can assist with management of energy loads by water agencies.

Figure 9 shows typical water demand profiles for six categories of retail water customers: residential indoor, irrigation, commercial, industrial, public and institutional users. These profiles are based on various data sources,were developed prior to the initiation of Study 3and are meant to represent typical hourly demand patterns for their respective customer categories. Each curve shows the percent of the total daily water demand for the category occurring in each hour of the day.

Figure 8: Treated Water Demand Profiles[15]

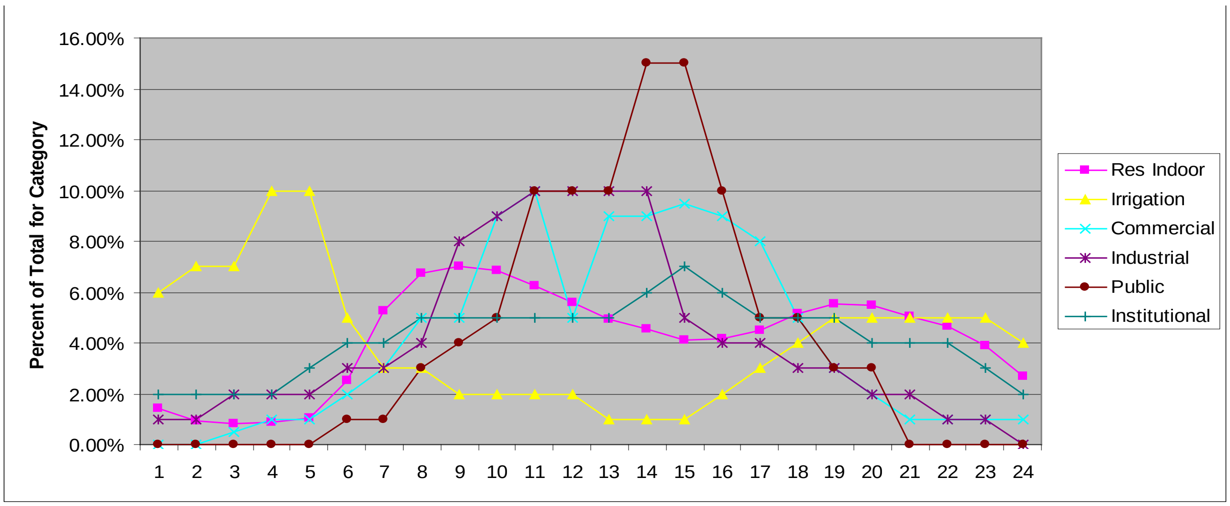


Figure 11 shows the total water demand on the water treatment facility that is derived from knowing the total number of customers in each category, their average summer day demands, and the respective demand profiles for each category. Note that the graph shows the volume of water demanded for each category in millions of gallons (MG) during each hour of the day. The total retail demand for the entire group is shown as the top line in the graph. These range from a minimum of 1.16 MG to a maximum of 2.63 MG during the course of the day. Of these retail water demands, 17 percent occur between 2:00 and 5:00 PM, during the peak energy demand period in California.

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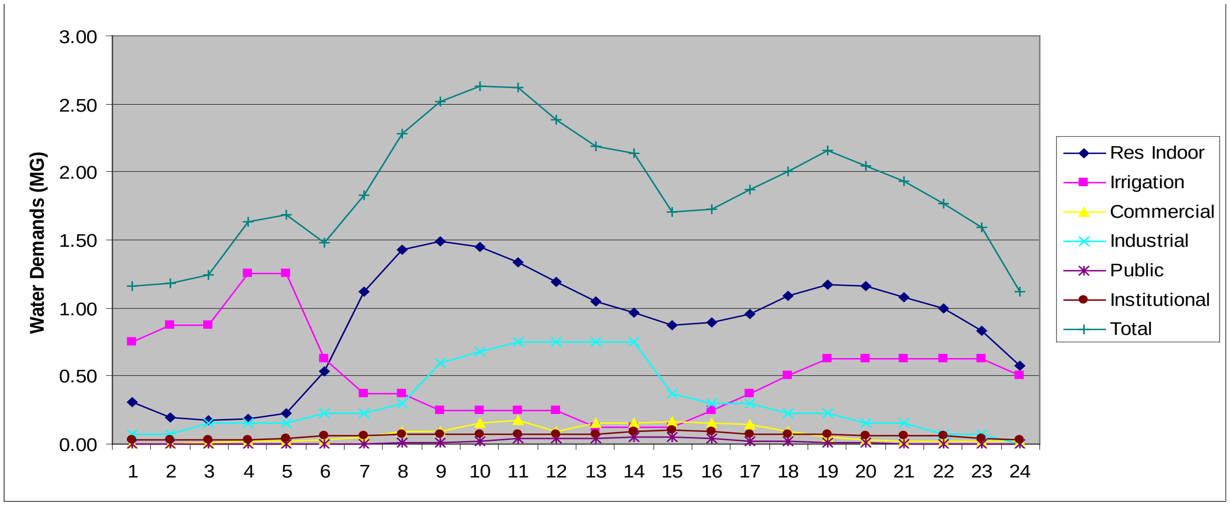
[15] Data from Peter W. Mayer, William B. DeOreo and Eva Optiz, *Residential End Uses of Water* (Denver: American Water Works Association Research Foundation, 1999), and pro-forma from various data.

Figure 9: Hourly Retail Demands Derived From Demand Profiles[16]



There are two ways of reducing the embedded energy in the water that is treated and delivered by the local water agency. First, the total amount of water that needs to be treated and delivered can be reduced, which will also reduce the amount of energy consumed by the water agency. Second, the time pattern of the water demands can be modified to reduce the amount of water load during peak energy demand periods. This shifts water and energy loads to less expensive, off-peak energy demand periods.

To the extent that end-user water demands occur during peak energy demand periods, any water conservation program that reduces water use during that time may reduce the peak energy demands for the water agency. However, this will depend on the time lag between water treatment and delivery by the agency, and water use (and/or conservation) at the customer site. Using storage to meet water demands during peak energy demand periods is another way to reduce peak energy demands by reducing the rate of production at the water treatment plant. Since most water treatment plants are designed to meet the peak day water demand of their systems, on most days of the year they have excess capacity. This excess capacity can be used to replenish system-treated water storage drawn down during the peak energy period should the water treatment system is curtailed to avoid the peak energy demand period. With the right combination of water agency treatment and delivery capacity, treated water storage and hourly end-user water demand patterns, it should be possible to significantly reduce water agency energy demands during the peak energy demand periods.

Clearly, knowledge of the timing of water demands at the end-user level can assist with the development of energy conservation strategies. For this reason, Study 3 was conducted to update and refine the existing water demand profiles.

[16] Data from Peter W. Mayer, William B. DeOreo and Eva Optiz, *Residential End Uses of Water* (Denver: American Water Works Association Research Foundation, 1999), and pro-forma from various data.

2.2 Study Goals

The primary goal of Study 3 is to provide accurate current California end-user hourly water demand profiles in order to better understand the opportunities for linking water-efficiency and energy-efficiency programs. A related objective is to quantify the percent of total daily water demands that occurred during the peak daily electric demand period from 2:00 PM to 5:00 PMfor end-user (customer)[17] categories.In D.07-12-050, the CPUC notes that there are two sources of energy savings associated with water use efficiency: cold water savings related to water agency activities (both upstream and downstream of the end-user); and hot water savings related to energy used to heat water for water demand profile category purposes. The Decision states that "it is the former that comprises the embedded savings opportunities that are the focus of these applications."[18]Therefore, this researchexamined cold-water use for six end-user categories, plus urban irrigation. This report documents the water demand profiles of these categories, and elaborates on the methodologies used to determine them.

2.3 Data Collection and Analysis

Much of the data required for Study 3had already been collected in earlier water demand profiling studies conducted by the author.[19] As a result, it was possible to generate much of the information needed for Study 3 without having to undertake additional field work in the residential single-family and commercial end-user categories. To supplement existing data, new flow traces were collected from customers in water agencies located in PG&E, SCE and SDG&E service territories.It was not possible to select samples that were statistically representative from each of these categories, but the researchers attempted to obtain examples from the most important water using components of each.Table 7 summarizes the water demand profiles that were measured, the sample size, and type of data collected for each end-user category.

[17] "End-user" is used instead of "customer" when discussing Study 3 participants to avoid confusion related to references to water agency customers and energy utility customers.

[18] CPUC D. 12-07-050, 8.

[19] For example, Aquacraft maintains a detailed end-use hourly demand profile database from a sample of more than 700 single-family homes sampled from 15 geographically distributed water utilities in California as part of the California Single Family Water Use Efficiency Study (CSFWUES). See Section 4.2, Appendix A: Sites in Existing Database and Appendix B: California Single Family Water Use Efficiency Study Information for more information on sources of existing data.

Table 4: End-user Category, Water Demand Profile Category, Sample Size and Data Source

End-user Category	Water Demand Profile Category	Sample Size	Source of Hourly Demand Profile Data
Residential: -Single-family -Low-income Single-family	-Baths -Showers -Toilets -Clothes Washers -Dishwashers -Faucets -Leaks -Other -Irrigation	Existing: 361 single-family homes Existing: 54 low-income single-family homes	Existing database
Residential: -Low-income Multi-family		New: 159 individually-metered units	EBMUD, IRWD and City of San Diego customer flow traces
Commercial: -General Retail -Hotels and Motels -Offices -Supermarkets -Restaurants -Large Retail[20] -Laundromats -Car Washes -Automotive Service[21]	-Continuous -Indoor/Process -Outdoor/Irrigation	Existing: 35 sites New: 14 sites Total: 49 sites	EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Urban Irrigation	-Continuous -Indoor/Domestic -Outdoor/Irrigation	Existing: 7 sites New: 12 sites Total: 19 sites	EBMUD, City of Santa Rosa, IRWD, CVWD and City of San Diego customer flow traces, and existing database
Public Buildings: -Public Buildings -Schools -Hospitals	-Continuous -Indoor/Domestic -Outdoor/Irrigation	Existing: 65 sites New: 16 sites Total: 81 sites	EBMUD, City of Santa Rosa, CVWD, IRWD and City of San Diego customer flow traces, and existing database
Industrial	-Continuous -Process -Outdoor/Irrigation	Existing: 5 sites New: 12 sites Total: 17 sites	EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Agricultural	-Continuous -Process -Outdoor/Irrigation	New: 10 sites	EBMUD, City of Petaluma, City of Lodi, Cal Water, CVWD and City of San Diego customer flow traces

[20] Large retail was defined for this study as comprising regional shopping centers or large retail outlet "superstores."
[21] This sub-category includes gas stations with convenience marts, drive-through and self-car washes, and auto shops.

The combination of existing and new data outlined in Table 7 was analyzed using flow trace analysis to generate hourly demand profiles as a percent of total daily use. Flow trace analysis, described in more detail in Section 4.6, obtains precise information about water use patterns: Where, when, and how much water is used by a variety of devices. On small meters, which give many pulses per gallon, it is generally possible to identify devices such as toilets, showers, baths, faucets, clothes washers, dishwashers, hand-held and automatic irrigation systems, evaporative coolers, home water treatment systems, leaks, and others. On large meters, which include most of the commercial, public building[22] and industrial sites, the analysis can identify indoor, outdoor and continuous uses, but, due to a lack of precision from the meter, the analysis cannot differentiate individual fixtures and appliances.

Flow trace data gathering involves attaching a data logger to customer water meters. A software package designed by Aquacraft (Trace Wizard©)[23] was used to disaggregate many of the flow traces into the water demand profile categories. This methodology has been used in numerous demand profiling studies in California, 14 other U.S. states and around the globe since 1996 to analyze flow trace data collected from customer water meters.

2.3.1 Drought Restrictions and Data

In June 2008, Governor Schwarzenegger issued a statewide drought declaration, with Executive Order S-06-08 directing the California Department of Water Resources (DWR) to take immediate actions to address the state's current and anticipated drought and associated water supply/delivery limitations. In order to determine the likelihood that drought restrictions might affect the validity of Study 3 results, each of the agencies serving territories from which data were collected was questioned as to what, if any, drought restrictions were in place during the logging period. If serious restrictions were found, the results were to be either modified to account for the restrictions or, if this was not possible, then qualified to alert users of potential problems.

Table 9 shows water agency areas where drought restrictions existed during data collection. Only one water agency, the City of San Diego, had active drought restrictions in place during this period. Although none of the other agency areas included had imposed restrictions, it should be noted that there was a general understanding that the state was in a declared drought emergency, which may have affected water usage.

As only one site was operating under active drought restrictions, it seems logical to assume that such restrictions had only a minimal impact on hourly water use profiles. It is unlikely the San Diego drought restrictions affected domestic or business operations, but they might have caused a decrease in water used for irrigation. The irrigation restrictions were not likely to cause a change in the general time of day that customers watered outdoor areas, but would cause watering to occur on fewer days, and for shorter periods of time. The existing data is, thus, likely to show similar hourly usage patterns as a percent of total use, but with lower total

[22] Per terminology used in D.12-07-050, Study 3 uses the term "public building" for facilities owned and/or operated by federal, state and local governmental agencies. In other contexts the term "institutional" is used to describe such facilities.
[23] See Appendix C: Flow Trace Analysis and Trace Wizard for more information.

volumes. However, drought conditions did affect the researchin another way – by creating a heavier workload for the agency staffs, which caused some delays in data acquisition.

Table 5: Water Agency Drought Restrictions

Water Agency	Drought Restrictions	Comments
Cal Water	No	N/A
City of Lodi	No	N/A
City of Petaluma	No	N/A
City of Santa Rosa	No	N/A
City of San Diego	Yes	During data collection the City of San Diego was at a Level 2 Drought Condition.[24]
CVWD	No	N/A
EBMUD	No	N/A
IRWD	No	IRWD has tiered water rates, a "conservation rate structure." Accounts that exceed their allocation pay more in varying increments.

2.3.2 Cool Weather Patterns During Logging Period

Many of the non-residential Study 3 site water use profiles were logged during June, July and August 2010. During this time, regions of the San Francisco Bay Area were experiencing the coolest summer in 40 years, though the weather was normal to average throughout the rest of the state during this period.[25] It is possible that total water use by cooling towers (which were used at several industrial and public building sites studied) declined during unusually cool summer days relative to historic summer days. However, without more detailed onsite water use reviews that included sub-metering of water using features such as cooling towers, it was not feasible to perform a correction to the data.

[24] Level 2 is considered "First Stage Drought" and requires voluntary conservation, heightened awareness and increased preparation. For more detail on what this entails, see the California Drought Contingency Plan at http://www.waterplan.water.ca.gov/docs/meeting_materials/drought/2010.08.10/CA_Drought_Contingency_Plan-Public_Review_Draft-081010.pdf. Additional drought information can be found on the California DWR drought website (http://www.water.ca.gov/drought/).

[25] Western Regional Climate Center California Climate Tracker http://www.wrcc.dri.edu/ .

3 Literature Review

The literature discussed below summarizes the body of knowledge relevant to Study 3 goal (i.e., to provide accurate current California end-user water demand profiles in order to better understand the opportunities for linking water-efficiency and energy-efficiency programs.)

3.1 Water-related Energy Use Literature

California's Water – Energy Relationship Final Staff Report CEC-700-2005-011-SF[26]

Serving as the impetus for the Embedded Energy in Water Studies, the CEC's*California's Water – Energy Relationship Final Staff Report CEC-700-2005-011-SF*, prepared in support of the CEC's*2005 Integrated Energy Policy Report CEC-100-2005-007CM (2005 IEPR)*[27], provided insights to the linkages between California's water and energy demands. The report estimates that 19 percent of the state's electricity demands and 32 percent of its non-power-plant natural gas demands are water-related..The report goes on to state that "[w]ater supply and treatment account for 22 percent of water-related electricity consumption; 70 percent is required by urban [i.e., non-agricultural] water users and 30 percent by agriculture. On-farm agricultural water use consumes additional energy, estimated at 15 percent of water-related electricity demand. Residential, commercial, and industrial end uses combined represent 58 percent of the electricity consumed. Wastewater treatment accounts for 4 percent."[28]

Most important to Study 3 are the CEC estimates of the water-related energy use for urban water supply and treatment, and wastewater treatment -and that cold-water energy use of these categories accounts for 3.8 percent[29] of California's electricity consumption. The water demand profiles produced for Study 3 will aid in understanding how various end-uses are contributing to that 3.8 percent. Ultimately, the combined Embedded Energy in Water Studies will help determine the potential for savings within the 3.8 percent.

The *2005 IEPR* offers the following recommendations for reducing the embedded energy in water usage:

- Evaluate and conduct research to better understand the interactions between water and energy within the state.
- Identify new and innovative technologies and measures for achieving energy and water efficiency savings.
- Address potential savings throughout the water cycle, especially in Southern California where the energy intensity of water is greatest.
- Focus on identifying and implementing cost-effective retrofits in the water system that increase efficiency and provide both energy and peak savings.

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[26] California Energy Commission, *California's Water – Energy Relationship Final Staff Report CEC-700-2005-011-SF* (Sacramento: California Energy Commission, 2005).

[27] California Energy Commission, *Integrated Energy Policy Report CEC-100-2005-007CMF* (Sacramento: California Energy Commission, 2005).

[28] California Energy Commission, *California's Water – Energy Relationship Final Staff Report CEC-700-2005-011-SF*, 8-9.

[29] Derived from CEC estimates per the paragraph above, (19 % * 22 % * 70 %) + (22 % * 4 %) = 3.8% of total California electricity use.

- Examine opportunities to increase savings through the development of [time-of-use] water tariffs and meters, along with increased flexibility in water deliveries.[30]

Water Supply-related Electricity Demand in California[31]

Another report prepared for the CEC, *Water Supply-related Electricity Demand in California*, considered when customer water-use-related peak energy demands at the water agency might be shifted to off-peak. That is, this report looked at the "ability to estimate" where a change in the time of use by water customers results in a shift from peak to off-peak energy loading at the water agency. Noting the difficulty in reconciling regionally available water consumption data with data from within electric utility boundaries, the report used the *California Water Plan Update 2005*[32] statewide average water use values. Water supply related peak day energy demands at water/sewer agencies were found to vary between the service areas of PG&E, SCE and SDG&E. Since the residential sector represents the largest share of urban water demand, this report estimates that if homes shifted one half of their indoor and outdoor water use away from peak periods, then demand for on-peak electricity could be reduced by about 300 MW. Water storage by water agencies was also noted for its potential in reducing on-peak energy demands related to water uses.

Supply and Demand Side Water-Energy Efficiency Opportunities[33]

Supply and Demand Side Water-Energy Efficiency Opportunities, a 2007 report prepared for PG&E, estimated the energy required in its service area for multiple water/wastewater agencies to provide water to customers and to treat wastewater. In addition to providing detailed estimates of embedded energy in individual water agency systems, this report also estimated the potential energy savings that might result in cold water savings from water use efficiency measures. Where detailed information about the disaggregate stages of water agency systems was missing, the stages were aggregated. This study found that of the agencies studied, Santa Clara Valley Water District held the greatest potential energy savings from implementing commercial, industrial and institutional water-use efficiency measures.

Climate Change Scoping Plan[34]

The California Air Resources Board's *Climate Change Scoping Plan* recommends a continued focus on using water efficiently as a means to reducing embedded energy demands, thereby reducing GHG emissions. The plan proposes measures targeted at reducing the energy requirements of providing and using potable water, stating "[s]ix greenhouse gas emissions reduction strategies measures are proposed for the Water sector…. Three of the measures target reducing energy requirements associated with providing reliable water supplies and two measures are aimed at reducing the amount of non-renewable electricity associated with

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[30] California Energy Commission, *Integrated Energy Policy Report CEC-100-2005-007CMF*, 151.
[31] Water and Energy Consulting, and the Demand Response Research Center, *Water Supply-related Electricity Demand in California* (Sacramento: California Energy Commission, Public Interest Energy Research Program, 2007).
[32] California Department of Water Resources, *California Water Plan Update 2005* (Sacramento: California Department of Water Resources, 2005).
[33] Green Building Studio, *Supply and Demand Side Water-Energy Efficiency Opportunities Final Report* (San Francisco: Pacific Gas and Electric Company, 2007).
[34] California Air Resources Board, *Climate Change Scoping Plan* (Sacramento: California Air Resources Board, 2008).

conveying and treating water. The final measure focuses on providing sustainable funding for implementing these actions."[35] According to the plan, water-use efficiency has the potential to reduce GHG emissions by as much as 1.4 million metric tons of CO_2 equivalent by 2020..

California Water Plan Update 2009[36]

Further linking state water- and energy-sector policy priorities and recognizing the value of water-use efficiency measures as an action strategy for reducing demand on energy and for the resulting reductions in GHG emissions, Objective 9 in Chapter 7, Volume 1 of the *California Water Plan Update 2009*reads: "Reduce the energy consumption of water and wastewater management systems to mitigate greenhouse gas emissions."[37]Objective 2 in Chapter 7, Volume 1 of the *California Water Plan Update 2009* states:

> As directed by Governor Schwarzenegger, DWR in collaboration with the State Water Resource Control Board (Water Board) and its nine Regional Water Quality Control Boards (Regional Boards), California Energy Commission, the California Public Utilities Commission, the California Department of Public Health, and other agencies will implement strategies to increase regional water supply self-sufficiency and achieve a statewide 20 percent reduction in per capita urban water use by 2020. …
>
> - Local and regional water use efficiency programs - residential, commercial, industrial, institutional, and agricultural - should emphasize those measures that reduce both water and energy consumption, notwithstanding other water management objectives.[38]

California Water Plan Update 2005

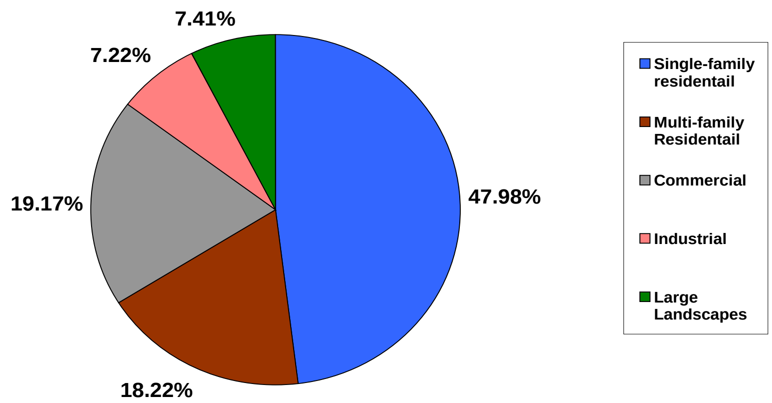
The *California Water Plan Update 2005* includes estimates of water use by five major urban categories: single-family residential, multi-family residential, commercial, industrial and large landscape.[39]

Figure 13:2001 Urban Water Use in California

Figure 13is generated from the 2001 data contained in the *California Water Plan Update 2005* and illustrates that residential single-family uses in California predominate, followed by commercial, residential multi-family, industrial and large landscape.

[35] California Energy Commission, *California's Water – Energy Relationship Final Staff Report CEC-700-2005-011-SF* (Sacramento: California Energy Commission, 2005), 66.
[36] California Department of Water Resources, *California Water Plan Update 2009* (Sacramento: California Department of Water Resources, 2009).
[37] Ibid, 1:7-33.
[38] Ibid, 1:7-12.
[39] California Department of Water Resources, *California Water Plan Update 2005* (Sacramento: California Department of Water Resources, 2005), vol. 3, 1-18.

Figure 10: 2001 Urban Water Use in California[40]

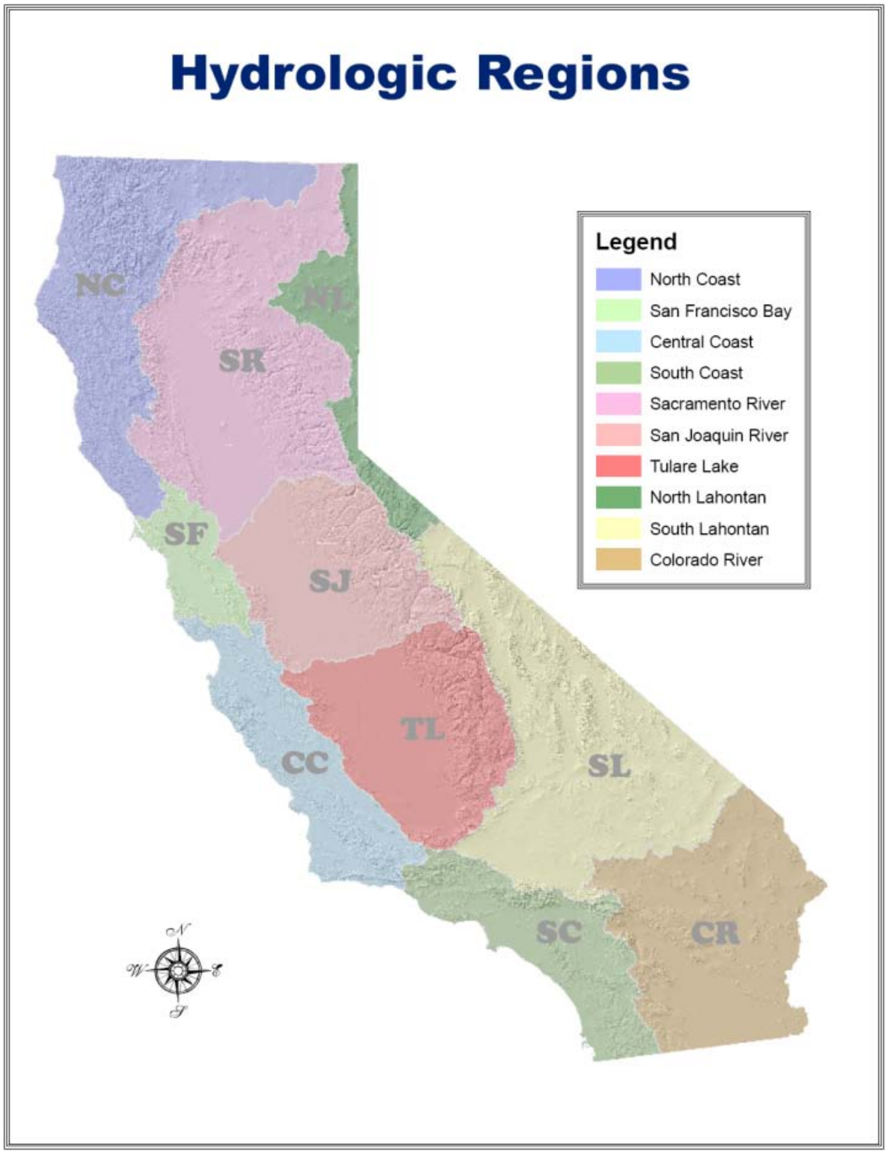


The *California Water Plan Update 2005* divides the planning boundaries for surface and groundwater into ten major hydrologic regions. These regions correspond to the major drainage basins' natural runoff. Each region is then divided into smaller sub-regions for greater detailed planning and data collecting. Figure 15 shows the 10 hydrologic regions throughout California.[41]

[40] Generated from data in California Department of Water Resources, *California Water Plan Update 2005* (Sacramento: California Department of Water Resources, 2005), vol. 3, 1-18, table 1-4. The *California Water Plan Update 2005* categorization does not specifically include agricultural users of potable urban water supplies, which are included in Study 3.

[41] California Department of Water Resources, *California Hydrologic Regions* (Sacramento: California Department of Water Resources, 2005) http://www.waterplan.water.ca.gov/regions/statewide/ (accessed March 2009).

Figure 11: California Hydrologic Regions



Each hydrologic region serves as a planning region, with water supply and usage data recorded for the basin. Table 11 is generated from the 2001 data contained in the *California Water Plan Update 2005* and illustrates how water use data has been categorized and how it has fluctuated from region to region.

Table 6: 2001 Water Use by Category and Hydrologic Region[42]

Hydrologic Region	Single-family Residential	Multi-family Residential	Commercial	Industrial	Large Landscape
North Coast	47.06%	11.79%	11.22%	21.01%	8.92%
San Francisco Bay	41.61%	22.22%	21.41%	6.07%	8.69%
Central Coast	51.47%	18.03%	18.15%	8.61%	3.74%
South Coast	48.81%	17.41%	23.32%	5.53%	4.94%
Sacramento River	47.63%	13.02%	15.78%	9.76%	13.82%
San Joaquin River	49.84%	22.94%	6.51%	14.85%	5.86%
Tulare Lake	48.00%	32.00%	7.00%	10.00%	3.00%
North Lahontan	23.10%	14.21%	21.03%	35.54%	6.11%
South Lahontan	77.06%	8.88%	9.11%	2.55%	2.40%
Colorado River	37.63%	8.64%	28.65%	0.90%	24.18%

These data have been used in earlier water-related energy use studies, however note that it difficult to reconcile DWR water consumption boundaries with IOU service area boundaries.[43]Study 3 used IOU service area boundaries to develop and report water demand profiles for six end-user categories and urban irrigation, providing, for the first time, IOU service area detailed hourly water consumption data, disaggregated by multiple water demand profile categories (including agricultural uses of potable water).

While the California *Water Plan Update 2005* does not specifically mention a need for water demand profiles, it does reiterate that the number one action for achieving sustainability in California's water supply is efficient use of water, and its number one recommendation is to invest in water efficiency. To the extent that energy-use and water-use efficiency are linked, actions taken by the energy sector to enhance energy efficiency through water conservation will also help reach the goal of achieving a sustainable water resource system for the state.

3.2 Customer Category Literature

Only a limited a number of studies have addressed embedded energy in water demands by customer category.Relevant studies are summarized below.

3.2.1 Residential Single-family and Low-income Single-family

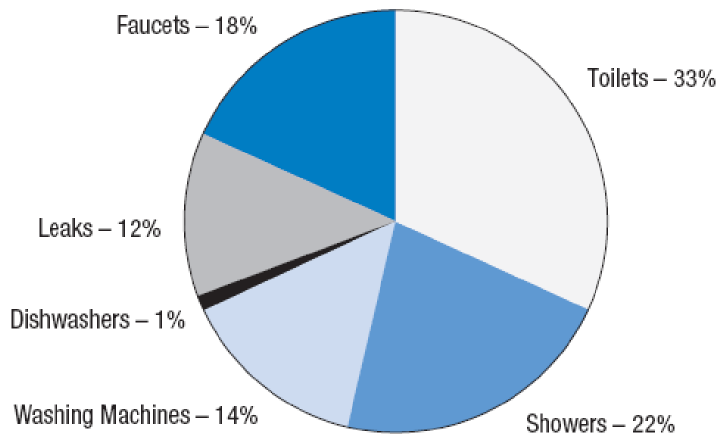
The methodology employed for *Waste Not Want Not: The Potential for Urban Water Conservation in California* combined data from several sources to determine residential indoor

[42] California Department of Water Resources, *California Water Plan Update 2005*, vol. 3, 1-18, tabl 1-4. The *California Water Plan Update 2005* categorization does not specifically include agricultural users of potable urban water supplies, which are included in Study 3.

[43] Water and Energy Consulting, and the Demand Response Research Center, *Water Supply-related Electricity Demand in California* (Sacramento: California Energy Commission, Public Interest Energy Research Program, 2007).

and outdoor demand profiles and penetration of technologies.[44] The report's estimated residential indoor home water demands are shown in Figure 17. This report did not include analyses of hourly water use data.

Figure 12: Estimated 2000 Residential Indoor Water Use[45]



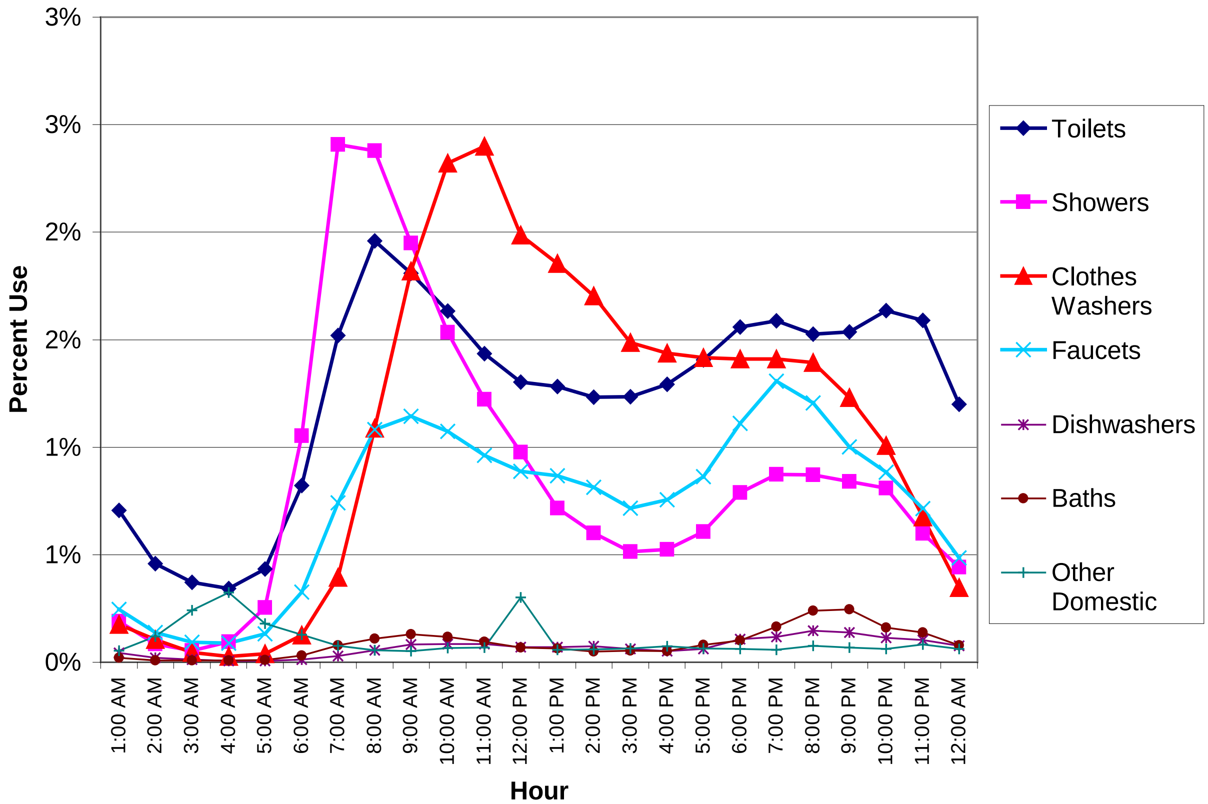
The 1999 *Residential End Uses of Water Study (REUWS*), published by the American Water Works Association Research Foundation (AWWARF), is a comprehensive multi-state collection of single-family household survey and data logger information.[46] The study collected surveys and disaggregated two- week flow trace data collected at 10-second intervals from sites in 12 cities in Colorado, Florida, Arizona, Ontario, Canada and California. The methodology used in the *REUWS* involved a combination of systematic random sampling of study homes in each study site, a survey instrument and flow trace analysis. Approximately four weeks of flow trace data were collected from a total of 1,188 households and disaggregated into end uses of water (e.g., shower, toilet flush and clothes washer cycle). Data were collected by attaching a data logger to household water meters and recording the flow trace information. The flow trace data were collected in two, two-week intervals spaced in time to attempt to capture summer (peak) and winter (off-peak, primarily indoor water use) time frames.

The *REUWS* provides a benchmark for hourly single-family water use patterns for the period 1996-1998 when the data were collected. . The homes in the *REUWS* are generally typical of pre-National Energy Policy Act (EPAct) homes in that few of them were equipped with ultra-low-flush toilets, and fewer had high-efficiency clothes washers.[47] As such they represented a

[44] Peter H. Gleick, Dana Haasz, Christine Henges-Jeck,Veena Srinivasan, Gary Wolff, Katherine Kao Cushing, et al., *Waste Not, Want Not: The Potential for Urban Water Conservation in California* (Oakland, CA: Pacific Institute for Studies in Development, Environment, and Security, 2003).
[45] Ibid, 6, figure ES-2.
[46] Peter W. Mayer, William B. DeOreo and Eva Optiz, *Residential End Uses of Water* (Denver: American Water Works Association Research Foundation, 1999).
[47] Gleick et al., *Waste Not*, *Want Not*, Appendix C: 1. The 1992 EPAct required all toilets sold in the U.S. to be ultra-low flush toilets using a standard 1.6 gallons per flush (gpf). Pre-EPAct homes typically have 5.0 to 7.0 gpf toilets if built before 1978 and 3.5 gpf if built between 1978 and 1992.

good sample of "standard" homes built without any special water conservation features. Data analysis demonstrated that between locations the ranges in the amount and frequency of water use for toilets, showers, washing machines and other fixtures across all the studied cities was significantly similar; thus giving *REUWS* findings significant transfer value. Results of the analyses are shown in Figure 19.

Figure 13: Indoor Hourly Use Patterns, 12 Study Sites[48]



In 2005 a study of single-family water use, the *California Single Family Water Use Efficiency Study (CSFWUES)*, began under a Proposition 50 grant from the California DWR to the Irvine Ranch Water District.[49]The purpose of the study was to obtain current water use information on representative samples of single-family customers in California. This study used a similarmethodology similar to that used for the *REUWS*, and information on indoor and outdoor end uses of water and efficiency levels were important targets of the analysis. Fortunately, the basic data from the study homes in the *CSFWUES*is available and provides a recent picture of detailed water demand load shapes for single-family homes in both northern and southern California. A total of 735 homes from 13 water agencies throughout the state were sampled as

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[48] Mayer et al., *Residential End Uses of Water*, xxxii, figure 5-22.

[49] Aquacraft, Inc., *California Single Family Water Use Efficiency Study* (Boulder: California Department of Water Resources, 2011). The *CSFWUES* report remains in draft form at time of publication. For more on the *CSFWUES*, see Appendix B: California Single Family Water Use Efficiency Study Information.

part of this study. Hourly demand data by end use was extracted from the water use database for inclusion in Study 3 as the most recent and accurate water demand profile data of California's residential single-family homes. Detailed household survey data accompany individual home water demand profiles, enabling determination of income-level category, and electric utility service area.

3.2.2 Residential Multi-family

Waste Not Want Not: The Potential for Urban Water Conservation in California, published by the Pacific Institute, estimates that "there is little difference in per capita shower duration or toilet use between single-family and multi-family residences," but that there are "significant differences in penetration rates of appliances" between these two residential categories.[50] Since there was not much information on the differences between single- and multi-family home water uses they were considered together as "residential."

The *National Multiple Family Submetering and Billing Allocation Program Study* developed a considerable database of annual water use by multi-family customers.[51]These data are not disaggregated by residential unit by individual end uses. Rather, most of the multi-family data are from a single master meter serving a number of units. The primary goal of this study was to quantify differences in annual water use per unit that could be linked to differences in how the residents were billed for water. For each site the total indoor water use and the number of units fed by the meter were known as the primary variables. Billing methods and other factors obtained from surveys were used as explanatory variables of per unit annual water use. This study does not provide information on time of use of water in the residences.

Analysis of Water Use Patterns in Multi-Family Residences, completed in 2008, used a combination of survey responses and billing data from individually metered multi-family residences to search for factors that explained the variations.[52] The explanatory variable included the type of unit (apartment, condominium), its age, and number of residents, bathrooms and bedrooms. As with other studies discussed here, this study did not include flow trace data, so time-of-day analyses could not be conducted.

3.2.3 Commercial

The *Commercial and Institutional End Uses of Water Study* (*CIEUWS*) published by AWWARF collected a great deal of data from existing and new sources on patterns in commercial and institutional water use.[53] This group of water users is highly variable, and it is often difficult to obtain disaggregated water billing data due to the lack of billing data specificity. Most of the information in this report was based on billing data for samples of disaggregated commercial and industrial customers.

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[50] Gleick et al., *Waste Not, Want Not*, 41.

[51] Peter W. Mayer, Erin Towler, William B. DeOreo, Erin Caldwell, Tom Miller, Edward R. Osann, et al., *National Multiple Family Submetering and Allocation Billing Program Study*. (Boulder: Aquacraft, Inc. and East Bay Municipal Utility District, 2004).

[52] William DeOreo and Matt Hayden, *Analysis of Water Use Patterns in Multi-Family Residences* (Boulder: Aquacraft, Inc., 2008).

[53] Benedykt Dziegielewski, Jack C. Kiefer, Eva M. Optiz, Gregory A. Porter, Glen L. Lantz, William DeOreo, et al., *Commercial and Institutional End Uses of Water* (Denver: American Water Works Association Research Foundation and American Water Works Association, 2000).

In order to express the relative importance of commercial sub-categories with respect to overall commercial consumption, the *CIEUWS* used the parameter "scaled average daily use," which has the units of gallons per day per customer (gpdc). The scaled average daily use is calculated as the average annual daily use in the sub-category times the percent of total commercial use attributed to the sub-category. So, in order to have a large scaled average daily use, a sub-category (e.g., car washes) must have customers (e.g., car wash owner/water account holder) who individually use large quantities of water per site, and the sub-category as a whole must use a large portion of the water used by the commercial category overall. Results using this method suggested the following hierarchy of commercial and industrial water use: urban irrigation, schools, hotels, laundries/laundromats, office buildings, hospitals, restaurants, food stores, auto shops, membership organizations and car washes. Five of these categories, schools, hotels, office buildings, restaurants and food stores, were selected for more detailed analysis, which included flow trace collection from which time-of-day use could be derived. Table 13, extracted from a table in the *CIEUWS*, outlines the water use characteristics of the significant commercial and industrial categories.

Table 7: Characteristics of Significant Commercial and Industrial Customer Water Use[54]

Customer Category Description	Average Annual Daily Use (gpdc)	Percent of Total CI* Use	Scaled Average Daily Use (gpdc)
Urban Irrigation	2,596	28.5%	739
Schools and Colleges	2,117	8.8%	187
Hotels and Motels	7,113	5.8%	414
Laundries/Laundromats	3,290	4.0%	130
Office Buildings	1,204	10.2%	123
Hospitals and Medical Offices	1,236	3.9%	48
Restaurants	906	9.0%	80
Food Stores	729	2.9%	21
Auto Shops	687	6.7%	14
Membership Organizations[55]	629	2.0%	12
Car Washes	3,031	0.8%	25

*Commercial/Industrial

The 2003 *Demonstration of Water Conservation Opportunities in Urban Supermarkets* provides accurate measures of the potential for water-use efficiency due to advanced water treatment on supermarket cooling systems.[56] According to this study, appropriately managing the cycles of concentration of cooling systems in California supermarkets resulted in an average 709 Kgal/year water savings. Supermarkets were studied because their refrigeration needs account for a significant portion of water use within the commercial customer category. At each

[54] Extracted from Dziegielewski et al., *Commercial and Institutional End Uses of Water*, 11, table 3.2.
[55] e.g., Business associations and religious organizations.
[56] Aquacraft, Inc., *Demonstration of Water Conservation Opportunities in Urban Supermarkets* (Boulder: California Department of Water Resources/U.S. Bureau of Reclamation, CalFed Bay-Delta Program, 2003).

supermarket studied, refrigeration was found to contribute at least half of the site's total water demand.

Waste Not Want Not: The Potential for Urban Water Conservation in California provides aggregated information of water demands from California's commercial sectors such as schools, hotels, restaurants, retail, offices, hospitals, golf courses and laundries. Offices represent the largest demand (339,000 AF/year), with schools (251,000 AF/year) and golf courses (229,000 AF/year) close behind.[57]

3.2.4 Industrial

Industrial water use is highly dependent on the type of industries and the processes used by each. At this time there is very little water use research in the industrial category. Industrial site data collecting for Study 3 generated detailed water load shapes of industrial water users throughout much of California.

The *California Water Plan Update 2005*, as discussed in section 3.1 and shown in Table 11, quantified the percentages of water being used for industrial purposes in each of the ten hydrologic regions of the state, but it did not go into greater detail about types of industries or times of water use. Other authors have used simple models based on industrial workers within each hydrologic region as a way of projecting industrial water use.[58]

In accordance with the Urban Water Management Planning Act of 1983,[59] every urban water supplier that delivers water to more than 3,000 customers or provides more than 3,000 acre-feet annually must submit an urban water management plan (UWMP) to DWR. Each UWMP provides detailed information of the water supplier's service area demands, and reports water deliveries by customer category. The UWMPs are a good source of information to identify which agencies are the most active in supplying industrial users. Table 15shows the fifteen water agencies solicited to participate in Study 3,[60] and their UWMP-reported disaggregate water deliveries. Several water agencies supply a large number of industrial customers.

[57] Gleick et al., *Waste Not, Want Not*, 27.
[58] David Groves, Scott Matyac and Tom Hawkins, *Quantified Scenarios of 2030 California Water Demand*, vol. 4 of *California Water Plan Update 2005* (Sacramento: California Department of Water Resources, 2005).
[59] Urban Water Management Planning Act (September 22, 1983), *California Water Code,* Division 6, Part 2.6 § 10610-10656 (2010).
[60] Ultimately, eight of these 15 water agencies participated in Study 3. See Table 17 for a list of participating agencies.

Table 8: Example of Disaggregated Water Use Data Available from Urban Water Management Plans

<table>
<tr><th rowspan="2">Water Provider</th><th colspan="8">% Water Use by Customer Category</th></tr>
<tr><th>Single-family</th><th>Multi-family</th><th>Commercial</th><th>Industrial</th><th>Government / Public</th><th>Non-revenue / Unmetered</th><th>Irrigation / Landscape</th><th>Agriculture</th></tr>
<tr><td>City of Davis Public Works</td><td>47%</td><td>20%</td><td>11%</td><td>-</td><td>20%</td><td>-</td><td>3%</td><td>-</td></tr>
<tr><td>City of Petaluma</td><td>59%</td><td>9%</td><td colspan="2">18%</td><td>5%</td><td>-</td><td>9%</td><td>-</td></tr>
<tr><td>City of Redwood City</td><td>52%</td><td>17%</td><td>17%</td><td>-</td><td>-</td><td>1%</td><td>13%</td><td>-</td></tr>
<tr><td>City of San Diego Water Dept.</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>City of Santa Rosa</td><td>55%</td><td>16%</td><td colspan="3">17%</td><td>-</td><td>12%</td><td>-</td></tr>
<tr><td>East Bay Municipal Utilities District</td><td>52%</td><td>17%</td><td>9%</td><td>12%</td><td>5%</td><td>-</td><td>5%</td><td>-</td></tr>
<tr><td>Helix Water District</td><td>51%</td><td>26%</td><td>12%</td><td>3%</td><td>4%</td><td>4%</td><td>3%</td><td>-</td></tr>
<tr><td>Irvine Ranch Water District</td><td>33%</td><td>6%</td><td>10%</td><td>8%</td><td>4%</td><td>-</td><td>29%</td><td>11%</td></tr>
<tr><td>Las Virgenes Municipal Water District[1]</td><td>60%</td><td>5%</td><td colspan="2">6%</td><td>-</td><td>5%</td><td>4%</td><td>0.7%</td></tr>
<tr><td>Los Angeles Dept of Water and Power</td><td>38%</td><td>22%</td><td>21%</td><td>4%</td><td>7%</td><td>8%</td><td>-</td><td>-</td></tr>
<tr><td>North Marin Water District[2]</td><td>59%</td><td>14%</td><td colspan="2">11%</td><td>7%</td><td>10%</td><td>10%</td><td>-</td></tr>
<tr><td>Otay Water District[3]</td><td>52%</td><td>8%</td><td colspan="2">4%</td><td>6%</td><td>1%</td><td>23%</td><td>-</td></tr>
<tr><td>Rincon Del Diablo MWD[4]</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>San Francisco PUC – Retail[5]</td><td>22%</td><td>34%</td><td>-</td><td>-</td><td>2%</td><td>9%</td><td>-</td><td>-</td></tr>
<tr><td>Sweetwater Authority[4]</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

[1] 20% of Las Virgenes water demand is from other categories: Recycled & Non-Domestic, Detector Check and Temporary/Other
[2] Represents 2004 Marin water use and is shown as percentage of the Total Billed Use. Non-revenue represents percent of total billed and non-billed.
[3] 6% not listed is in an "Other" category in the Otay UWMP
[4] Both Rincon Del Diablo and Sweetwater UWMP were unavailable at Department of Water Resources Office of Water Use Efficiency & Transfers http://www.owue.water.ca.gov/urbanplan/uwmp/uwmp.cfm
[5] San Francisco PUC UWMP breaks Commercial & Industrial into various sub-categories. Categories listed reflect "In-city Customers" only.

Waste Not Want Not: The Potential for Urban Water Conservation in California provides estimates of water use by various industries, however, water demand profiles are not provided. Annual water use by California industries is reported as follows:

- Beverage processing facilities: 45 percent for processing and 5 percent for cooling
- Textile industries: 90 percent for processing and 5 percent for cooling
- Paper and pulp industries: 88 percent for processing and 4 percent for cooling
- Metal fabricating industries: 67 percent for processing and 15 percent for cooling

- High tech industries: 70 percent for processing and 20 percent for cooling
- Petroleum refining industries: 6 percent for processing, 57 percent for cooling and 34 percent for boilers.[61]

The U.S. Department of the Interior's Bureau of Reclamation (BOR) Water and Energy Efficiency Program report, *Cataloguing Commercial, Industrial, and Institutional Customer Classes,* is focused on assessing potential opportunities, identify barriers, and examine local and statewide benefits of a regional program that enables water, wastewater and energy utilities to create incentives that will promote the installation of water and energy efficiency measures within the industrial, commercial and institutional sectors throughout southern California.[62]

3.2.5 Public Buildings

At the time of publication, there waslimited research in the public buildings category. The *CIEUWS*provides information on water use at schools and colleges, and hospitals and medical offices. Schools and colleges primarily use water for domestic purposes (49 percent) and landscaping (37 percent). For hospitals and medical offices, domestic usage accounts for 33 percent, cooling for 31 percent and landscaping only 9 percent.[63]

3.2.6 Agriculture

There is little information related to water agency delivered potable or recycled water use by agricultural processing and cold storage facilities in California. The source of water to agricultural facilities is highly variable in the state and can be from either an on-site groundwater well or delivery from a local water agency or district. Since there is no regulation requiring reporting of the volume or how such water is used by these industries, most information has been a result of specific surveys of facilities that are willing to release this information. Water agencies keep records of total potable water delivered to such facilities[64]

According to the 2005 UWMP, some water agencies provide varying percentages of total water deliveries to agricultural customers. For example, 11 percent of IRWD and 0.7 percent of Las Virgenes Municipal Water District water deliveries are for agricultural customers (see Table 15).

Waste Not Want Not: The Potential for Urban Water Conservation in California provides information on water use in meat and dairy processing, and preserved fruits and vegetable processing.[65] The report shows that processing and cooling (refrigeration) constitute the largest water demands at these facilities. Water use at these facilities is reported as follows: Meat facilities use 58 percent for processing and 33 percent for cooling; dairy facilities use 23 percent for processing and 71 percent for cooling; and preserved fruits and vegetable facilities use 73

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[61] Gleick et al., *Waste Not, Want Not,* Appendix F.
[62] Bureau of Reclamation, *Cataloguing Commercial, Industrial, and Institutional Customer Classes,* vol. 2, *Water and Energy Efficiency Program for Commercial, Industrial, and Institutional Customer Classes in Southern California* (Washington, DC: U.S. Department of the Interior, Bureau of Reclamation, 2009).
[63] Dziegielewski et al., *Commercial and Institutional End Uses of Water*, 18-21.
[64] D.L. Scruggs (Chief, Water Conservation and Land and Water Use Section, California Department of Water Resources San Joaquin District), interview by Andrew Funk, 2009.
[65] Gleick et al., *Waste Not, Want Not*, Appendix F.

percent for processing and 22 percent for cooling. The percentage use originating from water agency delivered potable or recycled water is not indicated.

More recent research out of the University of California, Davis, the *Benchmarking Study of the Refrigerated Warehousing Industry Sector in California*, performed a survey of refrigerated warehouses used to store perishable foods (i.e., meat, poultry and dairy products, and fruits, vegetables and processed foods).[66] It was estimated that in 2004 in California there are 309 million cubic feet of storage in publically-owned warehouses and 139 million cubic feet in privately-owned ones. This refrigerated storage accounts for an estimated 20 percent of the state's food industry's energy demand. The study set targets for energy efficiency improvements in refrigerated warehouses by using survey data to develop benchmarks of energy performance. The research approach, however, did not include water use measurements or the embedded energy in water use for refrigeration.

[66] Paul Singh, *Benchmarking Study of the Refrigerated Warehousing Industry Sector in California* (Sacramento: California Energy Commission, Public Interest Energy Research Program, 2008).

4 Methodology

4.1 Overview

The following summary series of tasks was conducted for each Study 3 end-user category:

- Task 1. Assemble relevant existing data
- Task 2: Solicit participation from key water/wastewater agencies
- Task 3. Identify Study 3 site candidates
- Task 4. Obtain historic billing data from participating water agencies
- Task 5. Select sample
- Task 6. Collect data
- Task 7. Disaggregate flow trace data using Trace Wizard
- Task 8. Develop central database and demand profiles
- Task 9. Analyze results
- Task 10: Prepare report on findings

4.2 Existing Data

Aquacraft maintains a collection of flow trace data from a broad range of residential and commercial customers from which end-use water demand profiles can be created. These data were evaluated for their usefulness and applicability to Study 3, and were employed in analyses as appropriate. After assessing these data in light of Study 3 needs, site selection for collecting new flow traces was undertaken in order to focus on end-uses that were not well represented in existing data. From the existing data, a total of 415 single-family residential sites, and 112 non-residential and urban irrigation sites were included in the analysis.

The data from existing sites come from a series of previous studies. Commercial data come from the sites analyzed as part of the *CIEUWS*,[67] and from audits conducted in 2002 for the Sacramento Regional Water Authority which were never part of a published report. Data for supermarkets were obtained from the study of conservation opportunities in five supermarkets in Southern California.[68]Additional commercial and industrial data were obtained from research conducted for the City of Westminster, Colorado.[69]

Descriptions of the numbers and types of sites included in Study 3 from existing data are provided in the sections of the report that describe each category. It should be noted that existing data sites were selected due to theirsimilarity to the new sites from which data were collected for Study 3.For details on sites in the existing database, see Appendix A: Sites in Existing Database.

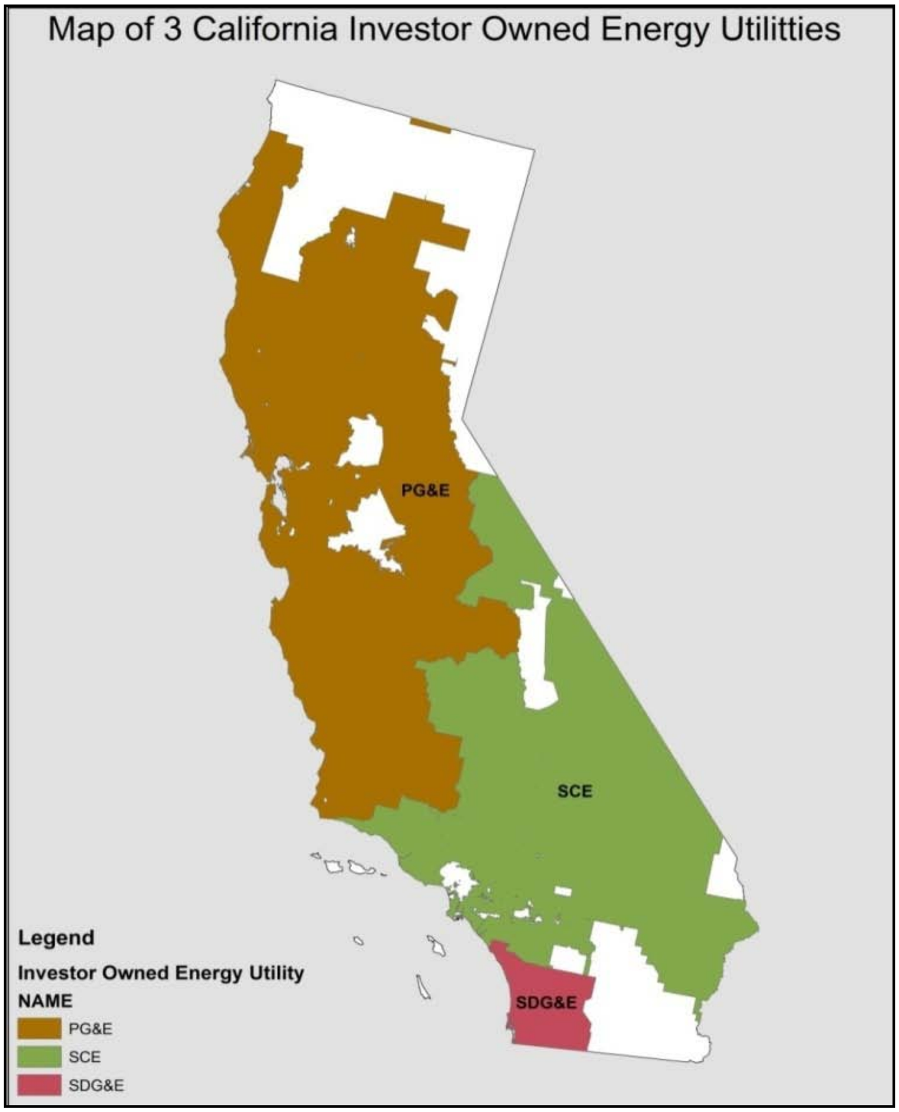
[67] Dziegielewski et al., *Commercial and Institutional End Uses of Water*.
[68] Aquacraft, Inc., *Demonstration of Water Conservation Opportunities in Urban Supermarkets*.
[69] Aquacraft, Inc., *Comparison of Demand Patterns Among Residential and CI Customers in Westminster, Colorado* (Boulder: Aquacraft, Inc., 1998).

4.3 *Water Agency Involvement*

4.3.1 Link to Use of Electric Energy

Hourly water use data was collected from end-users within the service areas of each of the three California IOUs that provide electric service (PG&E, SCE and SDG&E).[70] The focus of this study was on electric use, rather than natural gas use, since the purpose of the research was to develop end-use specific load profiles that may later be used together with energy-use load shapes to assess the value of electric energy efficiency programs. Figure 21 shows the service areas of IOUs that provide electricity.

Figure 14: California Electric-service IOU Service Areas



Eight water agencies within these IOU service areas participated in Study 3:

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[70] SoCalGas, the fourth California IOU, was not included as it does not provide electric service.

- Five in the PG&E service area:
    - Cal Water
    - City of Lodi
    - City of Petaluma
    - City of Santa Rosa
    - EBMUD
- Two in the SCE service area:
    - CVWD
    - IRWD
- One in the SDG&E service area:
    - City of San Diego

Table 17 describes each participating water agency.

Table 9: Study 3 Water Agencies

Water Agency	IOU Service Area	Description
California Water Service Company (Cal Water)	PG&E	The San Jose-based company serves more than 460,000 customers through 28 Customer and Operations Centers throughout California. For Study 3 purposes, only Centers and customers located in the PG&E service area were considered.
City of Lodi Public Works	PG&E	Provides water and wastewater services to Lodi's 70,000 residents and businesses.
City of Petaluma Water Resources and Conservation Department	PG&E	Maintains water and sewer service to 60,000 customers in the City of Petaluma.
City of San Diego Water Department	SDG&E	Serves about 1.3 million customers throughout San Diego's metro area
City of Santa Rosa Utilities Department	PG&E	Serves nearly 50,000 residential and commercial customers in Santa Rosa, and operates sub-regional wastewater treatment and disposal.
Cucamonga Valley Water District (CVWD)	SCE	Serves 186,000 customers in the City of Rancho Cucamonga, portions of the cities of Upland, Ontario and Fontana, and some unincorporated areas of San Bernardino County
East Bay Municipal Utility District (EBMUD)	PG&E	Serves over 1.2 million water and wastewater customers in parts of Alameda and Contra Costa counties on the eastern side of the San Francisco Bay.
Irvine Ranch Water District (IRWD)	SCE	Independent special district that servesCentral Orange County and provides water and wastewater services to more than 330,000 customers

4.4 Request for Sample Customers and Sample Selection

As a general approach, the participating water agencies were provided with instruction on generating lists of water customers in each end-user category. Study 3 sites were selected and sampled based on these lists. While IRWD did not provide such a list, they did participate in a limited but important fashion. Study 3 was concurrent with embedded energy in water pilot programs and the *Embedded Energy in Water Pilot Programs Impact Evaluation*[71](see Table 5).

[71] ECONorthwest et al., *Embedded Energy in Water Pilot Programs Impact Evaluation* (San Francisco: California Public Utilities Commission, 2011).

These were implemented in IRWD service area and provided a source of baseline flow trace data, used in Study 3 for hourly demand profiling. Table 19 defines Study 3 end-user categories.

Table 10: Study 3 End-user Categories

End-User Category	Definition
Residential Single-family	Retail water customer residential unit with a single water meter. Usually detached, but can also be attached (e.g., duplex)
Residential Low-income Single-family	Retail water customer residential unit with a single water meter, and the inhabitants of which meet the criteria established by the CPUC for the low-income energy efficiency programs. Usually detached, but can also be attached (e.g., duplex)
Residential Low-income Multi-family	Retail water customer residential units in a property in which multiple separate housing units are contained within one building, such as an apartment building, the inhabitants of which meet the income criteria established by the CPUC for the low income energy efficiency programs.
Commercial	Retail water customer non-residential facilities used to distribute a product or service, and which are not public buildings.
Urban Irrigation	Commercial or industrial retail water customer accounts (including public buildings) for which water meters measure irrigation uses either solely or predominantly.
Public Building	Retail water customer facilities operated and/or owned by federal, state and local governments. (Note that the term “public building” is used in Study 3 per CPUC D.07-12-050, however in other contexts the term “institutional” is used to describe facilities with similar characteristics, e.g., schools and government buildings.)
Industrial	Retail water customer non-residential facilities used to manufacture or process non-agricultural goods.
Agricultural	Retail water customer facilities using potable and/or recycled water delivered by the water agency for either irrigation or post-harvest processing/cold storage.

4.4.1 Residential Single-family and Low-income Single-family

As the author maintains several large data sets of water demand profiles for residential single-family and low-income single-family customers in California and elsewhere in the United States and Canada, it was not necessary to approach water agencies about collecting new data for these categories for Study 3. The most recent of these data in the existing data sets were collected between 2006 and 2008 from water agencies across California. The homes included in the group cover the full spectrum of income levels. Study 3used these existing data for the residential single-family and low-income single-family end-user customer categories.

The data used for the single-family and low-income single-family analyses were drawn from a database collected for the *CSFWUES*. Using this information, it was possible to identify low-income households approximately meeting the CPUC criteria for low-income energy-efficiency programs.[72]A sampling methodology based on historic water use patterns was employed for the residential single-family and residential low-income single-family categories. That is, the water use of sites in the sample matched that of the water agency service area population of single-family homes as a whole at the 95 percent confidence level. The example in Figure 23 is taken from the *CSFWUES* report discussion of sampling in Redwood City and describes in greater detail the sampling methodology, which used billed water demand as the sole selection criteria.[73]

Figure 15: Example of Sampling Methodology for *CSFWUES*

Redwood City Logging Sample

The Redwood City staff provided the descriptive statistics for their entire population of single-family homes, and then selected a random group of approximately 1,000 homes from which the logging sample was to be selected. The table below shows the summary statistics for the three groups of homes. Records were extracted for a total of 15,777 single-family accounts in the Redwood City service area. The average annual consumption of the entire population was 101 kgal. The median annual consumption was 88.3 kgal. The statistics for the 1000 home sample (Q_{1000}) matched those of the population very closely, as shown in the table. A total of 70 homes were selected from the Q_{1000}. After houses with less than 15 kgal/yr of consumption, houses which declined to participate and houses that were found to be unusable in the field—for instance because of a bad meter or vacancy—were trimmed from the sample the final group of 60 homes on which loggers were installed had an average annual use of 106 kgal and a median use of 98 kgal. Elimination of the houses with very low, or only partial year consumption caused the mean of the logging group to be slightly larger than the mean of the population, but was thought to constitute a more meaningful sample because of this trimming.

Summary Statistics for Redwood City Logging Sample

	Population	***Q_{1000}***	***Log Sample Q_{60}***
	Kgal	*Kgal*	*Kgal*
Mean	*101.09*	*101.66*	*105.89*
95% Conf. Interval	*1.04*	*4.10*	*13.45*
Median	*88.26*	*88.26*	*98.36*
Count	*15777*	*1046*	*60*

In addition to selecting samples that were representative of the agencies participating in the *CSFWUES*, every effort was made to select an overall sample of homes that was representative

[72] The CPUC required that Study 3 use criteria for defining low-income status as defined in the Health and Human Services poverty guidelines for the lower 48 states (HHS, 2008). The poverty guidelines are updated periodically in the Federal Register by the U.S. Department of Health and Human Services under the authority of 42 U.S.C. 9902(2). Customer sites used in Study 3 either met these criteria or similar criteria used for water agency-administered low-income programs. See Appendix D: Description of Low-income Criteria for more information.
[73] Aquacraft, Inc., 2011..

of the general population of single-family homes in California. The sample was chosen to parallel the proportion of population by counties.[74]

4.4.2 Residential Low-income Multi-family

While a substantial volume of data exists on single-family and low-income single-family water use, very few data exist for multi-family homes. To help fill this gap, three water agencies (City of San Diego, IRWD and EBMUD) were asked to provide assistance in identifyingindividually-metered multi-family customers within their service areas. These agencies were also asked to assist us in identifying customers that met low-income criteria. Using information provided by these agencies, multi-family units from within the three electric IOU service areas were randomly selected for inclusion in Study 3. For purposes of creating the water demand profile for communal water-usage (i.e., outdoor irrigation), properties in which the majority of units were identifiable as housing low-income residents were considered "low-income multi-family."

4.4.3 Commercial

A specific component of Study 3 was existing commercial flow trace files that the author collected in the last several years from commercial sites for other studies to create hourly water demand load shapes. New commercial accounts were sampled in areas not already present in the database to make the data set more robust.

Each water agency was asked to select from their customer databases a list of the top 25 percent of commercial water users with business classification codes (BCC) corresponding with the type of accounts falling in Study 3 end-user categories. More specifically, they were asked to provide a list of customers in sub-categories for which there were no available existing flow traces such as laundromats, car washes and automotive service facilities.

Study 3's commercial sample selection methodology was developed for the *CIEUWS.*[75] Hourly profile data for commercial sites were separated into sub-categories. For the commercialcategory, it was not feasible to select a representative sample, given the diverse end-use types. Commercial and industrial end-users are heterogeneous with highly variable water demand profiles. Selected study sites were narrowed down to those candidates that had the highest potential for measures that would lead to water conservation/savings.

4.4.4 Urban Irrigation

Because urban irrigation is by far the largest single sub-category of use, it is discussed here as a separate category. Urban irrigation accounts are those for which water meters measure irrigation uses either solely or predominantly. For Study 3 purposes, data collected from commercial, industrial or public building customer dedicated irrigation water meters have been included in the analyses and results of the urban irrigation category. Data collected from commercial, industrial or public building customer water meters monitoring both indoor and outdoor uses have been included in the analyses and results of the respective (sub-) category. Study 3 sites were chosen from the lists provided by water agencies of commercial, industrial and public

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[74] For more information on the *CSFWUES* see Appendix B: California Single Family Water Use Efficiency Study Information.

[75] Dziegielewski et al., *Commercial and Institutional End Uses of Water*.

building customers (and as described in those respective sections herein). Several flow traces from an existing database were used to enhance the analysis (see Section 4.2 for more on existing data.)

4.4.5 Public Buildings

Each water agency was asked to generate a list of its top 25 percent water-using public building customers, and 10 to 30 sites were selected from each agency list.

Public building Study 3 participants represent a cross-section of buildings from various California water agencies in the northern and southern regions. It was not feasible to generate a representative sample of public buildings. Hourly demand profiles were measured from lists of sites generated by the participating water agencies. In addition, existing data from public buildings were used to supplement the sample (see Section 4.2 for more on existing data.)

4.4.6 Industrial

Each water agency was asked to generate a list of its top 25 percent water-using industrial customers.

For the industrial site selection, *Cataloguing Commercial, Industrial, and Institutional Customer Classes* aided in identifying the highest water-using categories to target.[76] For this category, it was not feasible to select a representative sample, given the diverse end-use types. Commercial and industrial end-users are heterogeneous with highly variable water demand profiles. Selected Study 3 sites were narrowed down to those candidates with the highest potential for measures that would lead to water conservation/savings. For example, the industrial category is largely made up of high water-using food and beverage processing facilities.[77] The industrial water demand profiles are the result of data logging facilities representing the major types of water uses from various water agency service areas in California. In addition, existing data from industrial sites were used to supplement the sample (see Section 4.2 for more on existing data.)

4.4.7 Agricultural

Study 3 sought to identify the largest potable-water-using agricultural customers and select a balanced sample of approximately 10 agricultural sites to create hourly water demand load shapes. Because Study 3 measured use of cold water supplied from water-agency potable or recycled water systems, Study 3 sites selected in the agricultural sector were those that used potable or recycledwater for irrigation and/or potable water for agricultural post-harvest product processing such as fruit canning or dairy milk production. None of the sites included in Study 3 obtained recycled water, so this category was not included in the final analysis. Study 3 distinguishes between industrial and agricultural food processors. Essentially, a Study 3 site was considered “agricultural” if it processes a raw product (harvested produce, un-pasteurized milk, meat) into a food product. Water agencies that served such agricultural customers were asked to provide a list of customer accounts.

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[76] Bureau of Reclamation, *Cataloguing Commercial, Industrial, and Institutional Customer Classes,*

[77] See Appendix F: Characterization of Industrial Entities in the State of California.

Potable water-using agricultural customers in PG&E and SCE service areas were identified. It was not feasible to select a representative sample. Flow trace data were collected from agricultural end-users who obtain water from potable water systems, and sub-metering data were collected from two of those end-users.

4.5 Data Collection

The objective of Study 3 was to collect as large a set of demand profiles as possible from Study 3's seven categories of end-users in order to get better information on how their average daily demands affect the hourly demands on water agencies. Because the residential and non-residential end-user categories use water for such a large range of purposes, it was necessary to implement different strategies when collecting data for generating hourly demand profiles for each of them. Disaggregation of end-uses in the non-residential categories (domestic/indoor, outdoor, process and continuous uses) was more limited than in the residential categories.

4.5.1 Site Visits

When possible, field technicians met with Study 3 site facilities managers in person to collect information related to water use. Where practicable, technicians also visited the property for more detailed inspection of water-using features.

4.5.2 Collecting Data from Main Meters

Flow trace data, using Meter Master Flow Recorders (Model 100), were collected from the main water meters of all Study 3 sites.

4.5.3 Collecting Data from Sub-meters

It is often difficult to disaggregate flow trace data at large water-using facilities. To aid in this effort, Study 3 Team implemented two strategies. First, facilities managers were contacted and asked a series of questions from a Study Site Information Sheet (see Appendix G: Study Site Information Sheet for a sample). Second, industrial and some larger water-using agricultural Study 3 sites were invited to participate in a more detailed evaluation of facility use. To encourage participation, facilities managers were promised a summary report of Study 3 findings of their water usage. Two industrial and two agricultural end-users agreed to participate, and sub-meters were installed onto cooling towers and other locations deemed important.

At the two participating industrial facilities, sub-meters leading to key water using fixtures were already in place, allowing for installation of Meter Master 100 flow recorders. Neither of the two participating agricultural processing plants had sub-meters, so Omega paddlewheel flow sensors were used in unison with HOBO data loggers to record the flow of water to the towers. Photos of installed Meter Master 100 flow recorders, Omega paddlewheel flow sensors and HOBO data loggers are included in Appendix E: Meter Installation Examples.

This type of detailed water use data collection requires a significant level of cooperation by facility management staff. Moreover, sub-metering cooling towers requires water to be shut off during the installation. These factors often serve as a disincentive for providing the level of assistance necessary to proceed with a site water use review and sub-metering. When it was not possible to sub-meter larger industrial and agricultural sites, every effort was made to contact facilities managers to collect the basic information on Study 3 Site Information

Sheet.Responsesreceived and were used to determine the key water using devices on the site, including the presence of cooling, hours of operation, and use of alternative water supplies, as shown in Appendix G: Study Site Information Sheet.

4.5.4 Residential Single-family and Low-income Single-family

Data for the single-family and low-income single-family sites had been collected previously, for the *CSFWUES*. For that study, flow data recorders (data loggers) were attached to the household water meters and used to collect 10-second flow trace files. Information on the household income and the number of residents was collected for that study. Of about 700 single-family and low-income single-family homes that participated in the study, 415 (59 percent) completed and returned the surveys. The hourly water use and income data from these 415 homes, which could be reliably classified as either single-family or low-income single family based on this self-reported survey data, were used in Study 3 to develop the hourly demand patterns for single-family and low-income single-family homes, respectively (see Appendix D: Description of Low-income Criteria for details on income level reporting). Table 21 shows the water demand categories, sample sizes by income designation and the source of the data used to study single-family and low-income single-family home hourly water demands.

Table 11: Single-family and Low-income Single-family Water Demand Profile Categories, Sample Size and Data Source

End-user Category	Water Demand Profile Categories	Sample Size	Source of Hourly Demand Profile Data
Residential -Single-family -Low-income Single-family	-Baths -Showers -Toilets -Clothes washers -Dishwashers -Faucets -Leaks -Other -Irrigation	-361 Single-family -54 Low-income Single-family	Existing database

4.5.5 Residential Low-income Multi-family

Study 3 used data collected from random samples of individually-metered low-income multi-family homes, which were selected from customers of three water agencies within three IOU service areas. To examine hourly use patterns for these homes and to provide information on how water is used outdoors at multi-family properties, individually-metered indoor uses and property-metered outdoor demands were included in the analysis.

Flow trace data were obtained from each of the 159 participating individually-metered multi-family homes. The hourly water use and income data from these 159 homes were used in Study 3 to develop the hourly demand patterns for low-income multi-family homes. Table 23 shows the water demand categories, sample size and the source of the data used to study multi-family home hourly water demands.

In order to generate hourly demand patterns for outdoor water use at multi-family properties, the respective water agency identified irrigation water meters that were then logged for at least a two-week period to collect flow trace data. Note that outdoor use at these sites is for the whole property whereas indoor use is for designated individually metered units. At the time of the site visits, neither property management nor the water agency were able to assist in locating irrigation timers, and information on sub-meters serving pools and laundry rooms wasunobtainable.

Table 12: Multi-family Category Water Demand Profile Categories, Sample Size and Data Sources

End-user Category	Water Demand Profile Categories	Sample Size	Source of Hourly Demand Profile Data
Residential: Low-income Multi-family	-Baths -Showers -Toilets -Clothes washers -Dishwashers -Faucets -Leaks -Other -Irrigation	159 individually-metered units	EBMUD, IRWD and City of San Diego customer flow traces

4.5.6 Commercial

The commercial sub-categories listed in Table 13 above were found in the *CIEUWS* to be the most significant, using scaled average daily use as the measure. Of these, data were available from existing studies for hotels and motels, offices, restaurants and food stores. Data were also available for miscellaneous retail sub-categories analyzed for Study 3 although not among the top scaled average daily water users in the *CIEUWS*. The groups for which *CIEUWS* had no data were laundries/laundromats, auto shops, membership organizations and car washes.

For Study 3 new flow trace data collected in SDG&E, SCE and PG&E service areas, as well as flow trace data collected throughout California and other states for earlier studies were used. Table 25 outlines the commercial end-user categories and related sample sizes and data sources used for Study 3.

Table 13: Commercial Category Water Demand Profile Categories, Sample Size and DataSources(by Sub-category)

Commercial Sub-category	Water Demand Profile Category	Sample Size		Source of Hourly Demand Profile Data
		Existing[78]	New	
General Retail	-Continuous -Indoor/Process -Outdoor/Irrigation	7		EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Hotels and Motels		5		
Offices		7		
Supermarkets		9		
Restaurants		7		
Large Retail			1	
Laundromats			5	
Car Washes			4	
Automotive Service			4	
TOTAL		**49 sites**		

As part of Study 3, any water meters that served irrigation systems were classified as urban irrigation accounts, irrespective of the nature of the business on which the irrigation system was located (e.g., if a restaurant used water for irrigation, that water would be classified as urban irrigation). The water used for this irrigation was analyzed along with other urban irrigation accounts. Meters that served a business as a primary purpose were categorized according to the type of business served, and any irrigation water passing through the meter was disaggregated as an outdoor use for that business.

4.5.7 Urban Irrigation

Any water metered for non-residential irrigation-only uses was considered as used for "urban irrigation," irrespective of the category of the property on which the irrigation occurred. The *CIEUWS* identified urban irrigation as having the highest scaled averaged daily use among the "significant CI categories," having an average annual daily use of 2,596 gpdc, comprising 28.5 percent of total CI use, and a scaled averaged daily use of 739 gpdc.[79]Study 3 site selection and data logging of commercial, public building and industrial end-user categories resulted in identification of water meters serving only irrigation. These accounts were added to the irrigation traces obtained from the archives. The seven sites for which there were existing data were supplemented by 12. Table 27 outlines the urban irrigation end-user category water demand profile categories, sample sizes and data sources used for Study 3.

[78] See Section 4.2 for more on existing data.
[79] Dziegielewski et al., *Commercial and Institutional End Uses of Water*, 44.

Table 14: Urban Irrigation Category Water Demand Profile Categories, Sample Size and Data Sources

End-user Category	Water Demand Profile Category	Sample Size		Source of Hourly Demand Profile Data
		Existing	New	
Urban Irrigation	-Continuous -Indoor/Domestic -Outdoor/Irrigation	7 sites	12 sites	EBMUD, City of Santa Rosa, CVWD, IRWDand City of San Diego customer flow traces, and existing database
Total		**19 sites**		

4.5.8 Public Building

Study 3 site selection in the public building end-user category resulted in a cross section of sub-categories such as libraries, government offices, government laboratories and recreation centers. Flow traces from 15 public building sites were collected specifically for Study 3. These sites were well distributed among multiple water agencies and three IOU service areas, with four from within SDG&E's service area, four from SCE's service area, and seven from PG&E's. Public building water uses were logged from water meters serving their indoor and outdoor uses. The addition of existing public building flow traces provided Study 3 with an additional data set from 54 public buildings. Many of the public building meters also served on-site irrigation.

Primary and secondary schools, and county hospitals were each considered separate public building sub-categories and were analyzed separately for Study 3. Existing flow traces from 11 sites in California, Arizona and Colorado were considered for primary and secondary schools. Data from one county hospital in PG&E service area were analyzed. Table 29 outlines the public building end-user categories, and related water demand profile categories, sample sizes and data sources used for Study 3.

The *CIEUWS* identified schools and colleges, and hospitals and medical offices as having among the highest scaled averaged daily use among the "significant CI categories," Schools and colleges having an average annual daily use of 2,117 gpdc, comprising 8.8 percent of total CI use, and a scaled averaged daily use of 187 gpdc, and hospitals and medical offices having an average annual daily use of 1,236 gpdc, comprising 3.9 percent of total CI use, and a scaled averaged daily use of 48 gpdc.[80]

[80] Dziegielewski et al., *Commercial and Institutional End Uses of Water*, 44.

Table 15: Public Building Category Water Demand Profile Categories, Sample Size and Data Source (by Sub-category)

Public Building Sub-category	Water Demand Profile Category	Sample Size		Source of Hourly Demand Profile Data
		Existing	New	
Public Buildings	-Continuous -Indoor/Domestic -Outdoor/Irrigation	54	15	EBMUD, City of Santa Rosa, CVWD, IRWD and City of San Diego customer flow traces, and existing database
Schools		11	0	
Hospitals		0	1	
Total		**81 sites**		

4.5.9 Industrial

The primary source of information used in Study 3 for the industrial sector was the *Cataloguing Commercial, Industrial, and Institutional Customer Classes* report by the BOR, which summarizes the methodology for identifying commercial, industrial and institutional (CII) customer classes in Southern California.[81] In order to express the relative importance of water use by industrial sub-categories as compared to overall industrial water use, the BOR study data were used to calculate the scaled average daily use, including the units of gallons per day per customer. Using the scaled average daily use as the measure, the industrial categories listed in Appendix F: Characterization of Industrial Entities in the State of Californiawere found to be the most significant.

Study 3 site selection resulted in a cross section of industries that represent some of the largest water users in California, including industrial food and beverage processors, industrial coatings plants, industrial laundries and pharmaceutical companies. Flow trace files from 12 industrial Study 3 sites were collected to generate the hourly water demands, with two sites from SDG&E's service area, two from SCE's, and eight from PG&E's. Study 3 sites were distributed among multiple water agencies. Industrial Study 3 site water uses were logged from their indoor and outdoor (when available) water meters. Demand profiles of continuous indoor/process and outdoor/irrigation uses were developed, based on data logging combined with site visit information collected (when available) during data collection.

In addition to the data collected specifically for Study 3, an existing database containing a sample of five industrial sites that included two computer manufacturing facilities, a plastic molding site, a computer storage system, and a large winery was used.

Initial consideration was given to separating industrial sites by sub-category, but this proved unnecessary. Looking at Study 3 database hourly profiles alongside those of the existing database, it became clear the demand profile data from these two separate industrial samples were very similar. Additionally, sub-category populations would have proved too small to be

[81] Bureau of Reclamation, *Cataloguing Commercial, Industrial, and Institutional Customer Classes*.

useful. Consequently, all industrial facilities were combined into a single hourly profile. Table 31 outlines the industrial end-user category water demand profile categories, sample sizes and data sources used for Study 3.

Table 16: Industrial Category Water Demand Profile Categories, Sample Size and Data Source

End-user Category	Water Demand Profile Category	Sample Size		Source of Hourly Demand Profile Data
		Existing	New	
Industrial	-Continuous -Process -Outdoor/Irrigation	5 sites	12 sites	EBMUD, City of Santa Rosa, CVWD and City of San Diego customer flow traces, and existing database
Total		**17 sites**		

4.5.10 Agricultural

Unlike other end-user categories, for the agricultural category newly collected flow traces make up the complete data set.

Since Study 3 considered both irrigating and processing in the agricultural end-user category, hourly demand profiles are separated into these sub-categories. As the 2009 harvest season for many California crops occurred throughout the summer, and Study 3 work began in February, only two harvest processing facilities were solicited. The two large agricultural processing sites in PG&E's service area that participated are the source of cooling tower water demand load shapes.

These two sites, which process, package, and can a significant volume of California fruits for many large national brands, participated in on-site surveys. These two processing plants were visited several times. An initial site visit at the plants consisted of a water use review of the facilities. Technicians returned a second time prior to the harvest to install sub-meters on the inflow lines to cooling towers serving these plants. It was necessary to install sub-meters prior to the start of operations because the installation required shutting off critical water valves. Doing so during processing would have disrupted plant operations. Once the plants were operational, field technicians visited the sites to install and initialize data loggers on the main water meters serving the plants, as well as on the previously installed sub-meters. Data logging equipment remained in place for 50 days, after which time they were removed and their data downloaded. Table 33 outlines the agricultural end-user category water demand profile categories, sample sizes and data sources used for Study 3.

Table 17: Agricultural Category Water Demand Profile Categories, Sample Size and Data Source

End-user Category	Water Demand Profile Category	Sample Size	Source of Hourly Demand Profile Data
Agricultural	-Continuous -Process -Outdoor/Irrigation	New: 10 sites	EBMUD, City of Petaluma, City of Lodi, Cal Water, CVWD and City of San Diego customer flow traces

4.6 Flow Trace Analysis

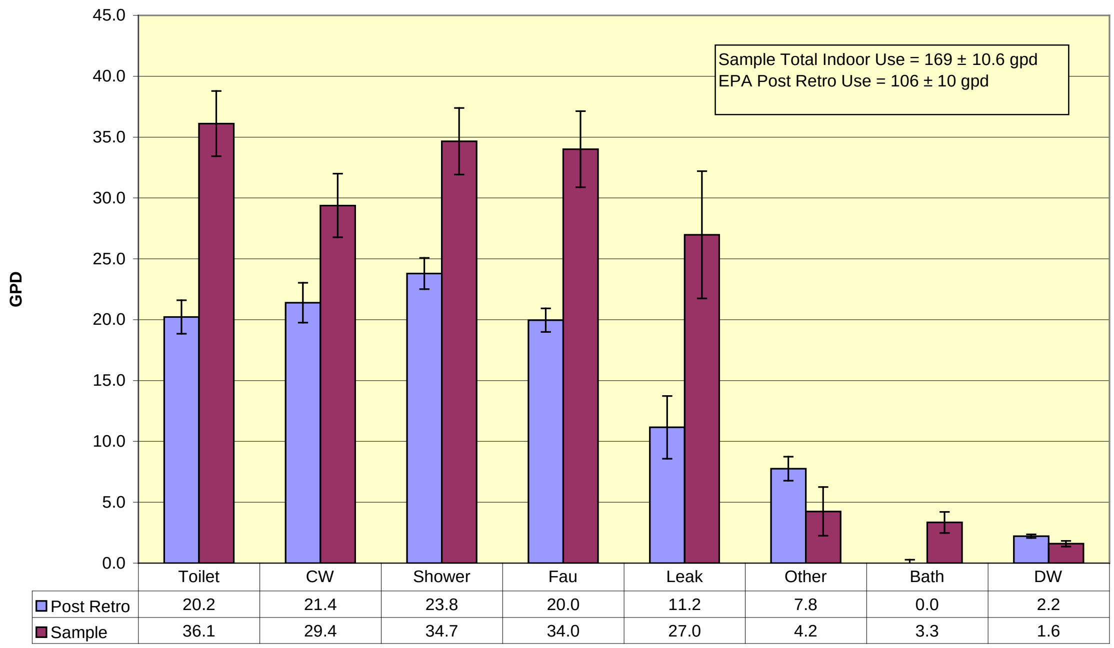
The combination of existing and new data collected as described above and outlined in Table 7 was analyzed using flow trace analysis to generate hourly demand profiles as a percent of total daily use. The purpose of flow trace analysis is to obtain precise information about water use patterns: Where, when, and how much water is used by a variety of devices such as toilets, showers, baths, faucets, clothes washers, dishwashers, hand-held and automatic irrigation systems, evaporative coolers and home water treatment systems, and in occurrences such as leaks. While data from large meters used for larger customer categories (e.g., industrial) can only be measured by demand profile changes in relatively coarse groupings such as domestic/indoor, process and other category water uses, the data collected from small meters (generally for residential customers) are precise enough that individual water use events such as a toilet flush, a clothes washer cycle or miscellaneous tap use can be isolated, quantified and then identified. This technique makes it possible to disaggregate most of the water use in a residential home and to quantify the effect of many conservation measures, from toilet and faucet retrofit programs to behavior modification efforts.

The flow trace methodology is based on the fact that there is consistency in the flow trace patterns of most water uses. For example, a specific toilet will generally flush with the same volume and flow rate day in and day out. A specific dishwasher exhibits the same series of flow patterns every time it is run. The same is true for clothes washers, showers, irrigation systems, etc. By recording flow data at 10-second intervals, a rate determined to optimize accuracy and logger memory, the resulting flow trace is accurate enough to quantify and categorize almost all individual water uses in each residential site studied.

Trace Wizard, a software package developed by Aquacraft Inc. specifically for the purpose of analyzing flow trace data, provides signal processing tools and a library of flow trace patterns for recognizing a variety of water-using fixtures. Any consistent flow pattern can be isolated, quantified, and categorized, including those of leaks, evaporative coolers, humidifiers, and swimming pools. Once all water use events have been isolated and quantified, and statistics generated, a set of parameters developed for each site is applied to categorize the water use events and assign a specific fixture designation to each event.

Figure 25 shows a typical analysis that can be performed on household flow traces with Trace Wizard software. In this example of a sample of single-family homes, the average baseline water demand profile for each of the domestic categories is shown. These baseline data results are compared against a test group of homes in which the fixtures and appliances (minus the dishwashers) were retrofit to best available technology (circa 2000). This provides a clear comparison of the performance of the sample water demand profile against a known benchmark group. The 95 percent confidence intervals for each value are also shown.

Figure 16: Example of Water-use Analysis with Flow Trace Data Disaggregated by Trace Wizard*



*Bar denotes ± 95% confidence interval around the mean estimate for each for the categories.

The hourly water demand profiles generated in Study 3 for the six end-user categories plus urban irrigation indicate how much, when and where water is being used for purposes identified by the flow traces.

4.7 Analysis of Hourly Demand Patterns

4.7.1 Water Demand Profile Categories

Each of the seven end-user categories was assigned water demand profile categories in order to determine specific usage patterns and thereby activities that might be targeted for conservation and/or efficiency programs. These categories are shown inTable 35.

Table 18: Water Demand Profile Categories by End-user

End-user Category	Water Demand Profile Category	Notes
Residential: -Single-family -Low-income Single-family	-Baths -Showers -Toilets -Clothes Washers -Dishwashers -Faucets -Leaks -Other -Irrigation	"Other" includes uses of water such as water treatment systems, evaporative coolers, and other miscellaneous indoor uses.
Residential: -Low-income Multi-family		
Commercial: -General Retail -Hotels and Motels -Offices -Supermarkets -Restaurants -Large Retail -Laundromats -Car Washes -Automotive Service	-Continuous -Indoor/Process -Outdoor/Irrigation	-"Continuous" is any use of water that is maintained throughout the day, usually including leaks and cooling. -"Indoor/Process" is any water used for commercial processes. -"Outdoor/Irrigation" is any water used outdoors for irrigation.
Urban Irrigation	-Continuous -Indoor/Domestic -Outdoor/Irrigation	-"Continuous" is any use of water that is maintained throughout the day, usually leaks. -"Outdoor/Irrigation" is any water used outdoors for irrigation.
Public Buildings: -Public Buildings -Schools -Hospitals	-Continuous -Indoor/Domestic -Outdoor/Irrigation	-"Continuous" is any use of water that is maintained throughout the day, usually including leaks and cooling. -"Indoor/Domestic" is any water used indoors for domestic purposes. -"Outdoor/Irrigation" is any water used outdoors for irrigation.
Industrial	-Continuous -Process -Outdoor/Irrigation	-"Continuous" is any use of water that is maintained throughout the day, usually including leaks and cooling. -" Process" is any water used for industrial processes. -"Outdoor/Irrigation" is any water use that occurs outdoors for irrigation.
Agricultural	-Continuous -Process -Outdoor/Irrigation	-"Continuous" is any use of water that is maintained throughout the day, usually including leaks and cooling. -" Process" is any water used for processing raw agricultural product into food. -"Outdoor/Irrigation" is any water use that occurs outdoors for irrigation.

4.7.2 Analytic Procedure

Data collected from Study 3 site water meters were downloaded to a database. A "site" is associated with one or more traces. Multiple meters on a campus or non-overlapping traces from the same meter are good examples of using the site to logically associate distinct traces together. Volume is then calculated for each site, in this case for each hour logged. Traces with non-overlapping dates are effectively joined, while multiple simultaneous trace volumes are summed. Queries were run on the data to provide total gallons being used during each hour of the day. These total gallons were then averaged over the length of the trace to provide average gallons per hour.

The data were then disaggregated in a spreadsheet using a combination of information provided through inspection and knowledge of the uses metered. When combined-use meters were known to serve indoor, outdoor irrigation and continuous uses, the profiles were split into these three categories. First, continuous uses were identified by looking for the minimum night-time hourly flows. These served as the baseline. Nighttime uses were assigned to outdoor uses, unless it was known that there was no irrigation served by the meter. Daytime uses were the flows observed above the continuous use baseline during hours of operation. Data from sub-meters were broken into hourly flows and assigned to the use of the sub-metered operation. Sub-meter data were primarily obtained from cooling systems. The disaggregated data were summarized by the appropriate end-user category in summary spreadsheets, and the graphs and tables required for report presentation were prepared.

4.7.2.1 Residential Single-family and Low-income Single-family

Flow trace data obtained from residential single-family and low-income single-family water meters were disaggregated using the Trace Wizard program into individual events (e.g., toilet flush, shower, clothes washer cycle and faucet draw). A total of 361 flow traces were measured at single-family and 54 at low-income single-family homes. The disaggregated data were assembled into water-use event databases. In these databases, each water use event makes up a unique record which includes the following statistics: water-use category, volume, start time, end time, duration, max flow rate and mode flow rate as well as a unique ID number that identifies the house from which the data were obtained. This allowed the total use and percentage of total use for each category to be broken down on a 24-hour basis.

In order to determine low-income status within this Study 3 group, information on both the number of residents per home and that household's income level was obtained from Study 3 survey results[82]. The results of this process yielded the sample sizes for single-family and low-income single-family, as shown in Table 21.

Study 3 investigated both indoor and outdoor categories of hourly water use. The observed high variations in water use across geography and season indicate that seasonal water use patterns varied for the 415 residential single-family end-users. In order to provide hourly data that were typical of peak season use and to avoid skewing the irrigation data with "winter" water use (i.e.,

[82] As these were self-reported data, there is a certain level of unknown uncertainty about the accuracy of these reported numbers

not during the peak irrigation season), only flow traces taken between May 1 and September 30 of the calendar year were used for outdoor hourly analysis.

4.7.2.2 Residential Low-income Multi-family

Flow trace data were obtained from 159 individually-metered multi-family homes and were disaggregated into water demand profile category events using Trace Wizard. For each household, the water demand profile category, volume and start time were known for each event and listed in Study 3 database. This allowed the total use and percentage of total use for each category to be broken down on a 24-hour basis. Where information was provided by the water agencies for water meters serving properties' outdoor uses, such as irrigation, flow trace data were collected and hourly use profiles were developed. Additionally,flow traces were collected from dedicated irrigation meters at six low-income multi-family properties to measure outdoor use. These data were used to create the demand profiles for the low-income multi-family category.

4.7.2.3 Commercial

A total of 66 flow trace files (obtained from separate water meters) was available on 49 commercial sites. The sub-categories for these traces, number of sites and the number of traces obtained for each category is shown in Table 37.

Table 19: Existing and New Commercial Sites and Associated Traces

Commercial Sub-category	Existing Sites	New Sites	Existing Traces	New Traces
General Retail	7	0	9	0
Hotels and Motels	5	0	10	0
Offices	7	0	11	0
Supermarkets	9	0	14	0
Restaurants	7	0	8	0
Large Retail	0	1	0	1
Laundromats	0	5	0	5
Car Washes	0	4	0	4
Automotive Service	0	4	0	4
Sub-Total	**35**	**14**	**52**	**14**
Total	**49**		**66**	

4.7.2.4 Urban Irrigation

Twenty flow traces from dedicated irrigation meters serving 12 Study 3 sites were collected. The existing flow trace database provided a data set of an additional 10 traces from seven urban irrigation sites, resulting in a total of 30 flow traces from 19 Study 3 sites being analyzed for their hourly contribution to potable and reclaimed water demands for irrigation. The combined new and existing flow traces were collected in the same manner as discussed throughout this report, using data loggers.

4.7.2.5 Public Buildings

From the combined new and existing databases, hourly water demands of a total of69public buildings were analyzed. At each location, the building's main water meter or combined meters were fitted with data loggers, and the flow trace data recorded for a period of at least two weeks. Demand profiles of continuous, indoor/domestic and outdoor/irrigation uses were developed, based on data logging of new and existing study sites combined with site visit information (when available). Where irrigation was apparent, the seasonal variation in water uses was estimated using the combined historic billing data and logged data. In addition, Study 3 analyzed hourly water demands of eleven schools from an existing database and one hospital from a new database.

Table 20: Existing and New Public Buildings Sites and Associated Traces

Public Buildings Sub-category	Existing Sites	New Sites	Existing Traces	New Traces
Public Buildings	54	15	69	25
Schools	11	0	26	0
Hospitals	0	1	0	4
Sub-total	**65**	**16**	**85**	**29**
Total	**81**		**114**	

4.7.2.6 Industrial

Study 3 collected flow trace and historic consumption data from 12 industrial facilities, yielding 26 traces. A total of six existing industrial flow trace files for five sites collected in previous studies were also used to create hourly water demand profiles.

4.7.2.7 Agricultural

A total of 22 flow trace files obtained from separate water meters were available on 10 agricultural sites. Two sites were in SCE's service area, and eight in PG&E's. The sub-categories for these traces, number of sites and the number of traces obtained for each category are shown in Table 40.

Table 21: Agricultural Sites and Associated Traces

Agricultural Sub-Category	New Sites	New Traces
Agricultural Irrigator	3	4
Agricultural Processor	7	18
Total	**10**	**22**

Two of the agricultural processing sites in PG&E's service area participated in the more detailed on-site review of water use. Data were logged from the processing plants' main water meters, and their cooling towers were analyzed separately, as they were recorded and stored on different data logging devices. Main water meter flow trace data were recorded using Meter Master data loggers, exported into a database and analyzed. The cooling tower data were collected with combined Omega Insertion Paddlewheel Flow meters and HOBO data loggers. The main water meter flow trace data from these two sites and that of the remaining eight agricultural sites were combined so the average volumes of all events that occurred in each hour of each day were summed together.

5 Results

A key component of the water-energy relationship is the time of day during which the water demands occur, i.e., the demand profiles of water use. By understanding these demand profiles in combination with the relationship between hourly water demand and energy use by the water agencies that supply the water, it is hoped that the overall impact of water use on energy demands in California can be better managed. The remainder of this report provides key information on these profiles.

5.1 Residential Single-family and Low-income Single-family

Residential water demands as a group make up the largest percentage of water use in most municipal water systems. A total of 361 single-family and 54 low-income single-family sites were included in Study 3.

5.1.1 Indoor Water Use

Daily profiles of use as a percentage of total indoor water use for single-family and low-income single-family households are shown in Figure 27 and Figure 29, respectively. Indoor use in these homes is disaggregated into:

- Baths
- Showers
- Toilets
- Clothes Washers
- Dishwashers
- Faucets
- Leaks
- Other, which includes:
    - Water treatment systems
    - Evaporative coolers
    - Other miscellaneous indoor uses[83]

[83] This includes outdoor hot tubs and swimming pools when a distinct pattern in the flow trace data could not be verified as pool/hot tub intermittent refilling.

Figure 17: Disaggregated Hourly Water Demand Profiles -Single-family Indoor

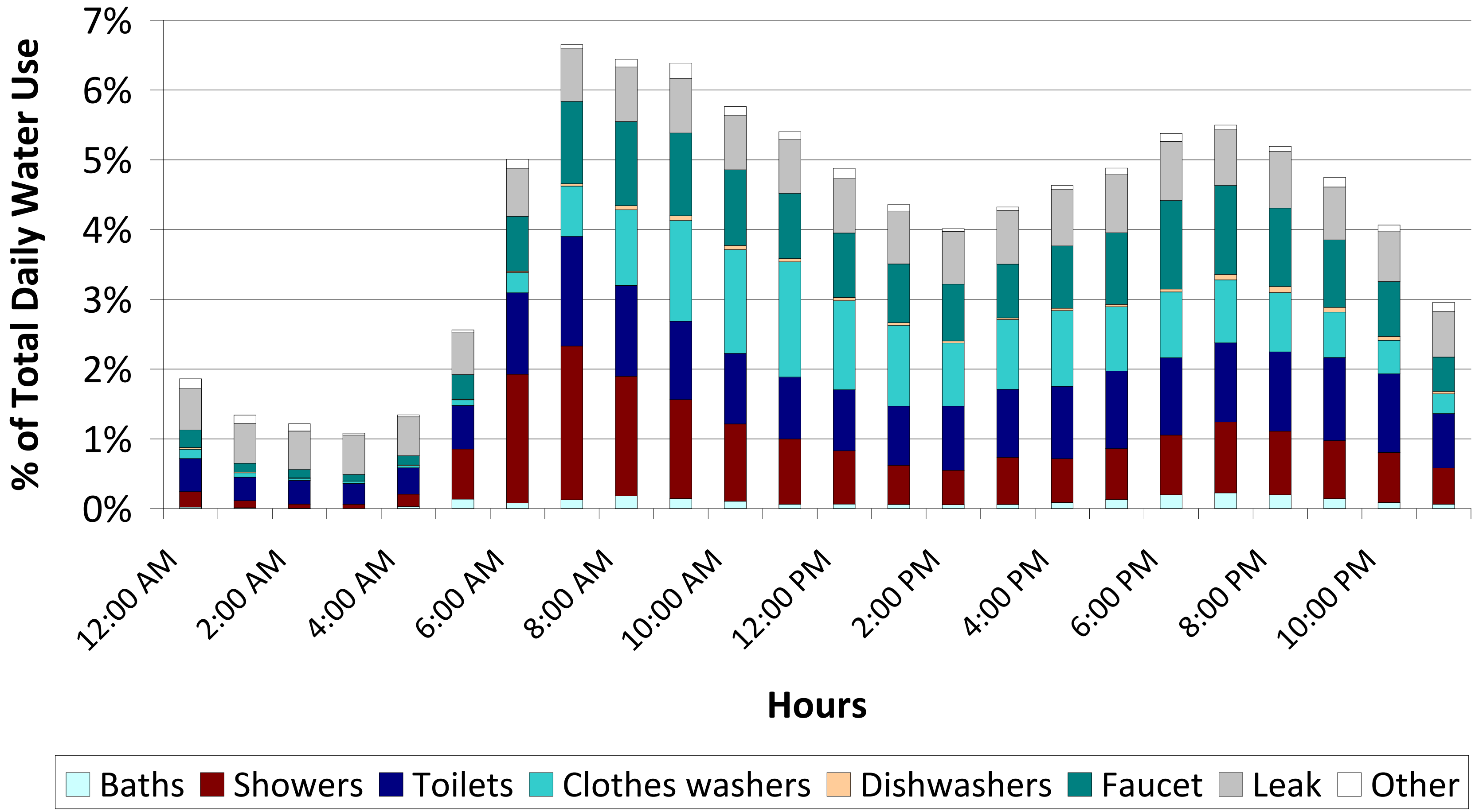


Figure 18: Disaggregated Hourly Water Demand Profiles -Low-income Single-family Indoor

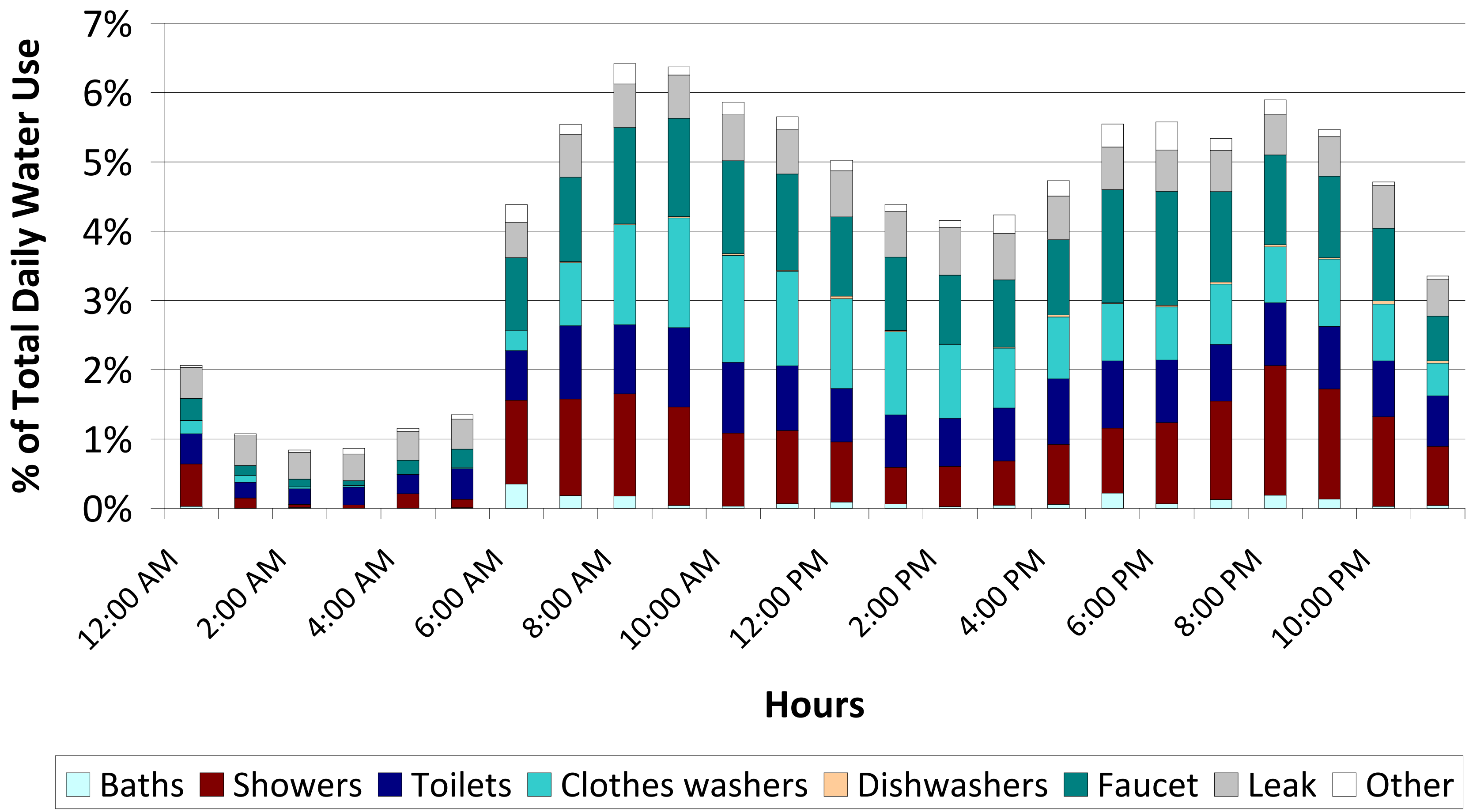


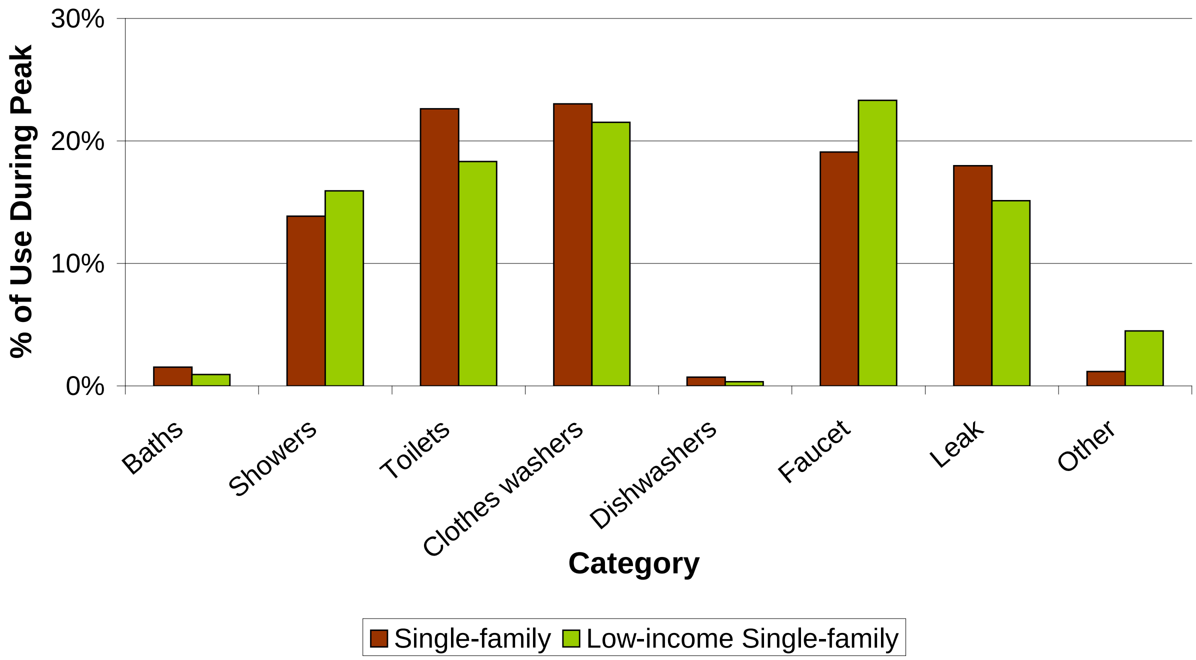
Table 22: Aggregated Hourly Water Demand – Single-family and Low-income Single-family Indoor

Hour	Single-family: % of Total Daily Indoor Water Use	Low-Income Single-family: % of Total Daily Indoor Water Use
12:00 AM	1.88%	2.06%
1:00	1.37%	1.08%
2:00	1.24%	0.84%
3:00	1.11%	0.86%
4:00	1.37%	1.15%
5:00	2.58%	1.35%
6:00	5.01%	4.38%
7:00	6.64%	5.54%
8:00	6.43%	6.42%
9:00	6.38%	6.37%
10:00	5.76%	5.86%
11:00	5.38%	5.65%
12:00 PM	4.86%	5.02%
1:00	4.34%	4.39%
Total Before Peak	**54%**	**51%**
2:00	4.00%	4.16%
3:00	4.31%	4.23%
4:00	4.62%	4.73%
Total During Peak	**13%**	**13%**
5:00	4.87%	5.55%
6:00	5.36%	5.58%
7:00	5.49%	5.34%
8:00	5.19%	5.90%
9:00	4.75%	5.47%
10:00	4.07%	4.71%
11:00	2.97%	3.35%
Total After Peak	**33%**	**36%**

Single-family household indoor water use had two peaks during the day, one at 7:00 AM and one at 7:00 PM. Low-income single-family households also had two distinguishable peaks in the daily water use: The first, one hour later than single-family homes, at 8:00 AM and the second at 8:00 PM., an hour later than single-family homes. The reason for these peak shifts is unknown and may simply be due to noise in the smaller sample size of the low-income single-family data set. Neither of these groups' peaks coincides with the peak energy demand. Table 42 shows the essentially identical patterns of peak indoor water demand for single-family and low-income single-family homes. Single-family homes use slightly more water prior to the peak, while the low-income single-family homes use slightly more water after the peak. Both groups use exactly the same 13 percent of their total indoor water use during the peak energy demand period.

It becomes clear that the there is little difference between single-family and low-income single-family groups when hourly demands for individual water demand profile categories are analyzed. Figure 31 shows the peak time percentage of indoor water use by category for the two groups.

Figure 19: Relative Peak Hour Water Use by Income Category – Single-family and Low-income Single-family Indoor



For indoor water use, the proportions of demands by various water demand profile categories are comparable. Faucet and leak patterns are typically hard to separate. In this case, the combination of faucet and leaks is likely similar for single-family and single-family low-income groups. These data show that a prudent approach to modeling residential indoor water use would reasonably consider that income level is not a significant factor unless it is combined with information on the number of residents. The data also show that energy efficiency and demand response programs might successfully target certain end uses, such as clothes washers, showers and toilets, which exhibit high water demand during peak energy demand periods, while others, such as dishwashing, may not be a good target for demand response programs, since few people are using dishwashers during the energy peak period (2:00-5:00 PM).

The goal of studying hourly single-family household water use is to provide accurate and current water demand profiles for various categories. Table 43and Table 45show, respectively, the indoor single-family and low-income single-family category hourly water use profile data in tabular format as percentages of total indoor water use.

Table 23: Disaggregated Hourly Water Demand Profiles - Single-family Indoor

Hour	Baths	Showers	Toilets	Clothes Washers	Dish-washers	Faucet	Leak	Other	Total
12 AM	0.02%	0.22%	0.47%	0.13%	0.02%	0.25%	0.59%	0.14%	1.9%
1:00	0.01%	0.10%	0.34%	0.06%	0.01%	0.13%	0.57%	0.12%	1.3%
2:00	0.00%	0.06%	0.34%	0.03%	0.01%	0.12%	0.55%	0.10%	1.2%
3:00	0.00%	0.06%	0.30%	0.03%	0.01%	0.10%	0.56%	0.03%	1.1%
4:00	0.03%	0.18%	0.38%	0.03%	0.01%	0.13%	0.56%	0.03%	1.3%
5:00	0.14%	0.72%	0.63%	0.08%	0.01%	0.36%	0.60%	0.04%	2.6%
6:00	0.08%	1.84%	1.17%	0.29%	0.02%	0.79%	0.68%	0.14%	5.0%
7:00	0.13%	2.20%	1.57%	0.72%	0.03%	1.18%	0.76%	0.06%	6.7%
8:00	0.18%	1.71%	1.30%	1.08%	0.06%	1.21%	0.78%	0.11%	6.4%
9:00	0.14%	1.42%	1.13%	1.44%	0.07%	1.19%	0.78%	0.22%	6.4%
10:00	0.10%	1.11%	1.01%	1.49%	0.06%	1.09%	0.78%	0.13%	5.8%
11:00	0.06%	0.94%	0.89%	1.65%	0.05%	0.93%	0.77%	0.11%	5.4%
12 PM	0.06%	0.77%	0.88%	1.28%	0.05%	0.93%	0.78%	0.15%	4.9%
1:00	0.06%	0.56%	0.85%	1.15%	0.04%	0.84%	0.76%	0.09%	4.4%
2:00	0.05%	0.49%	0.92%	0.90%	0.03%	0.81%	0.76%	0.04%	4.0%
3:00	0.06%	0.67%	0.98%	1.00%	0.02%	0.77%	0.77%	0.05%	4.3%
4:00	0.09%	0.63%	1.04%	1.08%	0.03%	0.89%	0.81%	0.06%	4.6%
5:00	0.13%	0.73%	1.11%	0.92%	0.03%	1.03%	0.83%	0.10%	4.9%
6:00	0.20%	0.86%	1.11%	0.94%	0.04%	1.27%	0.85%	0.12%	5.4%
7:00	0.22%	1.02%	1.13%	0.90%	0.08%	1.28%	0.81%	0.06%	5.5%
8:00	0.20%	0.91%	1.14%	0.85%	0.08%	1.12%	0.81%	0.07%	5.2%
9:00	0.14%	0.84%	1.19%	0.65%	0.07%	0.97%	0.76%	0.14%	4.8%
10:00	0.09%	0.72%	1.13%	0.48%	0.06%	0.79%	0.71%	0.10%	4.1%
11:00	0.06%	0.52%	0.78%	0.28%	0.03%	0.49%	0.65%	0.13%	3.0%
Total	**2.3%**	**19.3%**	**21.8%**	**17.5%**	**0.9%**	**18.7%**	**17.3%**	**2.3%**	**100%**

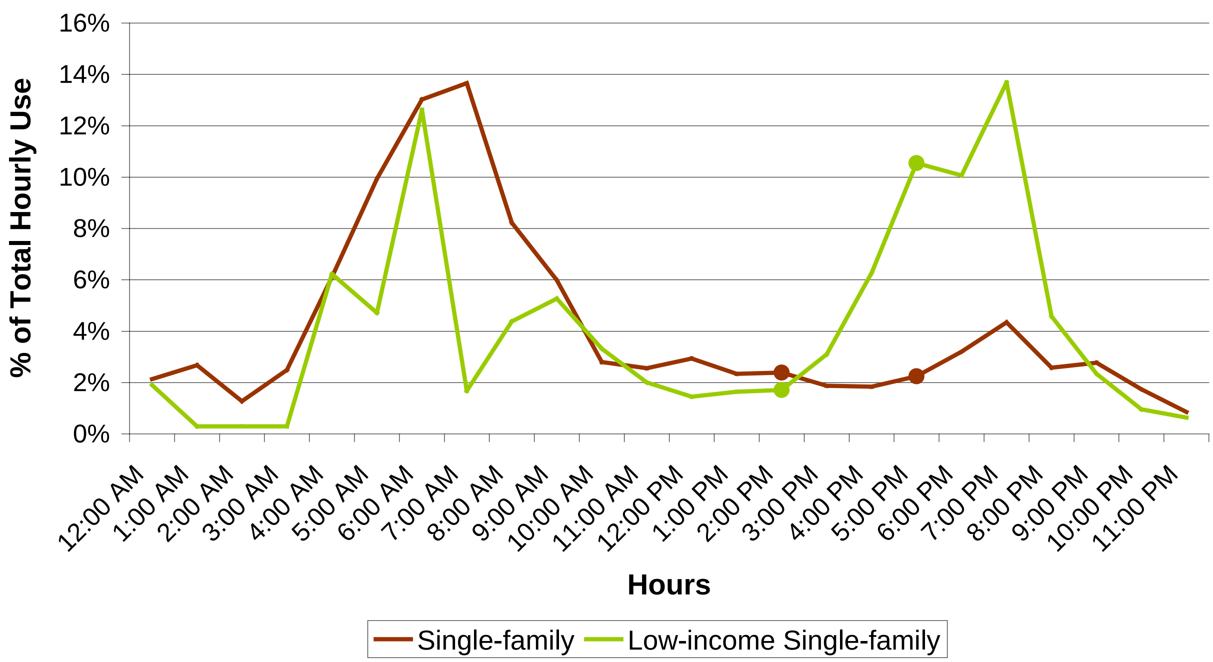
Table 24: Disaggregated Hourly Water Demand Profiles - Low-income Single-family Indoor

Hour	Baths	Showers	Toilets	Clothes Washers	Dish-washers	Faucet	Leak	Other	Total
12 AM	0.03%	0.61%	0.44%	0.19%	0.01%	0.32%	0.45%	0.03%	2.1%
1:00	0.00%	0.15%	0.23%	0.10%	0.00%	0.15%	0.43%	0.03%	1.1%
2:00	0.01%	0.04%	0.23%	0.03%	0.00%	0.11%	0.39%	0.03%	0.8%
3:00	0.00%	0.05%	0.26%	0.03%	0.00%	0.07%	0.38%	0.08%	0.9%
4:00	0.00%	0.21%	0.28%	0.01%	0.00%	0.20%	0.42%	0.04%	1.2%
5:00	0.01%	0.12%	0.44%	0.02%	0.00%	0.26%	0.43%	0.07%	1.4%
6:00	0.35%	1.21%	0.71%	0.30%	0.00%	1.05%	0.51%	0.26%	4.4%
7:00	0.18%	1.39%	1.06%	0.91%	0.01%	1.22%	0.61%	0.15%	5.5%
8:00	0.18%	1.47%	1.00%	1.44%	0.01%	1.39%	0.63%	0.29%	6.4%
9:00	0.04%	1.42%	1.15%	1.58%	0.02%	1.42%	0.62%	0.12%	6.4%
10:00	0.03%	1.06%	1.02%	1.54%	0.02%	1.34%	0.66%	0.18%	5.9%
11:00	0.07%	1.05%	0.94%	1.36%	0.02%	1.39%	0.65%	0.18%	5.7%
12 PM	0.09%	0.87%	0.77%	1.29%	0.04%	1.14%	0.67%	0.15%	5.0%
1:00	0.06%	0.53%	0.76%	1.20%	0.02%	1.06%	0.66%	0.10%	4.4%
2:00	0.03%	0.58%	0.69%	1.07%	0.00%	1.00%	0.69%	0.10%	4.2%
3:00	0.04%	0.64%	0.76%	0.86%	0.02%	0.97%	0.67%	0.26%	4.2%
4:00	0.06%	0.87%	0.95%	0.89%	0.03%	1.09%	0.62%	0.22%	4.7%
5:00	0.22%	0.94%	0.97%	0.83%	0.01%	1.63%	0.61%	0.33%	5.5%
6:00	0.06%	1.17%	0.90%	0.77%	0.02%	1.65%	0.60%	0.40%	5.6%
7:00	0.13%	1.42%	0.82%	0.87%	0.03%	1.31%	0.59%	0.17%	5.3%
8:00	0.19%	1.87%	0.91%	0.81%	0.03%	1.30%	0.59%	0.21%	5.9%
9:00	0.13%	1.59%	0.90%	0.97%	0.02%	1.18%	0.57%	0.11%	5.5%
10:00	0.03%	1.29%	0.81%	0.82%	0.05%	1.05%	0.62%	0.05%	4.7%
11:00	0.04%	0.85%	0.73%	0.47%	0.03%	0.65%	0.53%	0.05%	3.4%
Total	**2.0%**	**21.4%**	**17.7%**	**18.4%**	**0.4%**	**22.9%**	**13.6%**	**3.6%**	**100%**

5.1.2 Outdoor Water Use

In order to generate hourly demand patterns for outdoor use, all single-family and low-income single-family outdoor water use events for the period from May through September were extracted from Study 3's events database. These were predominantly irrigation events that were controlled by both automatic irrigation timers and manual applications. Study 3 statistics show that total outdoor water use for single-family homes was significantly higher than that for low-income single-family homes. However, the low-income single-family homes tended to have an afternoon irrigation peak that coincided at least partially with the peak energy demand period as well as a morning peak, while single-family homes exhibited only a morning peak. Figure 33 shows the hourly percentage of total hourly outdoor water use for these two groups. It should be kept in mind that since the total outdoor use volume is greater for the single-family group its hourly volumes of use will also be greater.

Figure 20: Hourly Water Demand Profiles– Single-family and Low-income Single-family Outdoor



••indicates peak energy demand period (2:00 PM – 5:00 PM)

5.1.3 Peak Hourly Outdoor Use Patterns

Peak outdoor water demand is different for single-family and low-income single-family homes, as shown in Table 47. These data show that a prudent approach to modeling residential outdoor use would consider income level to be a significant factor.

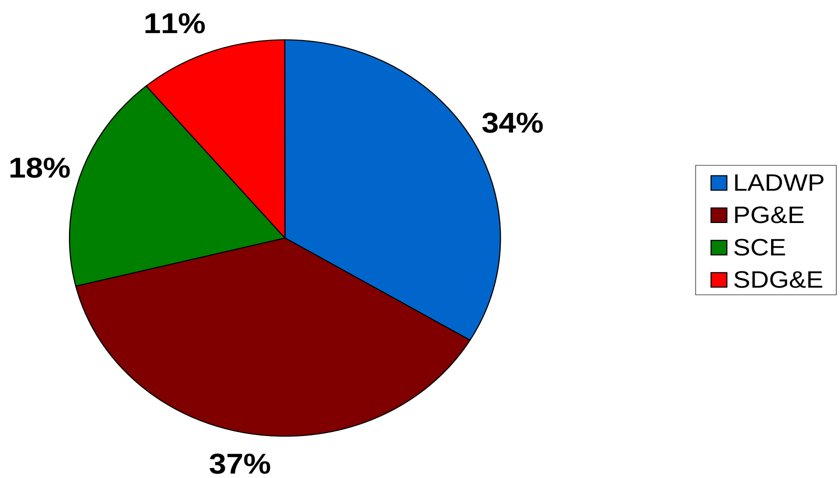
Table 25: Aggregated Hourly Water Demand – Single-family and Low-income Single-family Outdoor

Hour	Single-family: % of Total Daily Outdoor Water Use	Low-Income Single-family: % of Total Daily Outdoor Water Use
12:00 AM	2.12%	1.90%
1:00	2.66%	0.30%
2:00	1.25%	0.30%
3:00	2.47%	0.29%
4:00	6.11%	6.23%
5:00	9.97%	4.72%
6:00	13.09%	12.62%
7:00	13.73%	1.68%
8:00	8.25%	4.38%
9:00	6.00%	5.27%
10:00	2.79%	3.32%
11:00	2.56%	2.00%
12:00 PM	2.94%	1.45%
1:00	2.34%	1.64%
Total Before Peak	**76%**	**46%**
2:00	2.38%	1.71%
3:00	1.87%	3.10%
4:00	1.84%	6.28%
Total During Peak	**6%**	**11%**
5:00	2.24%	10.55%
6:00	3.21%	10.06%
7:00	4.34%	13.68%
8:00	2.56%	4.58%
9:00	2.75%	2.34%
10:00	1.72%	0.96%
11:00	0.83%	0.64%
Total After Peak	**18%**	**43%**

5.1.4 Single-family and Low-income Single-family Results by IOU Service Area

The Embedded Energy in Water Studies are focused on understanding the embedded energy in water use in various California IOU service areas. A geographic information system (GIS) analysis was performed to determine the combined percentage of single-family and low-income single-family homes used in this analysis that received service from each of the three IOUs providing electric service in the state (PG&E, SCE and SDG&E), as well as those in the Los Angeles Department of Water and Power (LADWP, a public utility).[84]Figure 35shows the percentage of Study 3 homes in each of these service areas.

Figure 21: Percentage of Single-family and Low-income Single-family Study 3 Sites by Electric Utility Service Area[85]



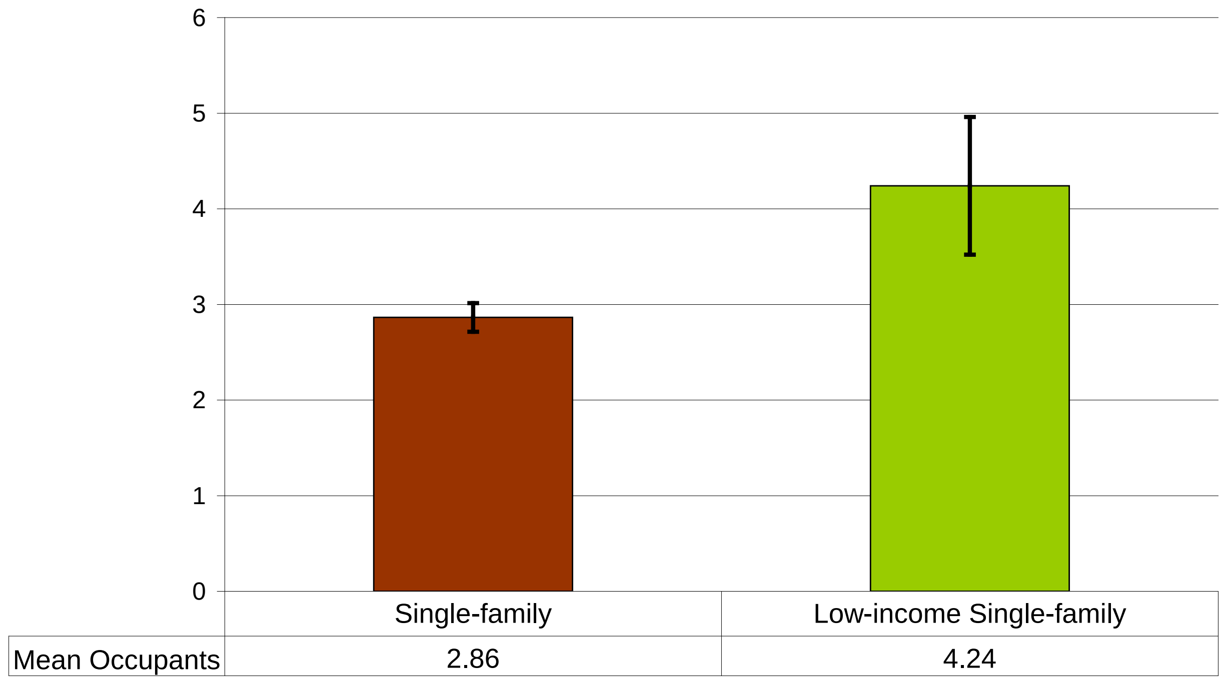
5.1.5 Comparison of Single-family Income Groups

Data analysis showed that there were several differences in the characteristics of the single-family and low-income single-family groups in California. The low-income single-family group showed a strong tendency toward a higher number of residents per household. Figure 37 shows that, on average, low-income single-family households had 1.38 more occupants than single-family households. The mean number of persons per household in the low-income single-family group was 4.24 ± 0.76, while that of the single-family group was 2.86 ± .014. The difference in the means is statistically significant at the 95 percent confidence level.

[84] For this analysis, Study 3 used data collected for the *CSFWUES* from 15 California water agency service areas, including that of Los Angeles Department of Water and Power (LADWP). It was assumed for Study 3's analysis that the single-family/low-income single-family water use in the LADWP service area is similar to that in SCE's service area. For more information on the *CSFWUE*, see Appendix B: California Single Family Water Use Efficiency Study Information.

[85] Data from Aquacraft, Inc., *California Single Family Water Use Efficiency Study*.

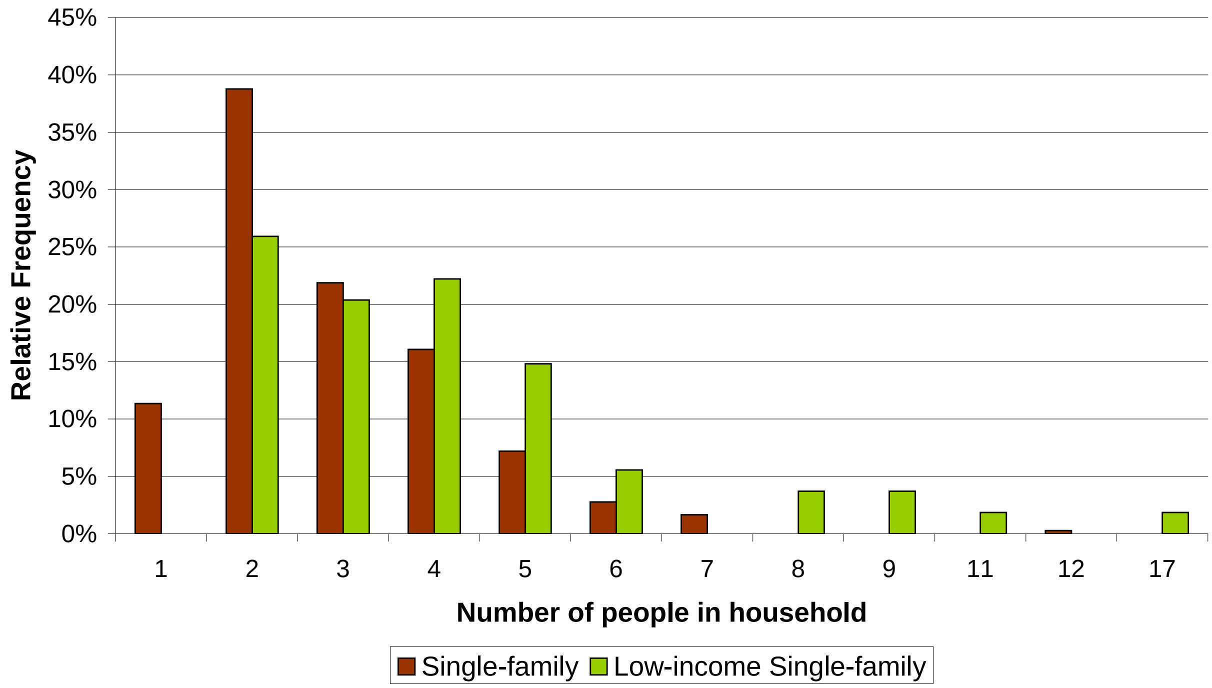
Figure 22: Mean Number of Occupants per Household - Single-family and Low-income Single-family*



*Bar denotes ± 95% confidence interval around the mean estimate for each for the categories.

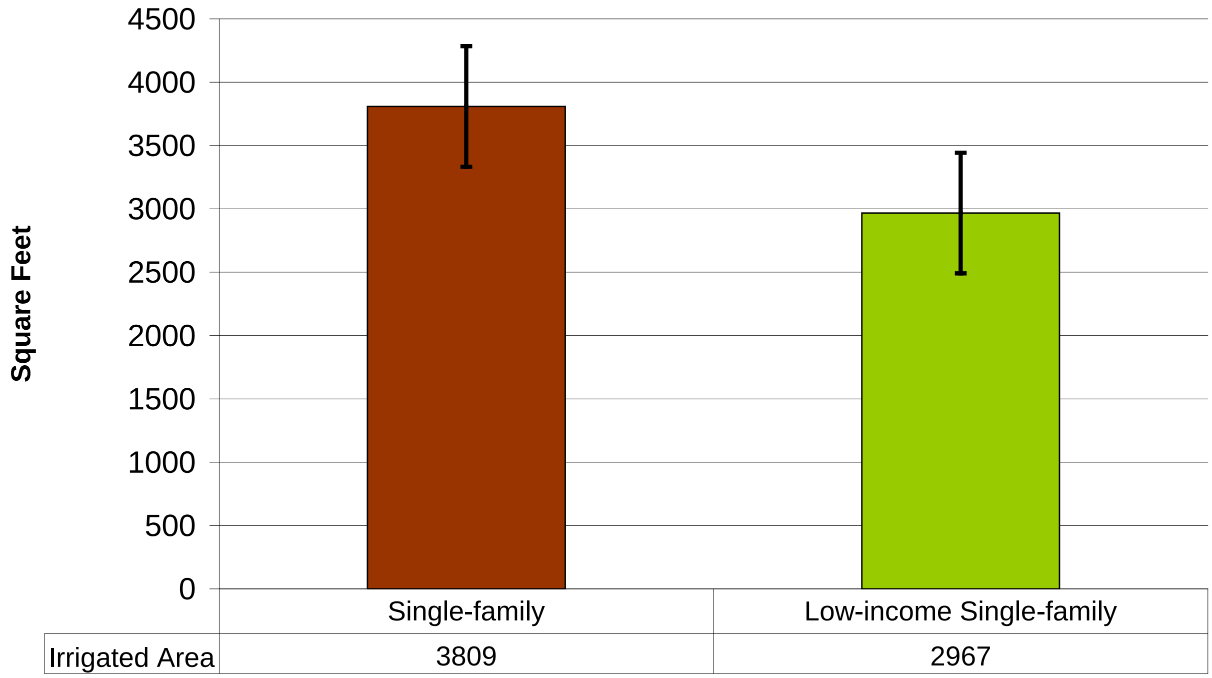
However, both groups include outliers at very high values between 12 and 17 occupants per household. Figure 39 shows the distribution of occupants per household in the single-family and low-income single-family groups. The accuracy of these data, including the outliers, is not known as they were self-reported, and no interviews or site visits were conducted with the residents.

Figure 23: Number of Household Occupants by Income Group - Single-family and Low-income Single-family



Physical aspects of single-family versus low-income single-family residences differ as well. On average, the total irrigated area for Study 3 low-income single-family residences is about 78 percent of that of single-family residences. Due to the variability in the data, the difference in the mean values is not statistically significant at the 95 percent confidence level. The data do, however, suggest that higher income households tend to have more irrigated landscape area. Figure 41 shows average irrigated areas by income group.

Figure 24: Average Irrigated Areas - Single-family and Low-income Single-family*



*Bar denotes 95% confidence interval around the mean estimate for each for the categories.

Proportionally, single-family residences used six percent of their outdoor water total during the peak energy demand hours between 2:00 PM – 5:00 PM, while low-income single-family residences used 11 percent of their outdoor total during the same period. However, care should be used when comparing these two percentages, as the single-family outdoor total is significantly higher than that of low-income single-family homes. A comparison of annual and peak volumes, shown in Table 49, reveals that the volumes of water used for outdoor purposes in low-income single-family households is lower on an annual basis and just slightly higher during the peak periods than those of single-family households.

Table 26: Comparison of Mean Outdoor Water Use Volume During Peak Energy Hours – Single-family and Low-income Single-family

Outdoor Water Use Volume Per Residence	Single-family	Low-Income Single-family
Outdoor Annual (kgal)	93.9	58.5
Annual Peak (kgal)	5.7	6.5
Annual Peak (CCF)	7.6	8.7

The average single-family residence does, indeed, have lower outdoor water demand during the peak energy demand period compared to the average low-income single-family residence. Overall, the impact of automatic irrigation systems is a likely explanation. Note that low-income single-family homes exhibit moderate use at 2:00 PM, possibly indicating that some have sprinkler timers. However, later in the afternoon, the average low-income single-family household begins to use comparatively more water than the average single-family household. Of the 415 single-family and low-income single-family homes surveyed, 393 answered questions relating to landscape irrigation methods. Survey response information in this area is shown in Table 51.

Table 27: Number of Survey Respondents Who Irrigate by Type and Income Group - Single-family and Low-income Single-family

Self-reported Irrigation Type	Single-family		Low-Income Single-family	
	N	%	N	%
Manual Irrigation	96	28%	30	61%
Automatic Irrigation System	248	72%	19	39%
Total	**344**	**100%**	**49**	**100%**

The data in Table 51 show a striking difference in the number of automatic irrigation systems across the two groups. Low-income single-family homes reported manual irrigation for 61 percent of homes and automatic controllers in only 39 percent. Of the single-family homes, only 28 percent reported manual irrigation, while 72 percent had automatic control systems. Considering that 72 percent of the single-family homes likely have irrigation timers, it is not unusual that this group uses a larger portion of water outdoors between 6:00 AM and 8:00 AM, and very little during peak energy demand hours.

5.1.6 Findings

Study 3 used data collected from a large sample of single-family and low-income single-family residences, which were randomly selected in 15 public water agencies throughout California, to examine hourly use patterns for both single-family and low-income single-family households. Both indoor and outdoor water use was included in the analysis. Key findings of this analysis follow.

5.1.6.1 Indoor Water Use

- The hourly water demands for indoor water use by single-family end-user categories show little variation by income group.
- The peak total indoor water use periods did not overlap with the peak energy demand period for either of the single-family income groups.
- Single-family and low-income single-family categories had a similar percent of total daily indoor water use coincident with peak energy demand (13 percent.)
- Certain indoor water demand profile categories do exhibit relatively high water demand during the peak energy demand period for single-family and low-income single-family groups. These include showers, toilets, clothes washers, faucets and leaks.
- Baths and dishwashers show relatively little water use coincident with the peak energy demand period for either the single-family or low-income single-family category.
- The number of residents in the low-income single-family group was significantly higher than in the single-family group.

5.1.6.2 Outdoor Water Use

- Total outdoor water use in the single-family group was significantly higher than that in the low-income single-family group.
- Eleven percent of outdoor water used by the low-income single-family group and six percent of that used by the single-family group was used during the peak energy demand periods. The greater incidence of manual irrigation associated with the low-income single-family group likely accounts for its higher percentage, as the hand-watering pattern causes more late afternoon water use.

5.2 *Residential Low-Income Multi-family*

The following sections provide water use results for individually-metered low-income multi-family households based on the analysis of the data collected in San Diego, Irvine and the San Francisco East Bay Area. A total of 159 low-income multi-family homes were studied and are included in the database for indoor and outdoor (or non-seasonal and seasonal) hourly water uses.

5.2.1 Indoor Water Use

Daily profiles of use as a percentage of total indoor water use for low-income multi-family households are shown in Figure 43. Water use was disaggregated into the same categories used for single-family and low-income single-family homes:

- Baths
- Showers
- Toilets
- Clothes Washers
- Dishwashers
- Faucets
- Leaks
- Other, which includes:
    - Water treatment systems
    - Evaporative coolers
    - Other miscellaneous indoor uses

Low-income multi-family household indoor water use has two peaks during the day, one between 9:00 AM and 10:00 AM and another between 6:00 PM and 7:00 PM. While these time periods represent the hours with the highest water use, each of these “peaks” may actually extend several additional hours. Neither of these peak periods coincides with the peak energy demand. Table 53 shows the peak indoor water demand for low-income multi-family homes. However, low-income multi-family homes use the same 13 percent of their total indoor water use during the peak energy demand period as do single-family/low-income single-family households.

Figure 25: Disaggregated Hourly Water Demand Profiles - Low-income Multi-family Indoor

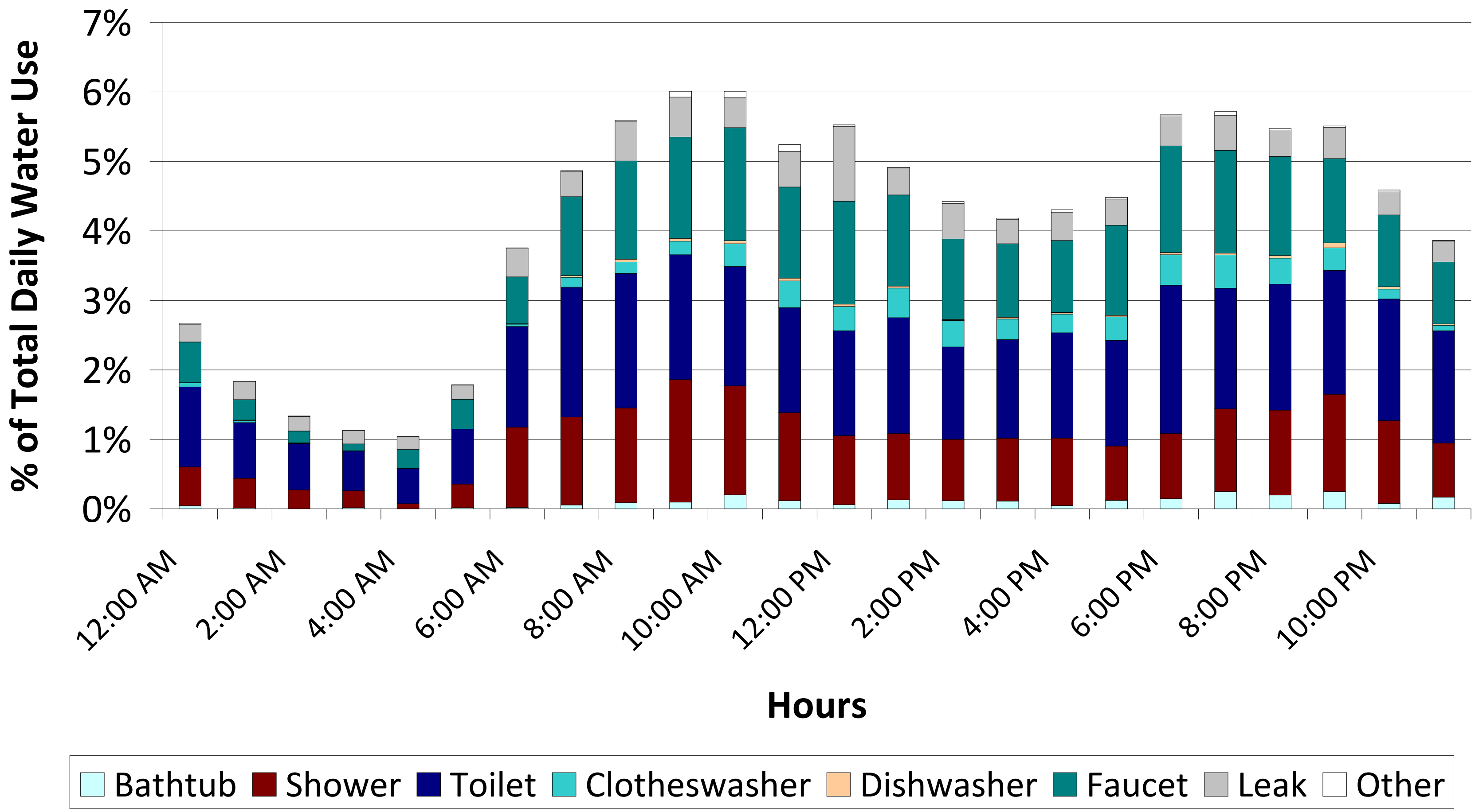


Table 28: Aggregated Hourly Water Demand - Low-income Multi-family Indoor

Hour	Low-income Multi- family: % of Total Daily Indoor Water Use
12:00 AM	2.67%
1:00	1.84%
2:00	1.34%
3:00	1.13%
4:00	1.04%
5:00	1.79%
6:00	3.76%
7:00	4.87%
8:00	5.60%
9:00	6.01%
10:00	6.01%
11:00	5.25%
12:00 PM	5.53%
1:00	4.92%
Total Before Peak	**52%**
2:00	4.43%
3:00	4.19%
4:00	4.31%
Total During Peak	**13%**
5:00	4.49%
6:00	5.68%
7:00	5.72%
8:00	5.48%
9:00	5.51%
10:00	4.59%
11:00	3.87%
Total After Peak	**35%**

Figure 45 shows the peak time percentage of indoor water use by water demand profile category for low-income multi-family homes. The percentage of use for most categories is higher than it is for single-family/low-income single-family homes (shown in Figure 31). However, there appears to be less water leakage in low-income multi-family homes.

Figure 26: Relative Peak Hour Water Use by Water Demand Profile Category – Low-income Multi-family

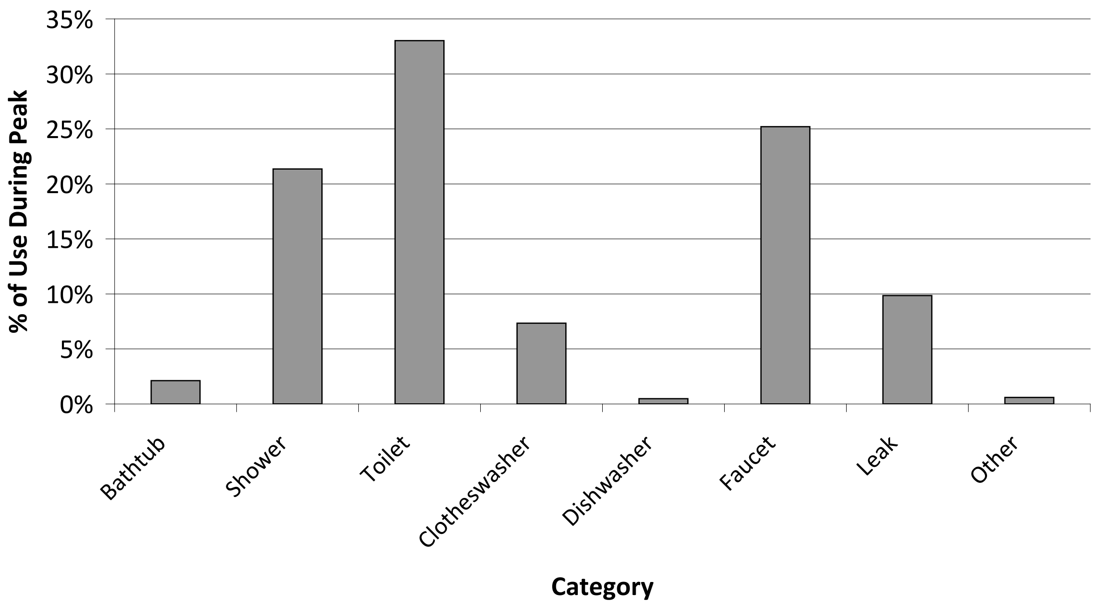


Table 55 shows the indoor low-income multi-family hourly use profile data in tabular format as percentages of total indoor water use.

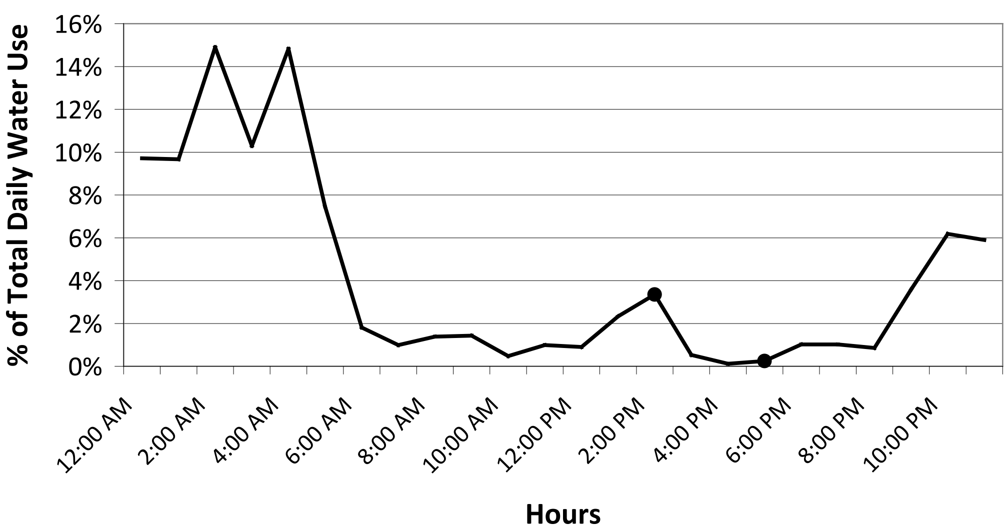
Table 29: Disaggregated Hourly Water Demand - Low-income Multi-family Indoor

Hour	Baths	Showers	Toilets	Clothes Washers	Dish-washers	Faucet	Leaks	Other	Total
12 AM	0.04%	0.56%	1.15%	0.06%	0.00%	0.58%	0.26%	0.01%	3%
1:00	0.01%	0.43%	0.80%	0.03%	0.01%	0.29%	0.26%	0.01%	2%
2:00	0.00%	0.27%	0.67%	0.01%	0.00%	0.17%	0.21%	0.00%	1%
3:00	0.02%	0.24%	0.57%	0.00%	0.00%	0.10%	0.20%	0.00%	1%
4:00	0.00%	0.07%	0.51%	0.01%	0.00%	0.27%	0.18%	0.00%	1%
5:00	0.02%	0.34%	0.79%	0.00%	0.00%	0.43%	0.21%	0.00%	2%
6:00	0.02%	1.16%	1.45%	0.03%	0.01%	0.68%	0.41%	0.01%	4%
7:00	0.06%	1.27%	1.87%	0.14%	0.02%	1.14%	0.36%	0.01%	5%
8:00	0.09%	1.36%	1.94%	0.16%	0.04%	1.42%	0.57%	0.01%	6%
9:00	0.09%	1.76%	1.80%	0.20%	0.04%	1.46%	0.57%	0.08%	6%
10:00	0.20%	1.57%	1.72%	0.33%	0.04%	1.63%	0.43%	0.09%	6%
11:00	0.12%	1.27%	1.51%	0.38%	0.04%	1.31%	0.52%	0.10%	5%
12 PM	0.06%	0.99%	1.51%	0.35%	0.03%	1.48%	1.07%	0.03%	6%
1:00	0.13%	0.95%	1.67%	0.43%	0.03%	1.31%	0.39%	0.01%	5%
2:00	0.12%	0.88%	1.33%	0.38%	0.02%	1.16%	0.51%	0.03%	4%
3:00	0.11%	0.90%	1.42%	0.30%	0.02%	1.06%	0.35%	0.02%	4%
4:00	0.05%	0.97%	1.52%	0.27%	0.02%	1.04%	0.41%	0.03%	4%
5:00	0.12%	0.78%	1.53%	0.34%	0.02%	1.30%	0.38%	0.03%	4%
6:00	0.14%	0.94%	2.14%	0.44%	0.03%	1.54%	0.43%	0.02%	6%
7:00	0.25%	1.19%	1.74%	0.48%	0.03%	1.48%	0.51%	0.05%	6%
8:00	0.20%	1.22%	1.81%	0.38%	0.04%	1.43%	0.38%	0.02%	5%
9:00	0.25%	1.40%	1.79%	0.32%	0.07%	1.21%	0.45%	0.02%	6%
10:00	0.08%	1.19%	1.75%	0.14%	0.04%	1.04%	0.33%	0.03%	5%
11:00	0.17%	0.78%	1.62%	0.08%	0.02%	0.89%	0.31%	0.01%	4%
Total	**2%**	**23%**	**35%**	**5%**	**1%**	**24%**	**10%**	**1%**	**100%**

5.2.2 Outdoor Water Use

In order to generate hourly demand patterns for outdoor use at low-income multi-family properties, the respective water agency identified irrigation water meters that were then logged for at least a two-week period to collect flow trace data. At the time of the site visits, neither property management nor the water agency were able to assist in locating irrigation timers, and information on sub-meters serving pools and laundry rooms were unattainable. The timing of outdoor use at multi-family properties shows that most of the water demand occurs in the evening through early morning, and that these properties tend to have a minimal irrigation peak of 4 percent that coincides with the peak energy demand period. Figure 47 shows the percentage of total hourly outdoor use at low-income multi-family properties. This figure and Figure 49 illustrate that low-income multi-family properties tend to irrigate over night. Irrigation patterns will be discussed in more detail later in this section.

Figure 27: Hourly Water Demand Profile – Low-income Multi-family Outdoor



••indicates peak energy demand period (2:00 PM – 5:00 PM)

5.2.2.1 Outdoor Peak Hourly Use Patterns

As Table 57 shows, only four percent of the total daily multi-family outdoor water use occurred during the peak energy demand period (2:00 PM – 5:00 PM).

Table 30: Aggregated Hourly Water Demand – Low-income Multi-family Outdoor

Hour	Low-income Multi- family: % of Total Daily Outdoor Water Use
12:00 AM	9.71%
1:00	9.67%
2:00	14.90%
3:00	10.30%
4:00	14.82%
5:00	7.46%
6:00	1.81%
7:00	0.99%
8:00	1.38%
9:00	1.43%
10:00	0.48%
11:00	0.99%
12:00 PM	0.90%
1:00	2.33%
Total Before Peak	**77%**
2:00	3.35%
3:00	0.53%
4:00	0.12%
Total During Peak	**4%**
5:00	0.25%
6:00	1.02%
7:00	1.02%
8:00	0.85%
9:00	3.59%
10:00	6.18%
11:00	5.90%
Total After Peak	**19%**

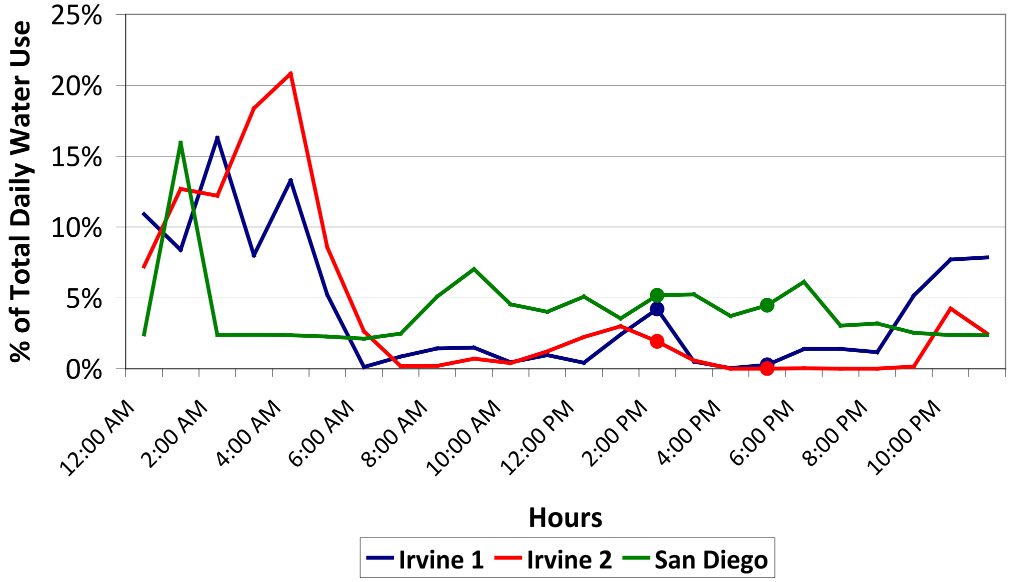
One of Study 3 objectives was to identify hourly demands for reclaimed water by end-use category (when possible). During the data collection events, three of the multi-family property water meters serving outdoor uses were identified as reclaimed water lines. These three meters represented 34 percent of the total daily use during the logging period. Table 59 shows the percent of reclaimed outdoor water use at multi-family properties at each hour of the day and during peak energy demand hours. As compared to that for non-reclaimed water, the hourly use pattern here is even more heavily skewed to the night-time period, with slightly less (one percent less) reclaimed water being used during peak energy demand hours.

Table 31: Aggregated Hourly Water Demand – Low-income Multi-family Outdoor Reclaimed Water

Hour	Low-income Multi-family: % of Total DailyOutdoor Reclaimed Water Use
12:00 AM	14.02%
1:00	8.71%
2:00	14.90%
3:00	5.51%
4:00	14.30%
5:00	7.21%
6:00	0.20%
7:00	1.28%
8:00	1.24%
9:00	0.54%
10:00	0.27%
11:00	0.99%
12:00 PM	0.52%
1:00	2.63%
Total Before Peak	**72%**
2:00	2.84%
3:00	0.08%
4:00	0.04%
Total During Peak	**3%**
5:00	0.53%
6:00	2.73%
7:00	2.49%
8:00	2.28%
9:00	3.17%
10:00	4.55%
11:00	8.99%
Total After Peak	**25%**

Figure 49 shows the hourly demand pattern for outdoor water use at the three multi-family properties at which irrigated areas and irrigation meters were accessible for Study 3 (two in Irvine and one in San Diego). These three properties tended to have a lower afternoon outdoor water demand that coincides with the peak energy demand period. Three percent of the average hourly use occurred during this window. The two Irvine sites were logged in the summer and demonstrate a clear early morning demand pattern, which is expected with properly programmed automatic irrigation timers. Data logging occurred in the winter in San Diego and during a severe rainstorm (at the start of the logging period), possibly explaining a less defined, but still similar, hourly pattern.

Figure 28: Hourly Water Demand Profiles- Select Low-income Multi-family Properties



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Although the total water use for irrigation is likely to change with seasonal changes in evapotranspiration (ET),[86] as in the summer peak ET period, it is unlikely that the hours of irrigation would change purely based on ET, and thus, using different hourly profiles for peak ET periods is not recommended.

5.2.3 Low-income Multi-family Results by IOU Service Area

The sample of 159 low-income multi-family homes in Study 3 were approximately equally represented in the three California electric IOU service areas: 52 homes in PG&E's service area, 56 in SCE's, and 51 in SDG&E's.

5.2.4 Findings

Study 3 used data collected from random samples of individually-metered low-income multi-family homes, which were selected from customers of three water agencies and three IOU service areas. To examine hourly use patterns for these homes and to provide information on how water is used outdoors at multi-family properties, individually-

[86] A measurement of the water requirement of plants. According to CIMIS, ET is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water is needed by crops, lawn, garden, trees, etc. for healthy growth and productivity. The change in ET during the year mirrors the change in outdoor water use. For example, the peak ET observed during 2008-2009 occurred during July.

metered indoor uses and property-metered outdoor demands were included in the analysis. Findings of this analysis include:

- The peak total indoor water use periods did not overlap with the peak energy demand period for the low-income multi-family group.
- The low-income multi-family category used 13 percent of its total daily indoor water use coincident with peak energy demand.
- For the low-income multi-family group, showers, toilets and faucets also show relatively high water demand during the peak energy demand period. Clothes washers, leaks, baths and dishwashers do not.
- The low-income multi-family group used four percent of its total daily outdoor water usedduring the peak energy demand period.
- The hourly pattern for reclaimed outdoor water use at multi-family properties differs somewhat from that for non-reclaimed water. While use coincident with the peak energy demand period is similar (three percent for reclaimed as compared to four percent for non-reclaimed), reclaimed water use is six percentage points higher than non-reclaimed after peak, and five percentage points lower before peak.

5.3 Commercial

The following sections provide water use results for commercial end-users based on the analysis of new flow trace data collected in SDG&E, SCE and PG&E service areas, as well as flow trace data collected throughout California and other states for earlier studies. Daily profiles of water use as a percentage of the total average hourly demand at commercial sites are also provided. These profiles are included in the database for commercial hourly water uses.

Commercial end-users include a wide variety of water users who are engaged in some sort of commercial activity. This is a highly variable category, but the common and defining characteristic is that each provides a product or a service for sale to the public, or is in support of these types of commercial activities. Private entities that provide goods or services make up the commercial sector. Public buildings are covered in a separate section below.

As a reminder, for Study 3 purposes, data collected from commercial or industrial customer dedicated irrigation water meters have been included in the analyses and results of the urban irrigation category. Data collected from commercial or industrial customer water meters monitoring both indoor and outdoor uses have been included in the analyses and results of the respective (sub-)category.

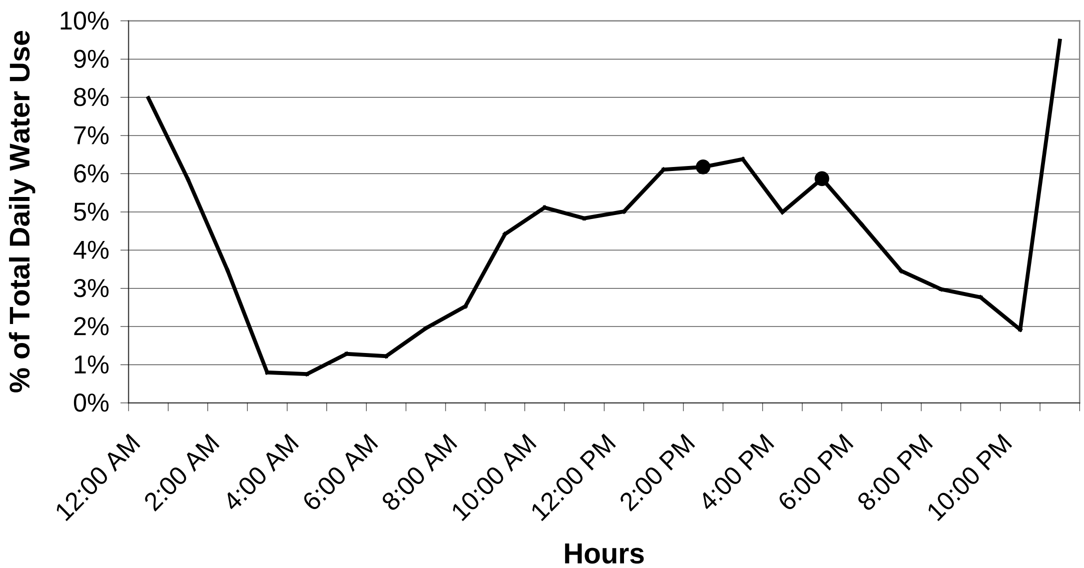
Night-time use in the traces typically reflects irrigation, as the meters used to collect these data are often combined indoor and outdoor meters. Other night-time uses may include refrigeration or be cleaning-related. Day-time peaks are associated with indoor commercial uses. A discussion of each sub-category follows.

5.3.1 General Retail

There were seven general retail sites in the existing database from which nine trace files were obtained. Among these were an auto supply store, a pet store, a liquor store, a strip mall and an electronics retailer. The data were collected between 1997 and 2005. Since many general retail customers have a multi-use meter that serves both indoor and outdoor uses, irrigation use is included in this analysis.

These retail customers showed night-time peaks due to irrigation and then typical indoor use patterns that peaked in the afternoon. Nearly 18 percent of the daily use occurred during the peak electric demand period. The percent of total average hourly use is shown in Figure 51 and the data are shown in tabular form in Table 61.

Figure 29: Aggregated Hourly Water Demand Profile - General Retail



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 32: Aggregated Hourly Water Demand - General Retail

Hour	General Retail % of Total Daily Water Use
12:00 AM	7.98%
1:00	5.85%
2:00	3.47%
3:00	0.80%
4:00	0.76%
5:00	1.28%
6:00	1.22%
7:00	1.95%
8:00	2.53%
9:00	4.42%
10:00	5.11%
11:00	4.83%
12:00 PM	5.01%
1:00	6.11%
Total Before Peak	**51%**
2:00	6.18%
3:00	6.38%
4:00	4.99%
Total During Peak	**18%**
5:00	5.87%
6:00	4.67%
7:00	3.45%
8:00	2.98%
9:00	2.76%
10:00	1.92%
11:00	9.48%
Total After Peak	**31%**

Figure 53 and Table 63 show the percentage of the total average hourly water use at general retail sites disaggregated into the following water demand profile categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

Figure 30: Disaggregated Hourly Water Demand Profiles - General Retail

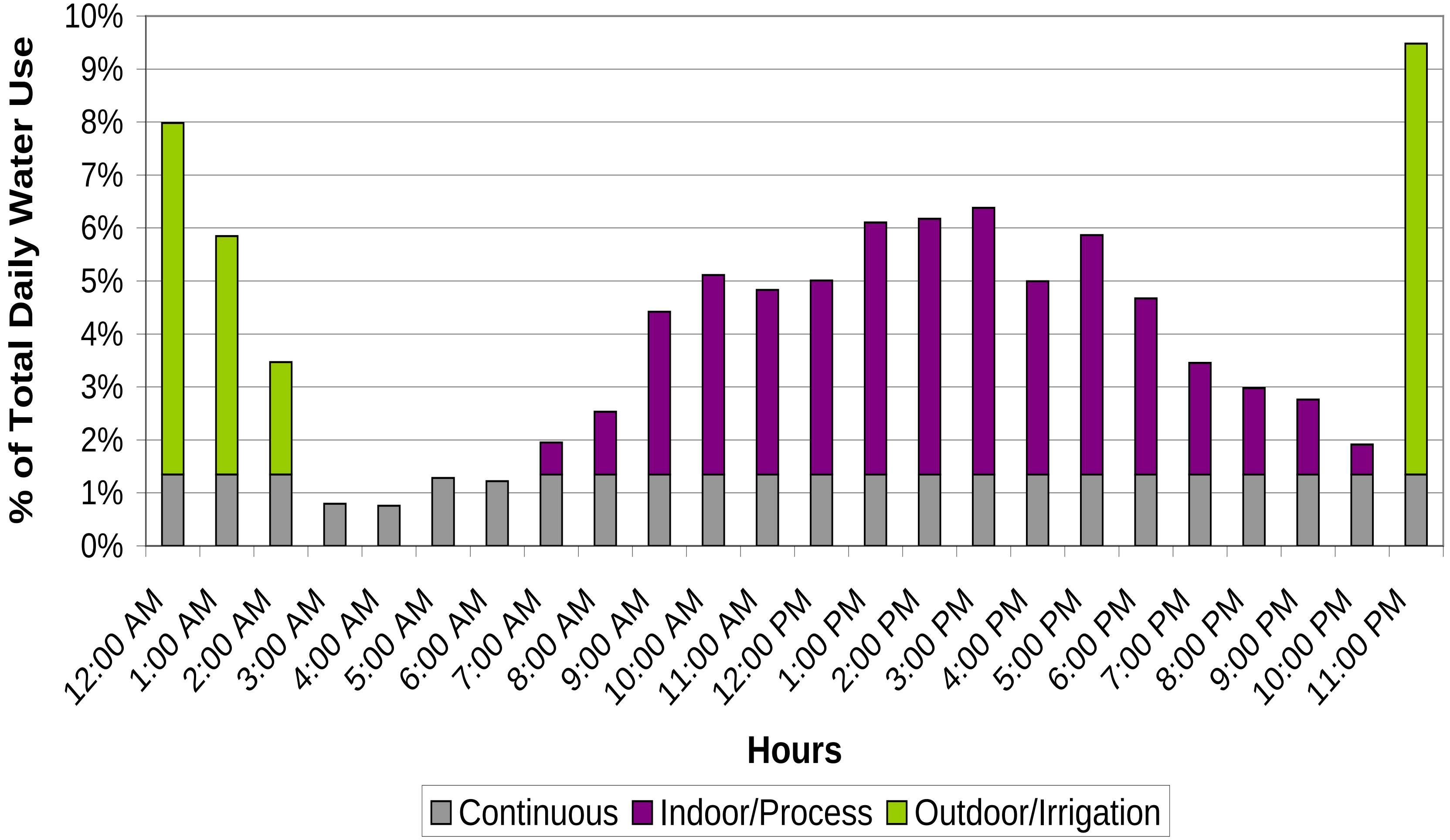


Table 33: Disaggregated Hourly Water Demand– General Retail

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12 AM	1.35%	0.00%	6.63%	8%
1:00	1.35%	0.00%	4.50%	6%
2:00	1.35%	0.00%	2.12%	3%
3:00	0.80%	0.00%	0.00%	1%
4:00	0.76%	0.00%	0.00%	1%
5:00	1.28%	0.00%	0.00%	1%
6:00	1.22%	0.00%	0.00%	1%
7:00	1.35%	0.60%	0.00%	2%
8:00	1.35%	1.18%	0.00%	3%
9:00	1.35%	3.07%	0.00%	4%
10:00	1.35%	3.76%	0.00%	5%
11:00	1.35%	3.48%	0.00%	5%
12 PM	1.35%	3.66%	0.00%	5%
1:00	1.35%	4.76%	0.00%	6%
2:00	1.35%	4.83%	0.00%	6%
3:00	1.35%	5.03%	0.00%	6%
4:00	1.35%	3.64%	0.00%	5%
5:00	1.35%	4.52%	0.00%	6%
6:00	1.35%	3.32%	0.00%	5%
7:00	1.35%	2.10%	0.00%	3%
8:00	1.35%	1.63%	0.00%	3%
9:00	1.35%	1.41%	0.00%	3%
10:00	1.35%	0.57%	0.00%	2%
11:00	1.35%	0.00%	8.13%	9%
Total	**31%**	**48%**	**21%**	**100%**

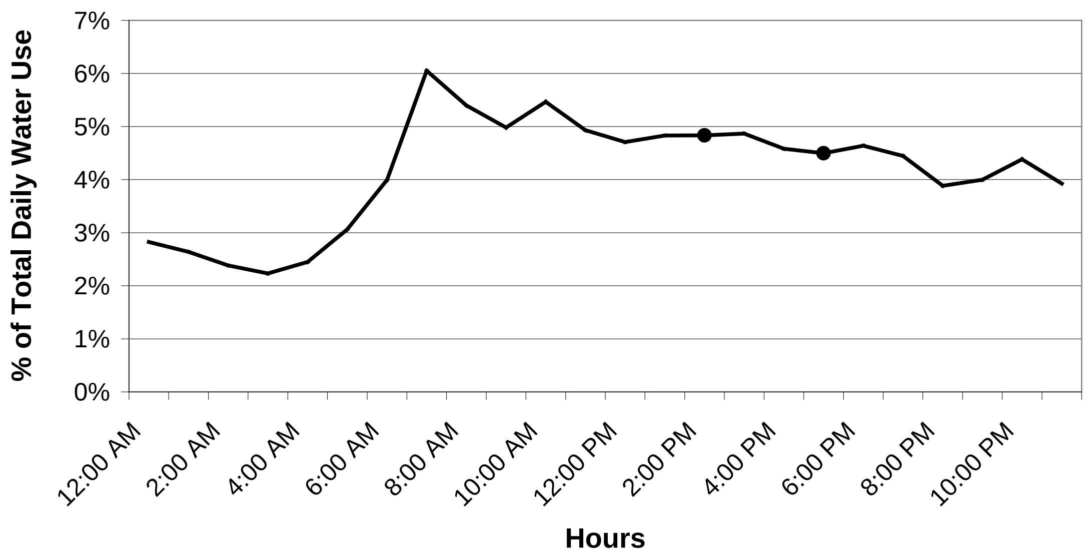
"Continuous" use drops between 3:00 and 5:00 AM for General Retail, whereas in other sectors it is same for all hours. It is likely this is because during this period the continuous use derives only from leakage, which during the rest of the day comprises a mixture of leaks, cooling and various continuous indoor uses. Since these data come from a large group of customers no single factor explains the variation in use patterns.

5.3.2 Hotels and Motels

There were a total of 10 flow trace files from five hotels/motels in the existing database. Types ranged from simple motel facilities with no restaurants to a luxury hotel in Beverly Hills with full service and 80-gallon soaking tubs in the rooms. All of the hotels/motels did on-site washing of linen, and all had swimming pools.

The hotels/motels in the data set did not appear to have significant irrigation measured by the same meters used for domestic uses. Night-time use was relatively low, and was probably due to cooling, cleaning and normal domestic uses associated with residential use. The largest peak of the day occurred in the morning between 7:00 and 8:00 AM. Over 14 percent of average daily use occurred during the peak electric demand period.

Figure 31: Aggregated Hourly Water Demand Profile – Hotels and Motels



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 34: Aggregated Hourly Water Demand - Hotels and Motels

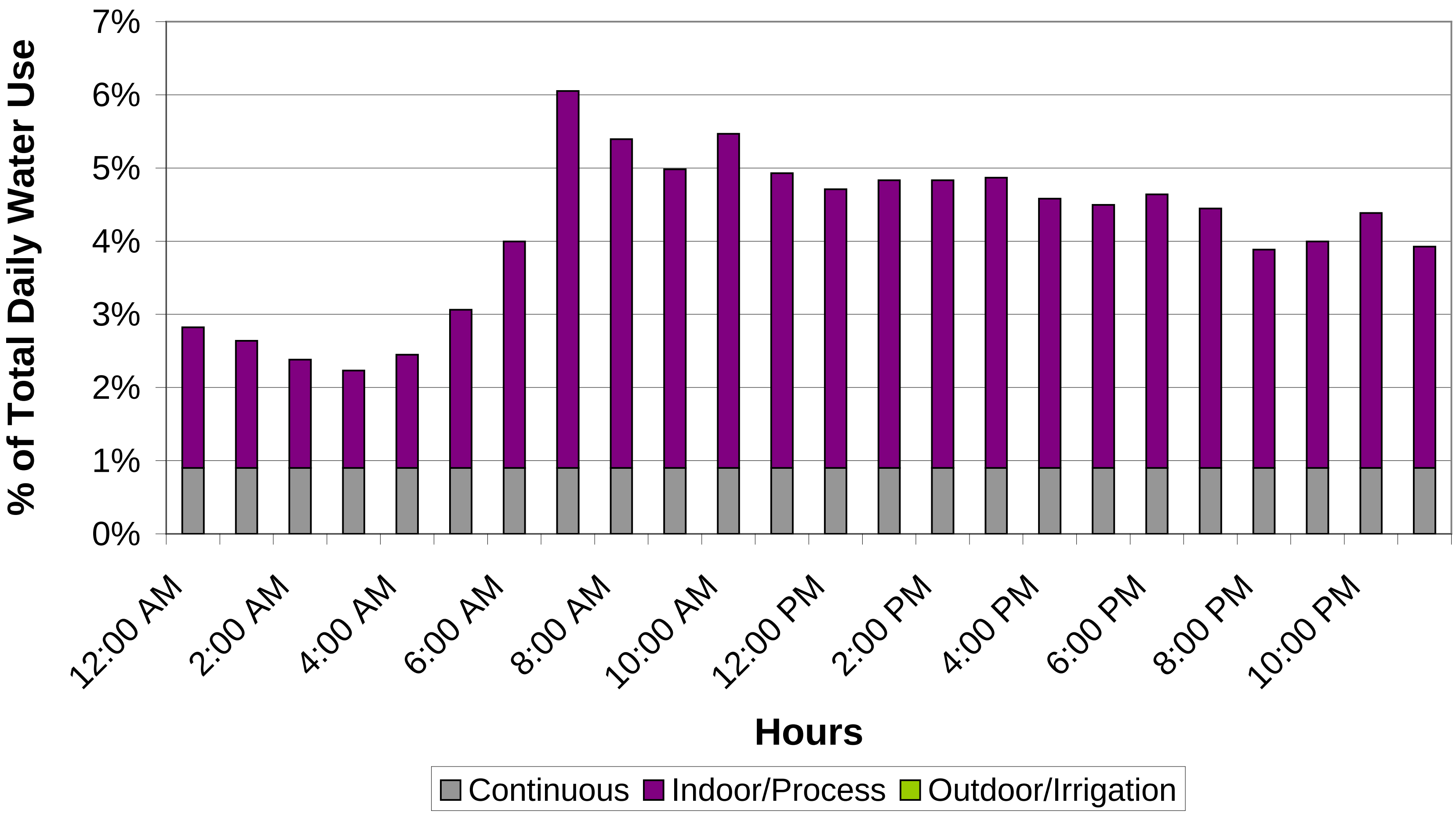
Hour	Hotels and Motels % of Total Daily Water Use
12:00 AM	2.82%
1:00	2.64%
2:00	2.38%
3:00	2.23%
4:00	2.45%
5:00	3.06%
6:00	4.00%
7:00	6.05%
8:00	5.40%
9:00	4.98%
10:00	5.47%
11:00	4.93%
12:00 PM	4.71%
1:00	4.83%
Total Before Peak	**56%**
2:00	4.83%
3:00	4.87%
4:00	4.58%
Total During Peak	**14%**
5:00	4.50%
6:00	4.64%
7:00	4.44%
8:00	3.88%
9:00	4.00%
10:00	4.38%
11:00	3.93%
Total After Peak	**30%**

Figure 56and Table 66show the percentage of the total average hourly water use at hotel/motel sites disaggregated into:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

None of the hotels/motels in Study 3 group had meters serving both indoor uses and outdoor irrigation. For Study 3, loggers were installed on meters that monitored indoor uses at hotels/motels. Consequently, there is no irrigation use shown in eitherFigure 56orTable 66

Figure 32: Disaggregated Hourly Water Demand – Hotels and Motels[87]



[87] The logged water meters for Study 3 hotel and motel sites only serve indoor uses and not irrigation. Consequently, there is no irrigation use shown.

Table 35: Disaggregated Hourly Water Demand– Hotels and Motels[88]

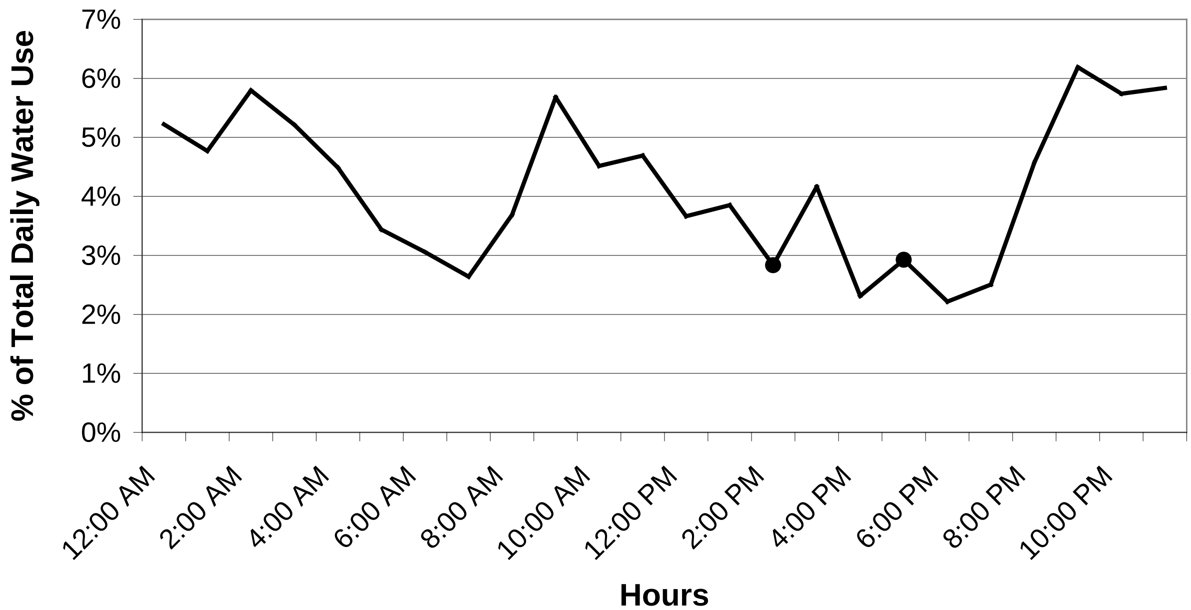
Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12AM	0.90%	1.92%	0.00%	3%
1:00	0.90%	1.74%	0.00%	3%
2:00	0.90%	1.48%	0.00%	2%
3:00	0.90%	1.33%	0.00%	2%
4:00	0.90%	1.55%	0.00%	2%
5:00	0.90%	2.16%	0.00%	3%
6:00	0.90%	3.10%	0.00%	4%
7:00	0.90%	5.15%	0.00%	6%
8:00	0.90%	4.50%	0.00%	5%
9:00	0.90%	4.08%	0.00%	5%
10:00	0.90%	4.57%	0.00%	5%
11:00	0.90%	4.03%	0.00%	5%
12PM	0.90%	3.81%	0.00%	5%
1:00	0.90%	3.93%	0.00%	5%
2:00	0.90%	3.93%	0.00%	5%
3:00	0.90%	3.97%	0.00%	5%
4:00	0.90%	3.68%	0.00%	5%
5:00	0.90%	3.60%	0.00%	4%
6:00	0.90%	3.74%	0.00%	5%
7:00	0.90%	3.54%	0.00%	4%
8:00	0.90%	2.98%	0.00%	4%
9:00	0.90%	3.10%	0.00%	4%
10:00	0.90%	3.48%	0.00%	4%
11:00	0.90%	3.03%	0.00%	4%
Total	**22%**	**78%**	**0%**	**100%**

[88] The logged water meters for Study 3 hotel and motel sites only serve indoor uses and not irrigation. Consequently, there is no irrigation use shown.

5.3.3 Offices

The data set for this sub-category contained 11 traces from seven office buildings. The duplicate water meters at the sites were for irrigation. Several of the single meters also supplied irrigation for the properties, which appears to be quite typical for office complex use. The high night-time demands were a reflection of irrigation use. During the day, office water use peaks between 10:00 and 11:00 AM, and then declines through the day with a second, smaller, peak mid-afternoon. Just over nine percent of total daily use occurs during the peak electric demand period. Traces were collected during the summer and fall. During the winter irrigation peaks would be much lower. Figure 58 and Table 68 show the aggregated percentage of total daily water use by hour at office building sites.

Figure 33:Aggregated Hourly Water Demand Profile - Offices



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 36: Aggregated Hourly Water Demand - Offices

Hour	Offices % of Total Daily Water Use
12:00 AM	5.22%
1:00	4.77%
2:00	5.80%
3:00	5.21%
4:00	4.49%
5:00	3.44%
6:00	3.05%
7:00	2.64%
8:00	3.69%
9:00	5.68%
10:00	4.51%
11:00	4.69%
12:00 PM	3.66%
1:00	3.85%
Total Before Peak	**61%**
2:00	2.83%
3:00	4.17%
4:00	2.31%
Total During Peak	**9%**
5:00	2.93%
6:00	2.22%
7:00	2.51%
8:00	4.57%
9:00	6.19%
10:00	5.74%
11:00	5.84%
Total After Peak	**30%**

Figure 60 and Table 70 show the percentage of the total average hourly water use at office building sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

Figure 34: Disaggregated Hourly Water Demand Profiles - Offices

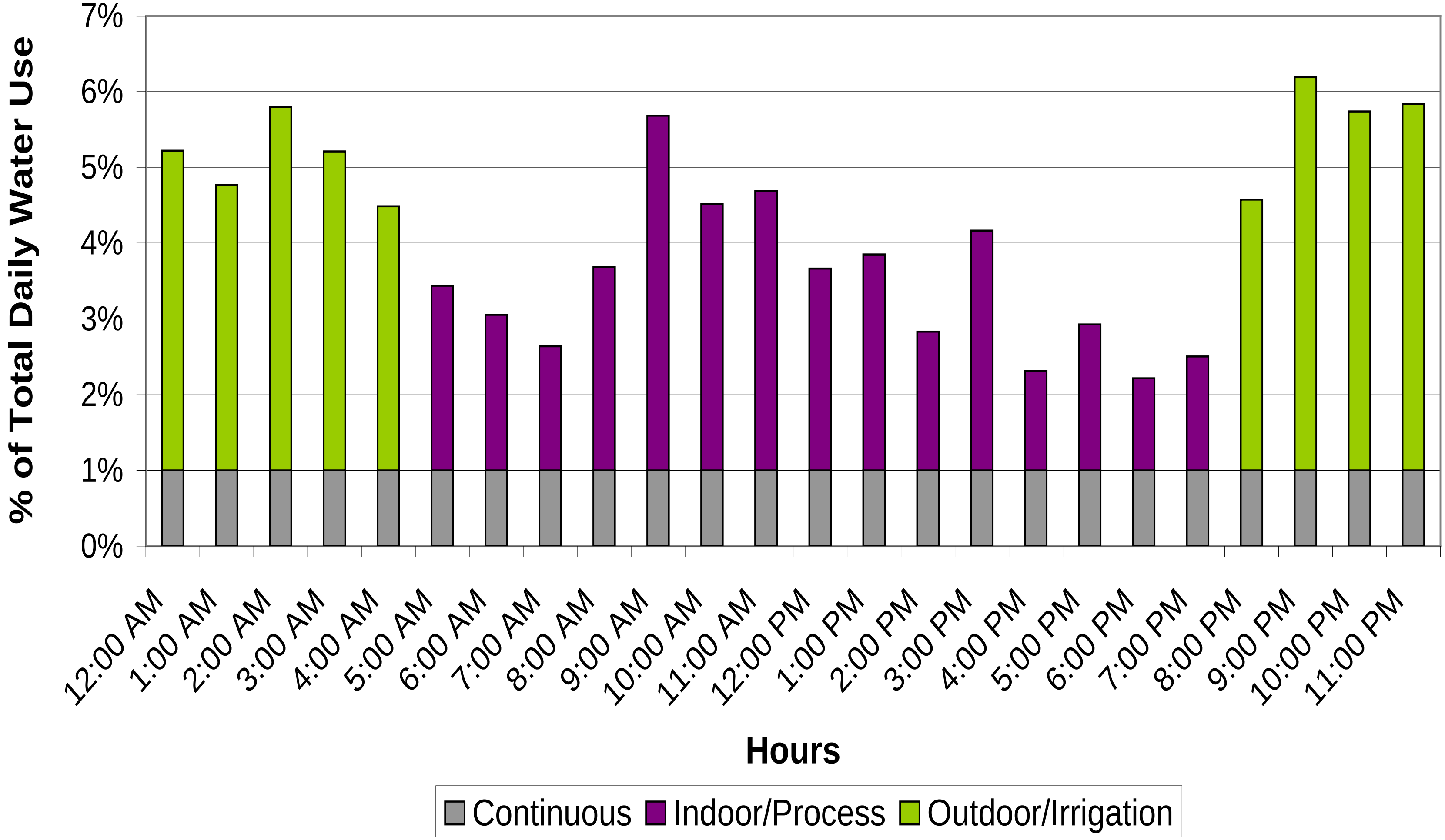


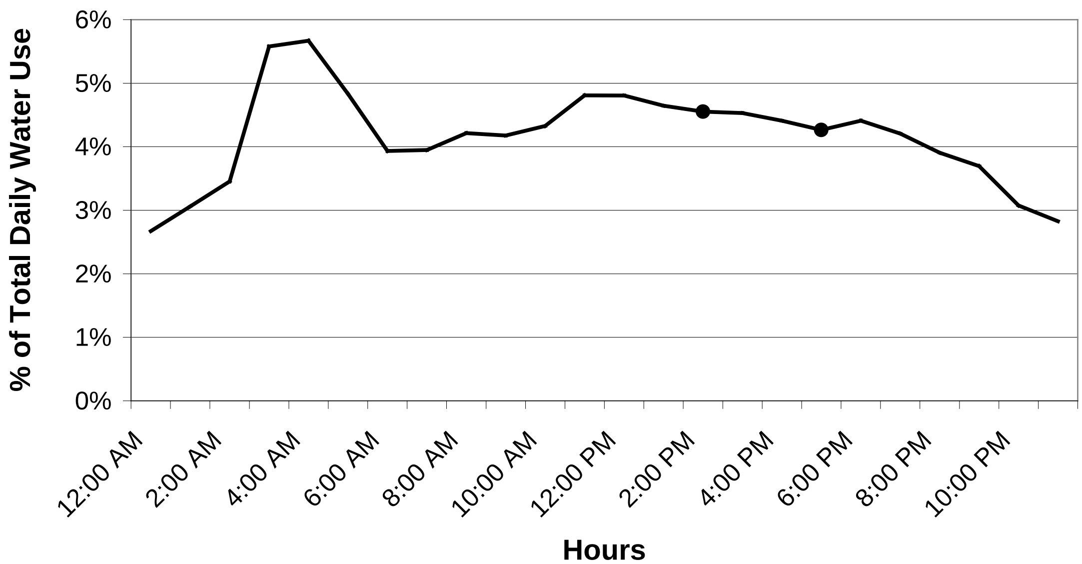
Table 37: Disaggregated Hourly Water Demand- Offices

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12 AM	1.00%	0.00%	4.22%	5%
1:00	1.00%	0.00%	3.77%	5%
2:00	1.00%	0.00%	4.80%	6%
3:00	1.00%	0.00%	4.21%	5%
4:00	1.00%	0.00%	3.49%	4%
5:00	1.00%	2.44%	0.00%	3%
6:00	1.00%	2.05%	0.00%	3%
7:00	1.00%	1.64%	0.00%	3%
8:00	1.00%	2.69%	0.00%	4%
9:00	1.00%	4.68%	0.00%	6%
10:00	1.00%	3.51%	0.00%	5%
11:00	1.00%	3.69%	0.00%	5%
12 PM	1.00%	2.66%	0.00%	4%
1:00	1.00%	2.85%	0.00%	4%
2:00	1.00%	1.83%	0.00%	3%
3:00	1.00%	3.17%	0.00%	4%
4:00	1.00%	1.31%	0.00%	2%
5:00	1.00%	1.93%	0.00%	3%
6:00	1.00%	1.22%	0.00%	2%
7:00	1.00%	1.51%	0.00%	3%
8:00	1.00%	0.00%	3.57%	5%
9:00	1.00%	0.00%	5.19%	6%
10:00	1.00%	0.00%	4.74%	6%
11:00	1.00%	0.00%	4.84%	6%
Total	**24%**	**37%**	**39%**	**100%**

5.3.4 Supermarkets

The data set contained 14 traces from nine supermarkets. In this case, the duplicate traces were repeat readings for one or more meters. None of the meters were for irrigation only, and little water for the sites was used for irrigation. There was a very distinct peak in use during the early morning hours, which was for food preparation and cleaning. Nearly 14 percent of total daily water use occurred during the peak energy demand period. The remaining water use was split approximately equally between in-store use and cooling, as was evidenced in the detailed study of water use in supermarkets done for the California DWR and the Metropolitan Water District (MWD) of Southern California.[89] This study also showed that there was considerable potential for water savings in the cooling systems of the markets.

Figure 35: Aggregated Hourly Water Demand Profile - Supermarkets



••indicates peak energy demand period (2:00 PM – 5:00 PM)

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[89] Aquacraft, Inc., *Demonstration of Water Conservation Opportunities in Urban Supermarkets*.

Table 38: Aggregated Hourly Water Demand - Supermarkets

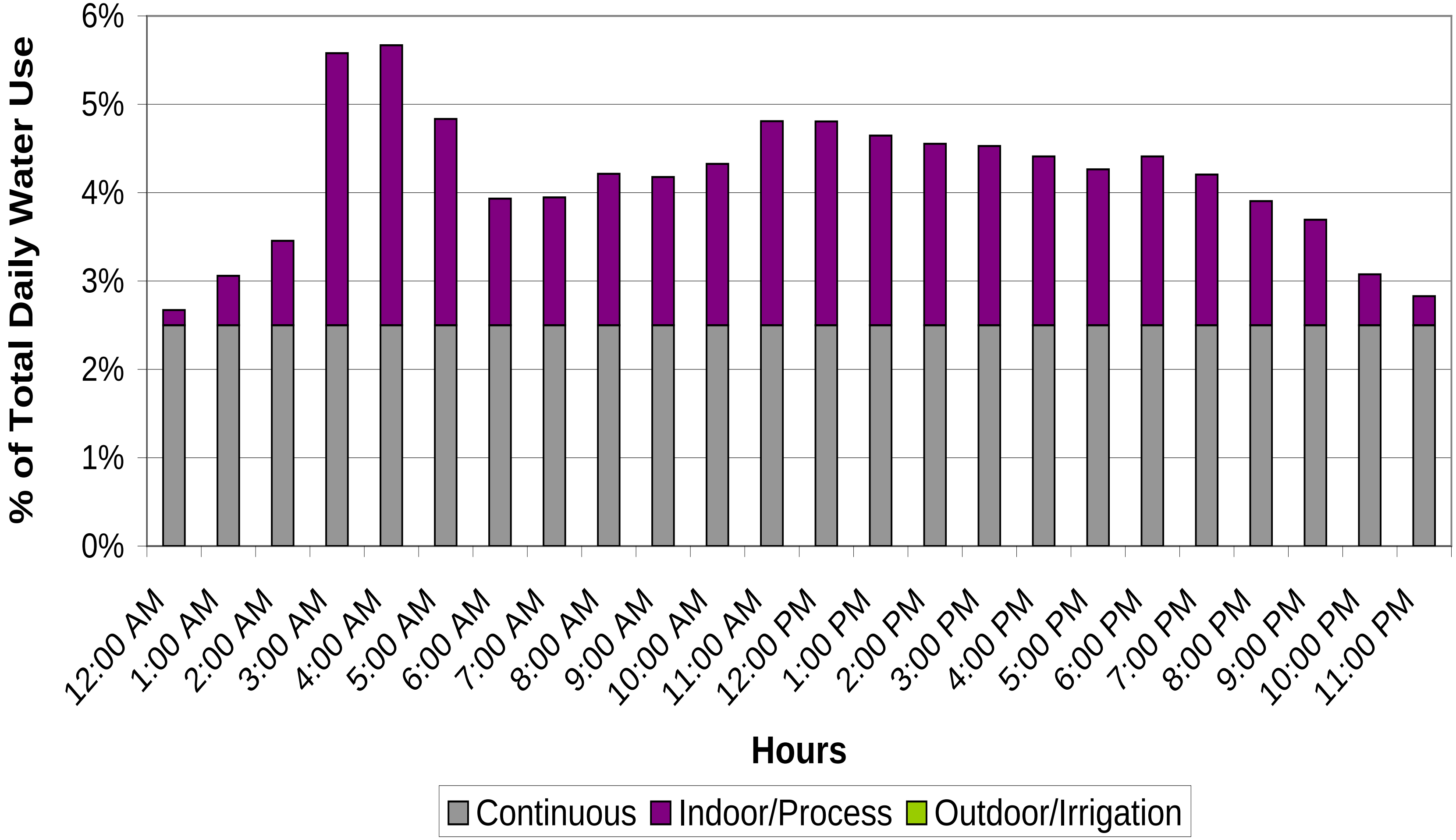
Hour	Supermarkets % of Total Daily Water Use
12:00 AM	2.67%
1:00	3.06%
2:00	3.45%
3:00	5.58%
4:00	5.67%
5:00	4.83%
6:00	3.93%
7:00	3.95%
8:00	4.21%
9:00	4.18%
10:00	4.33%
11:00	4.81%
12:00 PM	4.81%
1:00	4.65%
Total Before Peak	**60%**
2:00	4.55%
3:00	4.53%
4:00	4.41%
Total During Peak	**14%**
5:00	4.26%
6:00	4.41%
7:00	4.21%
8:00	3.90%
9:00	3.69%
10:00	3.08%
11:00	2.83%
Total After Peak	**26%**

Figure 63 and Table 73 show the percentage of the total average hourly water use at supermarket sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

None of the supermarkets in Study 3 group had meters that served both indoor uses and outdoor irrigation. For Study 3, loggers were installed on meters that monitored indoor uses at supermarkets. Consequently, there is no irrigation use shown in either Figure 63 or Table 73.

Figure 36: Disaggregated Hourly Water Demand Profiles - Supermarkets[90]



[90] Logged water meters serving Study 3 supermarket sites only served indoor uses and not irrigation. Consequently, there is no irrigation use shown.

Table 39: Disaggregated Hourly Water Demand - Supermarkets[91]

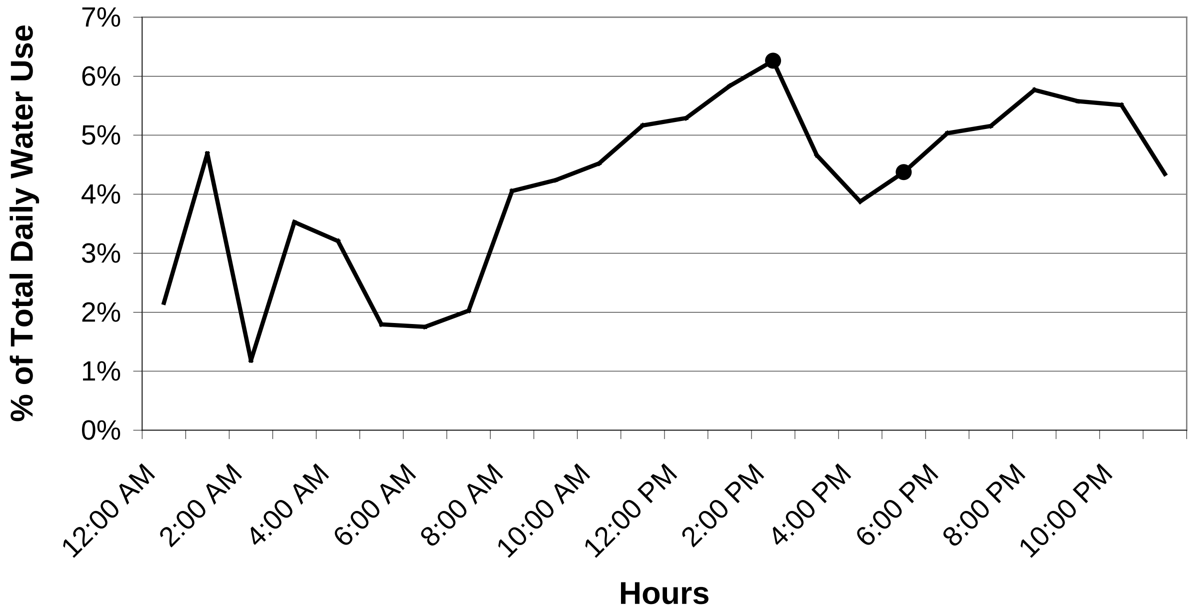
Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12:00 AM	2.50%	0.17%	0.00%	3%
1:00	2.50%	0.56%	0.00%	3%
2:00	2.50%	0.95%	0.00%	3%
3:00	2.50%	3.08%	0.00%	6%
4:00	2.50%	3.17%	0.00%	6%
5:00	2.50%	2.33%	0.00%	5%
6:00	2.50%	1.43%	0.00%	4%
7:00	2.50%	1.45%	0.00%	4%
8:00	2.50%	1.71%	0.00%	4%
9:00	2.50%	1.68%	0.00%	4%
10:00	2.50%	1.83%	0.00%	4%
11:00	2.50%	2.31%	0.00%	5%
12:00 PM	2.50%	2.31%	0.00%	5%
1:00	2.50%	2.15%	0.00%	5%
2:00	2.50%	2.05%	0.00%	5%
3:00	2.50%	2.03%	0.00%	5%
4:00	2.50%	1.91%	0.00%	4%
5:00	2.50%	1.76%	0.00%	4%
6:00	2.50%	1.91%	0.00%	4%
7:00	2.50%	1.71%	0.00%	4%
8:00	2.50%	1.40%	0.00%	4%
9:00	2.50%	1.19%	0.00%	4%
10:00	2.50%	0.58%	0.00%	3%
11:00	2.50%	0.33%	0.00%	3%
Total	**60%**	**40%**	**0%**	**100%**

[91] Logged water meters serving Study 3 supermarket sites only served indoor uses and not irrigation. Consequently, there is no irrigation use shown.

5.3.5 Restaurants

There were a total of eight traces from seven restaurants in the data set. Most of these were part of the *CIEUWS*.[92] Night-time uses in these restaurants included some irrigation, cooling and leakage. Day-time uses included miscellaneous faucet use, (food prep, pot washing, etc), dishwasher operation, bathroom uses, ice making and clothes washing (in one restaurant). Almost 15 percent of total daily use occurs during the peak energy demand period.

Figure 37: Aggregated Hourly Water Demand Profile - Restaurants



••indicates peak energy demand period (2:00 PM – 5:00 PM)

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[92] Dziegielewski et al., *Commercial and Institutional End Uses of Water*.

Table 40: Aggregated Hourly Water Demand - Restaurants

Hour	Restaurants % of Total Daily Water Use
12:00 AM	2.16%
1:00	4.69%
2:00	1.18%
3:00	3.53%
4:00	3.21%
5:00	1.79%
6:00	1.75%
7:00	2.02%
8:00	4.06%
9:00	4.24%
10:00	4.52%
11:00	5.17%
12:00	5.29%
1:00	5.84%
Total Before Peak	**49%**
2:00	6.26%
3:00	4.66%
4:00	3.88%
Total During Peak	**15%**
5:00	4.37%
6:00	5.03%
7:00	5.16%
8:00	5.77%
9:00	5.58%
10:00	5.51%
11:00	4.34%
Total After Peak	**36%**

Figure 66 and Table 76 show the percentage of the total average hourly water use at restaurant sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

Figure 38: Disaggregated Hourly Water Demand Profiles - Restaurants

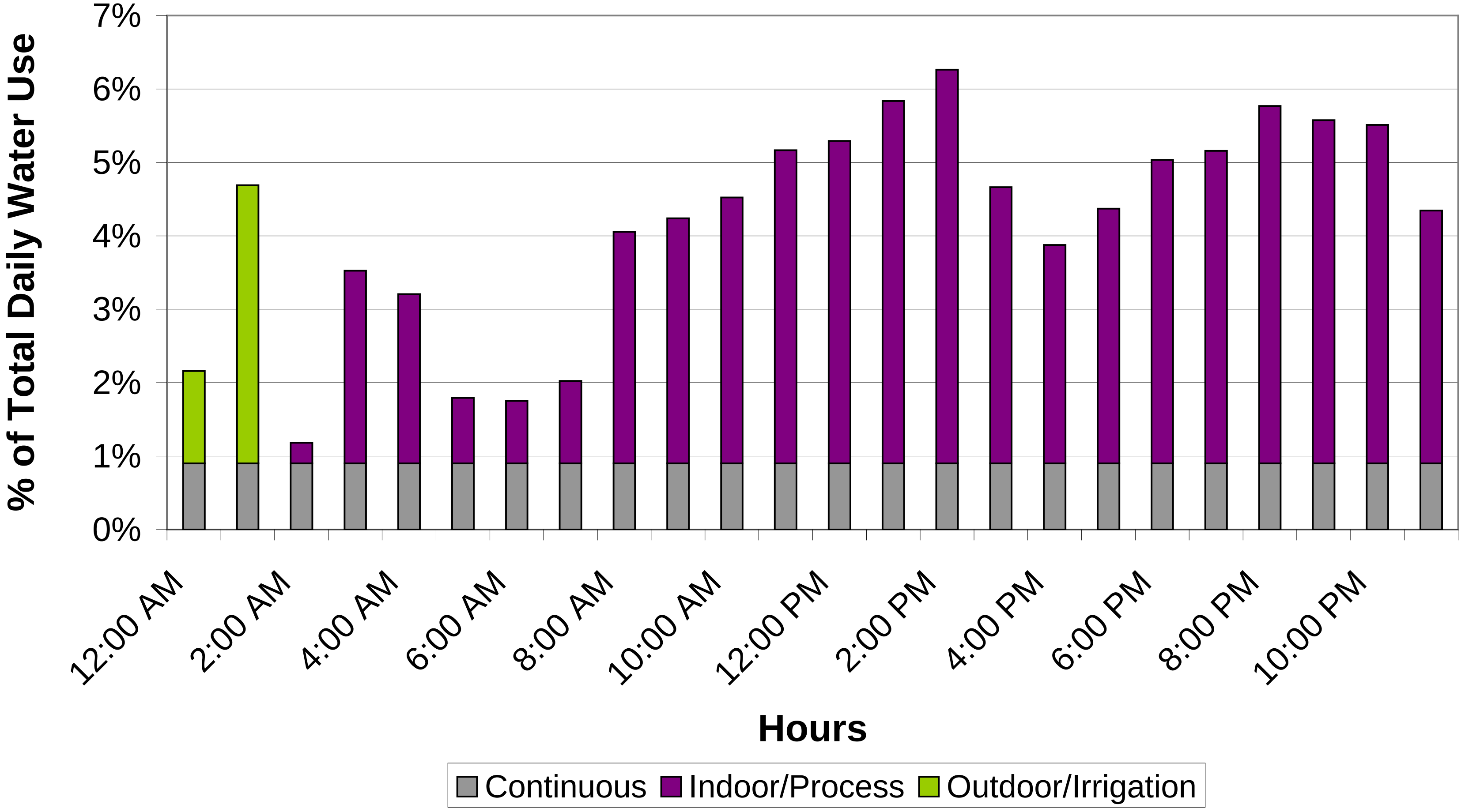


Table 41: Disaggregated Hourly Water Demand - Restaurants

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12:00 AM	0.90%	0.00%	1.26%	2%
1:00	0.90%	0.00%	3.79%	5%
2:00	0.90%	0.28%	0.00%	1%
3:00	0.90%	2.63%	0.00%	4%
4:00	0.90%	2.31%	0.00%	3%
5:00	0.90%	0.89%	0.00%	2%
6:00	0.90%	0.85%	0.00%	2%
7:00	0.90%	1.12%	0.00%	2%
8:00	0.90%	3.16%	0.00%	4%
9:00	0.90%	3.34%	0.00%	4%
10:00	0.90%	3.62%	0.00%	5%
11:00	0.90%	4.27%	0.00%	5%
12:00 PM	0.90%	4.39%	0.00%	5%
1:00	0.90%	4.94%	0.00%	6%
2:00	0.90%	5.36%	0.00%	6%
3:00	0.90%	3.76%	0.00%	5%
4:00	0.90%	2.98%	0.00%	4%
5:00	0.90%	3.47%	0.00%	4%
6:00	0.90%	4.13%	0.00%	5%
7:00	0.90%	4.26%	0.00%	5%
8:00	0.90%	4.87%	0.00%	6%
9:00	0.90%	4.68%	0.00%	6%
10:00	0.90%	4.61%	0.00%	6%
11:00	0.90%	3.44%	0.00%	4%
Total	**22%**	**73%**	**5%**	**100%**

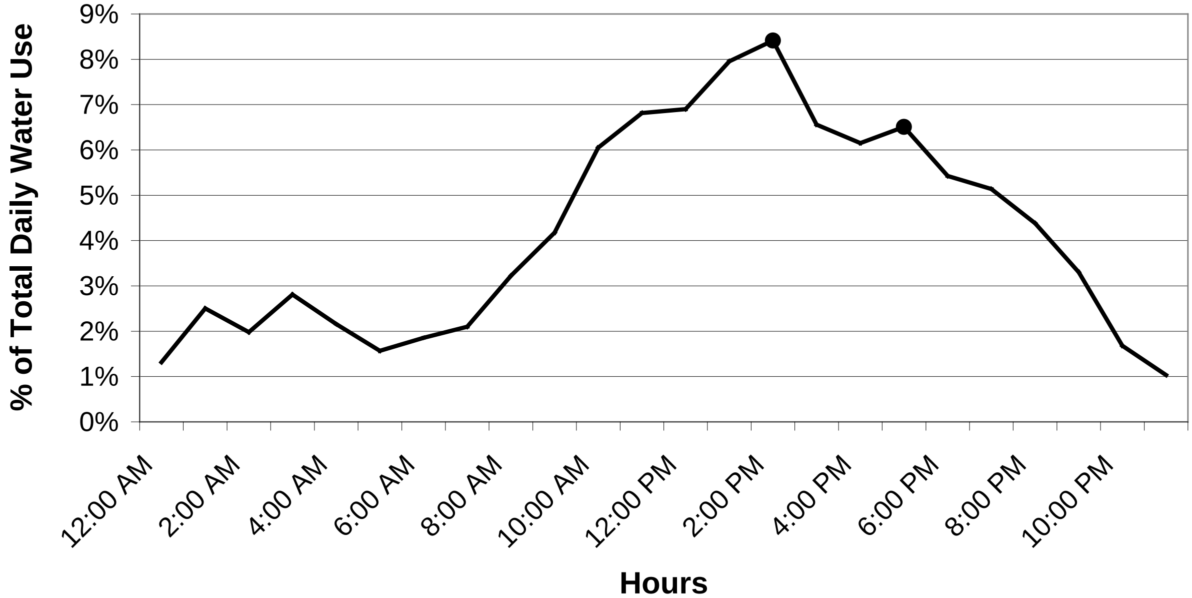
Note that outdoor irrigation occurs only between midnight and 2:00AM. This is likely because these sites are irrigating whatever irrigated areas they maintain with automatic irrigation systems. None of the restaurants in the database included nighttime kitchen or bakery use.

5.3.6 Large Retail

One large retail Study 3 site had one flow trace. Night-time uses in this retail store included some irrigation, cooling and leakage. Day-time uses were for miscellaneous bathroom and faucet uses, and a garden center.

This store showed two afternoon peaks spanning the peak energy demand period. Approximately 21 percent of the daily use occurred during this window. The percent of total average hourly use is shown in Figure 68 and the data are shown in tabular form in Table 78.

Figure 39: Aggregated Hourly Water Demand Profile - Large Retail



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 42: Aggregated Hourly Water Demand - Large Retail

Hour	Large Retail % of Total Daily Water Use
12:00 AM	1.32%
1:00	2.50%
2:00	1.98%
3:00	2.81%
4:00	2.16%
5:00	1.57%
6:00	1.85%
7:00	2.10%
8:00	3.22%
9:00	4.18%
10:00	6.05%
11:00	6.81%
12:00 PM	6.90%
1:00	7.96%
Total Before Peak	**51%**
2:00	8.41%
3:00	6.56%
4:00	6.15%
Total During Peak	**21%**
5:00	6.51%
6:00	5.43%
7:00	5.14%
8:00	4.38%
9:00	3.30%
10:00	1.68%
11:00	1.03%
Total After Peak	**28%**

Figure 70and Table 80 show the percentage of the total average hourly water use at this large retail site disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

Figure 40: Disaggregated Hourly Water Demand Profiles - Large Retail

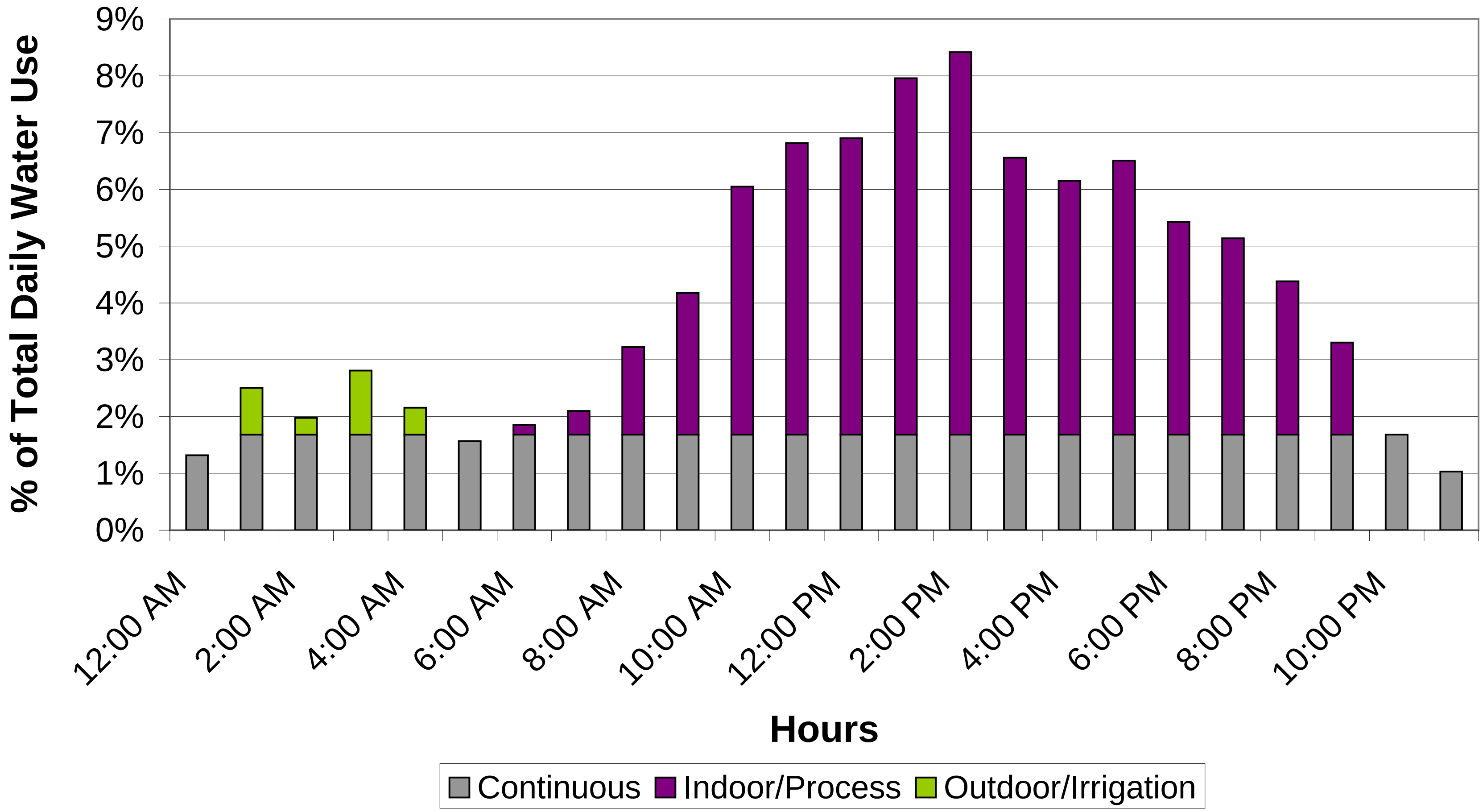


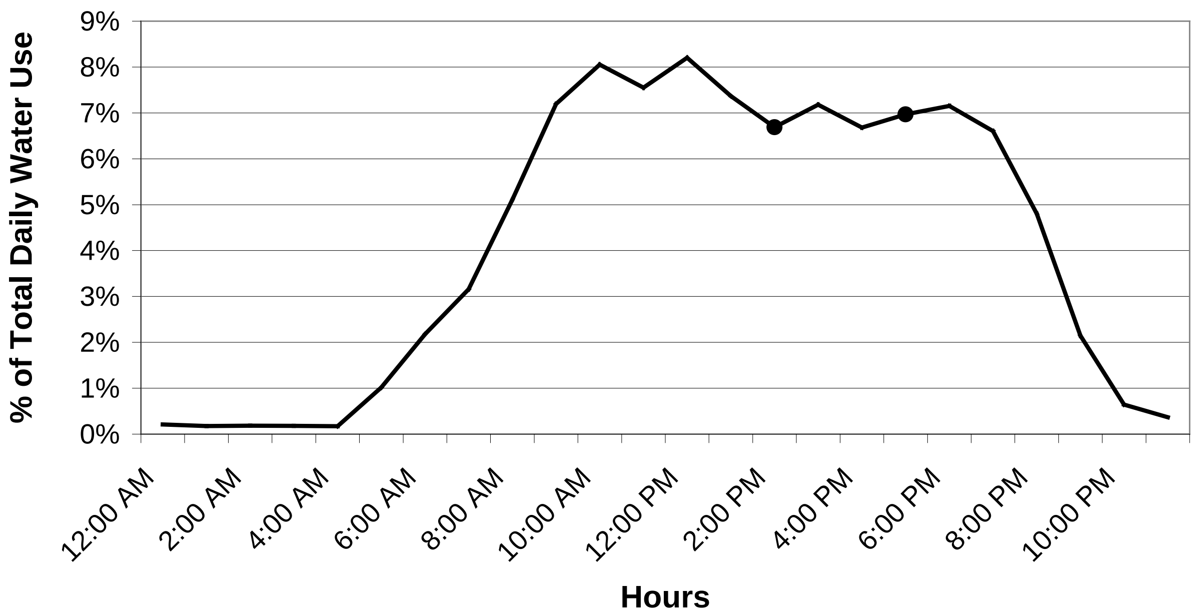
Table 43: Disaggregated Hourly Water Demand– Large Retail

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12:00 AM	1.32%	0.00%	0.00%	1%
1:00	1.68%	0.00%	0.82%	3%
2:00	1.68%	0.00%	0.30%	2%
3:00	1.68%	0.00%	1.13%	3%
4:00	1.68%	0.00%	0.47%	2%
5:00	1.57%	0.00%	0.00%	2%
6:00	1.68%	0.17%	0.00%	2%
7:00	1.68%	0.42%	0.00%	2%
8:00	1.68%	1.54%	0.00%	3%
9:00	1.68%	2.49%	0.00%	4%
10:00	1.68%	4.37%	0.00%	6%
11:00	1.68%	5.13%	0.00%	7%
12:00 PM	1.68%	5.22%	0.00%	7%
1:00	1.68%	6.27%	0.00%	8%
2:00	1.68%	6.73%	0.00%	8%
3:00	1.68%	4.87%	0.00%	7%
4:00	1.68%	4.47%	0.00%	6%
5:00	1.68%	4.82%	0.00%	7%
6:00	1.68%	3.74%	0.00%	5%
7:00	1.68%	3.46%	0.00%	5%
8:00	1.68%	2.70%	0.00%	4%
9:00	1.68%	1.62%	0.00%	3%
10:00	1.68%	0.00%	0.00%	2%
11:00	1.03%	0.00%	0.00%	1%
Total	**39%**	**58%**	**3%**	**100%**

5.3.7 Laundromats

There were a total of five traces from five laundromats collected for Study 3 data set. Day-time uses were for coin-operated clothes washing. These laundromats showed three day-time peaks with the third one extending into the peak energy demand period. Nearly 21 percent of the daily use occurred during this window. The percent of total average hourly water use is shown in Figure 72 and the data are shown in tabular form in Table 82.

Figure 41: Aggregated Hourly Water Demand Profile - Laundromats



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 44: Aggregated Hourly Water Demand - Laundromats

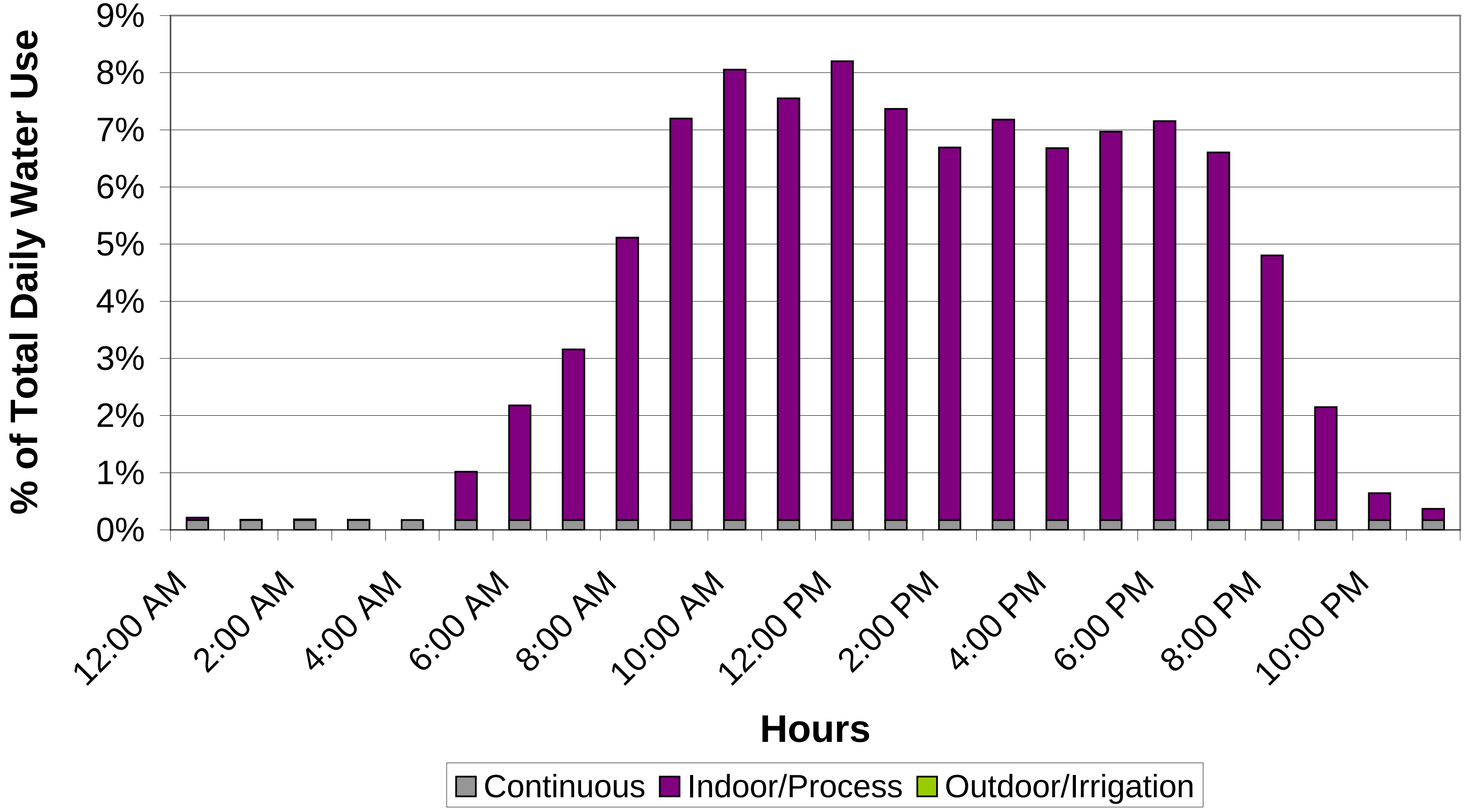
Hour	Laundromats % of Total Daily Water Use
12:00 AM	0.21%
1:00	0.18%
2:00	0.19%
3:00	0.18%
4:00	0.17%
5:00	1.02%
6:00	2.18%
7:00	3.16%
8:00	5.11%
9:00	7.20%
10:00	8.05%
11:00	7.55%
12:00 PM	8.20%
1:00	7.37%
Total Before Peak	**51%**
2:00	6.69%
3:00	7.18%
4:00	6.68%
Total During Peak	**21%**
5:00	6.97%
6:00	7.15%
7:00	6.60%
8:00	4.80%
9:00	2.15%
10:00	0.64%
11:00	0.37%
Total After Peak	**29%**

Figure 74 and Table 84show the percentage of the total average hourly water use at laundromat sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

None of the laundromats in Study 3 group had meters that served both indoor uses and outdoor irrigation. For Study 3, loggers were installed on meters that monitored indoor uses at laundromats. Consequently, there is no irrigation use shown for them in either Figure 74 or Table 84 .

Figure 42: Disaggregated Hourly Water Demand Profiles - Laundromats[93]



[93] Logged water meters for Study 3 laundromat sites only served indoor uses and not irrigation. Consequently, there is no irrigation use shown for them.

Table 45: Disaggregated Hourly Water Demand - Laundromats[94]

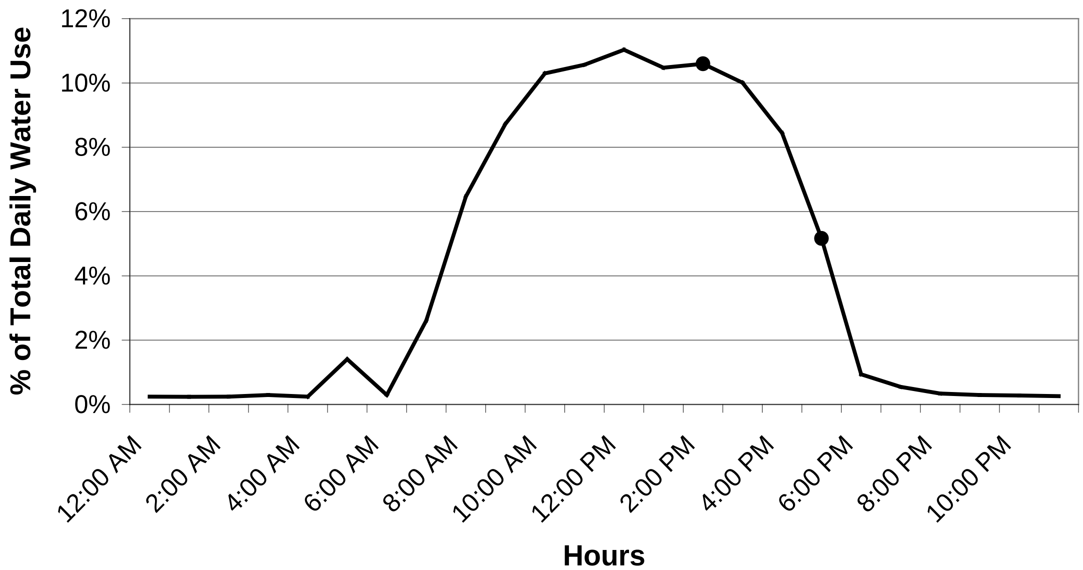
Hour	Continuous	Indoor/ Process	Outdoor /Irrigation	Total
12:00 AM	0.17%	0.04%	0.00%	0%
1:00	0.17%	0.01%	0.00%	0%
2:00	0.17%	0.01%	0.00%	0%
3:00	0.17%	0.01%	0.00%	0%
4:00	0.17%	0.00%	0.00%	0%
5:00	0.17%	0.85%	0.00%	1%
6:00	0.17%	2.01%	0.00%	2%
7:00	0.17%	2.99%	0.00%	3%
8:00	0.17%	4.94%	0.00%	5%
9:00	0.17%	7.03%	0.00%	7%
10:00	0.17%	7.88%	0.00%	8%
11:00	0.17%	7.38%	0.00%	8%
12:00 PM	0.17%	8.03%	0.00%	8%
1:00	0.17%	7.19%	0.00%	7%
2:00	0.17%	6.52%	0.00%	7%
3:00	0.17%	7.01%	0.00%	7%
4:00	0.17%	6.51%	0.00%	7%
5:00	0.17%	6.80%	0.00%	7%
6:00	0.17%	6.98%	0.00%	7%
7:00	0.17%	6.43%	0.00%	7%
8:00	0.17%	4.63%	0.00%	5%
9:00	0.17%	1.98%	0.00%	2%
10:00	0.17%	0.47%	0.00%	1%
11:00	0.17%	0.20%	0.00%	0%
Total	**4%**	**96%**	**0%**	**100%**

[94] Logged water meters for Study 3 laundromat sites only served indoor uses and not irrigation. Consequently, there is no irrigation use shown for them

5.3.8 Car Washes

There were a total of four traces from four car washes collected for Study 3 data set. These car wash sites showed a mid-day peak that declines following the start of the peak energy demand period. Over 29 percent of the daily use occurred during this window. . The percent of total average hourly water use is shown in Figure 76 and the data are shown in tabular form in Table 86.

Figure 43: Aggregated Hourly Water Demand Profile - Car Washes



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 46: Aggregated Hourly Water Demand - Car Washes

Hour	Car Washes % of Total Daily Water Use
12:00 AM	0.24%
1:00	0.24%
2:00	0.24%
3:00	0.29%
4:00	0.24%
5:00	1.41%
6:00	0.30%
7:00	2.61%
8:00	6.46%
9:00	8.72%
10:00	10.30%
11:00	10.57%
12:00 PM	11.03%
1:00	10.47%
Total Before Peak	**63%**
2:00	10.60%
3:00	10.01%
4:00	8.44%
Total During Peak	**29%**
5:00	5.16%
6:00	0.94%
7:00	0.55%
8:00	0.34%
9:00	0.30%
10:00	0.28%
11:00	0.26%
Total After Peak	**8%**

Figure 78 and Table 88 show the percentage of the total average hourly water use at car wash sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

Figure 44: Disaggregated Hourly Water Demand – Car Washes

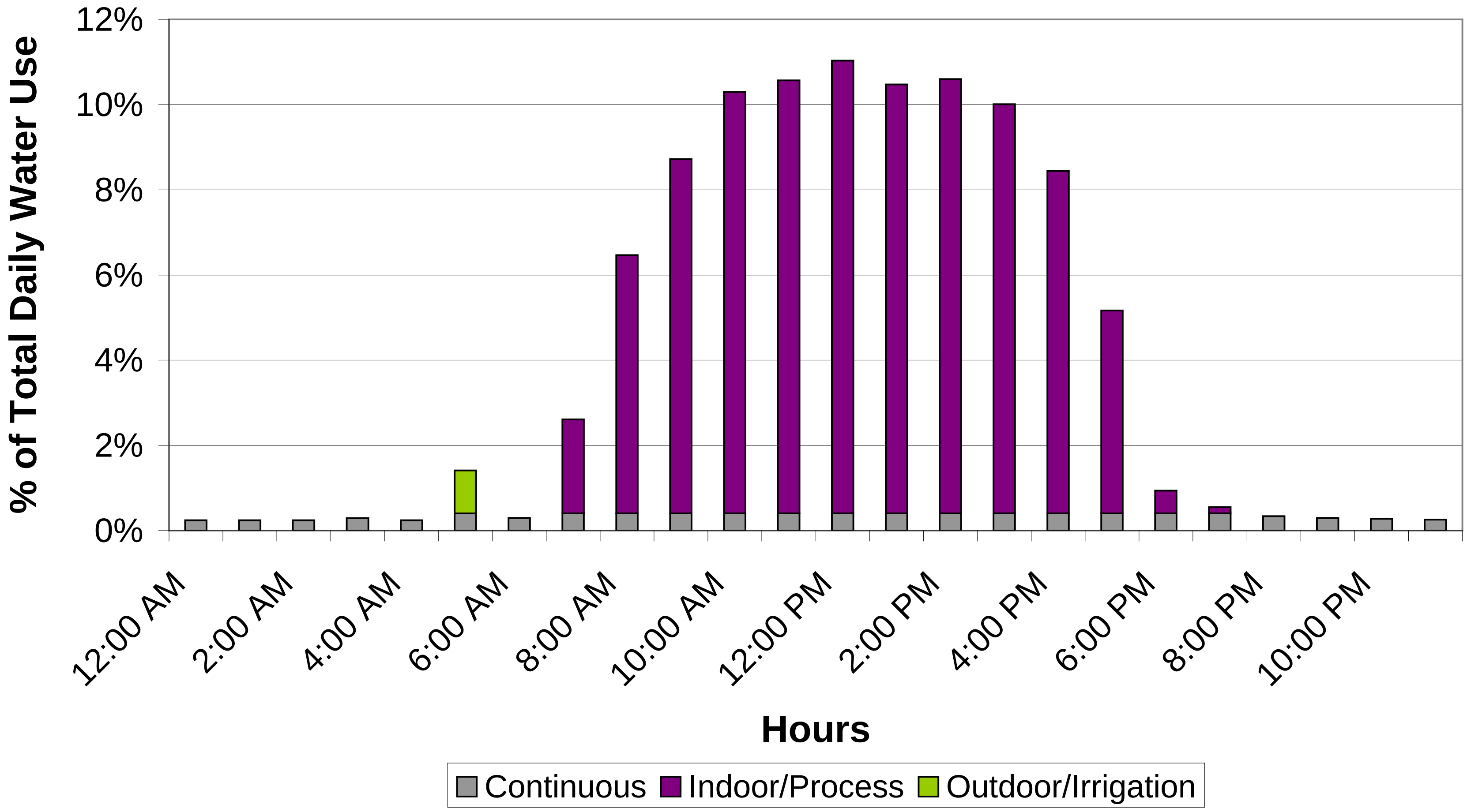


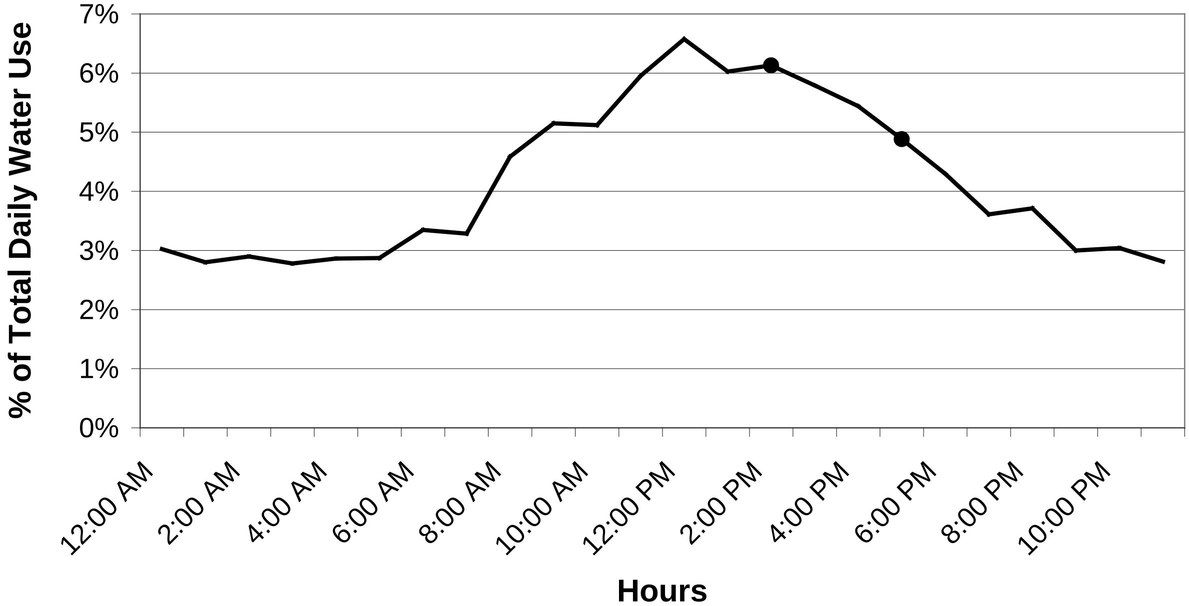
Table 47: Disaggregated Hourly Water Demand - Car Washes

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12:00 AM	0.24%	0.00%	0.00%	0%
1:00	0.24%	0.00%	0.00%	0%
2:00	0.24%	0.00%	0.00%	0%
3:00	0.29%	0.00%	0.00%	0%
4:00	0.24%	0.00%	0.00%	0%
5:00	0.40%	0.00%	1.01%	1%
6:00	0.30%	0.00%	0.00%	0%
7:00	0.40%	2.21%	0.00%	3%
8:00	0.40%	6.06%	0.00%	6%
9:00	0.40%	8.32%	0.00%	9%
10:00	0.40%	9.89%	0.00%	10%
11:00	0.40%	10.16%	0.00%	11%
12:00 PM	0.40%	10.63%	0.00%	11%
1:00	0.40%	10.07%	0.00%	10%
2:00	0.40%	10.19%	0.00%	11%
3:00	0.40%	9.61%	0.00%	10%
4:00	0.40%	8.04%	0.00%	8%
5:00	0.40%	4.76%	0.00%	5%
6:00	0.40%	0.53%	0.00%	1%
7:00	0.40%	0.15%	0.00%	1%
8:00	0.34%	0.00%	0.00%	0%
9:00	0.30%	0.00%	0.00%	0%
10:00	0.28%	0.00%	0.00%	0%
11:00	0.26%	0.00%	0.00%	0%
Total	**8%**	**91%**	**1%**	**100%**

5.3.9 Automotive Service

A total of four traces from four sites were collected for Study 3 data set. These sites include gas stations with convenience marts, drive-through and self-car washes, and auto shops. These sites showed a noon peak in water use with a gradual decline into the peak energy demand period. Over 17 percent of the daily use occurred during this window. The percent of total average hourly use is shown in Figure 80 and the data are shown in tabular form in Table 90.

Figure 45: Aggregated Hourly Water Demand Profile - Automotive Service



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 48: Aggregated Hourly Water Demand - Automotive Service

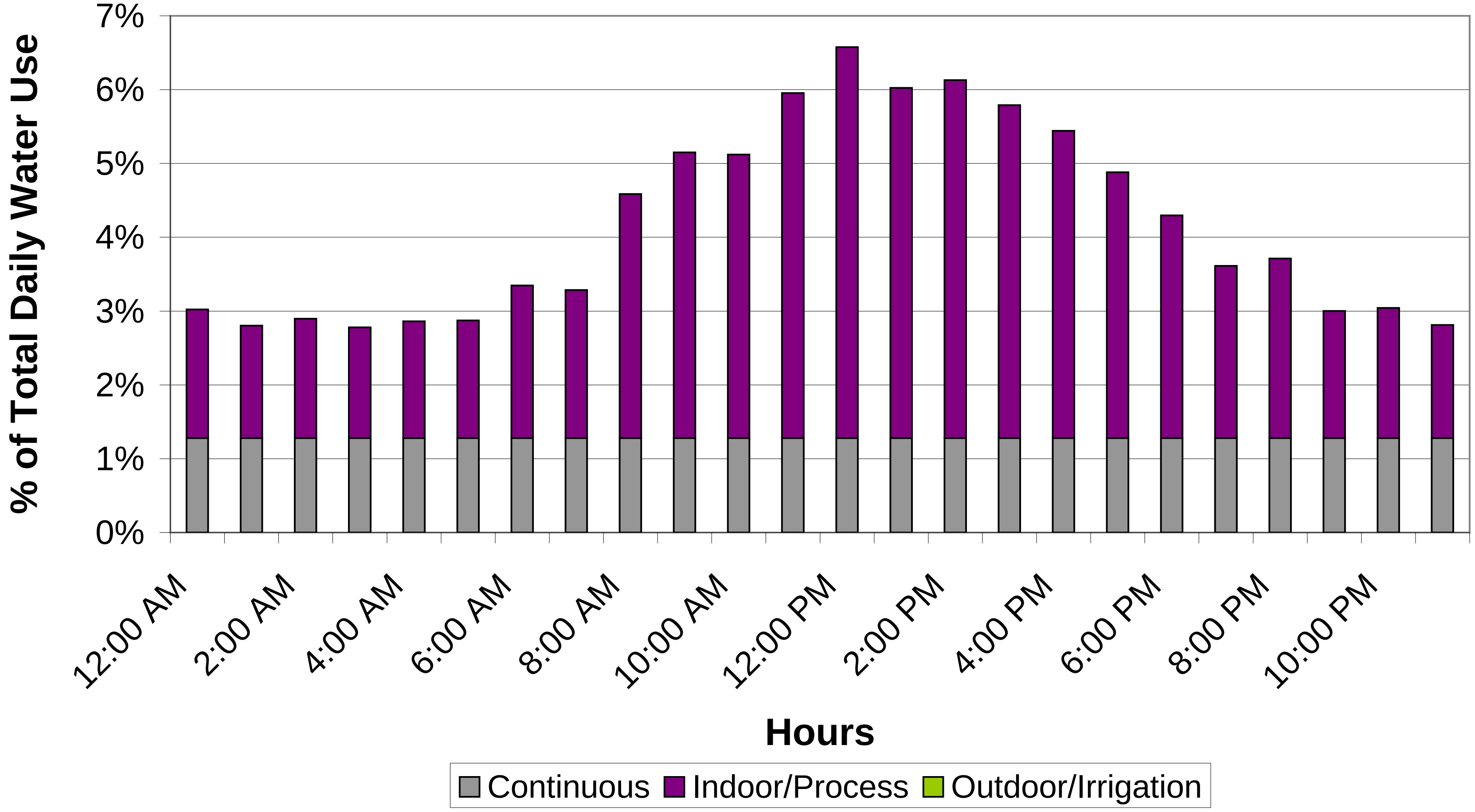
Hour	Automotive Service % of Total Daily Water Use
12:00 AM	3.02%
1:00	2.80%
2:00	2.90%
3:00	2.78%
4:00	2.86%
5:00	2.87%
6:00	3.35%
7:00	3.29%
8:00	4.59%
9:00	5.15%
10:00	5.12%
11:00	5.95%
12:00 PM	6.58%
1:00	6.03%
Total Before Peak	**57%**
2:00	6.13%
3:00	5.79%
4:00	5.44%
Total During Peak	**17%**
5:00	4.88%
6:00	4.30%
7:00	3.61%
8:00	3.71%
9:00	3.00%
10:00	3.04%
11:00	2.81%
Total After Peak	**25%**

Figure 82 and Table 92 show the percentage of the total average hourly water use at automotive service sites disaggregated into the following categories:

- Continuous
- Indoor/Process
- Outdoor/Irrigation

None of the automotive service sites in Study 3 group had meters serving both indoor uses and outdoor irrigation. For Study 3, loggers were installed on meters that monitored indoor uses at automotive service sites. Consequently, there is no irrigation use shown in either Figure 82 or Table 92.

Figure 46: Disaggregated Hourly Water Demand Profiles - Automotive Service[95]



[95] Logged automotive service Study 3 site water meters served indoor and car wash, and not irrigation. Consequently, there is no irrigation use shown.

Table 49: Disaggregated Hourly Water Demand - Automotive Service[96]

Hour	Continuous	Indoor/ Process	Outdoor/ Irrigation	Total
12:00 AM	1.28%	1.74%	0.00%	3%
1:00	1.28%	1.52%	0.00%	3%
2:00	1.28%	1.62%	0.00%	3%
3:00	1.28%	1.50%	0.00%	3%
4:00	1.28%	1.58%	0.00%	3%
5:00	1.28%	1.59%	0.00%	3%
6:00	1.28%	2.07%	0.00%	3%
7:00	1.28%	2.01%	0.00%	3%
8:00	1.28%	3.31%	0.00%	5%
9:00	1.28%	3.87%	0.00%	5%
10:00	1.28%	3.84%	0.00%	5%
11:00	1.28%	4.67%	0.00%	6%
12:00 PM	1.28%	5.30%	0.00%	7%
1:00	1.28%	4.75%	0.00%	6%
2:00	1.28%	4.85%	0.00%	6%
3:00	1.28%	4.51%	0.00%	6%
4:00	1.28%	4.16%	0.00%	5%
5:00	1.28%	3.60%	0.00%	5%
6:00	1.28%	3.02%	0.00%	4%
7:00	1.28%	2.33%	0.00%	4%
8:00	1.28%	2.43%	0.00%	4%
9:00	1.28%	1.72%	0.00%	3%
10:00	1.28%	1.76%	0.00%	3%
11:00	1.28%	1.53%	0.00%	3%
Total	**31%**	**69%**	**0%**	**100%**

[96] Logged automotive service Study 3 site water meters served indoor and car wash, and not irrigation. Consequently, there is no irrigation use shown.

5.3.10 Findings

Findings for the commercial end-user category include:

- Commercial sites' daytime water use tended to include domestic, process and continuous applications. Irrigation tended to occur during the late night and early morning hours.
- Commercial sub-categories varied in the percentage of daily water use occurring during the peak energy demand period. Table 94 lists these percentages, from highest to lowest:

Table 50: Daily Water Use Coincident with Peak Energy Demand by Sub-category-Commercial

Commercial Sub-category	Percent of Total Daily Water Use Coincident with Peak Energy Demand Period
Car Washes	29%
Laundromats	21%
Large Retail	21%
General Retail	18%
Automotive Service	17%
Restaurants	15%
Hotels/Motels	14%
Supermarkets	14%
Offices	9%

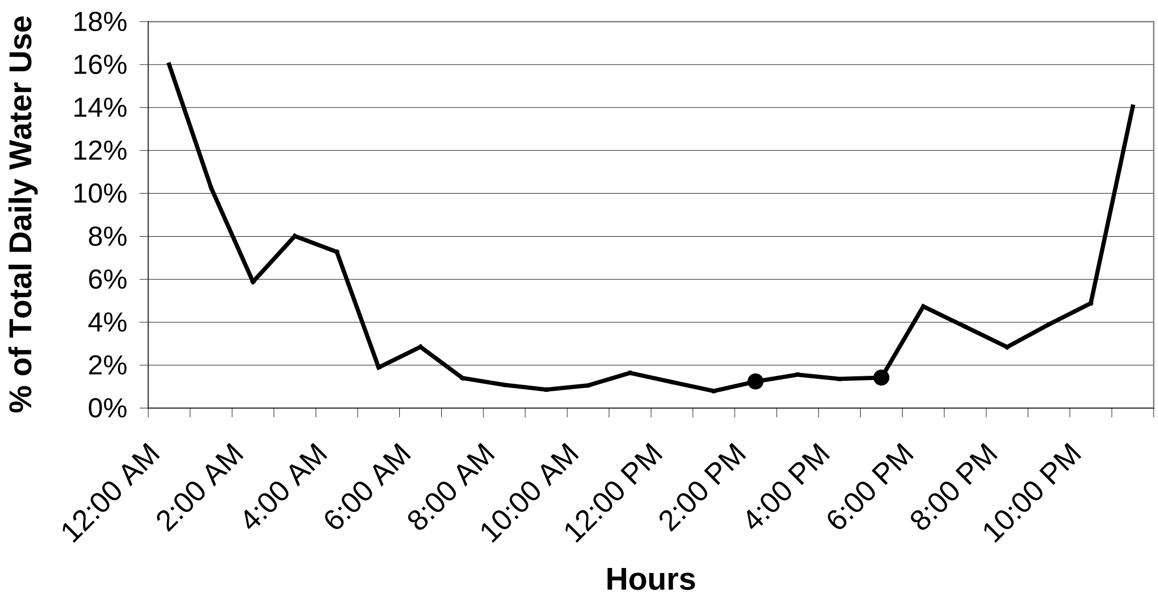
- The general retail category showed night-time peaks due to irrigation and then typical indoor use patterns that peaked in the afternoon.
- Hotels and motels did not appear to have significant irrigation measured by the same meters used for domestic uses. Night-time use was relatively low, and was probably due to cooling, cleaning and normal domestic uses associated with residential use. The largest peak of the day occurred in the morning between 7:00 and 8:00 AM.
- Office daytime water use peaks between 10:00 and 11:00 AM, and then declines through the day with a second, smaller, peak mid-afternoon. High night-time demands were a reflection of irrigation use. Note, however, that traces were collected during the summer and fall; during the winter irrigation peaks would be much lower.
- Supermarkets sites exhibited a very distinct peak in water use during the early morning hours, which was for food preparation and cleaning.
- Restaurant day-time water uses included miscellaneous faucet use, (food prep, pot washing, etc), dishwasher operation, bathroom uses, ice making and clothes washing (in one restaurant). Night-time uses included some irrigation, cooling and leakage.
- Large retail day-time uses were for miscellaneous bathroom and faucet uses, and a garden center, and night-time uses included some irrigation, cooling and leakage. The single store studied showed two afternoon peaks spanning the peak energy demand period.
- Laundromat day-time uses were for coin-operated clothes washing. These sites showed three day-time peaks with the third one extending into the peak energy demand period.

- Car wash sites showed a mid-day peak that declines following the start of the peak energy demand period.
- Automotive service sites showed a noon peak in water use with a gradual decline into the peak energy demand period.

5.4 Urban Irrigation

Urban irrigation is the top water user within the commercial and public building groups, and obtaining information on urban irrigation demand profiles was one of the top goals of Study 3. Water demand profiles were measured from the dedicated irrigation water meters and disaggregated into hourly profiles. Consequently, no indoor use is shown in the disaggregated profiles. The following sections provide water use results for urban irrigation meters based on the analysis of new flow trace data collected from sites in SDG&E, SCE and PG&E service areas, combined with data from previous studies. Figure 84 shows the daily profiles of water use as a percentage of the total average hourly water use for urban irrigation. These profiles are included in the database for non-residential urban irrigation hourly water uses.

Figure 47: Aggregated Hourly Water Demand Profile - Urban Irrigation



••indicates peak energy demand period (2:00 PM – 5:00 PM)

The water demand profile for urban irrigation is a mirror image of other end-user categories. The peaks occur during the night, and day-time irrigation use is relatively minor. The afternoon peaks occur after the energy peak demand period, with just over four percent of typical daily use occurring between 2:00 PM and 5:00 pm.

Table 51: Aggregated Hourly Water Demand - Urban Irrigation

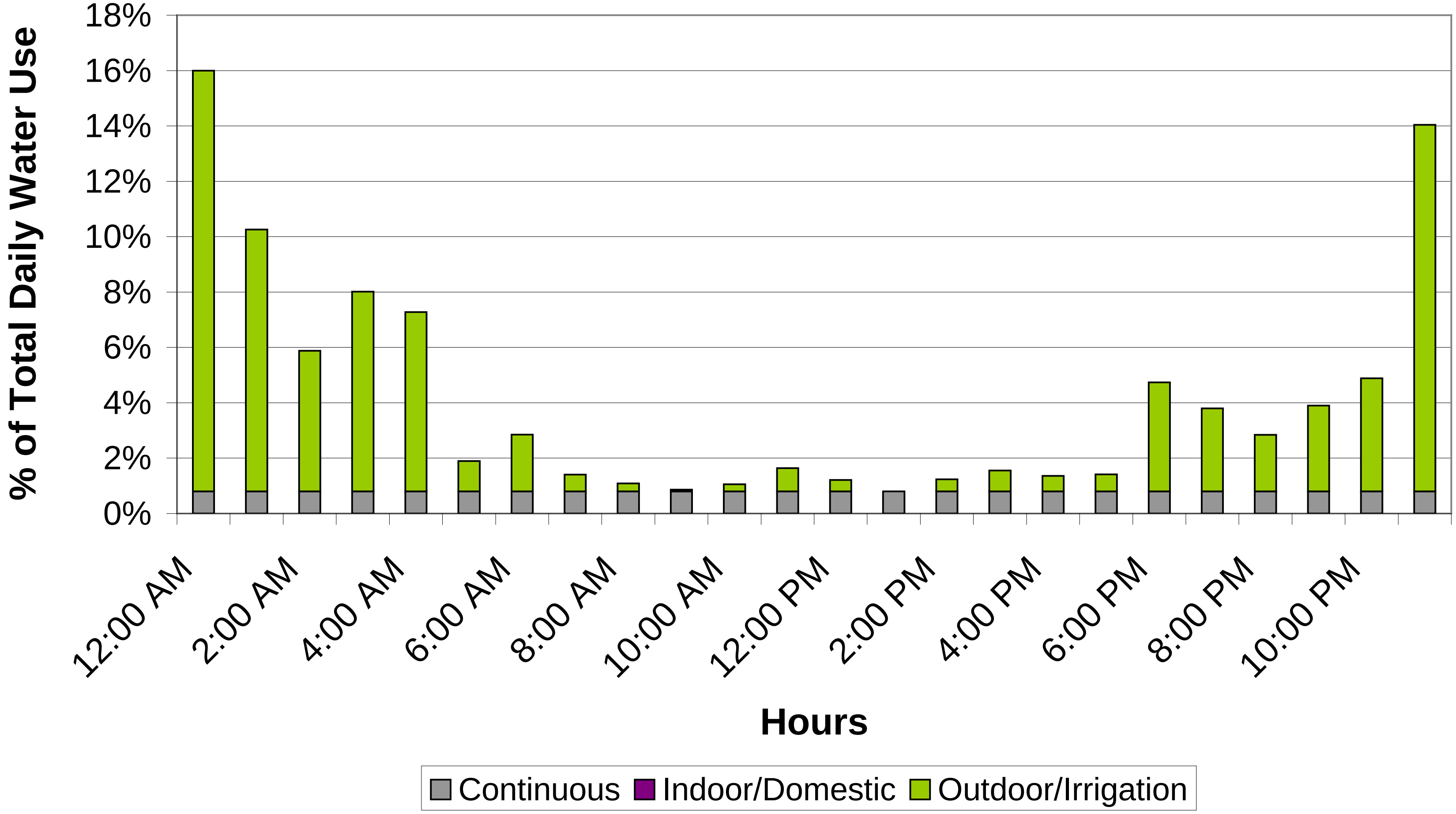
Hour	Urban Irrigation % of Total Daily Water Use
12:00 AM	16.00%
1:00	10.26%
2:00	5.88%
3:00	8.01%
4:00	7.28%
5:00	1.90%
6:00	2.85%
7:00	1.40%
8:00	1.09%
9:00	0.86%
10:00	1.06%
11:00	1.64%
12:00 PM	1.21%
1:00	0.80%
Total Before Peak	**60%**
2:00	1.24%
3:00	1.55%
4:00	1.36%
Total During Peak	**4%**
5:00	1.41%
6:00	4.74%
7:00	3.79%
8:00	2.84%
9:00	3.90%
10:00	4.88%
11:00	14.04%
Total After Peak	**36%**

Figure 86 and Table 97show the percentage of the total average hourly water use for urban irrigation disaggregated into the following categories:

- Continuous
- Indoor/Domestic
- Outdoor/Irrigation

The combined data clearly indicated night-time and early morning water usage patterns, with the majority serving outdoor/irrigation. Some of Study 3 sites' flow trace data revealed continuous uses (likely leaks).

Figure 48: Disaggregated Hourly Water Demand Profiles - Urban Irrigation[97]



[97] Logged water meters at urban irrigation sites were dedicated to irrigation and did not serve indoor uses. Consequently, no indoor/domestic use is shown.

Table 52: Disaggregated Hourly Water Demand– Urban Irrigation[98]

Hour	Continuous	Indoor/ Domestic	Outdoor/ Irrigation	Total
12:00 AM	0.80%	0.00%	15.20%	16%
1:00	0.80%	0.00%	9.46%	10%
2:00	0.80%	0.00%	5.08%	6%
3:00	0.80%	0.00%	7.21%	8%
4:00	0.80%	0.00%	6.48%	7%
5:00	0.80%	0.00%	1.10%	2%
6:00	0.80%	0.00%	2.05%	3%
7:00	0.80%	0.00%	0.61%	1%
8:00	0.80%	0.00%	0.29%	1%
9:00	0.80%	0.00%	0.06%	1%
10:00	0.80%	0.00%	0.26%	1%
11:00	0.80%	0.00%	0.84%	2%
12:00 PM	0.80%	0.00%	0.41%	1%
1:00	0.80%	0.00%	0.00%	1%
2:00	0.80%	0.00%	0.44%	1%
3:00	0.80%	0.00%	0.76%	2%
4:00	0.80%	0.00%	0.56%	1%
5:00	0.80%	0.00%	0.62%	1%
6:00	0.80%	0.00%	3.94%	5%
7:00	0.80%	0.00%	3.00%	4%
8:00	0.80%	0.00%	2.04%	3%
9:00	0.80%	0.00%	3.10%	4%
10:00	0.80%	0.00%	4.09%	5%
11:00	0.80%	0.00%	13.24%	14%
Total	**19%**	**0%**	**81%**	**100%**

5.4.1 Findings

Findings for the urban irrigation category include:

- The water demand profile for urban irrigation is a mirror image of other end-user categories. The peaks occur during the night, and day-time irrigation use is relatively minor. The afternoon peaks occur after the energy peak demand period.
- Urban irrigation end-users showed only about four percent of their daily use occurring during the peak energy demand period.
- A significant portion of water is used during off-peak energy demand periods for outdoor/irrigation, particularly during late night-time and early morning hours.

[98] Logged water meters at urban irrigation Study 3 sites were dedicated to irrigation and did not serve indoor uses. Consequently, no indoor/domestic use is shown.

- Continuous uses (likely leaks) accounted for approximately 19 percent of urban irrigation total water use.

5.5 Public Buildings

5.5.1 Public Buildings (excluding Schools and Hospitals)

The following sections provide hourly water use results for public buildings based on the analysis of new flow trace data collected in SDG&E, SCE and PG&E service areas, as well as flow trace data collected in earlier studies. Historic consumption data were obtained representing a total of 69 flow traces from 54 public building sites(see Figure 88). Public building water uses were logged from water meters serving their indoor and outdoor uses. The addition of existing public building flow traces provided a data set containing total of 94 flow traces from 69public buildings. Many of the public building meters also serve on-site irrigation.

Daily profiles of water use as a percentage of the total average hourly demand at public buildings are shown in Figure 90 and Table 99. These profiles are included in the database for public building hourly water uses. Where irrigation was apparent, the seasonal variation in water uses was estimated using the combined historic billing data and logged data. Figure 88 shows the historic consumption patterns, representing 15 public building sites. The increase in water usage in the spring and summer months is due to increased irrigation during these periods, as shown by the disaggregated hourly demand profiles in Figure 92.

Figure 49: Historic Monthly Water Demand - Public Buildings (excluding Schools and Hospitals)

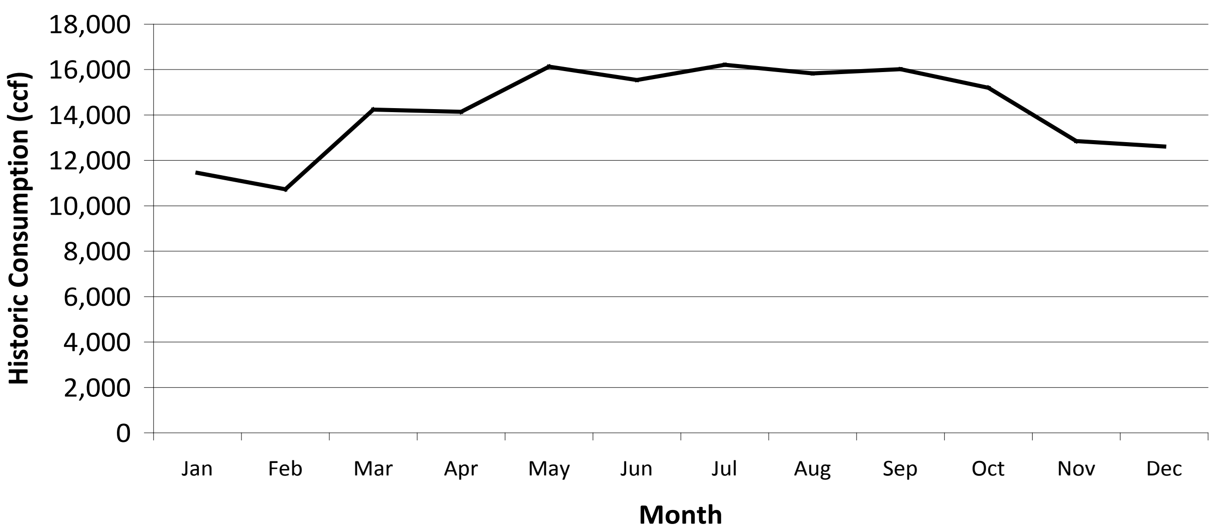
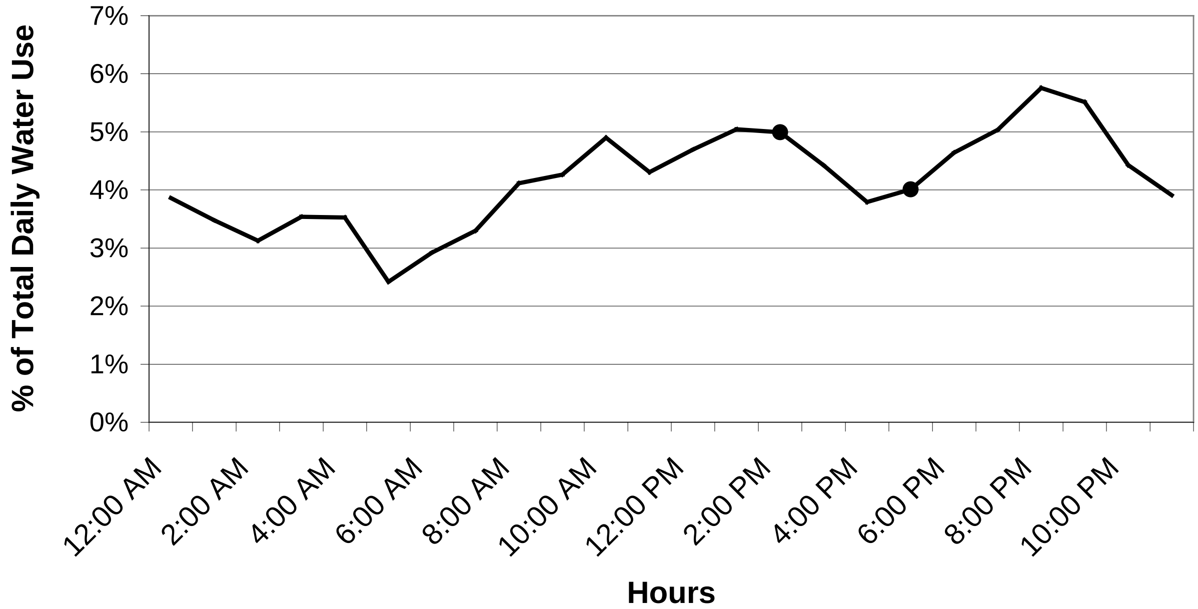


Figure 50: Aggregated Hourly Water Demand Profile - Public Buildings (excluding Schools and Hospitals)



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Table 53: Aggregated Hourly Water Demand - Public Buildings (excluding Schools and Hospitals)

Hour	Public Buildings (excl. Schools and Hospitals) % of Total Daily Water Use
12:00 AM	3.86%
1:00	3.48%
2:00	3.13%
3:00	3.54%
4:00	3.52%
5:00	2.42%
6:00	2.92%
7:00	3.30%
8:00	4.12%
9:00	4.26%
10:00	4.90%
11:00	4.31%
12:00 PM	4.70%
1:00	5.04%
Total Before Peak	**53%**
2:00	4.99%
3:00	4.42%
4:00	3.79%
Total During Peak	**13%**
5:00	4.01%
6:00	4.64%
7:00	5.04%
8:00	5.76%
9:00	5.51%
10:00	4.43%
11:00	3.91%
Total After Peak	**33%**

These public building sites show a late morning to mid-afternoon water use peak followed by a larger late evening water use peak at 8:00 PM. These peaks are likely due to typical workday hours at these sites. Over 13 percent of the daily water use occurred during the peak energy demand period.

At public buildings indoor water use shows peaks in the late morning, afternoon, and again in the late evening. Irrigation use begins in the evening, peaks at 10:00 PM and then decreases throughout the early morning until close to 5:00 AM.

Figure 92and Table 101 show the percentage of the total average hourly water use at public buildings disaggregated into the following categories:

- Continuous
- Indoor/Domestic
- Outdoor/Irrigation

Figure 51: Disaggregated Hourly Water Demand Profiles - Public Buildings (excluding Schools and Hospitals)

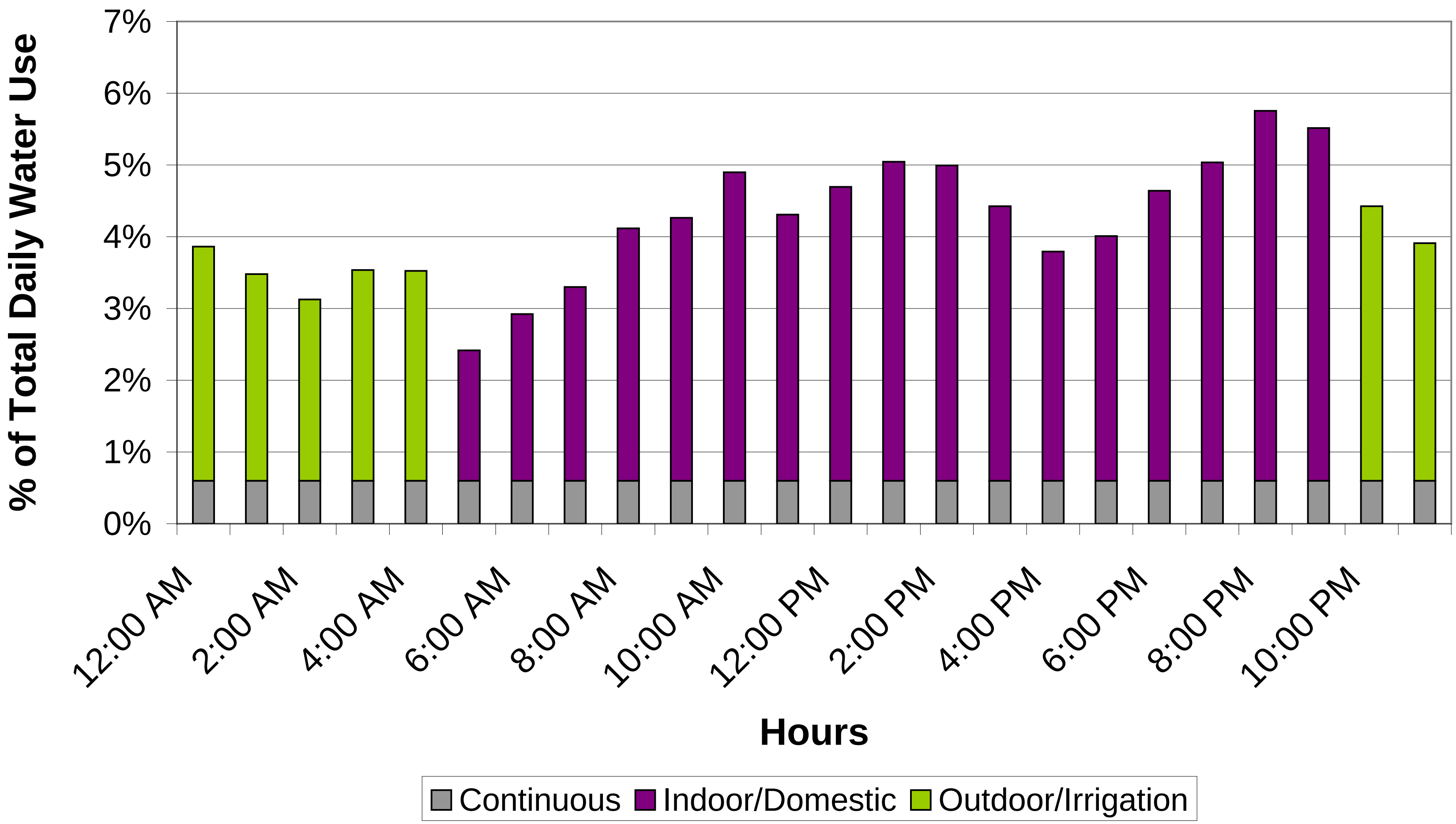


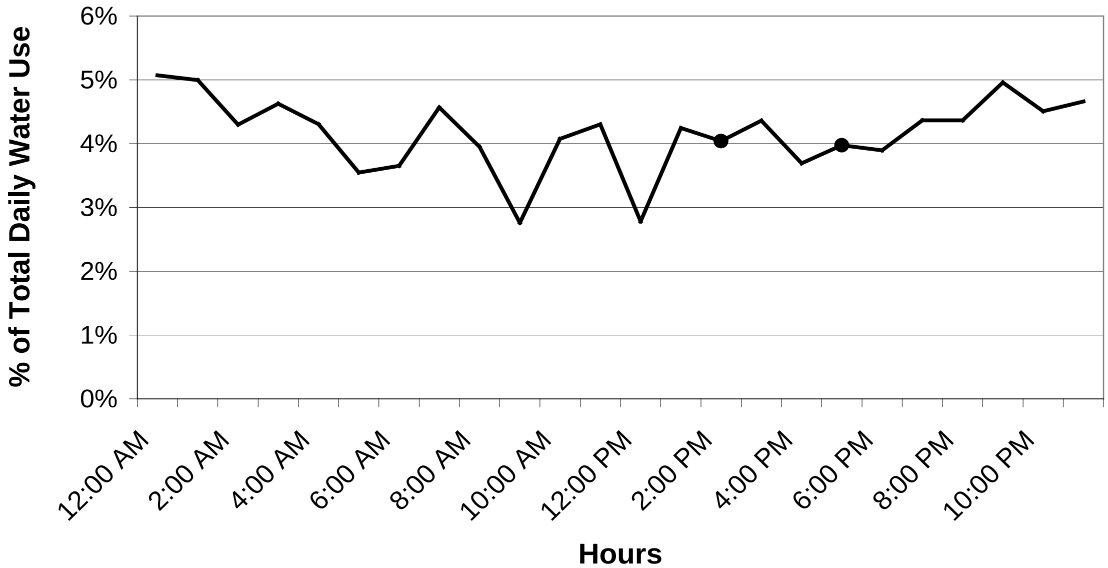
Table 54: Disaggregated Hourly Water Demand– Public Buildings (excluding Schools and Hospitals)

Hour	Continuous	Indoor/ Domestic	Outdoor/ Irrigation	Total
12:00 AM	0.60%	0.00%	3.26%	4%
1:00	0.60%	0.00%	2.88%	3%
2:00	0.60%	0.00%	2.53%	3%
3:00	0.60%	0.00%	2.94%	4%
4:00	0.60%	0.00%	2.92%	4%
5:00	0.60%	1.82%	0.00%	2%
6:00	0.60%	2.32%	0.00%	3%
7:00	0.60%	2.70%	0.00%	3%
8:00	0.60%	3.52%	0.00%	4%
9:00	0.60%	3.66%	0.00%	4%
10:00	0.60%	4.30%	0.00%	5%
11:00	0.60%	3.71%	0.00%	4%
12:00 PM	0.60%	4.10%	0.00%	5%
1:00	0.60%	4.44%	0.00%	5%
2:00	0.60%	4.39%	0.00%	5%
3:00	0.60%	3.82%	0.00%	4%
4:00	0.60%	3.19%	0.00%	4%
5:00	0.60%	3.41%	0.00%	4%
6:00	0.60%	4.04%	0.00%	5%
7:00	0.60%	4.44%	0.00%	5%
8:00	0.60%	5.16%	0.00%	6%
9:00	0.60%	4.91%	0.00%	6%
10:00	0.60%	0.00%	3.83%	4%
11:00	0.60%	0.00%	3.31%	4%
Total	**14%**	**64%**	**22%**	**100%**

5.5.2 Primary and Secondary Schools

The existing data set contained 26 traces obtained from 11 school sites. These include schools from large urban high schools in Santa Monica and Phoenix, to small private day schools in Lafayette, CO[99]. Many of the school traces include irrigation, which was the primary night-time use. Figure 94 shows the percent of total average hourly water use.

Figure 52: Aggregated Hourly Water Demand Profile - Schools



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Between 8:00 AM and 5:00 PM water use in schools was variable, did not have a clear trend, and averaged around four percent of total daily use per hour. Approximately 12 percent of the daily water use occurred during the peak energy demand period. The percent of total average daily use is shown in tabular form in Table 103.

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[99] In order to have as robust a sample as possible, both private and public schools in and outside of California were included in the analysis. These were drawn from an existing database.

Table 55: Aggregated Hourly Water Demand - Schools

Hour	Schools % of Total Daily Water Use
12:00 AM	5.07%
1:00	5.00%
2:00	4.30%
3:00	4.62%
4:00	4.31%
5:00	3.55%
6:00	3.65%
7:00	4.57%
8:00	3.95%
9:00	2.76%
10:00	4.08%
11:00	4.30%
12:00 PM	2.78%
1:00	4.25%
Total Before Peak	**57%**
2:00	4.04%
3:00	4.36%
4:00	3.69%
Total During Peak	**12%**
5:00	3.98%
6:00	3.89%
7:00	4.37%
8:00	4.37%
9:00	4.96%
10:00	4.51%
11:00	4.66%
Total After Peak	**31%**

Figure 96 and Table 105 show the percentage of the total average hourly water use at schools disaggregated into the following categories:

- Continuous
- Indoor/Domestic
- Outdoor/Irrigation

Figure 53: Disaggregated Hourly Water Demand Profiles - Schools

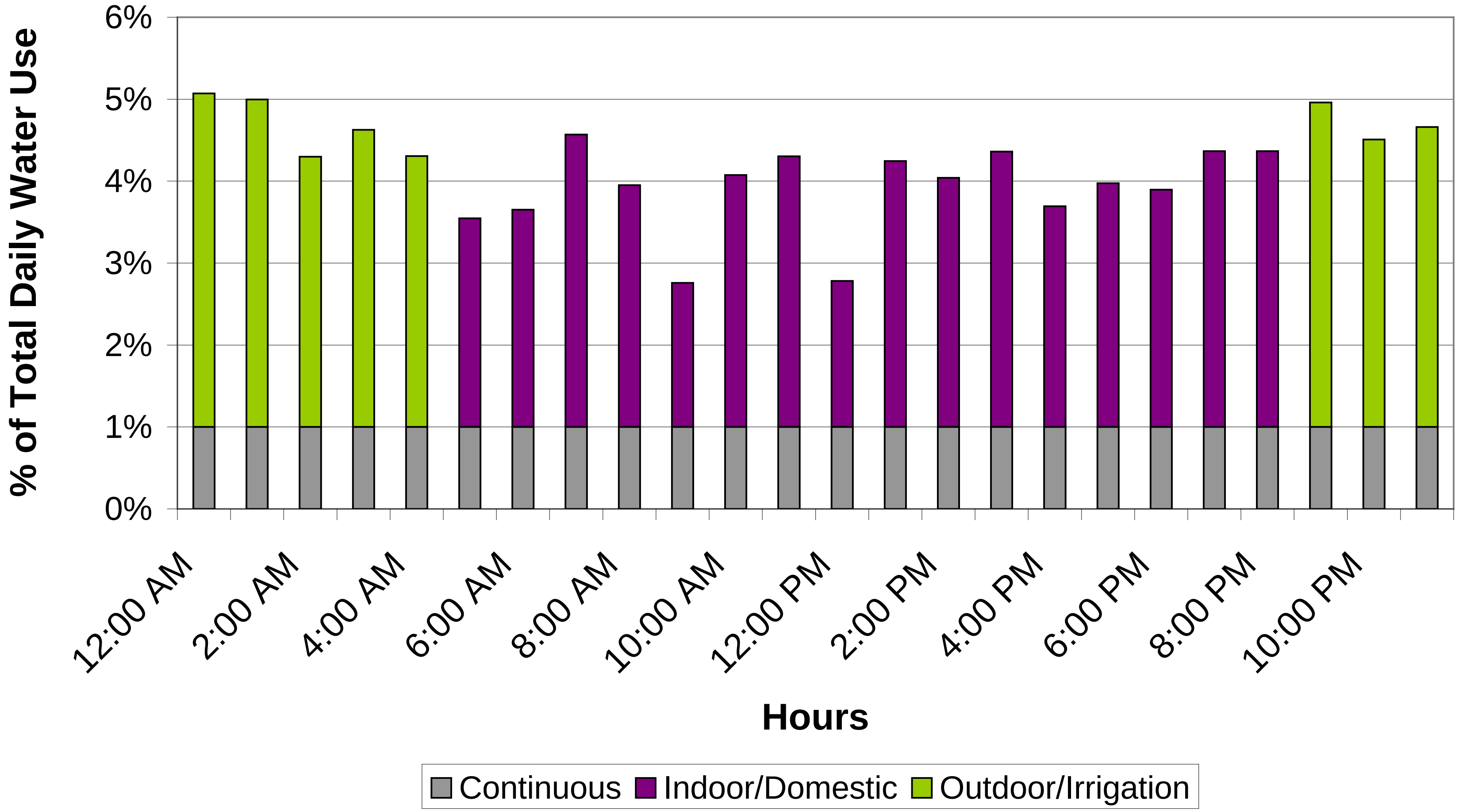


Table 56: Disaggregated Hourly Water Demand Profiles - Schools

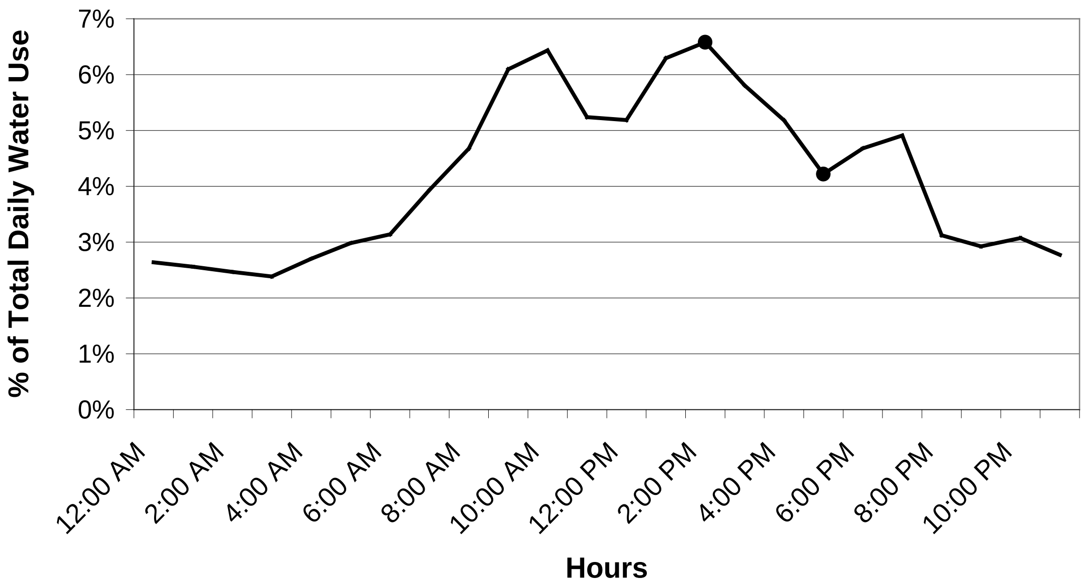
Hour	Continuous	Indoor/ Domestic	Outdoor/ Irrigation	Total
12:00 AM	1.00%	0.00%	4.07%	5%
1:00	1.00%	0.00%	4.00%	5%
2:00	1.00%	0.00%	3.30%	4%
3:00	1.00%	0.00%	3.62%	5%
4:00	1.00%	0.00%	3.31%	4%
5:00	1.00%	2.55%	0.00%	4%
6:00	1.00%	2.65%	0.00%	4%
7:00	1.00%	3.57%	0.00%	5%
8:00	1.00%	2.95%	0.00%	4%
9:00	1.00%	1.76%	0.00%	3%
10:00	1.00%	3.08%	0.00%	4%
11:00	1.00%	3.30%	0.00%	4%
12:00 PM	1.00%	1.78%	0.00%	3%
1:00	1.00%	3.25%	0.00%	4%
2:00	1.00%	3.04%	0.00%	4%
3:00	1.00%	3.36%	0.00%	4%
4:00	1.00%	2.69%	0.00%	4%
5:00	1.00%	2.98%	0.00%	4%
6:00	1.00%	2.89%	0.00%	4%
7:00	1.00%	3.37%	0.00%	4%
8:00	1.00%	3.37%	0.00%	4%
9:00	1.00%	0.00%	3.96%	5%
10:00	1.00%	0.00%	3.51%	5%
11:00	1.00%	0.00%	3.66%	5%
Total	**24%**	**47%**	**29%**	**100%**

Water use at schools appears to be largely for indoor/domestic use throughout the day. Irrigation use begins in the evening, peaks just around midnight and then decreases throughout the early morning until around 5:00 AM.

5.5.3 Hospitals

The new data set contains four traces obtained from one hospital in PG&E's service area. This hospital has in-patient and out-patient wards. A facility tour revealed that continuous uses from cooling towers and vacuum/pressure pumps dominate the daily water usage. Figure 98 shows the hourly percent of total water use.

Figure 54: Aggregated Hourly Water Demand Profile - Hospitals



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Hospital water use shows two peaks at 10:00 AM and 2:00 PM. Fifty-one percent of the total daily use occurred between the hours of 8:00 AM and 4:00 PM. Approximately 18 percent of the daily water use occurred during the peak energy demand period. The percent of total average daily use is shown in tabular form in Table 107.

Table 57: Aggregated Hourly Water Demand - Hospitals

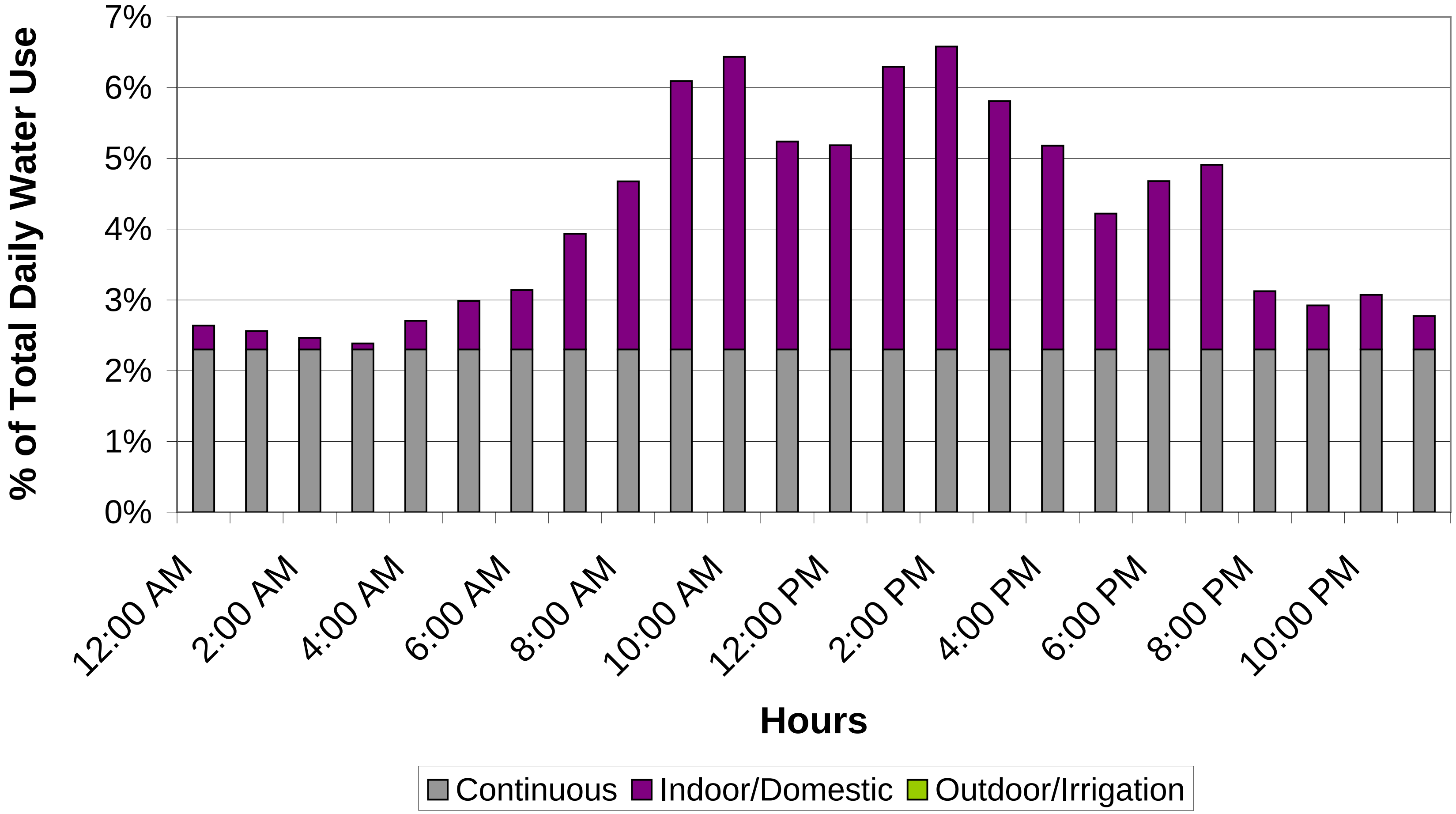
Hour	Hospitals % of Total Daily Water Use
12:00 AM	2.64%
1:00	2.56%
2:00	2.47%
3:00	2.38%
4:00	2.70%
5:00	2.98%
6:00	3.14%
7:00	3.93%
8:00	4.68%
9:00	6.10%
10:00	6.43%
11:00	5.24%
12:00 PM	5.19%
1:00	6.29%
Total Before Peak	**57%**
2:00	6.58%
3:00	5.81%
4:00	5.18%
Total During Peak	**18%**
5:00	4.22%
6:00	4.68%
7:00	4.91%
8:00	3.12%
9:00	2.92%
10:00	3.07%
11:00	2.77%
Total After Peak	**26%**

Figure 100 and Table 109 show the percentage of the total average hourly water use at the hospital disaggregated into the following categories:

- Continuous
- Indoor/Domestic
- Outdoor/Irrigation

The hospital site did not have meters serving both indoor uses and outdoor irrigation. For Study 3, loggers were installed on meters that monitored indoor uses at the hospital site. Consequently, there is no irrigation use shown in either Figure 100 or Table 109.

Figure 55: Disaggregated Hourly Water Demand Profiles - Hospitals[100]



[100] Logged water meters for Study 3 hospital site only served indoor uses and not irrigation. Consequently, there is no irrigation use shown.

Table 58: Disaggregated Hourly Water Demand - Hospitals[101]

Hour	Continuous	Indoor/ Domestic	Outdoor/ Irrigation	Total
12:00 AM	2.30%	0.34%	0.00%	3%
1:00	2.30%	0.26%	0.00%	3%
2:00	2.30%	0.17%	0.00%	2%
3:00	2.30%	0.08%	0.00%	2%
4:00	2.30%	0.40%	0.00%	3%
5:00	2.30%	0.68%	0.00%	3%
6:00	2.30%	0.84%	0.00%	3%
7:00	2.30%	1.63%	0.00%	4%
8:00	2.30%	2.38%	0.00%	5%
9:00	2.30%	3.80%	0.00%	6%
10:00	2.30%	4.13%	0.00%	6%
11:00	2.30%	2.94%	0.00%	5%
12:00 PM	2.30%	2.89%	0.00%	5%
1:00	2.30%	3.99%	0.00%	6%
2:00	2.30%	4.28%	0.00%	7%
3:00	2.30%	3.51%	0.00%	6%
4:00	2.30%	2.88%	0.00%	5%
5:00	2.30%	1.92%	0.00%	4%
6:00	2.30%	2.38%	0.00%	5%
7:00	2.30%	2.61%	0.00%	5%
8:00	2.30%	0.82%	0.00%	3%
9:00	2.30%	0.62%	0.00%	3%
10:00	2.30%	0.77%	0.00%	3%
11:00	2.30%	0.47%	0.00%	3%
Total	**55%**	**45%**	**0%**	**100%**

5.5.4 Findings

Study 3 findings for the public building category include:

- Public Building sub-categories varied in daily indoor water use patterns. Where outdoor irrigation was measured, it tended to occur during the late night and early morning hours.
- Water demand coincident with the peak energy demand period varied across the public building groups from 12 to 18 percent.
- Public building sites (excluding schools and hospital) showed a late morning to mid-afternoon water use peak followed by a larger late evening water use peak at 8:00 PM. These peaks were likely due to typical workday hours at these sites. Over 13 percent of the daily water use occurred during the peak energy demand period.

[101] Logged water meters for Study 3 hospital only served indoor uses and not irrigation. Consequently, there is no irrigation use shown.

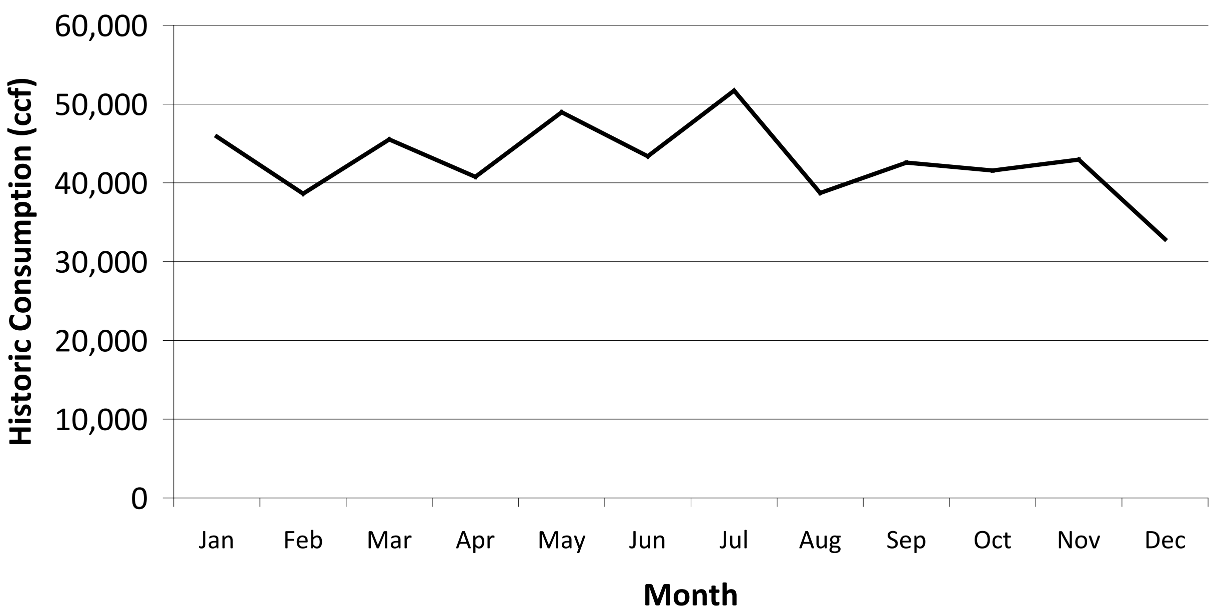
- Water use at schools appeared to be largely for indoor/domestic use throughout the day. Irrigation use began in the evening, peaks just around midnight and then decreasedthroughout the early morning until around 5:00 AM. Slightly over 12 percent of the daily water use occurred during the peak energy demand period.
- Water use at the hospital included in Study 3 was largely for continuous uses(55 percent) throughout the day. Indoor use occurred primarily from the early morning to mid-evening around 7: 00 PM. Nearly 18 percent of the daily water use occurred during the peak energy demand period.

5.6 Industrial

The following sections provide hourly water use results for industrial facilities based on the analysis of new flow trace data, as well as flow trace data collected in earlier studies. A total of 26flow trace files from 12 industrial sites were collected to generate the hourly water demands, with two sites from SDG&E's service area, two from SCE's, and eight from PG&E's. In addition to the data collected specifically for Study 3, an existing database containing a sample of five industrial sites was used.

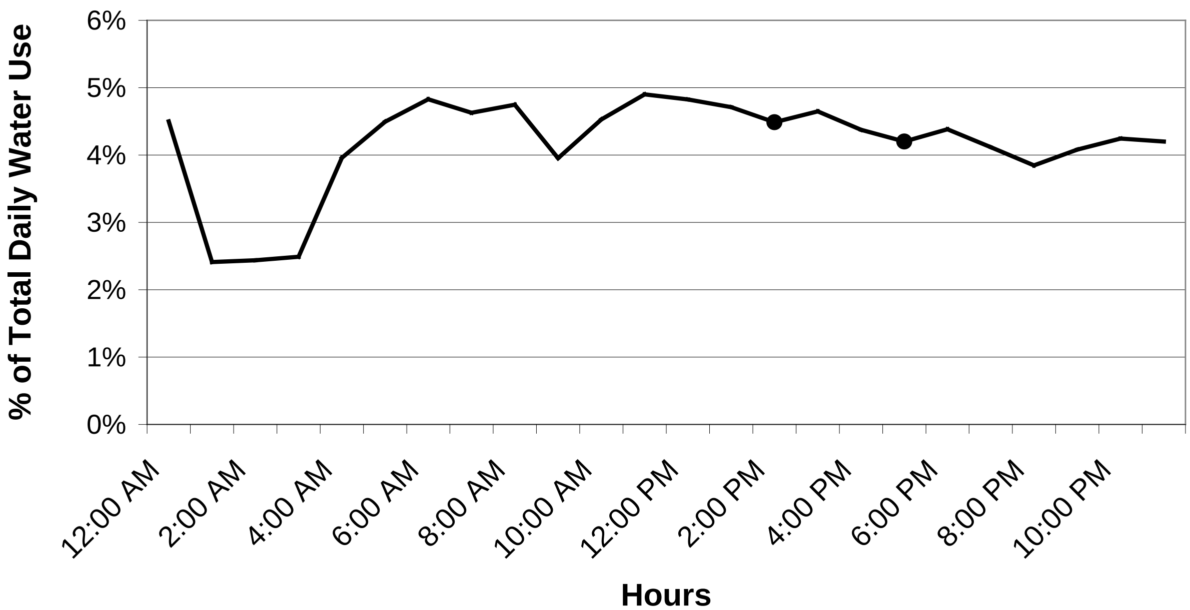
Figure 102 shows the historic consumption pattern of the 12 industrial sites for which related data were obtained. The consumption data pattern reflects the fact that some of the water agencies bill bi-monthly.

Figure 56: Historic Monthly Water Demand - Industrial



Daily profiles of water use as a percentage of the total average hourly demand at industrial facilities are shown in Figure 104. These profiles represent the combined hourly profile data from all 17industrial sites in Study 3 database.

Figure 57: Aggregated Hourly Water Demand Profile - Industrial



••indicates peak energy demand period (2:00 PM – 5:00 PM)

The water use data collected at industrial Study 3 sites show a decline in use between 1:00 AM and 3:00 AM, and a fairly steady demand throughout the rest of the day. Nearly 14 percent of the daily water use occurred during the peak energy demand period.

Table 59: Aggregated Hourly Water Demand - Industrial

Hour	Industrial % of Total Daily Water Use
12:00 AM	4.50%
1:00	2.41%
2:00	2.44%
3:00	2.49%
4:00	3.96%
5:00	4.49%
6:00	4.83%
7:00	4.63%
8:00	4.75%
9:00	3.95%
10:00	4.53%
11:00	4.90%
12:00 PM	4.83%
1:00	4.71%
Total Before Peak	**57%**
2:00	4.49%
3:00	4.65%
4:00	4.37%
Total During Peak	**14%**
5:00	4.20%
6:00	4.38%
7:00	4.12%
8:00	3.85%
9:00	4.08%
10:00	4.25%
11:00	4.20%
Total After Peak	**29%**

Industrial Study 3 site water uses were logged from their indoor and outdoor (when available) water meters. Demand profiles were developed based on data logging combined with site visit information collected (when available).

Figure 106 and Table 112 show the percentage of the total average hourly water use at industrial facilities disaggregated into the following categories:

- Continuous
- Process
- Outdoor/Irrigation

Figure 58: Disaggregated Hourly Water Demand Profiles - Industrial

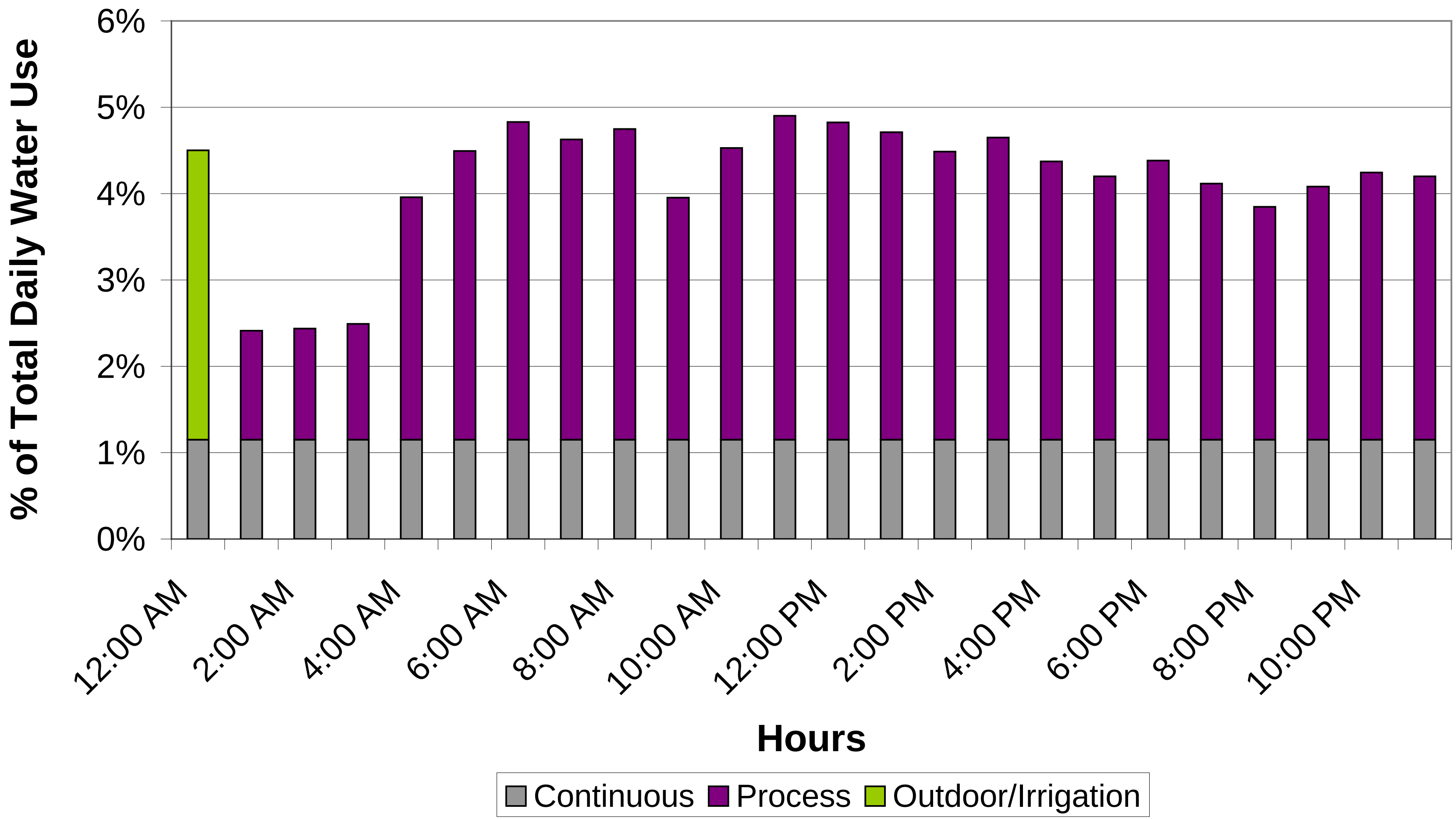


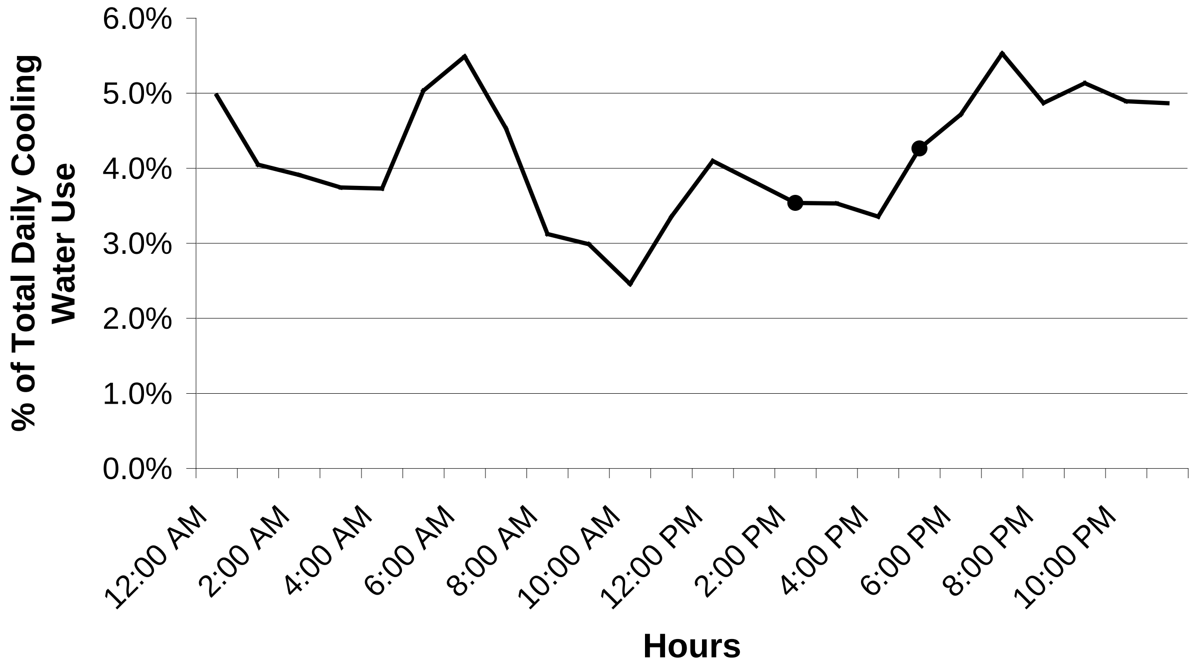
Table 60: Disaggregated Hourly Water Demand - Industrial

Hour	Continuous	Process	Outdoor/ Irrigation	Total
12:00 AM	1.15%	0.00%	3.35%	5%
1:00	1.15%	1.26%	0.00%	2%
2:00	1.15%	1.29%	0.00%	2%
3:00	1.15%	1.34%	0.00%	2%
4:00	1.15%	2.81%	0.00%	4%
5:00	1.15%	3.34%	0.00%	4%
6:00	1.15%	3.68%	0.00%	5%
7:00	1.15%	3.48%	0.00%	5%
8:00	1.15%	3.60%	0.00%	5%
9:00	1.15%	2.80%	0.00%	4%
10:00	1.15%	3.38%	0.00%	5%
11:00	1.15%	3.75%	0.00%	5%
12:00 PM	1.15%	3.68%	0.00%	5%
1:00	1.15%	3.56%	0.00%	5%
2:00	1.15%	3.34%	0.00%	4%
3:00	1.15%	3.50%	0.00%	5%
4:00	1.15%	3.22%	0.00%	4%
5:00	1.15%	3.05%	0.00%	4%
6:00	1.15%	3.23%	0.00%	4%
7:00	1.15%	2.97%	0.00%	4%
8:00	1.15%	2.70%	0.00%	4%
9:00	1.15%	2.93%	0.00%	4%
10:00	1.15%	3.10%	0.00%	4%
11:00	1.15%	3.05%	0.00%	4%
Total	**28%**	**69%**	**3%**	**100%**

Note that irrigation occurred only at the midnight hour. This is likely because the data came from a number of sites and one had significant use at this time. It is also possible that some of the use earlier in the evening shown as process use may have been irrigation. Because these data came from a large number of facilities they represent averages.

Cooling towers were sub-metered at one of the industrial Study 3 facilities. Researchers were allowed to visit this site, an industrial food processor that maintains cooling towers for the cooling of canned foods and cold storage, for more detailed measurements. Data were collected between June and July 2010. Each day during the logging period at this site, an average of about 154,518 gallons of potable water was used. Since cooling towers can use a large amount of water (depending on how the system is maintained), they typically show strong potential for water efficiency improvements. Figure 108 shows the hourly demand pattern of for cooling at this site.

Figure 59: Aggregated Hourly Water Demand Profile - Industrial Cooling Towers, Food Processor



••indicates peak energy demand period (2:00 PM – 5:00 PM)

Sub-metering the inflow lines to the cooling towers at this facility showed a fairly continuous demand for cooling water, but with two peak times during the periods of 5:00 AM to 7:00 AM, and 7:00 PM to 12:00 PM. Table 114reveals that nearly 11 percent of the cooling tower water demand occurred during peak energy demand periods.

Table 61: Aggregated Hourly Water Demand - Industrial Cooling Towers, Food Processor

Hour	Industrial Cooling Towers, Food Processor % of Total Daily Water Use
12:00 AM	4.97%
1:00	4.05%
2:00	3.91%
3:00	3.75%
4:00	3.73%
5:00	5.03%
6:00	5.49%
7:00	4.53%
8:00	3.12%
9:00	2.99%
10:00	2.46%
11:00	3.36%
12:00 PM	4.10%
1:00	3.82%
Total Before Peak	**55%**
2:00	3.54%
3:00	3.53%
4:00	3.36%
Total During Peak	**10%**
5:00	4.26%
6:00	4.72%
7:00	5.53%
8:00	4.87%
9:00	5.13%
10:00	4.89%
11:00	4.87%
Total After Peak	**34%**

When cooling towers are maintained appropriately they use less water. Significantly less water is required when a cooling system is operated at a pH concentration ratio[102] between 5.0 and 7.0 than at one between 1.0 and 4.0.

Water samples from the cooling towers at the industrial food processor included in Study 3 were collected during site visits and analyzed for their cycles of concentration,[103]pH and total

[102] Concentration ratio is the ratio of the salinity in the circulating water to that in the make-up water in a cooling system.
[103] The term "cycles of concentration" compares the level of solids of the recirculating cooling tower to the level of solids of the original raw make up water. For example, if the circulating water has four times the solids concentration than that of the make-up water, then the cycles are 4.

dissolved solids. Table 116 shows the measured pH concentration ratios from the three cooling towers. The measured concentration ratios highlight a potential for an efficiency improvement in how these cooling towers are operated. The water use in these cooling towers could be significantly reduced if the concentration ratios were raised up to at least five cycles or more.

Table 62: Concentration Ratios of Industrial Cooling Towers

	Cooling Tower 1 [ratio]	Cooling Tower 2 [ratio]	Cooling Tower 3 [ratio]
Industrial Food Processor	3.10	3.10	2.77

5.6.1 Findings

Study 3 findings for the industrial category include:

- Industrial sites' daytime water use tended to include process and continuous applications. Irrigation tended to occur during the midnight hour.
- Industrial end-users used nearly 14 percent of their total daily water during the peak energy demand period.
- Industrial end-users exhibited high continuous use throughout the day.
- Sub-metering of cooling towers showed a small portion of water use during peak energy demand periods.
- Concentration ratio measurements at cooling towers revealed a significant potential for water savings under improved system management regimes.[104]

[104] It would be worth exploring the cost of use of pH control, which would allow the systems to operate at up to 10 cycles of concentration and reduce their water use.

5.7 Agricultural

At the beginning of Study 3 work on the agricultural category, it was determined that very little (if any) information existed on the potable and recycled water demands of either irrigation or food processing. The data collected and analyzed for this category are believed to be the first time that hourly water use profiles have been measured, as defined in Study 3.

The processing of fruit at Study 3 sites uses a series of steps. The first step of fruit washing appears to use the most water. Approximately half of the water used for this washing is recaptured and reused in the processing. Fresh water make-up is controlled with float valves in the flumes. A significant volume of water is also used for syrup production, which is used for canning the processed fruit. Cooling of cooked canned fruit and other cold storage at these facilities requires cooling towers, which are major water users as well. Wastewater from these facilities is reused for irrigation of crops, not for human consumption.

The following sections provide hourly water use results for agricultural Study 3 sites that use potable water at agricultural irrigator and processing facilities. The results are based on the analysis of new flow trace data collected from Study 3 sties in SCE and PG&E service areas.

Historic consumption data were collected for all the agricultural end-users studied. Figure 110and Figure 112show the historic consumption pattern of irrigators and processing facilities, respectively. For agricultural irrigators, the mix of monthly and bi-monthly data shows an increase in use in the spring and early summer, with a larger increase in the fall. The pattern of agricultural processors reflects the fact that typically these types of water customers use more water throughout the summer months to process harvested produce and dairy products. These data are from a relatively small number of sites and reflect lagged billing periods which may vary from month to month. It is suggested that if monthly use patterns are use that the curve be averaged to eliminate the spikes

Figure 60: Historic Monthly Water Demand – Agricultural Irrigators

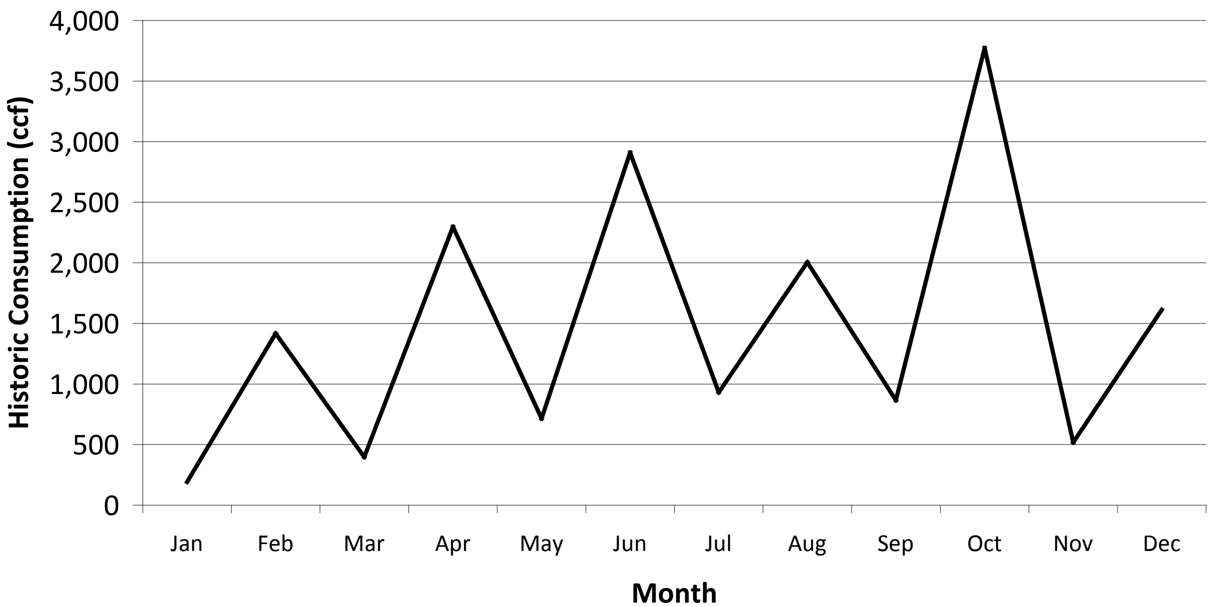
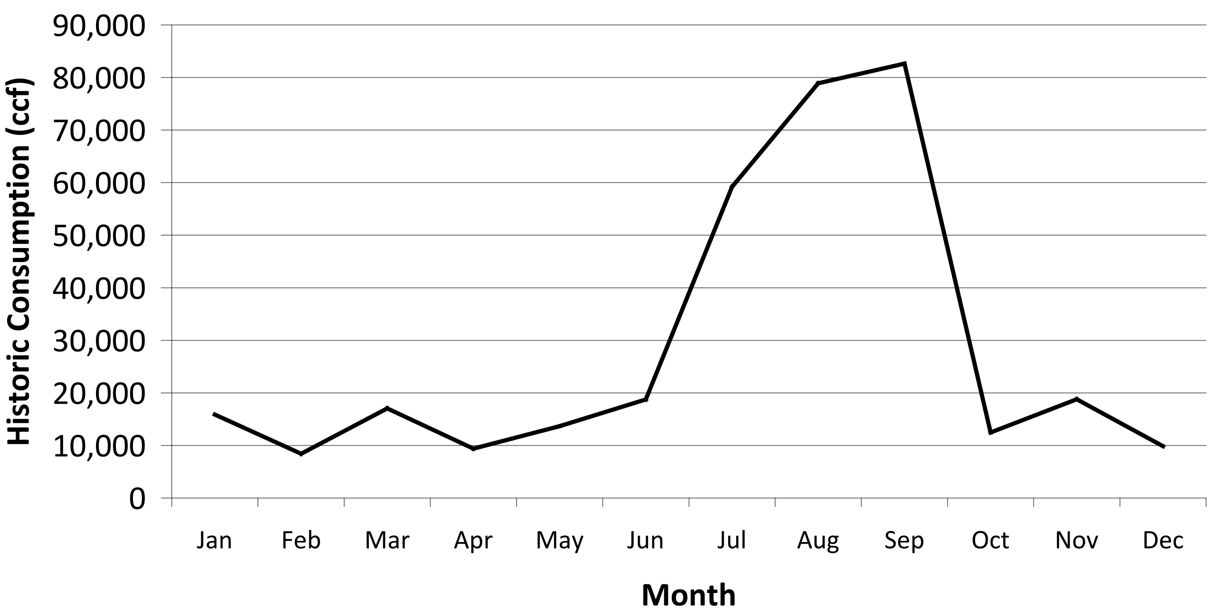


Figure 61: Historic Monthly Water Demand – Agricultural Processors

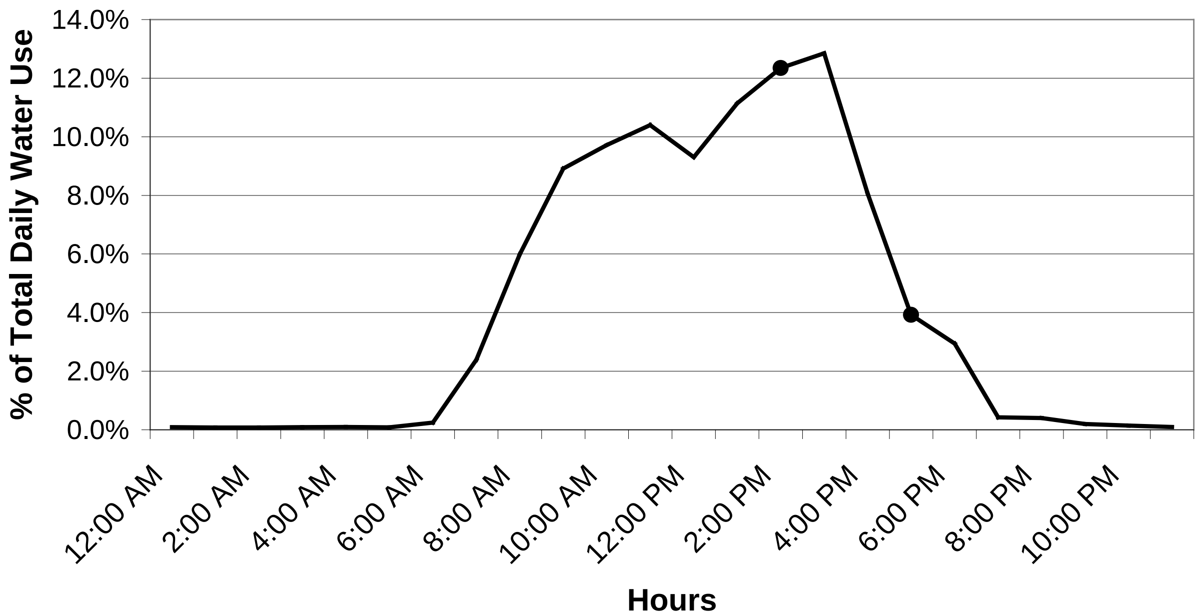


5.7.1 Agricultural Irrigators

For the agricultural irrigator sub-category, a total of four flow trace files from three Study 3 sites were collected to generate hourly water demands. These Study 3 sites include orchard and plant nurseries that irrigate with agency-supplied water. Note that these are not "typical" agricultural irrigators, but rather, for Study 3, irrigators using potable water supplied by a water agency. At each facility, the main water meter, or combined meters, was fitted with data loggers and the flow trace data recorded for a period of one month. These flow trace data were disaggregated into demand profile categories of continuous, process and outdoor/irrigation use.

Hourly profiles of water use as a percentage of the total average daily demand at agricultural irrigator sites are shown in Figure 114. These profiles are included in the database for agricultural hourly water uses.

Figure 62: Aggregated Hourly Water Demand Profile - Agricultural Irrigators



••indicates peak energy demand period (2:00 PM – 5:00 PM)

The water use data collected at agricultural irrigator sites show a sharp increase around 7:00 AM and a decline around 4:00 PM. Over 33 percent of the daily water use occurred during the peak energy demand period. The percent of total average daily use is shown in tabular form in Table 118.

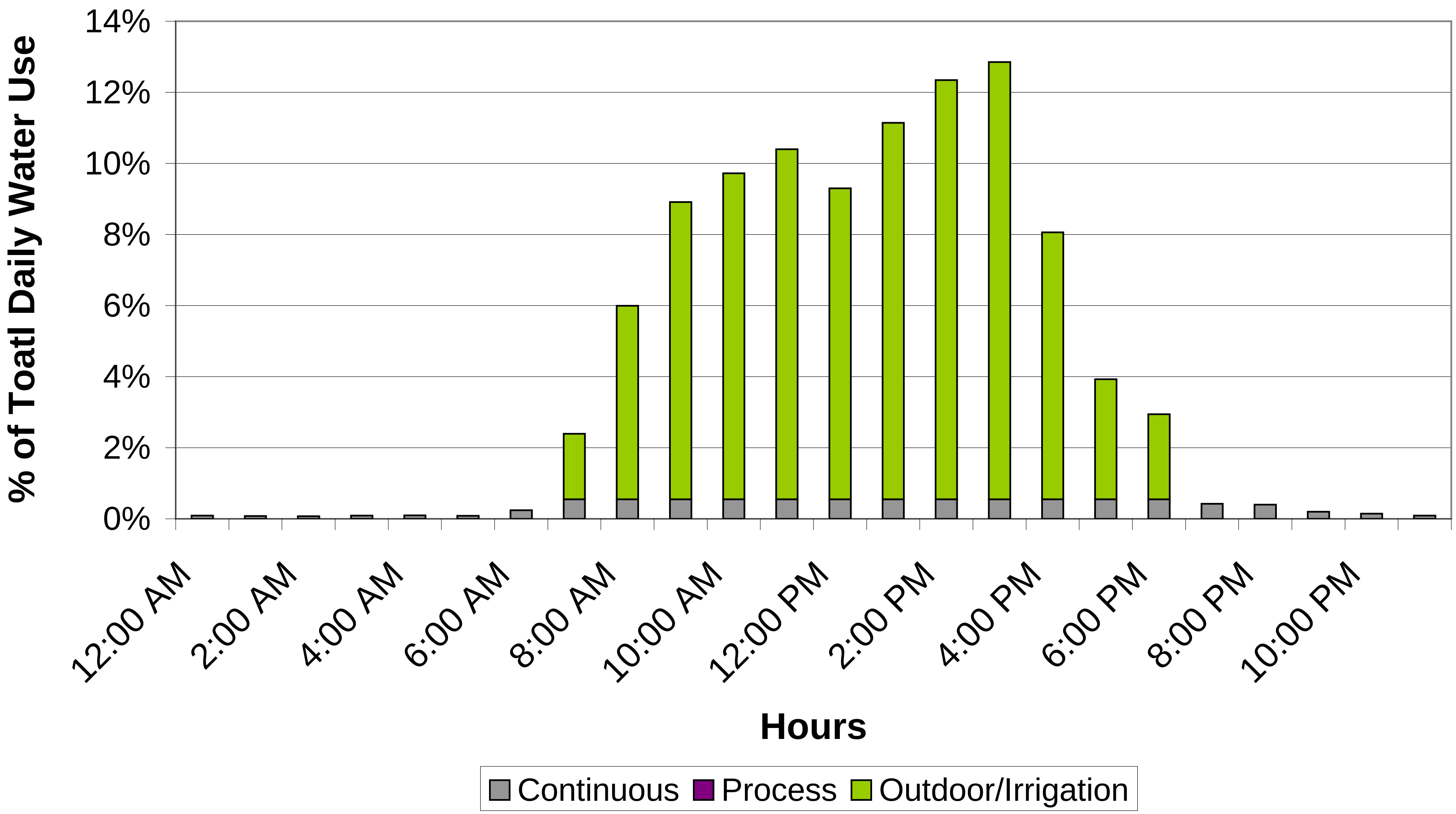
Table 63: Aggregated Hourly Water Demand - Agriculture Irrigators

Hour	Agricultural Irrigators % of Total Daily Water Use
12:00 AM	0.09%
1:00	0.08%
2:00	0.08%
3:00	0.09%
4:00	0.10%
5:00	0.08%
6:00	0.24%
7:00	2.39%
8:00	5.99%
9:00	8.91%
10:00	9.72%
11:00	10.40%
12:00 PM	9.30%
1:00	11.14%
Total Before Peak	**59%**
2:00	12.34%
3:00	12.85%
4:00	8.06%
Total During Peak	**33%**
5:00	3.93%
6:00	2.94%
7:00	0.42%
8:00	0.40%
9:00	0.20%
10:00	0.14%
11:00	0.09%
Total After Peak	**8%**

Figure 116 and Table 120 show the percentage of the total average hourly water use at agricultural irrigator sites disaggregated into the following categories:

- Continuous
- Process
- Outdoor/Irrigation

Figure 63: Disaggregated Hourly Water Demand Profiles - Agricultural Irrigators[105]



[105] Logged agricultural irrigator water meters only served continuous use and irrigation, and no process use. Consequently, no process use is shown.

Most of the water use during the day was for outdoor/irrigation. As would be expected for irrigator sites, no process use was detected in the flow trace data.

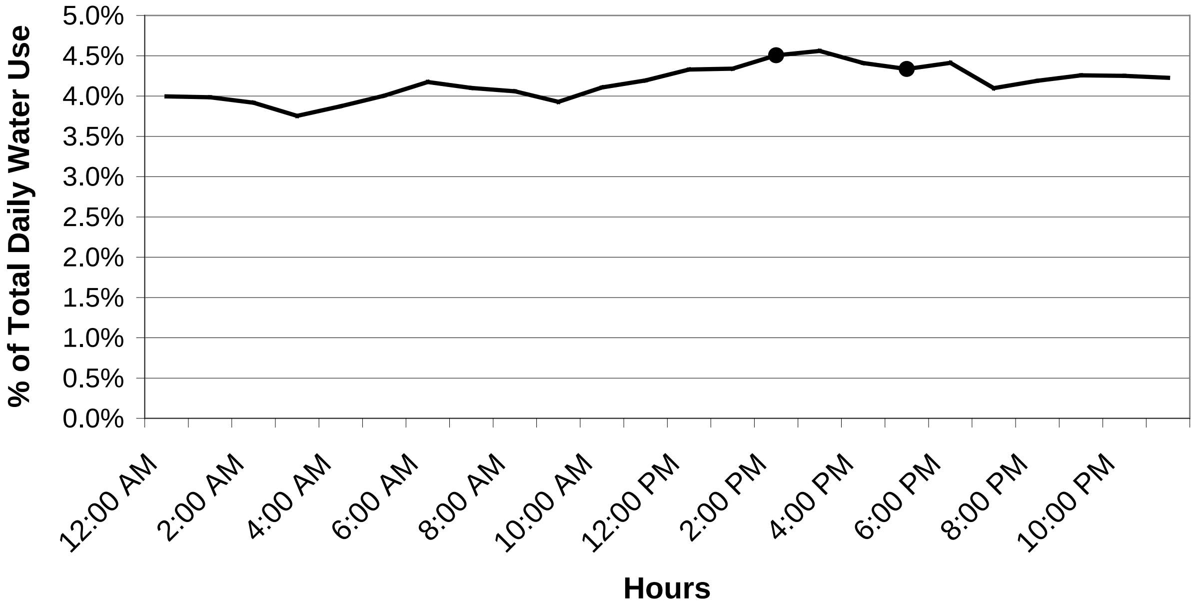
Table 64: Disaggregated Hourly Water Demand – Agricultural Irrigators

Hour	Continuous	Process	Outdoor/ Irrigation	Total
12:00 AM	0.09%	0.00%	0.00%	0%
1:00	0.08%	0.00%	0.00%	0%
2:00	0.08%	0.00%	0.00%	0%
3:00	0.09%	0.00%	0.00%	0%
4:00	0.10%	0.00%	0.00%	0%
5:00	0.08%	0.00%	0.00%	0%
6:00	0.24%	0.00%	0.00%	0%
7:00	0.55%	0.00%	1.84%	2%
8:00	0.55%	0.00%	5.44%	6%
9:00	0.55%	0.00%	8.36%	9%
10:00	0.55%	0.00%	9.17%	10%
11:00	0.55%	0.00%	9.85%	10%
12:00 PM	0.55%	0.00%	8.75%	9%
1:00	0.55%	0.00%	10.59%	11%
2:00	0.55%	0.00%	11.79%	12%
3:00	0.55%	0.00%	12.30%	13%
4:00	0.55%	0.00%	7.51%	8%
5:00	0.55%	0.00%	3.37%	4%
6:00	0.55%	0.00%	2.39%	3%
7:00	0.42%	0.00%	0.00%	0%
8:00	0.40%	0.00%	0.00%	0%
9:00	0.20%	0.00%	0.00%	0%
10:00	0.14%	0.00%	0.00%	0%
11:00	0.09%	0.00%	0.00%	0%
Total	**9%**	**0%**	**91%**	**100%**

5.7.2 Agricultural Processors

The agricultural processor sub-category has a total of 18 flow trace files from seven sites. These sites include produce, dairy and meat processors. The water meters serving each of these facilities were fitted with data loggers and the flow trace data recorded for a period of one month. These flow trace data were disaggregated into a demand profile categories of continuous, process and outdoor/irrigation use. Hourly profiles of water use as a percentage of the total average daily demand at agricultural processor sites are shown in Figure 118. These profiles are included in the database for agricultural hourly water uses.

Figure 64: Aggregated Hourly Water Demand Profile - Agricultural Processor



••indicates peak energy demand period (2:00 PM – 5:00 PM)

The water use data collected at agricultural processor facilities show a steady demand throughout the day with a slight peak around 3:00 PM. Nearly 14 percent of the daily water use occurred during the peak energy demand period. The percent of total average daily use is shown in tabular form in Table 122.

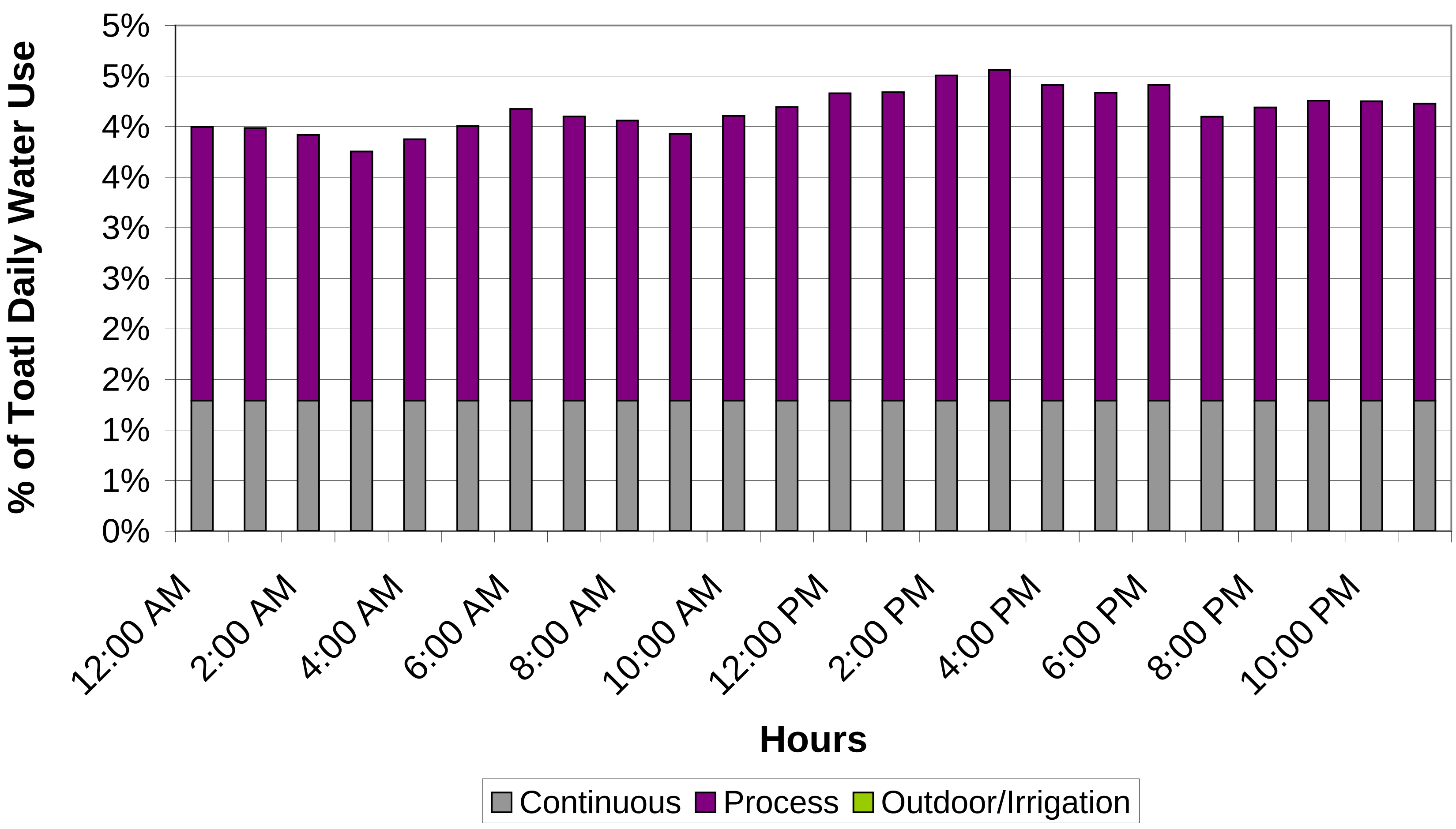
Table 65: Aggregated Hourly Water Demand - Agricultural Processor

Hour	Agricultural Processor % of Total Daily Water Use
12:00 AM	4.00%
1:00	3.98%
2:00	3.92%
3:00	3.75%
4:00	3.87%
5:00	4.00%
6:00	4.17%
7:00	4.10%
8:00	4.06%
9:00	3.93%
10:00	4.11%
11:00	4.19%
12:00 PM	4.33%
1:00	4.34%
Total Before Peak	**57%**
2:00	4.51%
3:00	4.56%
4:00	4.41%
Total During Peak	**14%**
5:00	4.34%
6:00	4.41%
7:00	4.10%
8:00	4.19%
9:00	4.26%
10:00	4.25%
11:00	4.23%
Total After Peak	**30%**

Figure 120 and Table 124show the percentage of the total average hourly water use at agricultural processor sites disaggregated into the following categories:

- Continuous
- Process
- Outdoor/Irrigation

Figure 65: Disaggregated Hourly Water Demand Profiles - Agricultural Processors[106]



[106] Logged agricultural processor water meters only served continuous and process uses. Consequently, no irrigation use is shown.

Table 66: Disaggregated Hourly Water Demand - Agricultural Processors[107]

Hour	Continuous	Process	Outdoor/ Irrigation	Total
12:00 AM	1.29%	2.71%	0.00%	4%
1:00	1.29%	2.69%	0.00%	4%
2:00	1.29%	2.63%	0.00%	4%
3:00	1.29%	2.46%	0.00%	4%
4:00	1.29%	2.58%	0.00%	4%
5:00	1.29%	2.71%	0.00%	4%
6:00	1.29%	2.88%	0.00%	4%
7:00	1.29%	2.81%	0.00%	4%
8:00	1.29%	2.77%	0.00%	4%
9:00	1.29%	2.64%	0.00%	4%
10:00	1.29%	2.82%	0.00%	4%
11:00	1.29%	2.90%	0.00%	4%
12:00 PM	1.29%	3.04%	0.00%	4%
1:00	1.29%	3.05%	0.00%	4%
2:00	1.29%	3.22%	0.00%	5%
3:00	1.29%	3.27%	0.00%	5%
4:00	1.29%	3.12%	0.00%	4%
5:00	1.29%	3.05%	0.00%	4%
6:00	1.29%	3.12%	0.00%	4%
7:00	1.29%	2.81%	0.00%	4%
8:00	1.29%	2.90%	0.00%	4%
9:00	1.29%	2.97%	0.00%	4%
10:00	1.29%	2.96%	0.00%	4%
11:00	1.29%	2.94%	0.00%	4%
Total	**31%**	**69%**	**0%**	**100%**

Water using fixtures were sub-metered from two of the aforementioned agricultural processing facilities that agreed to allow researchers onto their facilities to conduct a more detailed onsite evaluation of their water using equipment. These data were collected between June and September 2009.

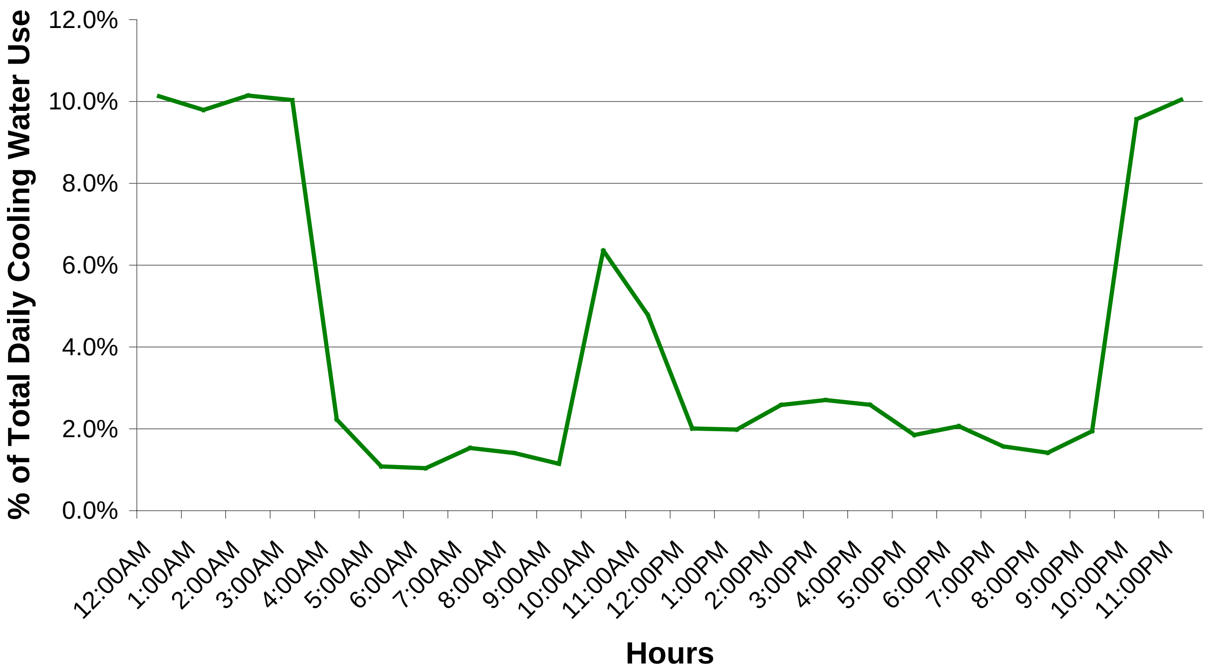
. Since processing at the two facilities continues on a 24-hour and six-day schedule, the significant volumes of daily water use is distributed during each hour[108].

[107] Logged agricultural processor water meters only served continuous and process uses. Consequently, no irrigation use is shown. .

[108] Site 1 processes fruit harvests for about 9 weeks after July 4. Site 2 processes fruit harvests for about 13 weeks after July 4.

Both of the agricultural processing facilities maintained cooling towers for cooling of canned fruit and cold storage. Since cooling towers can use a large amount of water (depending on how the system is maintained), they typically demonstrate an area where water efficiency improvements are possible. The three cooling towers at these two sites were sub-metered for further hourly demand profiling analysis. Figure 122shows the hourly demand pattern of for cooling at the two facilities.

Figure 66: Aggregated Hourly Water Demand Profile -Agricultural Cooling Towers



Sub-metering the inflow lines to the towers showed the largest portion of the hourly demand for cooling occurs between 10:00 PM and 3:00 AM. This is likely because the primary use of cooled water is for cooling canned produce that has been cooked in large cookers. The cooling towers provide cooled water for a flume/bath the cans run through. It is likely the flume/bath for cooling cans was drained and refilled during night-time hours. Refilling the flume/bath would result in draining of water from the system and the refilling of cooling tower reservoirs.Table 126reveals that only about eight percent of the cooling tower water demand occurred during the peak energy demand period.

Table 67: Aggregated Hourly Water Demand - Agricultural Cooling Towers

Hour	Agricultural Cooling Towers % of Total Daily Water Use
12:00 AM	10.13%
1:00	9.80%
2:00	10.15%
3:00	10.03%
4:00	2.23%
5:00	1.08%
6:00	1.04%
7:00	1.53%
8:00	1.41%
9:00	1.15%
10:00	6.36%
11:00	4.79%
12:00 PM	2.01%
1:00	1.98%
Total Before Peak	**64%**
2:00	2.58%
3:00	2.70%
4:00	2.59%
Total During Peak	**8%**
5:00	1.85%
6:00	2.06%
7:00	1.57%
8:00	1.42%
9:00	1.94%
10:00	9.57%
11:00	10.04%
Total After Peak	**29%**

As discussed above, if cooling towers are maintained appropriately they use less water. Significantly less water is required when a cooling system is operated at a pH concentration ratio between 5.0 and 7.0 than at one between 1.0 and 4.0.

Water samples from the three agricultural processing plant cooling towers were collected during site visits and analyzed for their cycles of concentration, pH and level of chloride ions. Table 128shows the measured concentration ratios from the three cooling towers studied. The measured pH concentration ratios highlight a potential for efficiency improvements for continuous use. The water use in these cooling towers could be significantly reduced if all pH concentration ratios were raised to at least three cycles. The fact that the towers are not used continuously complicates the water treatment, and may make advanced treatment, such as pH control, less practical. But there is no reason that they could not be operated at cycles between 3 and 4, which would reduce the water use.

Table 68: Concentration Ratios of Agricultural Processing Cooling Towers

	Cooling Tower 1 [ratio]	Cooling Tower 2 [ratio]	Cooling Tower 3 [ratio]
Site 1	1.42	--	--
Site 2	--	2.64	3.38

5.7.3 Findings

Study 3 findings for the agricultural end-user category include:

- Agricultural sites' varied rather dramatically depending on the type of facility being considered. Daytime water use tended to be dominated by irrigation for agricultural irrigators and split between process and continuous uses for agricultural processors. Nighttime use was similar to daytime use for agricultural processors and almost non-existent for agricultural irrigators.
- Agricultural sub-categories varied in the percentage of daily water use occurring during the peak energy demand period from 8 to 33 percent.
    - Agricultural irrigators showed a sharp increase in water use around 7:00 AM and a decline around 4:00 PM and used a significant portion (over 33 percent) of their water during the peak energy demand period.
    - Agricultural irrigators exhibited an increase in use in the spring and early summer, with a larger increase in the fall.
    - Agricultural processors tended to use more water throughout the summer months to process harvested produce and dairy products. The first step of agricultural processing, fruit washing, appeared to use the most water. Approximately half of the water used for this washing was recaptured and reused in the processing.
    - Agricultural processors exhibited a steady demand throughout the day with a slight peak around 3:00 PM, and use only about 14 percent of their total water during the peak energy demand period.
    - Sub-metering of cooling towers showedthe largest portion of the hourly demand for cooling occurred between 10:00 PM and 3:00 AM, with only a small portion of water use during peak energy demand periods.
    - Concentration ratio measurements at cooling towers reveal a significant potential for water savings under improved system management regimes.[109]

[109] It would be worth exploring the cost of use of pH control, which would allow the systems to operate at up to 10 cycles of concentration and reduce their water use.

6 Summary and Conclusions

This report has outlined the findings of the *End-use Water Demand Profiles* study, which examined the baseline hourly water uses in both residential and non-residential end-user categories. Hourly profile data were collected in multiple water demand profile categories throughout California and (when possible) combined with data collected from California and other states in earlier studies.

Samples of customers were selected from single-family, multi-family, commercial, urban irrigation, public building, industrial and agricultural end-users in the service areas of the three California electric IOUs. It was not possible to select samples that were statistically representative from each of these categories, but the researchers attempted to obtain examples from the most important water using components of each.

Flow trace data were used to generate hourly demand profiles from each end-user category. These were expressed in terms of the percent of total daily use occurring in each hour of the day for each category. In general, there were four patterns of use observed: morning and evening, night-time, daytime, and continuous. Residential end-users tend to demand water during morning and evening periods. Irrigation tends to occur during night-time hours. While many commercial and public building facilities are daytime users, those in the industrial category are the most likely to be continuous users.

Residential uses were disaggregated into various domestic water demand profile categories, for such things as toilets, showers and clothes washers. Non-residential uses were broken down into indoor/process uses, outdoor/irrigation users, and continuous uses. The percentage of each category occurring by hour of the day was determined.

Hourly demand patterns determined in Study 3 can be used to model overall water agency demands in a way that show how changes in use by one category affect the hourly demand patterns for the system as a whole, and in wastewater load generation. The results from the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*[110]study can then be used to determine how changes in the hourly water and wastewater load profiled affect the energy requirements at the water agency level. In that way, Study 3 results complement those of the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles* study to show the energy relationships in water treatment systems. This earlier study confirmed just how variable water agency configurations can be, depending on factors such as the size of their distribution system, topology of their service areas, and technologies used to treat water.

With the right combination of water agency treatment and delivery capacity, treated water storage and hourly end-user water demand patterns, it should be possible to significantly reduce water agency energy demands during the peak energy demand periods. Note that even with this understanding of water agency operations, additional information will be necessary to link the

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[110] G.E.I. Consulting and Navigant Consulting, Inc., *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*.

timing of the effect of water conservation at a customer site with energy use at the water agency site.

6.1 Summary Findings

Study 3 findings indicate that if hourly demands of all end-user types were combined, they would tend to be fairly constant throughout the day for a water agency with a mix of residential, commercial, public building, urban irrigation, industrial and agricultural customers using treated water. Hourly water demands for residential customers tend to fall before and after the business day, while the non-residential demands fall during the day. These tend to balance each other out.

As discussed above, the daily water use coincident with the peak energy demand period for the primary end-user categories analyzedwas of particular interest to Study 3. Table 130 summarizes related Study 3 findings.

Table 69: Daily Water Use Coincident with Peak Energy Demand Period by End-user Category

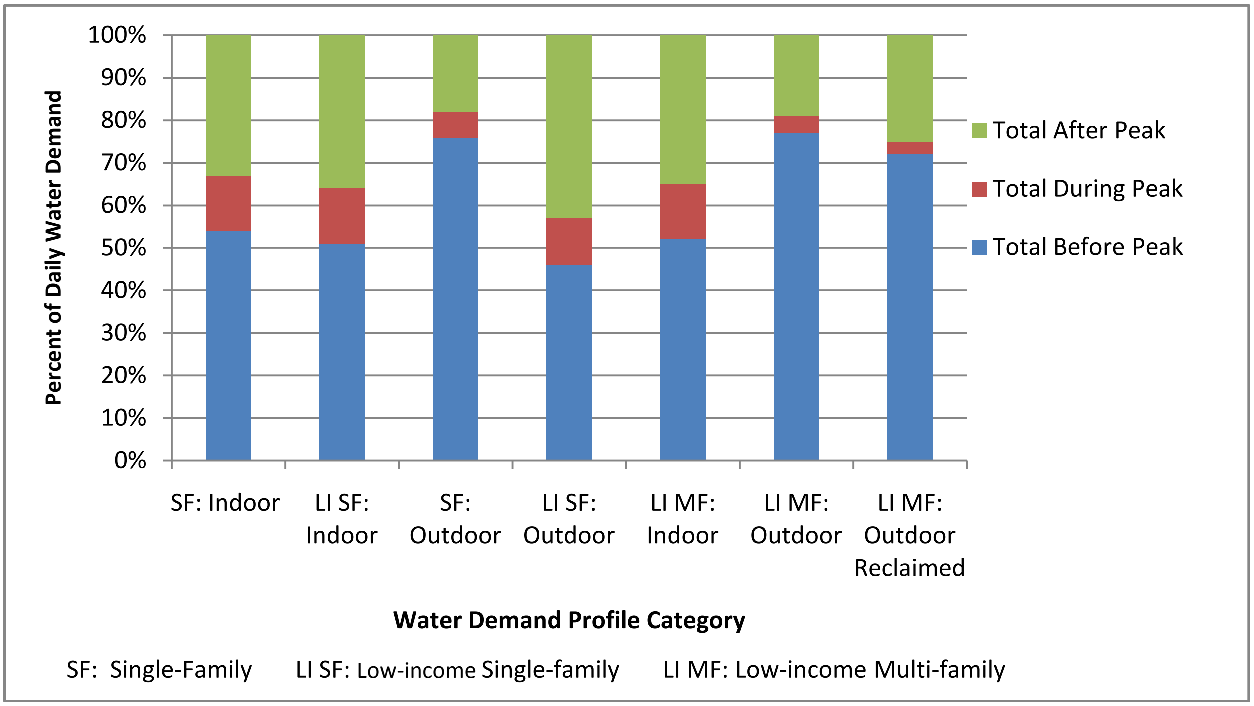
End-user Category	Percent of Total Daily Water Use Coincident with Peak Energy Demand Period
Residential	
Single-family - Indoor	13%
Single-family - Outdoor	6%
Low-income Single-family - Indoor	13%
Low-income Single-family - Outdoor	11%
Low-income Multi-family - Indoor	13%
Low-income Multi-family - Outdoor	4%
Low-income Multi-family - Reclaimed	3%
Commercial	
General Retail	18%
Hotels/Motels	14%
Offices	9%
Supermarkets	14%
Restaurants	15%
Large Retail	21%
Laundromats	21%
Car Washes	29%
Automotive Service	17%
Urban Irrigation	
Urban Irrigation	4%
Public Buildings	
Public Buildings (excluding Schools and Hospitals)	13%
Primary and Secondary Schools	12%
Hospitals	18%
Industrial	
Industrial	14%
Cooling Towers	10%
Agricultural	
Agricultural Irrigator	33%
Agricultural Processor	14%
Cooling Towers	8%

Additional findings by end-user category follow.

6.1.1 Residential

Residential water demands as a group make up the largest percentage of water use in most municipal water systems. Water demand profiles for a variety of end-uses tended to be similar across residential groups, with a few exceptions. The residential sample included 361 single-family, 54 low-income single-family and 159 low-income multi-family sites.

Figure 67: Aggregated Daily Water Demand – Residential



- The hourly water demands for indoor water use by single-family end-user categories show little variation by income group.
- Total outdoor water use in the single-family group was significantly higher than that in the low-income single-family group.
- The peak total indoor water use periods did not overlap with the peak energy demand period for any of the residential categories (single-family, low-income single-family and low-income multi-family.)
- Single-family, low-income single-family and low-income multi-family categories all had a similar percent of total daily indoor water use coincident with peak energy demand (13 percent.)
- Certain indoor water demand profile categories do exhibit relatively high water demand during the peak energy demand period for single-family and low-income single-family groups. These include showers, toilets, clothes washers, faucets and leaks.
- Baths and dishwashers show relatively little water use coincident with the peak energy demand period for either the single-family or low-income single-family category.
- For the low-income multi-family group, showers, toilets and faucets also show relatively high water demand during the peak energy demand period. Clothes washers, leaks, baths and dishwashers do not.
- Eleven percent of outdoor water used by the low-income single-family group, six percent of that used by the single-family group and four percent of that used by the low-income multi-family group was used during the peak energy demand periods. The greater incidence of manual irrigation associated with the low-income single-family group likely accounts for its higher percentage, as the hand-watering pattern causes more late afternoon water use.

- The hourly pattern for reclaimed outdoor water use at multi-family properties differs somewhat from that for non-reclaimed water. While use coincident with the peak energy demand period is similar (three percent for reclaimed as compared to four percent for non-reclaimed), reclaimed water use is six percentage points higher than non-reclaimed after peak, and five percentage points lower before peak.
- The number of residents in the low-income single-family group was significantly higher than in the single-family group.

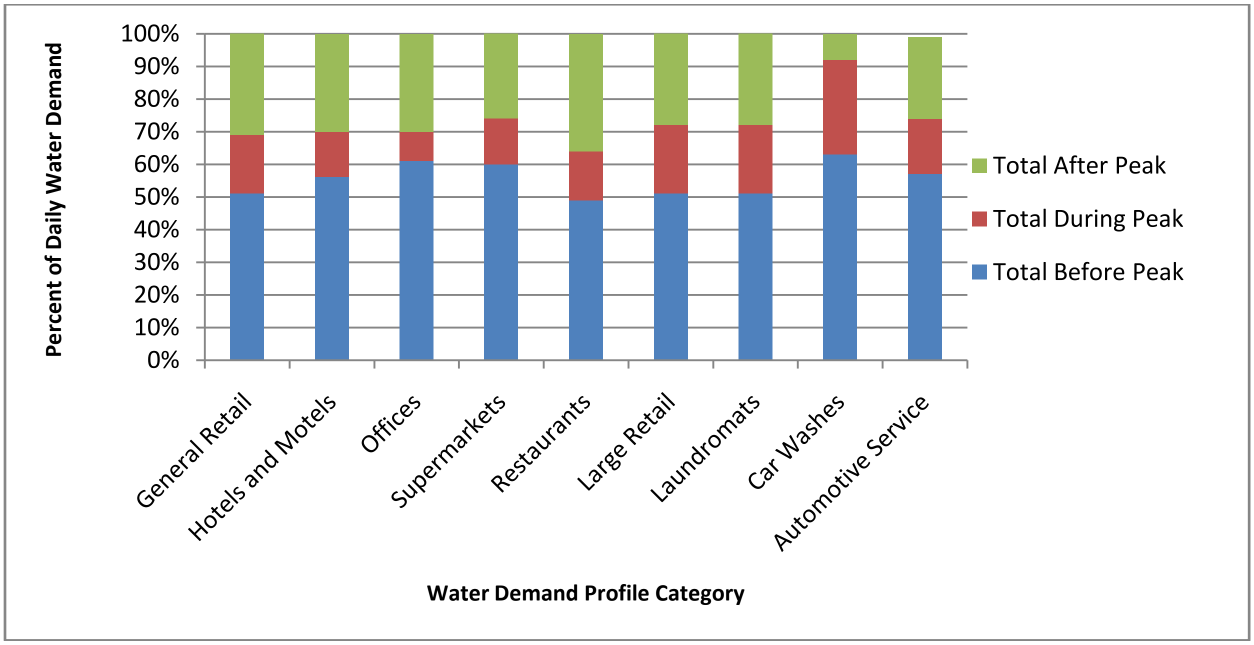
Table 70: Aggregated Hourly Water DemandPercent of Total Daily Use – Residential

Hour	Single-family: Indoor	Low-Income Single-family: Indoor	Single-family: Outdoor	Low-Income Single-family: Outdoor	Low-income Multi-family: Indoor	Low-income Multi-family: Outdoor	Low-income Multi-family: Outdoor Reclaimed
12:00 AM	1.88%	2.06%	2.12%	1.90%	2.67%	9.71%	14.02%
1:00	1.37%	1.08%	2.66%	0.30%	1.84%	9.67%	8.71%
2:00	1.24%	0.84%	1.25%	0.30%	1.34%	14.90%	14.90%
3:00	1.11%	0.86%	2.47%	0.29%	1.13%	10.30%	5.51%
4:00	1.37%	1.15%	6.11%	6.23%	1.04%	14.82%	14.30%
5:00	2.58%	1.35%	9.97%	4.72%	1.79%	7.46%	7.21%
6:00	5.01%	4.38%	13.09%	12.62%	3.76%	1.81%	0.20%
7:00	6.64%	5.54%	13.73%	1.68%	4.87%	0.99%	1.28%
8:00	6.43%	6.42%	8.25%	4.38%	5.60%	1.38%	1.24%
9:00	6.38%	6.37%	6.00%	5.27%	6.01%	1.43%	0.54%
10:00	5.76%	5.86%	2.79%	3.32%	6.01%	0.48%	0.27%
11:00	5.38%	5.65%	2.56%	2.00%	5.25%	0.99%	0.99%
12:00 PM	4.86%	5.02%	2.94%	1.45%	5.53%	0.90%	0.52%
1:00	4.34%	4.39%	2.34%	1.64%	4.92%	2.33%	2.63%
Total Before Peak	**54%**	**51%**	**76%**	**46%**	**52%**	**77%**	**72%**
2:00	4.00%	4.16%	2.38%	1.71%	4.43%	3.35%	2.84%
3:00	4.31%	4.23%	1.87%	3.10%	4.19%	0.53%	0.08%
4:00	4.62%	4.73%	1.84%	6.28%	4.31%	0.12%	0.04%
Total During Peak	**13%**	**13%**	**6%**	**11%**	**13%**	**4%**	**3%**
5:00	4.87%	5.55%	2.24%	10.55%	4.49%	0.25%	0.53%
6:00	5.36%	5.58%	3.21%	10.06%	5.68%	1.02%	2.73%
7:00	5.49%	5.34%	4.34%	13.68%	5.72%	1.02%	2.49%
8:00	5.19%	5.90%	2.56%	4.58%	5.48%	0.85%	2.28%
9:00	4.75%	5.47%	2.75%	2.34%	5.51%	3.59%	3.17%
10:00	4.07%	4.71%	1.72%	0.96%	4.59%	6.18%	4.55%
11:00	2.97%	3.35%	0.83%	0.64%	3.87%	5.90%	8.99%
Total After Peak	**33%**	**36%**	**18%**	**43%**	**35%**	**19%**	**25%**

6.1.2 Commercial

Commercial end-users include a wide variety of water users who are engaged in some sort of commercial activity. This is a highly variable category, but the common and defining characteristic is that each provides a product or a service for sale to the public, or is in support of these types of commercial activities. The commercial sample included 49 sites (seven general retail, five hotels/motels, seven offices, nine supermarkets, seven restaurants, one large retail, five laundromats, four car washes and four automotive service.)

Figure 68: Aggregated Daily Water Demand – Commercial



- Commercial sites' daytime water use tended to include domestic, process and continuous applications. Irrigation tended to occur during the late night and early morning hours.
- Commercial sub-categories varied in the percentage of daily water use occurring during the peak energy demand period from 9 to 29 percent.
  - The general retail category showed night-time peaks due to irrigation and then typical indoor use patterns that peaked in the afternoon. Nearly 18 percent of the daily use occurred during the peak electric demand period.
  - Hotels and motels did not appear to have significant irrigation measured by the same meters used for domestic uses. Night-time use was relatively low, and was probably due to cooling, cleaning and normal domestic uses associated with residential use. The largest peak of the day occurred in the morning between 7:00 and 8:00 AM. Over 14 percent of average daily use occurred during the peak electric demand period.
  - Office daytime water use peaks between 10:00 and 11:00 AM, and then declines through the day with a second, smaller, peak mid-afternoon. Just over nine percent of total daily use occurs during the peak electric demand period. High

night-time demands were a reflection of irrigation use. Note, however, that traces were collected during the summer and fall; during the winter irrigation peaks would be much lower

- Supermarkets sites exhibited a very distinct peak in water use during the early morning hours, which was for food preparation and cleaning. Nearly 14 percent of total daily water use occurred during the peak energy demand period. The remaining water use was split approximately equally between in-store use and cooling.
- Restaurant day-time water uses included miscellaneous faucet use, (food prep, pot washing, etc), dishwasher operation, bathroom uses, ice making and clothes washing (in one restaurant). Night-time uses included some irrigation, cooling and leakage. Almost 15 percent of total daily use occurs during the peak energy demand period.
- Large retail day-time uses were for miscellaneous bathroom and faucet uses, and a garden center, and night-time uses included some irrigation, cooling and leakage. The single store studied showed two afternoon peaks spanning the peak energy demand period. Approximately 21 percent of the daily use occurred during this window.
- Laundromat day-time uses were for coin-operated clothes washing. These sites showed three day-time peaks with the third one extending into the peak energy demand period. Nearly 21 percent of the daily use occurred during this window
- Car wash sites showed a mid-day peak that declines following the start of the peak energy demand period. Over 29 percent of the daily use occurred during this window.
- Automotive service sites showed a noon peak in water use with a gradual decline into the peak energy demand period. Over 17 percent of the daily use occurred during this window.

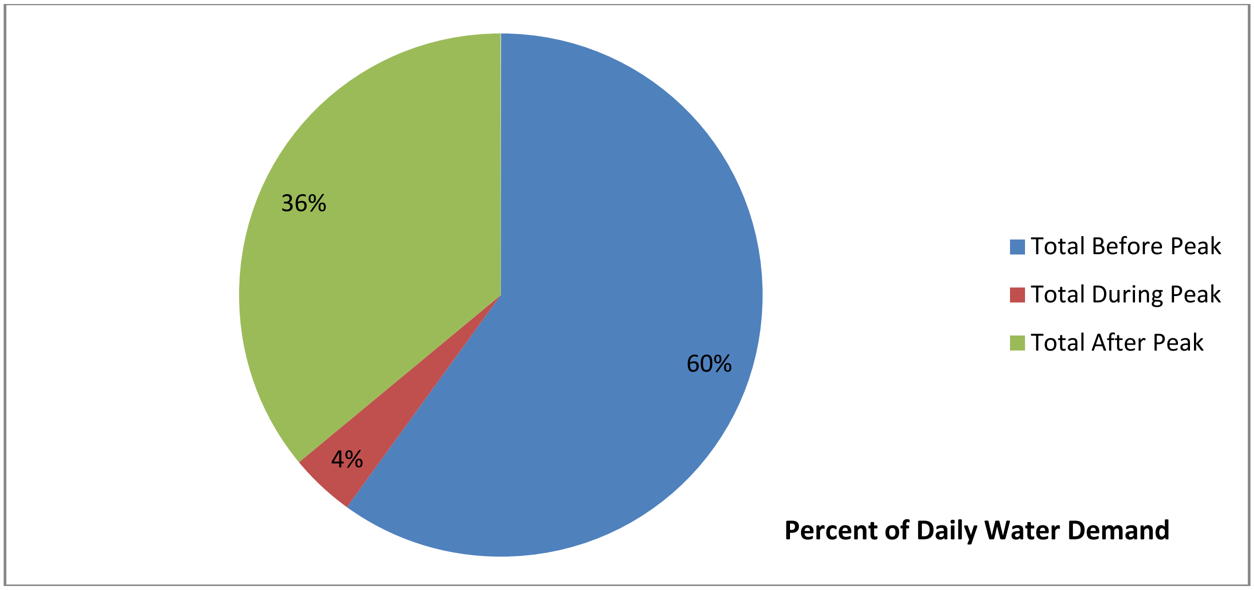
Table 71: Aggregated Hourly Water Demand Percent of Daily Use - Commercial

Hour	General Retail	Hotels and Motels	Offices	Supermarkets	Restaurants	Large Retail	Laundromats	Car Washes	Automotive Service
12:00 AM	7.98%	2.82%	5.22%	2.67%	2.16%	1.32%	0.21%	0.24%	3.02%
1:00	5.85%	2.64%	4.77%	3.06%	4.69%	2.50%	0.18%	0.24%	2.80%
2:00	3.47%	2.38%	5.80%	3.45%	1.18%	1.98%	0.19%	0.24%	2.90%
3:00	0.80%	2.23%	5.21%	5.58%	3.53%	2.81%	0.18%	0.29%	2.78%
4:00	0.76%	2.45%	4.49%	5.67%	3.21%	2.16%	0.17%	0.24%	2.86%
5:00	1.28%	3.06%	3.44%	4.83%	1.79%	1.57%	1.02%	1.41%	2.87%
6:00	1.22%	4.00%	3.05%	3.93%	1.75%	1.85%	2.18%	0.30%	3.35%
7:00	1.95%	6.05%	2.64%	3.95%	2.02%	2.10%	3.16%	2.61%	3.29%
8:00	2.53%	5.40%	3.69%	4.21%	4.06%	3.22%	5.11%	6.46%	4.59%
9:00	4.42%	4.98%	5.68%	4.18%	4.24%	4.18%	7.20%	8.72%	5.15%
10:00	5.11%	5.47%	4.51%	4.33%	4.52%	6.05%	8.05%	10.30%	5.12%
11:00	4.83%	4.93%	4.69%	4.81%	5.17%	6.81%	7.55%	10.57%	5.95%
12:00 PM	5.01%	4.71%	3.66%	4.81%	5.29%	6.90%	8.20%	11.03%	6.58%
1:00	6.11%	4.83%	3.85%	4.65%	5.84%	7.96%	7.37%	10.47%	6.03%
Total Before Peak	**51%**	**56%**	**61%**	**60%**	**49%**	**51%**	**51%**	**63%**	**57%**
2:00	6.18%	4.83%	2.83%	4.55%	6.26%	8.41%	6.69%	10.60%	6.13%
3:00	6.38%	4.87%	4.17%	4.53%	4.66%	6.56%	7.18%	10.01%	5.79%
4:00	4.99%	4.58%	2.31%	4.41%	3.88%	6.15%	6.68%	8.44%	5.44%
Total During Peak	**18%**	**14%**	**9%**	**14%**	**15%**	**21%**	**21%**	**29%**	**17%**
5:00	5.87%	4.50%	2.93%	4.26%	4.37%	6.51%	6.97%	5.16%	4.88%
6:00	4.67%	4.64%	2.22%	4.41%	5.03%	5.43%	7.15%	0.94%	4.30%
7:00	3.45%	4.44%	2.51%	4.21%	5.16%	5.14%	6.60%	0.55%	3.61%
8:00	2.98%	3.88%	4.57%	3.90%	5.77%	4.38%	4.80%	0.34%	3.71%
9:00	2.76%	4.00%	6.19%	3.69%	5.58%	3.30%	2.15%	0.30%	3.00%
10:00	1.92%	4.38%	5.74%	3.08%	5.51%	1.68%	0.64%	0.28%	3.04%
11:00	9.48%	3.93%	5.84%	2.83%	4.34%	1.03%	0.37%	0.26%	2.81%
Total After Peak	**31%**	**30%**	**30%**	**26%**	**36%**	**28%**	**29%**	**8%**	**25%**

6.1.3 Urban Irrigation

Urban irrigation is the top water user within the commercial and public building groups, and obtaining information on urban irrigation demand profiles was one of the top goals of Study 3. The urban irrigation sample included 19 sites.

Figure 69: Aggregated Daily Water Demand - Urban Irrigation



- The water demand profile for urban irrigation is a mirror image of other end-user categories. The peaks occur during the night, and day-time irrigation use is relatively minor. The afternoon peaks occur after the energy peak demand period.
- Urban irrigation end-users showed only about four percent of their daily use occurring during the peak energy demand period.
- A significant portion of water is used during off-peak energy demand periods for outdoor/irrigation, particularly during late night-time and early morning hours.
- Continuous uses (likely leaks) accounted for approximately 19 percent of urban irrigation total water use.

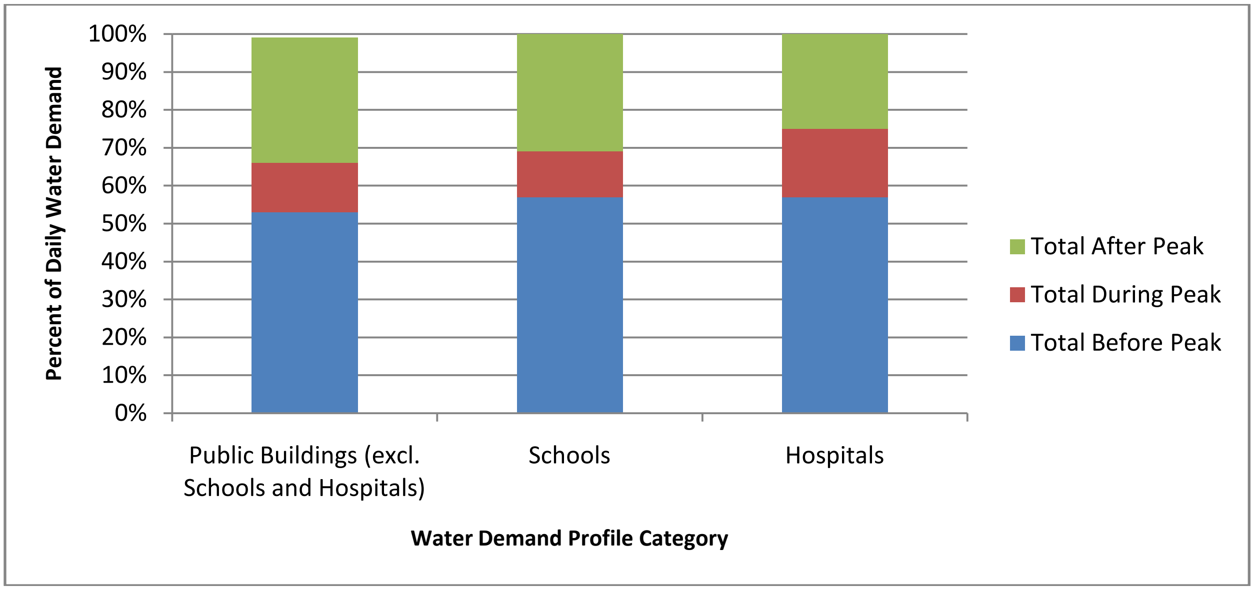
Table 72: Aggregated Hourly Water DemandPercent of Total Daily Use –Urban Irrigation

Hour	Urban Irrigation
12:00 AM	16.00%
1:00	10.26%
2:00	5.88%
3:00	8.01%
4:00	7.28%
5:00	1.90%
6:00	2.85%
7:00	1.40%
8:00	1.09%
9:00	0.86%
10:00	1.06%
11:00	1.64%
12:00 PM	1.21%
1:00	0.80%
Total Before Peak	**60%**
2:00	1.24%
3:00	1.55%
4:00	1.36%
Total During Peak	**4%**
5:00	1.41%
6:00	4.74%
7:00	3.79%
8:00	2.84%
9:00	3.90%
10:00	4.88%
11:00	14.04%
Total After Peak	**36%**

6.1.4 Public Buildings

Public buildings include retail water customer facilities operated and/or owned by federal, state and local governments.Note that the term “public building” is used in Study 3 per CPUC D.07-12-050, however, in other contexts the term “institutional” is used to describe facilities with similar characteristics, e.g., schools and government buildings.) Public building sub-categories include public buildings (with a sample of 69 sites), schools (with a sample of 11 sites) and hospitals (with a sample of 1 site).

Figure 70: Aggregated Daily Water Demand - Public Buildings



- Public Building sub-categories varied in daily indoor water use patterns. Where outdoor irrigation was measured, it tended to occur during the late night and early morning hours.
- Water demand coincident with the peak energy demand period varied across the public building groups from 12 to 18 percent.
    - Public building sites (excluding schools and hospitals) showed a late morning to mid-afternoon water use peak followed by a larger late evening water use peak at 8:00 PM. These peaks were likely due to typical workday hours at these sites.Irrigation use began in the evening, peaks at 10:00 PM and then decreased throughout the early morning until close to 5:00 AM. Over 13 percent of the daily water use occurred during the peak energy demand period.
    - Water use at schools appeared to be largely for indoor/domestic use throughout the day. Between 8:00 AM and 5:00 PM water use in schools was variable, did not have a clear trend, and averaged around four percent of total daily use per hour. Irrigation use began in the evening, peaks just around midnight and then decreases throughout the early morning until around 5:00 AM. Slightly over 12 percent of the daily water use occurred during the peak energy demand period.
    - Water use at the hospital included in Study 3 was largely for continuous uses from cooling towers and vacuum/pressure pumps (55 percent) throughout the day. Indoor use occurred primarily from the early morning to mid-evening around 7: 00 PM., with peaks at 10:00 AM and 2:00 PM. Nearly 18 percent of the daily water use occurred during the peak energy demand period.

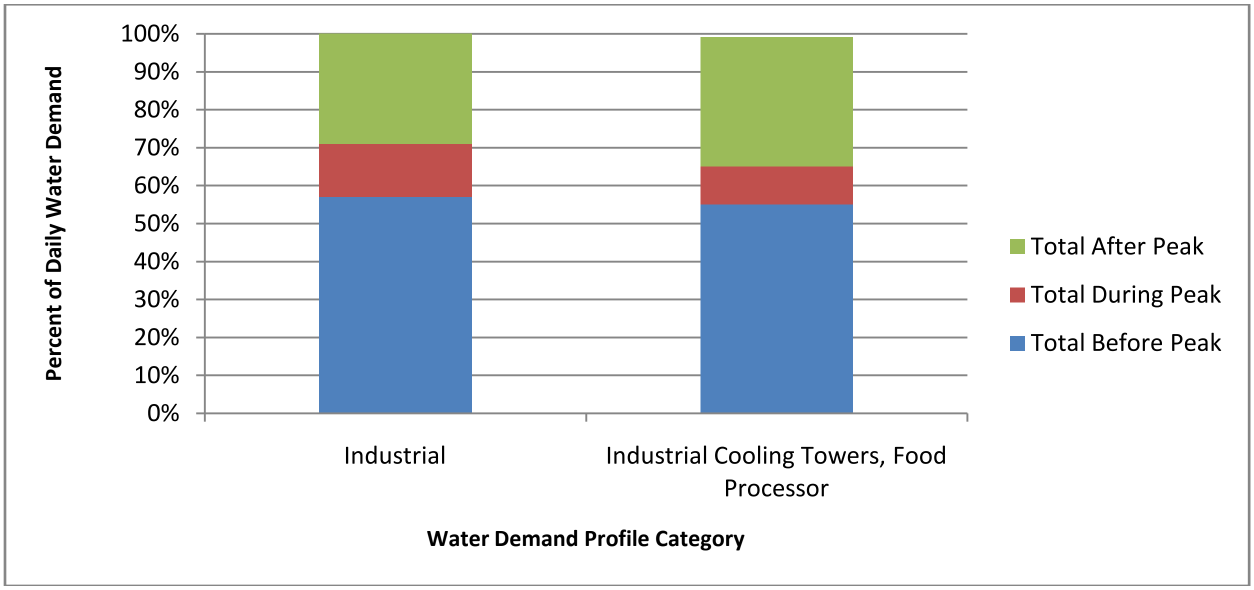
Table 73: Aggregated Hourly Water DemandPercent of Total Daily Use - Public Buildings

Hour	Public Buildings (excl. Schools and Hospitals)	Schools	Hospitals
12:00 AM	3.86%	5.07%	2.64%
1:00	3.48%	5.00%	2.56%
2:00	3.13%	4.30%	2.47%
3:00	3.54%	4.62%	2.38%
4:00	3.52%	4.31%	2.70%
5:00	2.42%	3.55%	2.98%
6:00	2.92%	3.65%	3.14%
7:00	3.30%	4.57%	3.93%
8:00	4.12%	3.95%	4.68%
9:00	4.26%	2.76%	6.10%
10:00	4.90%	4.08%	6.43%
11:00	4.31%	4.30%	5.24%
12:00 PM	4.70%	2.78%	5.19%
1:00	5.04%	4.25%	6.29%
Total Before Peak	**53%**	**57%**	**57%**
2:00	4.99%	4.04%	6.58%
3:00	4.42%	4.36%	5.81%
4:00	3.79%	3.69%	5.18%
Total During Peak	**13%**	**12%**	**18%**
5:00	4.01%	3.98%	4.22%
6:00	4.64%	3.89%	4.68%
7:00	5.04%	4.37%	4.91%
8:00	5.76%	4.37%	3.12%
9:00	5.51%	4.96%	2.92%
10:00	4.43%	4.51%	3.07%
11:00	3.91%	4.66%	2.77%
Total After Peak	**33%**	**31%**	**26%**

6.1.5 Industrial

Industrial sites include retail water customer non-residential facilities used to manufacture or process non-agricultural goods. Study 3 site data included those from a cross section of industries that represent some of the largest water users in California, including industrial food and beverage processors, industrial coatings plants, industrial laundries, pharmaceutical companies, computer manufacturing, plastic molding, computer storage systems, and a large winery. The industrial sample included 17 sites.

Figure 71: Aggregated Daily Water Demand - Industrial



- Industrial sites' daytime water use tended to include process and continuous applications. Irrigation tended to occur during the midnight hour.
- Industrial sites showed a decline in water use between 1:00 AM and 3:00 AM, and a fairly steady demand throughout the rest of the day.
- Industrial end-users exhibited high continuous water use throughout the day.
- Industrial end-users used nearly 14 percent of their total daily water during the peak energy demand period.
    - Sub-metering at industrial food processor cooling towers showed a fairly continuous demand for cooling water, but with two peak times during the periods of 5:00 AM to 7:00 AM, and 7:00 PM to 12:00 PM. Nearly 11 percent of cooling tower water demand occurred during peak energy demand periods.
    - Concentration ratio measurements at cooling towers revealed a significant potential for water savings under improved system management regimes.[111]

[111] It would be worth exploring the cost of use of pH control, which would allow the systems to operate at up to 10 cycles of concentration and reduce their water use.

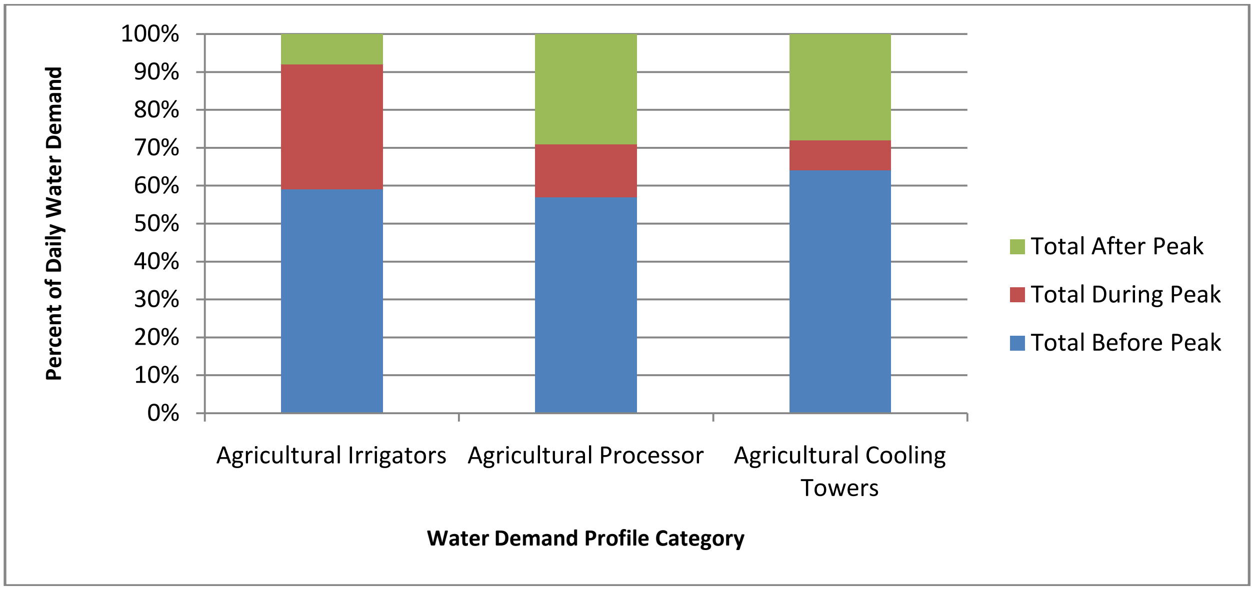
Table 74: Aggregated Hourly Water DemandPercent of Total Daily Use - Industrial

Hour	Industrial	Industrial Cooling Towers, Food Processor
12:00 AM	4.50%	4.97%
1:00	2.41%	4.05%
2:00	2.44%	3.91%
3:00	2.49%	3.75%
4:00	3.96%	3.73%
5:00	4.49%	5.03%
6:00	4.83%	5.49%
7:00	4.63%	4.53%
8:00	4.75%	3.12%
9:00	3.95%	2.99%
10:00	4.53%	2.46%
11:00	4.90%	3.36%
12:00 PM	4.83%	4.10%
1:00	4.71%	3.82%
Total Before Peak	**57%**	**55%**
2:00	4.49%	3.54%
3:00	4.65%	3.53%
4:00	4.37%	3.36%
Total During Peak	**14%**	**10%**
5:00	4.20%	4.26%
6:00	4.38%	4.72%
7:00	4.12%	5.53%
8:00	3.85%	4.87%
9:00	4.08%	5.13%
10:00	4.25%	4.89%
11:00	4.20%	4.87%
Total After Peak	**29%**	**34%**

6.1.6 Agricultural

Very little (if any) information existed on the potable and recycled water demands of either agricultural irrigation or food processing. The data collected and analyzed for this category are believed to be the first time that hourly water use profiles have been measured. Study 3 investigated irrigators using potable water supplied by a water agency rather than “typical” agricultural irrigators that use non-potable water. The agricultural sample included three agricultural irrigators and seven agricultural processors.

Figure 72: Aggregated Daily Water DemandPercent of Total Daily Use - Agricultural



- Agricultural sites' varied rather dramatically depending on the type of facility being considered. Daytime water use tended to be dominated by irrigation for agricultural irrigators and split between process and continuous uses for agricultural processors. Nighttime use was similar to daytime use for agricultural processors and almost non-existent for agricultural irrigators.
- Agricultural sub-categories varied in the percentage of daily water use occurring during the peak energy demand period from 8 to 33 percent.
  - Agricultural irrigators exhibited an increase in use in the spring and early summer, with a larger increase in the fall.
  - Agricultural irrigatorsshowed a sharp increase in water use around 7:00 AM and a decline around 4:00 PM., and use a significant portion (over 33 percent) of their water during the peak energy demand period.
  - Agricultural processors tended to use more water throughout the summer months to process harvested produce and dairy products. The first step of agricultural processing, fruit washing, appeared to use the most water. Approximately half of the water used for this washing was recaptured and reused in the processing.
  - Agricultural processors exhibited a steady demand throughout the day with a slight peak around 3:00 PM, and use only about 14 percent of their total water during the peak energy demand period.
  - Cooling of cooked canned fruit and other cold storage at agricultural processing facilities requires cooling towers, which are major water users, as well. Sub-metering the inflow lines to the towers showed the largest portion of the hourly demand for cooling occurred between 10:00 PM and 3:00 AM. This is likely because the primary use of cooled water is for cooling canned produce that has been cooked in large cookers. The cooling towers provide cooled water for a flume/bath the cans run through. It is likely the flume/bath for cooling cans was drained and refilled during night-time hours. Refilling the flume/bath would result in draining of water from the system and the refilling of cooling tower reservoirs.

Sub-metering of agricultural cooling towers showed a small portion (eight percent) of water use during peak energy demand periods.
- Concentration ratio measurements at cooling towers revealed a significant potential for water savings under improved system management regimes.[112]

Table 75: Aggregated Hourly Water DemandPercent of Total Daily Use - Agricultural

Hour	Agricultural Irrigators	Agricultural Processor	Agricultural Cooling Towers
12:00 AM	0.09%	4.00%	10.13%
1:00	0.08%	3.98%	9.80%
2:00	0.08%	3.92%	10.15%
3:00	0.09%	3.75%	10.03%
4:00	0.10%	3.87%	2.23%
5:00	0.08%	4.00%	1.08%
6:00	0.24%	4.17%	1.04%
7:00	2.39%	4.10%	1.53%
8:00	5.99%	4.06%	1.41%
9:00	8.91%	3.93%	1.15%
10:00	9.72%	4.11%	6.36%
11:00	10.40%	4.19%	4.79%
12:00 PM	9.30%	4.33%	2.01%
1:00	11.14%	4.34%	1.98%
Total Before Peak	**59%**	**57%**	**64%**
2:00	12.34%	4.51%	2.58%
3:00	12.85%	4.56%	2.70%
4:00	8.06%	4.41%	2.59%
Total During Peak	**33%**	**14%**	**8%**
5:00	3.93%	4.34%	1.85%
6:00	2.94%	4.41%	2.06%
7:00	0.42%	4.10%	1.57%
8:00	0.40%	4.19%	1.42%
9:00	0.20%	4.26%	1.94%
10:00	0.14%	4.25%	9.57%
11:00	0.09%	4.23%	10.04%
Total After Peak	**8%**	**30%**	**29%**

[112] It would be worth exploring the cost of use of pH control, which would allow the systems to operate at up to 10 cycles of concentration and reduce their water use.

6.2 Conclusion

The *End-use Water Demand Profile Study* (Study 3) supports the analysis of embedded energy in water by providing more accurate hourly water use profile data than were previously available. This will facilitate estimating the embedded electricity and natural gas savings and resultant avoided costs derived from the installation of water savings measures in residential and non-residential retail water customer categories. California end-user water demand profiles provided by Study 3 contribute to a better understanding of the opportunities for linking water-efficiency and energy-efficiency programs. Findings can be used to help target water conservation efforts that also lead to energy savings.

Hourly demand patterns determined in Study 3 can be used to model overall water agency demands in a way that show how changes in use by one category affect the hourly demand patterns for the system as a whole, and in wastewater load generation. The results from the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*[113]study can then be used to determine how changes in the hourly water and wastewater load profiled affect the energy requirements at the water agency level. In that way, Study 3 results complement those of the *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles* study to show the energy relationships in water treatment systems. This earlier study confirmed just how variable water agency configurations can be, depending on factors such as the size of their distribution system, topology of their service areas, and technologies used to treat water.

While this study, by itself, does not lead to any conclusions about whether changes in hourly water demand patterns may affect utility energy requirements, its results can be used as inputs to the models of water system operations developed to investigate relationships between retail water demand patterns and utility energy demands. With the right combination of water agency treatment and delivery capacity, treated water storage and hourly end-user water demand patterns, it should be possible to significantly reduce water agency energy demands during the peak energy demand periods. Note that even with this understanding of water agency operations, additional information will be necessary to link the timing of the effect of water conservation at a customer site with energy use at the water agency site.

[113] G.E.I. Consulting and Navigant Consulting, Inc., *Water Agency and Function Component Study and Embedded Energy-Water Load Profiles*.

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Appendix A: Sites in Existing Database

Table A-1 lists all of the sites for which flow traces were available in the existing database for commercial, public building, irrigation and industrial accounts.

Table A-1: List of Sites in Existing Database Used for Analysis

Category	Begins	Ends	TotalVolume	AvgOfPeakVolume	AvgOfDailyVolume	PeakVoumePct
commercial	8/14/1997	8/18/1997	1186	6	20	32%
commercial	6/28/1997	2/24/1998	3992	62	397	16%
commercial	12/6/2005	12/8/2005	7245	578	2415	24%
commercial	7/25/1997	8/7/1997	12209	221	1034	21%
commercial	12/7/2005	12/9/2005	14405	1059	4802	22%
commercial	6/16/1999	6/22/1999	89004	2253	13783	16%
commercial	7/2/1997	7/15/1997	243100	4593	21694	21%
hotel	3/17/1999	3/30/1999	3306	23	230	10%
hotel	12/16/1998	12/21/1998	4000	63	839	8%
hotel	12/6/2005	12/8/2005	101818	4898	33939	14%
hotel	7/15/1998	7/20/1998	111368	2531	18788	13%
hotel	7/14/1998	7/22/1998	169809	3771	25235	15%
industrial	1/27/2000	2/1/2000	5710	402	1394	29%
industrial	8/1/1997	9/10/1997	12714	71	1504	5%
industrial	7/2/1997	7/15/1997	272796	708	25048	3%
industrial	9/19/2000	10/2/2000	728541	8685	56723	15%
industrial	9/19/2000	9/25/2000	809432	17897	124524	14%
public building*	9/27/2007	10/1/2007	260	22	66	32%
public building	9/13/2007	9/18/2007	458	20	80	25%
public building	9/18/2007	9/20/2007	504	49	168	29%
public building	9/20/2007	9/27/2007	649	0	81	0%
public building	10/3/2007	10/10/2007	885	46	133	35%
public building	10/3/2007	10/10/2007	1316	58	200	29%
public building	9/21/2007	9/25/2007	1437	124	412	30%
public building	6/14/2007	6/19/2007	1444	65	325	20%
public building	7/13/2007	7/15/2007	1946	168	1496	11%
public building	6/29/2007	7/8/2007	2423	99	282	35%
public building	9/13/2007	9/16/2007	4248	13	1082	1%
public building	9/20/2007	10/1/2007	4308	151	437	35%
public building	9/20/2007	9/25/2007	4868	115	1163	10%
public building	6/15/2007	6/27/2007	8872	128	787	16%
public building	6/15/2007	6/27/2007	8985	225	808	28%
public building	6/20/2000	7/3/2000	9281	97	535	18%
public building	9/27/2007	10/1/2007	9286	104	231	45%
public building	6/14/2007	6/19/2007	10698	277	1950	14%
public building	6/14/2007	6/19/2007	13749	572	2776	21%
public building	9/13/2007	9/25/2007	16286	19	1794	1%
public building	4/15/1999	4/26/1999	16779	629	1954	32%
public building	6/14/2007	6/27/2007	17916	61	1392	4%
public building	9/25/2007	10/1/2007	20683	21	4119	1%
public building	9/21/2007	10/1/2007	21726	48	3050	2%
public building	9/20/2007	9/25/2007	22183	146	5420	3%

Category	Begins	Ends	TotalVolume	AvgOfPeakVolume	AvgOfDailyVolume	PeakVoumePct
public building	6/13/2007	6/19/2007	24941	1386	4577	30%
public building	3/20/2007	6/19/2007	25567	113	1815	6%
public building	9/20/2007	10/1/2007	27862	83	393	21%
public building	6/15/2007	6/19/2007	28317	350	6081	6%
public building	9/21/2007	10/1/2007	32064	234	2931	8%
public building	6/20/2000	7/3/2000	34783	248	2960	8%
public building	6/15/2007	6/27/2007	38527	1248	3418	37%
public building	9/20/2007	10/1/2007	38845	1332	4700	28%
public building	9/21/2007	10/1/2007	41447	209	5633	4%
public building	6/14/2007	6/19/2007	42221	60	10369	1%
public building	6/14/2007	6/19/2007	45691	726	7909	9%
public building	6/13/2007	6/19/2007	47186	1018	7095	14%
public building	9/13/2007	9/19/2007	48512	258	8036	3%
public building	6/21/2007	7/2/2007	49474	3268	4665	70%
public building	6/16/2007	6/27/2007	55244	1008	5091	20%
public building	6/13/2007	6/19/2007	62417	67	7685	1%
public building	6/13/2007	6/19/2007	73061	2237	9540	23%
public building	6/14/2007	6/19/2007	75543	132	14219	1%
public building	9/21/2007	10/10/2007	80449	114	6057	2%
public building	9/20/2007	10/10/2007	135804	293	10973	3%
public building	6/13/2007	6/26/2007	152301	1364	11397	12%
public building	9/22/2007	10/10/2007	171952	1540	9739	16%
public building	6/15/2007	6/27/2007	192087	1942	19843	10%
public building	7/13/2007	7/17/2007	227982	1900	48206	4%
public building	7/4/2001	7/17/2001	252949	2877	16198	18%
public building	6/29/2007	7/31/2007	257193	335	13008	3%
public building	7/19/2007	8/1/2007	625890	7811	43546	18%
public building	12/4/1998	12/25/1998	1509028	10983	73260	15%
public building	6/15/2007	6/27/2007	4411900	9789	246014	4%
irrigation	6/16/2001	6/21/2001	14186	219	2376	9%
irrigation	7/6/2001	7/16/2001	20011	566	4533	12%
irrigation	3/20/2007	6/19/2007	25567	113	1815	6%
irrigation	10/5/2000	10/11/2000	46679	60	445	13%
irrigation	6/16/2001	6/21/2001	51506	449	8732	5%
irrigation	8/3/2000	8/31/2000	103335	805	4771	17%
irrigation	7/3/1998	7/15/1998	567252	2362	59634	4%
office	8/22/1997	9/28/1997	10737	257	1077	24%
office	7/25/1997	8/6/1997	28792	320	2260	14%
office	7/15/1998	7/21/1998	58268	1694	9654	18%
office	7/18/1998	7/21/1998	78358	5544	26988	21%
office	7/14/1998	7/22/1998	112115	1251	12153	10%
office	7/3/1998	7/15/1998	1435996	4427	114681	4%
office	7/2/1998	7/15/1998	2338403	20429	189941	11%
restaurant	12/6/2005	12/8/2005	105	3	35	9%
restaurant	12/7/2005	12/9/2005	224	13	75	18%
restaurant	7/26/1997	9/28/1997	5233	95	540	18%
restaurant	7/15/1998	7/21/1998	10676	310	1489	21%
restaurant	7/14/1998	7/22/1998	20789	492	3172	16%
restaurant	7/15/1998	7/19/1998	50047	1630	9826	17%

Category	Begins	Ends	TotalVolume	AvgOfPeakVolume	AvgOfDailyVolume	PeakVoumePct
restaurant	7/24/1997	8/6/1997	115656	1036	9034	11%
school	6/26/1998	7/1/1998	9687	98	1623	6%
school	3/12/1999	3/25/1999	10553	219	743	29%
school	7/11/2008	7/13/2008	23334	659	15014	4%
school	7/25/1997	8/6/1997	34875	604	3663	16%
school	7/25/1997	8/6/1997	147442	3907	14399	27%
school	3/11/1999	3/24/1999	302804	3727	25411	15%
school	7/15/1998	7/20/1998	317714	1199	55518	2%
school	7/3/1998	7/15/1998	551487	265	44633	1%
school	7/4/2001	7/17/2001	1012894	8829	76403	12%
school	7/3/1998	7/15/1998	1265241	7855	108824	7%
school	7/4/2001	7/17/2001	6260628	62044	376382	16%
supermarket	4/30/2002	7/13/2002	30651	62	421	15%
supermarket	6/3/2002	7/11/2002	44085	184	1170	16%
supermarket	7/15/1998	7/20/1998	75434	1625	12868	13%
supermarket	7/15/1998	7/21/1998	100224	2193	14531	15%
supermarket	7/14/1998	7/22/1998	110485	2153	13263	16%
supermarket	5/3/2002	7/12/2002	392859	803	5670	14%
supermarket	4/28/2002	7/12/2002	753879	1603	10379	15%
supermarket	4/29/2002	7/13/2002	1252685	2590	18568	14%
supermarket	4/28/2002	7/11/2002	3205219	5180	44615	12%

*This category was called “institutional” in the original database but for consistency in Study 3 it was re-named “public building.”

Appendix B: California Single Family Water Use Efficiency Study Information

The *California Single Family Water Use Efficiency Study* (*CSFWUES*) group was chosen from single-family home customers in 15 water agency service areas.[114] Table B-1 shows the location of the study homes by county, the percent of the state population in each county, and the percent of the study group sample. During solicitation of water agencies for the *CSFWUES*, an attempt was made to obtain participation in counties in rough proportion to the percent of the state populations they contained. This table shows that there was a fairly good match between the percentage of the single-family residents by county and the study group sample.

In addition to measuring water uses, the *CSFWUES* also included a detailed survey of key household characteristics.Earlier studies have shown that (irrespective of income) several demographic factors are strongly correlated with the amount of water used by single-family customers, the most notable factors being the number of residents, the size of the home and the presence of high efficiency fixtures and appliances in the home. Other factors including lot size, evapotranspiration, landscape type, presence of a sprinkler system, and income are important in explaining outdoor water use.

[114] Aquacraft, Inc., *California Single Family Water Use Efficiency Study*.

Table B-1: Distribution of Sample Homes for *CSFWUES*

County	Percent Of State Population	Sample for Study	Percent of Sample
Los Angeles	28%	120	15%
Orange	8%	120	15%
San Diego	8%	120	15%
San Bernardino	5%	0	0%
Santa Clara	5%	0	0%
Riverside	5%	0	0%
Alameda	4%	60	8%
Sacramento	4%	60	8%
Contra Costa	3%	60	8%
Fresno	2%	0	0%
San Francisco	2%	60	8%
Ventura	2%	60	8%
San Mateo	2%	60	8%
Kern	2%	0	0%
San Joaquin	2%	0	0%
Sonoma/N Marin	1%	60	8%
Stanislaus	1%	0	0%
Monterey	1%	0	0%
Santa Barbara	1%	0	0%
Solano	1%	0	0%
Total	**89.2%**	**780**	**100%**

Appendix C: Flow Trace Analysis and Trace Wizard

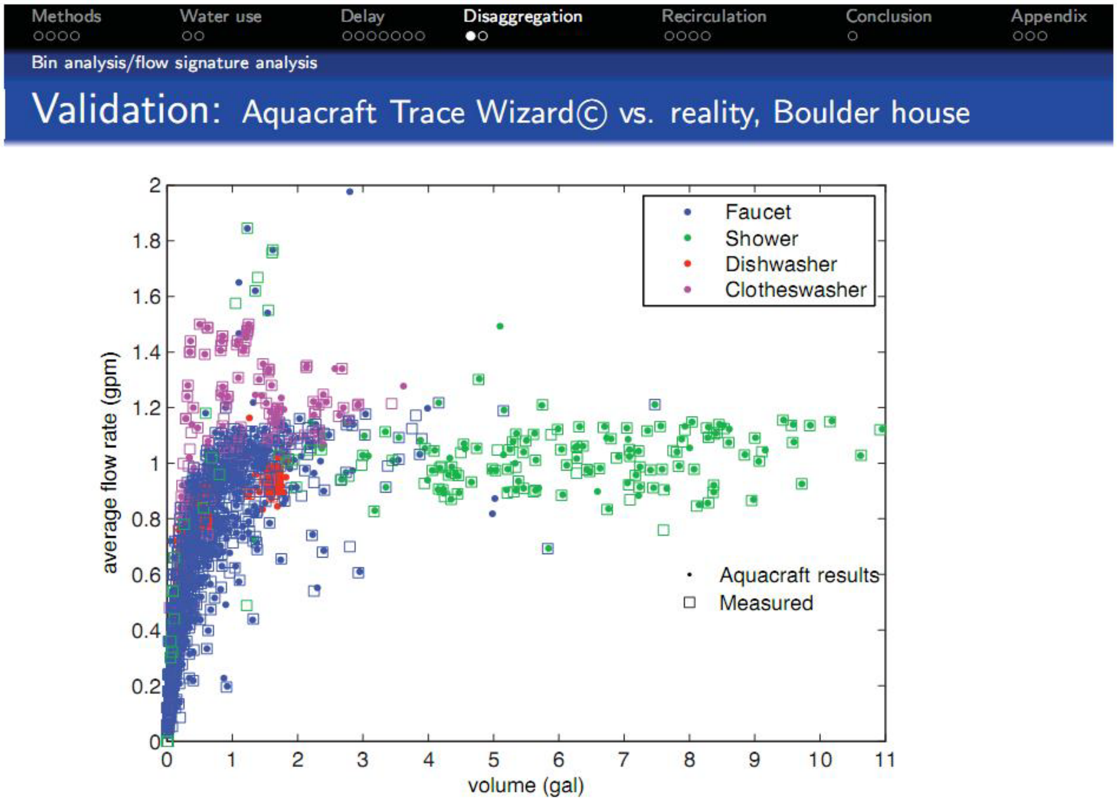
The flow trace analysis technique and the Trace Wizard software have been used as the fundamental analytic tool in a number of residential, commercial, industrial and institutional water use studies both in the U.S. and worldwide including:

- Heatherwood Residential End-use and Retrofit Studies – 1995-96, Aquacraft
- Westminster Water Use Study – 1998, Aquacraft*
- Perth Residential End Uses of Water Study – 1999, Australia
- Residential End Uses of Water – 1999, AWWA*
- Commercial and Institutional End Uses of Water – 2000, AWWA*
- Pinellas County Utilities Water Conservation Opportunities Study – 2002, Aquacraft
- Seattle Market Penetration Study – 2003, Aquacraft
- Yarra Valley Water District Residential End-use Study – 2003, Australia
- EPA Residential Retrofit Studies (Seattle, EBMUD, Tampa) – 2004, Aquacraft
- Water Efficiency Opportunities in California Supermarkets – 2004, Aquacraft*
- Monterey Pre-Rinse Spray Valve Study – 2005, Quantec
- Regional Water Authority of Sacramento CII Studies – 2005, Aquacraft*
- Santa Paula Residential End-use Study – 2006, RBF Consulting
- New Zealand Residential Demand Study – 2007, Branz
- Lathrop and American Canyon, CA End-use Studies – 2008, RBF Consulting
- California Residential End-use Baseline Study – 2009, Aquacraft*
- Gold Coast Water Residential End-use Study – 2009, Australia

* These studies are mentioned in the main body of Study 3 report text with full reference information in the References list.

Validation studies have confirmed the repeatability and reliability of the flow trace analysis methodology. The National Renewable Energy Lab (NREL) compared water demand profile category disaggregation using flow trace analysis to measurements based on in-line meters installed on individual water supply lines inside specifically equipped test homes in Boulder, Colorado. Figure C-1illustrates findings from this validation study (Magnusson 2009, 16).

Figure C-1: Comparison of Flow Trace Analysis Results to Sub-meter Measurements[115]



The results shown in Figure C-1 are based on flow trace analysis of a single meter on a line supplying hot water to all of the fixtures in the home. Individual faucet, shower, dishwasher and clothes washer events were sorted by flow rate and volume for both the Trace Wizard and sub-metered sets of measurements. Wherever the two points coincide there is agreement. These appear as boxes with dots in them. As can be seen in Figure C-1, there is excellent agreement between the flow trace and sub-meter measurements. When the measured water usage of faucet, shower, dishwasher, and clothes washer events were combined in the NREL study, Trace Wizard analysis and the in-line water meter data were 88 percent in agreement.

[115] Lee Magnusson, "Methods and Results for Measuring Hot Water Use at the Fixture," *2009 ACEEE Hot Water Forum* (Asilomar, CA: American Council for an Energy-Efficiency Economy, 2009), 16.

Appendix D: Description of Low-income Criteria

In order to apply these criteria to the study group it was necessary to have information on both the number of residents per home and that household's income level. Candidate survey respondents, therefore, needed to include both the number of occupants and income level. A total of 415 surveys indicated valid answers for both of these parameters, and were matched with a verified Trace Wizard log taken contemporaneously with the survey.

The survey question on income, shown in Figure D-1,[116] was a multiple-choice survey, so it's important to note that the survey answers in fact represent ranges. For example, ($30,000 to $39,999) represents a single answer centered around the midpoint $35,000, but equally likely to fall above or below the midpoint. In order to maximize the number of low-income households in the analysis all homes that fell into the bracket that contained the low-income point for the home were counted as low-income. Table D-1 shows how the homes were classified based on their survey responses.

Figure D-1: Income Survey Question[117]

57. About how much do you estimate your household's total income before taxes was last year? Please check the appropriate box below.

❑ Less than $30,000	❑ $120,000 to $139,999
❑ $30,000 to $39,999	❑ $140,000 to $159,999
❑ $40,000 to $49,999	❑ $160,000 to $179,999
❑ $50,000 to $59,999	❑ $180,000 to $199,999
❑ $60,000 to $69,999	❑ $200,000 to $224,999
❑ $70,000 to $79,999	❑ $225,000 to $249,999
❑ $80,000 to $89,999	❑ $250,000 to $274,999
❑ $90,000 to $99,999	❑ $275,000 to $299,999
❑ $100,000 to $119,999	❑ $300,000 or more

116 Aquacraft, *2011*.
117 Aquacraft, 2011.

Table D-1: Income Ranges Straddling the Low-income Threshold

Persons per Home	2008 Federal Poverty Level	Corresponding Low-Income Threshold	⇨	Survey answer for consideration as low-income:
1	$10,400	$20,800	Income is answered in $10,000 increments	Less than 30,000
2	$14,000	$28,000		Less than 30,000
3	$17,600	$35,200		30,000 - 39,999 or below
4	$21,200	$42,400		40,000 - 49,999 or below
5	$24,800	$49,600		40,000 - 49,999 or below
6	$28,400	$56,800		50,000 - 59,999 or below
7	$32,000	$64,000		60,000 - 69,999 or below
8	$35,600	$71,200		70,000 - 79,999 or below
9	$39,200	$78,400		70,000 - 79,999 or below
10	$42,800	$85,600		80,000 - 89,999 or below
11	$46,400	$92,800		90,000 - 99,999 or below
12	$50,000	$100,000	Income is answered in $20,000 increments	100,000 - 119,999 or below
13	$53,600	$107,200		
14	$57,200	$114,400		
15	$60,800	$121,600		120,000 - 139,999 or below
16	$64,400	$128,800		
17	$68,000	$136,000		
18	$71,600	$143,200		140,000 - 159,999 or below
19	$75,200	$150,400		
20	$78,800	$157,600		

Appendix E: Meter Installation Examples

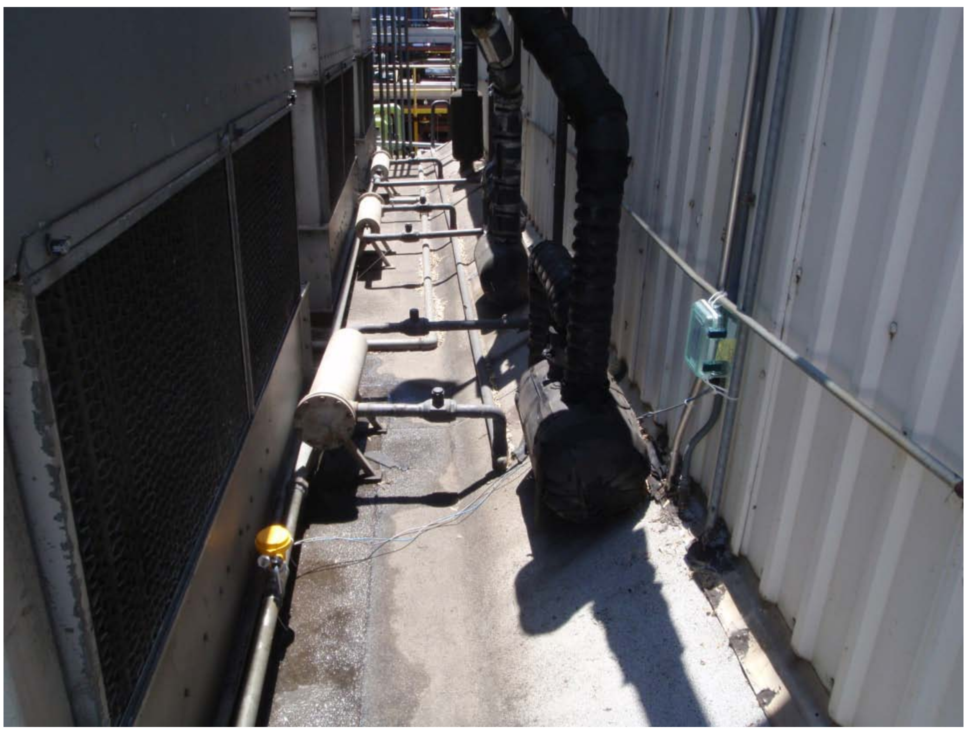
Figures E-1 and E-2 show typical installations onto residential and non-residential water meters, respectively.

Figure E-1: Meter Master 100 Flow Recorder Attached to Residential Water Meter

Figure E-2: Meter Master 100 Flow Recorder Attached to Commercial Water Meter

Figure shows these devices installed at the inflow line to a series of cooling towers.

Figure E-3: Installation of Paddlewheel Flow Sensor and Logger at Cooling Tower Inflow



Appendix F: Characterization of Industrial Entities in the State of California

In an effort to understand the nature of the industrial water users in California a large database of industrial entities was obtained from a commercial source that specializes in obtaining up-to-date listings on industrial and commercial companies across the United States (the Manufacturers' News Inc.(MNI) Database).[118] The MNIDatabase for the State of California contains 14,024 entries. Each entry contains various pieces of information about the company including its name, address, Standard Industrial Classification codes (SIC codes), number of employees, annual sales, and other contact information. If one assumes that this database is generally representative of the manufacturers in the State it can be used to characterize the types of industrial entities located in California and their relative percentages within each industrial category. This provides a good starting point for putting industrial water users in proper context within the state, and is the best source the researchers have been able to find on this topic, but unfortunately the database does not include information on water use.

The California Secretary of State (SOS) office maintains a complete record of every corporation, limited liability company, and limited partnership company in California.[119]If the wholesale, retail, and miscellaneous service companies are excluded, there are a total of 12,914 industrial companies in the SOS database. Unfortunately, these data also do not include information about water use by the companies, nor are they available in a tabulated format that lends itself to systematic analysis.

Table F-1 shows the SIC codes in the order in which the companies are ranked in the MNI Industrial Database. Ranking is based on the number of companies within a given group of codes. The codes are grouped by 100's with the top code of each group listed in the table. For example, the SIC code 3599 includes all codes from 3500 to 3599, and includes manufacturers of engines, turbines, computers, and office equipment. A total of 1,620 companies fell into this listing, which comprises 12.54 percent of all of the listings in the database. The SIC codes from 2000 to 4000 contain the major industrial categories. Codes outside of this range tend to be more service oriented, or are commercial wholesalers or retailers. Figure F-1 shows a histogram of the major industrial categories where each bin of 100 represents the percentage of industries with codes falling within that particular SIC category. Table F-2 shows the SIC categories in groups of 100 ordered from 2000 to 4000.

[118] Manufacturers' News Inc. Database, http://www.manufacturersnews.com/database.asp (accessed 2009).
[119] California Secretary of State Database of Corporations, http://kepler.sos.ca.gov/(accessed 2009). Database of all domestic stock, domestic nonprofit and qualified foreign corporations, limited liability company and limited partnership information of record with the California Secretary of State

Table F-1: California Industrial Categories Ranked by Number of Businesses Listed in MNI Database[120]

NAICS Code	SIC Code	Count	SIC Category Description	RelFreq
332, 333, 334, 336	3500-99	1,620	Engines, turbines, computers, office equipment	12.54%
332, 336, 337	3400-99	1,398	Misc. metal fabrication, sheet metal, bolts and nuts	10.83%
333, 335	3600-99	1,379	Electronic and electrical equipment (no computers)	10.68%
111, 311	2000-99	1,310	Food processing, slaughtering, baking, beverages, brewing	10.14%
323, 511, 516	2700-99	993	Printing and publishing	7.69%
326	3900-99	773	Tires, rubber products, gaskets, plastic products	5.99%
334	3800-99	755	Search, detection, navigation, medical devices, x-rays	5.85%
336	3700-99	686	Motor vehicle bodies, motor homes, motorcycles, ships, aircraft, missals	5.31%
314, 315, 336	2300-99	609	Clothing and textiles	4.72%
325	2800-99	580	Chemicals and allied products	4.49%
327	3200-99	501	Glass, concrete products, cut stone	3.88%
321	2400-99	489	Lumber and manufactured buildings	3.79%
337	2500-99	430	Furniture	3.33%
339	3900-99	408	Jewelry, games, artist materials	3.16%
331	3300-99	372	Steel works, foundries, tubing, rolling and extruding	2.88%
322	2600-99	307	Paper mills, containers	2.38%
313	2900-99	131	Textiles, mills, weaving	1.01%
324	2900-99	77	Petroleum refining	0.60%
316	3100-99	53	Leather and footwear	0.41%
211	1399	26	Oil and gas exploration	0.20%
212	1400-99	15	Non metal quarrying	0.12%
212	1000-99	1	Mining and ores	0.01%
212	1220-99	1	Bituminous coal and lignite mining	0.01%
		12,914	Total number of industrial customers in database	

[120] Manufacturers' News Inc. Database, http://www.manufacturersnews.com/database.asp (accessed 2009).

Figure F-1: Distribution of California Companies by Industrial Category from MNI Database[121]

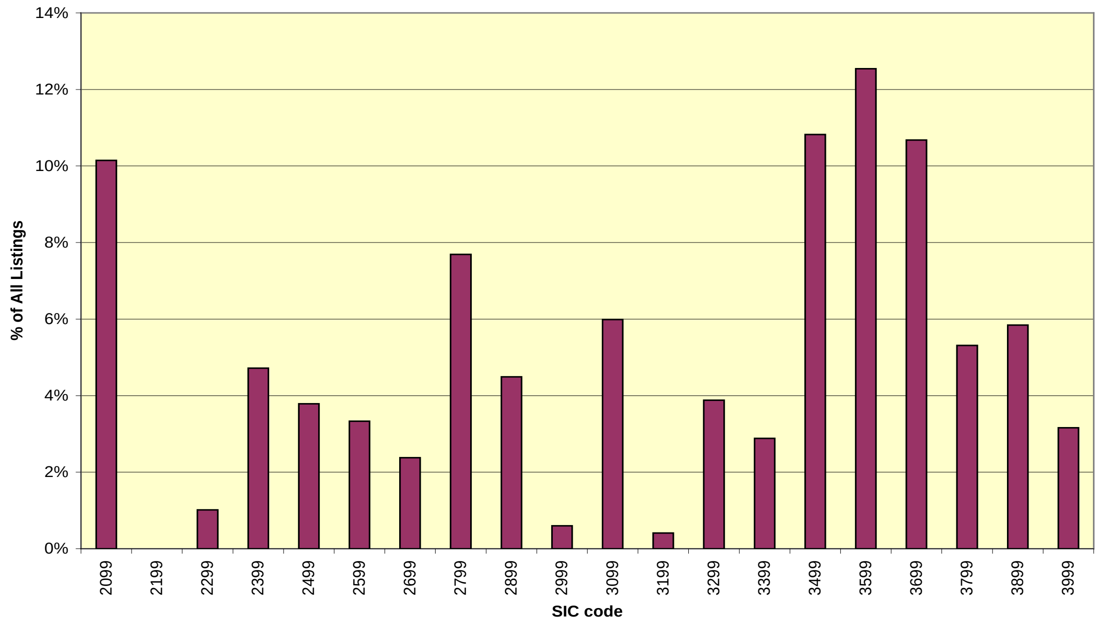


Table F-2: SIC Industrial Codes by Group Numbers in 100's

SIC Code	SIC Description
2099	Food processing, slaughtering, baking, beverages, brewing
2199	Tobacco Products
2299	Textiles, mills, weaving
2399	Clothing and textiles
2499	Lumber and manufactured buildings
2599	Furniture
2699	Paper mills, containers
2799	Printing and publishing
2899	Chemicals and allied products
2999	Petroleum refining
3099	Tires, rubber products, gaskets, plastic products
3199	Leather and footwear
3299	Glass, concrete products, cut stone
3399	Steel mills, foundries, tubing, rolling and extruding
3499	Misc. metal fabrication, sheet metal, bolts and nuts
3599	Engines, turbines, computers, office equipment
3699	Electronic and electrical equipment (no computers)
3799	Motor vehicle bodies, motor homes, motorcycles, ships, aircraft, missiles
3899	Search, detection, medical devices, x-rays,
3999	Jewelry, games, artist materials

[121] Manufacturers' News Inc. Database, http://www.manufacturersnews.com/database.asp (accessed 2009).

Water Use by Industry Type

While Table F-2 shows the number of accounts within a given SIC category it does not necessarily follow that the water use follows the same order. For conservation to be cost-effective it is important to target the type of industry that uses a significant amount of water as part of the manufacturing process.

Cataloguing Commercial, Industrial, and Institutional Customer Classes, a report released by the U.S. Department of the Interior Bureau of Reclamation in 2009, examined the water, energy, and wastewater use of CII customers in Southern California. The water use of industrial customers (manufacturing) was obtained from the billing data provided by the City of San Diego, West Basin Municipal Water District, and Central Basin Municipal Water District. Customers were ranked "according to their relative use of water and energy and by their number of accounts." The information was merged to identify categories that are large users of electricity and water, electricity and natural gas, and water and wastewater, and have a high number of accounts or presence in southern California.[122]

One of the difficulties in determining the water used for various industries is the inconsistency in defining customer classes from one utility to the next. Utilities may define customer classes for planning or accounting purposes, to establish rate structures, or other reasons not defined by the SIC or NAICS codes. However, for the purposes of this study, customers when classified using either SIC or NAICS codes which were then converted to 2002 NAICS codes. One advantage of the NAICS codes was the greater level of definition that they provided. Every effort was made to create an "apples-to-apples" categorization of CII customers from different billing sources in order to rank businesses by water, energy, or wastewater use.

Table F-3 ranks manufacturing type by scaled water use – a useful tool for targeting conservation measures. Scaled water use is the amount of water used per account in a given manufacturing group times the percentage of total water used for manufacturing by the group. For example, the scaled water use of Petroleum and Coal Products Manufacturing is 18,132 kgal/account/year nearly, which equals the average use of 44,316 kgal per account per year times the percent of the total industrial use, 40.9 percent, represented by the group. This is 18 times that of Textile Mills, next highest use group. The 113 accounts in this manufacturing group (2.3 percent of 4,298 manufacturing companies) use 5007.7 MG annually; 40.9 percent of the water used for manufacturing. The top two groups have fewer than 6 percent of the manufacturing accounts and yet combined use more than half of the water supplied for manufacturing in southern California.

The next two groups in Table F-3, Beverage and Tobacco Product Manufacturing and Food Manufacturing, are an example of the difference in the two classification systems and demonstrate the advantage of the NAICS codes. When initially classified these two groups were combined under SIC code 2000; the NAICS system uses code 312 for Beverage and Tobacco Product Manufacturing and 311 for Food Manufacturing. These two groups have a scaled water

[122] Bureau of Reclamation, *Cataloguing Commercial, Industrial, and Institutional Customer Classes*.

use of 376.7 and 317.6 respectively. Due to the smaller number of accounts and the higher scaled use, targeting conservation efforts at Beverage and Tobacco Product Manufacturing is likely to be more cost effective.

The top five manufacturing groups have 23 percent of the manufacturing accounts and yet use nearly 75 percent (9100MG) of the water used for manufacturing in southern California annually. In selecting industrial customers for demand load shape analysis the priorities should be given to the industrial categories with the higher scaled water use.

Table F-3: Ranking of Manufacturing Types by Scaled Water Use

Three-Digit NAICS Codes	Primary SIC Codes	Description	Kgal/Year	Number of Accounts	Kgal/ Account/ Year	% Total Water Use by Group	Scaled Water Use
324	2900	Petroleum and Coal Products Manufacturing	5,007,728	113	44,316	40.9%	18132.7
313	2200	Textile Mills	1,447,221	166	8,719	11.8%	1031.0
312	2000	Beverage and Tobacco Product Manufacturing	440,060	42	10,478	3.6%	376.7
311	2000	Food Manufacturing	1,265,477	412	3,071	10.3%	317.6
325	2800	Chemical Manufacturing	939,190	381	2,465	7.7%	189.1
314	2300	Textile Product Mills	240,937	50	4,819	2.0%	94.9
334	3600	Computer and Electronic Product Manufacturing	369,865	205	1,804	3.0%	54.5
326	3000	Plastics and Rubber Products Manufacturing	228,939	89	2,573	1.9%	48.1
322	2600	Paper Manufacturing	133,979	33	4,060	1.1%	44.4
336	3700	Transportation Equipment Manufacturing	315,033	216	1,459	2.6%	37.5
315	2300	Apparel Manufacturing	239,064	187	1,278	2.0%	25.0

Three-Digit NAICS Codes	Primary SIC Codes	Description	Kgal/Year	Number of Accounts	Kgal/ Account/ Year	% Total Water Use by Group	Scaled Water Use
332	3400	Fabricated Metal Product Manufacturing	322,379	428	753	2.6%	19.8
327	3200	Nonmetallic Mineral Product Manufacturing	208,904	195	1,071	1.7%	18.3
335	3600	Electrical Equipment, Appliance, and Component Manufacturing	195,626	196	998	1.6%	16.0
331	3300	Primary Metal Manufacturing	165,307	151	1,094	1.4%	14.8
333	3500	Machinery Manufacturing	190,991	304	628	1.6%	9.8
339	3800	Miscellaneous Manufacturing	343,415	1,150	298	2.8%	8.4
323	2700	Printing and Related Support Activities	105,561	205	515	0.9%	4.4
337	2500	Furniture and Related Product Manufacturing	60,332	220	275	0.5%	1.4
316	3100	Leather and Allied Product Manufacturing	7,828	32	245	0.1%	0.2
321	2400	Wood Product Manufacturing	10,947	153	72	0.1%	0.1
		TOTAL	**12,238,785**	**4,928**	**90,991**	**100.0%**	

Appendix G: Study Site Information Sheet

STUDY SITE INFORMATION

Site name: ____
Contact person & phone #: ____
Date contacted:____
Aquacraft interviewer:____
Hours of operation: ____
24-hour shifts & staff persons per shift: ___________________________________

Check all water uses that apply & comment on details of each:

- ❑ Pool____
- ❑ Locker room with showers____
- ❑ Cooling tower____
- ❑ Evaporative cooling ____
- ❑ Refrigeration____
- ❑ Cafeteria____
- ❑ Any special event during logging period______________________________
- ❑ Water feature OR fountain____
- ❑ On-site water treatment____
- ❑ On-site water recycling____
- ❑ On-site water storage/mixing tank(s)__________________________________
- ❑ How many units per day at site on average____________________________
- ❑ How many units per day at site during logging period____________________
- ❑ Use of non-potable/recycled water from city____________________________
- ❑ Any other special water using device_________________________________
- ❑ Irrigation timer____
- ❑ Any obvious leaks____

Comment on site details:
____
____
____