

**CALMAC STUDY ID CPU0050
VOLUME 4 OF 6
APPENDIX C**

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

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Appendix C Database for Retail Agency Water/Energy Loads

C.1 Introduction

CIEE-CPUC Water Energy Study 2 examines embedded energy in water at the retail functional component level of California's water system. The Study Team requested the participation of more than thirty water and wastewater agencies statewide that would represent the breadth of retail level treatment and delivery infrastructure utilized throughout the state. Agencies willing to participate were requested to take part in interviews regarding system operational strategies and practices, provide water and energy data for system facilities, and provide planning documentation pertaining to agency water management and capital improvement.

Due to the number of agencies requested to participate in the study and the level of detail of data requested, it was anticipated that there would be a large data storage requirement and intensive data analysis necessary to fulfill the study requirements. The Study Team discussed several platform options that would meet the data storage and analysis needs of the study. It was determined that Microsoft Access® was the best fit for the Water Energy Load Profiling (WELP) Tool because of its data storage capacity, available Graphical User Interface (GUI), and data reporting capabilities.

C.2 Water Energy Load Profiling (WELP) Tool

The WELP Tool was developed in order to produce and store 24-hour energy profiles and calculate energy intensity. The database uses input data to automatically calculate hourly energy profiles for each facility within an agency for each day in 2008. The resulting hourly data for the entire year is stored in the database and queried to produce output requested by the user by using the GUI.

Energy data were requested from each agency at the most detailed level possible for each facility in an agency's system. The level of detail was determined by the type of energy meter used at each facility. Energy data can be stored as energy and demand meter readings for specific billing periods, or as hourly interval meter data. Furthermore, energy service providers can categorize each hour of the day into either on-peak, partial peak, or off-peak categories. Energy data were requested in kilowatt hours (kWh), and demand data were requested in kilowatts (kW).

Water data were requested from each agency on a daily time-step. Water data were stored in the WELP Tool in units of millions of gallons (MG). These units were selected because of typical treatment plant capacity and metering is tracked in MG.

The GUI provides a simple way to retrieve and view analysis results of system facilities for each agency and analyze additional data. The GUI provides a series of options and lists to choose from to retrieve the appropriate level of data analysis results. The WELP Tool analyzes total energy and demand and energy intensity. The results of the energy consumption and demand analysis can be retrieved at four levels of detail; agency wide, sub-division, facility type, and facility specific. The results of the energy intensity analysis are reported by day and by month for each facility type.

This document discusses the data analysis processes and calculations, database setup and use, and data formatting requirements of the WELP Tool.

C.3 Platform

The platform for the tool was carefully considered using accessibility, ability to handle data, and anticipated number of users. Several platforms were considered including Microsoft Excel®, Microsoft Access®, and SQL. It was determined that Microsoft Access® was the best fit for the tool based on the selection criteria. It allows for large file sizes (2GB) to store significant amounts of data, can store a large number of objects (32,768) and is a commonly used platform that could operate on many computers.¹

C.4 WELP Tool Water and Energy Data Processing Algorithms

Energy data and water data were received in various forms. Energy data were received in the following time intervals: 15-minute data, hourly data, monthly utility bills, and time-of-use (TOU) monthly utility bills. Monthly utility bills do not necessarily conform to the beginning and end of a calendar month; they depend on the energy service provider's meter read date (bill end date) which could start on any given day in a month and can vary from facility to facility. Water data were received in the following time intervals: hourly, daily, monthly (calendar), and yearly. Each water agency provides data in varying time intervals for different facilities. For example, some facilities have 15-minute energy data while others have monthly energy bills; similarly, flow data may be daily for some facilities while monthly for others.

To produce 24-hour load profiles and estimate energy intensity, hourly energy data and daily water flow data are needed for each facility. This level of detail was not always available as data were provided with various levels of detail, as noted above. Thus, the Study Team developed data processing methods to convert water and energy data structures to this form. It is important to note that simplifying assumptions must be made to convert, for example, monthly data to hourly data. The following sections describe how the database produces hourly energy data given various forms of input data.

¹ Source - <http://office.microsoft.com/en-us/access/HA100307391033.aspx>

C.4.1 Water Flow Data Processing

The desired data are daily water flow data at each facility. Water data were provided in different forms: hourly, daily, and monthly. The processes that the Study Team employed to convert these different kinds of data to the daily form (as suitable input to the database WELP Tool) are described in this section.

In some cases, hourly flow data were provided to the Study Team. These hourly values were added to develop daily flows and were input to the database. Daily water flow data needed no processing and were put directly into the database tool.

Monthly water flow data needed to be processed to develop daily flow data. The method used depended on the granularity of corresponding energy data that was available for the facility.

Case 1: Only monthly energy data were available.

Monthly water flow data were spread to each day in the month equally. Absent additional information (such as operational strategies), this was the only way the Study Team could process monthly flow data without creating artificial detail in the dataset.

Case 2: Daily or hourly energy data were available

Monthly water flow was proportioned to each day of the month based on the daily energy consumption by the facility. If hourly energy data were available, the daily total energy was first totaled then used to allocate the monthly water flow to days. This method assumed the energy intensity of the facility is constant throughout the bill period month.

C.4.2 Energy Data Processing

The optimal energy data were hourly data for both energy (kWh) and demand (kW). Energy data were provided in different forms: hourly data, monthly utility bills, and time-of-use (TOU) monthly utility bills. Some data collected contained information on both energy and demand, others, just energy. The study team linked each set of energy data for each facility to the corresponding daily water flow data for that facility.

The database converted all forms of input energy data to the required hourly data for the entire year of 2008. The process and algorithms used to convert each data form to the desired hourly form is described below.

C.4.2.1 Interval Data (15-Minute Time Step)

Interval data were typically only available for high energy use facilities. Data were most often provided by water agency's energy service providers. However, some water agencies operate their own energy monitoring systems and logged this information themselves. Electric utilities typically record interval data for facilities with some threshold maximum demand (e.g., 1000 kW

is the threshold for PG&E). The data typically consisted of a power (kW) reading every 15 minutes. Both energy (kWh) and power (kW) was determined from this data.

Interval data were more detailed than needed; the data were aggregated to hourly values. Energy for a given hour was calculated by taking the average of four power data points during an hour. This is the mathematical equivalent of calculating the total energy used in each 15-minute interval and adding the four intervals together. Power for a given hour is calculated as the maximum of the interval data points within the hour. An example of these calculations is provided in Table C-1.

Table C-1. Interval Data Processing Example

Time	1:15 am	1:30 am	1:45 am	2:00 am
Raw Interval Data	0.2 kW	123.7 kW	169.5 kW	169.5 kW

Energy Consumption from 1am-2am	115.7 kWh
Power Consumption	169.5 kW

Hourly Data

Hourly energy data were already in the required form. Hourly data were either provided in units of kW (power) or kWh (energy). Both kW and kWh data were needed for this study; if one was absent from the data set, it was determined by using the other. If power data were provided, energy data were calculated simply by multiply the value of the power by one hour, thus the magnitude of power equaled that of energy. A similar operation was performed vice-versa determining power data by dividing energy data by one hour.

C.4.2.2 Monthly Utility Bill Data

Monthly energy bills were obtained from electric utilities; these data typically spanned 25-35 days (billing period) and represented the total amount of energy consumed during that time. Some billing periods can be longer (up to 90 days) if a utility does not read a meter on a monthly basis. These bills contained information on the end date (when the meter was read) and the number of days billed. There were two general monthly meter types to analyze: “Energy Meters” (kWh meters) and “Demand Meters.”

C.4.2.3 Monthly Utility Bill Data: Energy Meters (kWh Meters)

Energy meters record the total amount of energy consumed during a billing period in units of kWh; no additional energy or power data were collected. To develop a 24-hour load profile, the billed energy first needed to be spread to each day during the billing period then to each hour within each day. Several steps were taken do to this.

The bill start and end dates were determined:

billdays = Number of days billed (obtained from bill)

enddate = End of Billing Period (obtained from bill)

startdate = Start of Billing period (=enddate – billdays +1)

The corresponding daily water volume for all days during the billing period were determined. This was the total water volume that flows through the facility during the billing period.

$$W_T = \sum_{startdate}^{enddate} Daily_Water_Use$$

The billing period energy intensity was estimated using the total energy consumption as reported by the bill and the total water flow during the billing period calculated in step 3.

$$\overline{EI}_{Bill} = \frac{E_T}{W_T}$$

The billing period average energy intensity is multiplied by each day's water flow to determine the daily energy consumption for each day in the billing period, as illustrated in Table C-2.

Table C-2. Daily Energy Calculation Example

Day	EI	Water Flow	Daily Energy
1	EI_{Bill}	X	$=X * EI_{Bill}$
2	EI_{Bill}	Y	$=Y * EI_{Bill}$
3	...	...	...

Once the daily energy consumption was calculated, the daily energy was distributed evenly to the 24 hours in that day. This was done because no information was available to indicate the time of day when the energy was consumed. The Study Team assumed demand was equal in magnitude to energy consumption for these facilities. This process was repeated for each bill during 2008 for each facility.

C.4.2.4 Monthly Bill Data: Demand Meters

Demand meters record the same data as energy meters with the addition of peak demand (kW) during the billing period. Customers with these types of energy meters are billed not only for the total energy consumed but also for the peak demand during a billing period.

For these meters, the 24-hour energy profiles are determined using the same method for energy meters. However, these meters do provide some information on demand, thus 24-hour demand profiles can be created. Peak demand is reported as one number on the energy bill. Demand for these facilities is estimated to be a constant value equal to the billing period's peak demand for each hour of each day in the billing period.

C.4.2.5 Time of Use Monthly Utility Bill Data

Time of Use (TOU) meters are used for facilities that have high energy use for sustained periods. For example, PG&E requires TOU meters on facilities that consume more than 200kW of peak power for 3 consecutive months (this rule may vary for other utilities). TOU meters are used to charge different rates at different times of the day and different seasons of the year. This is to account for differences in the cost of energy generation by energy service providers at different times of the day. Most TOU billing differentiates between two seasons (Summer and Winter) and three time periods in a day (On-Peak, Partial Peak, Off-Peak)²

For example, PG&E's defined times and seasons are listed below and illustrated in Figure C-1.³

Summer (May 1 through October 31):

Peak: 12:00 noon to 6:00 p.m. Monday through Friday (except holidays)

Partial-peak: 8:30 a.m. to 12:00 noon and 6:00 p.m. to 9:30 p.m. Monday through Friday (except holidays)

Off-peak: 9:30 p.m. to 8:30 a.m. Monday through Friday, and All day Saturday, Sunday, and holidays

Winter (November 1 through April 30):

Partial-Peak: 8:30 a.m. to 9:30 p.m. Monday through Friday (except holidays)

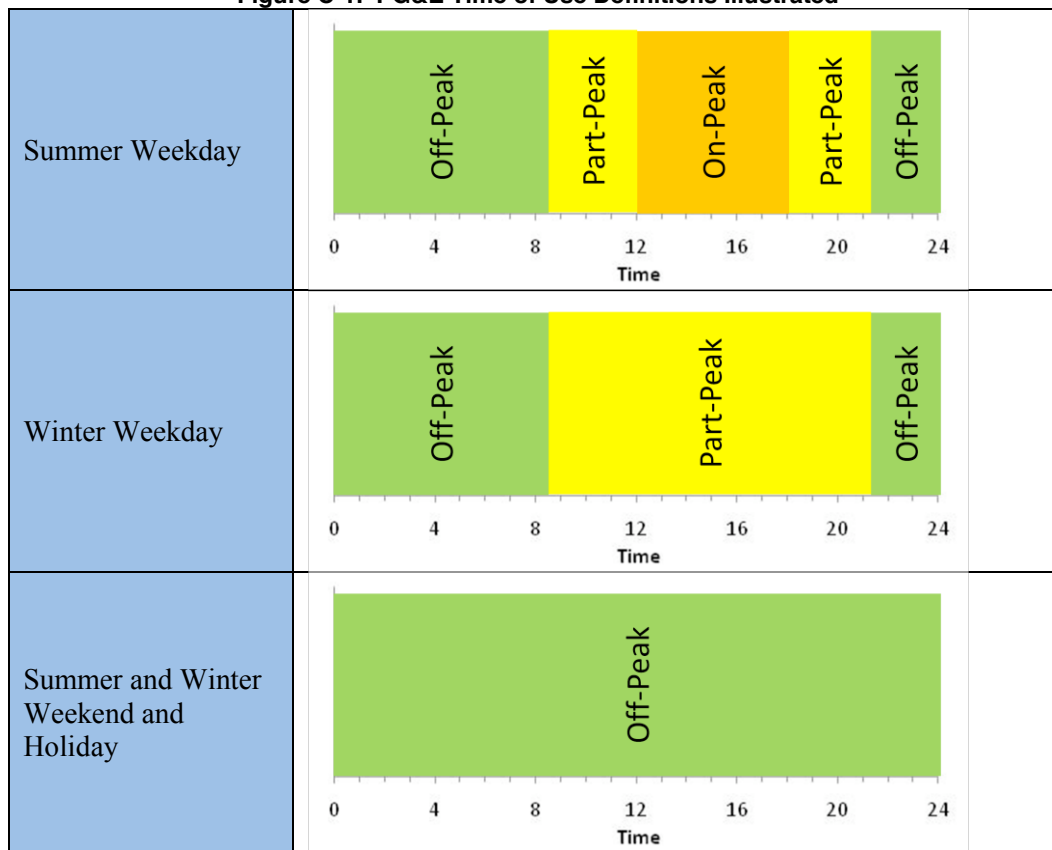
Off-Peak: 9:30 p.m. to 8:30 a.m. Monday through Friday (except holidays), All day Saturday, Sunday, and holidays

Holidays: New Year's Day, President's Day, Memorial Day, Independence Day, Labor Day, Veterans Day, Thanksgiving Day, and Christmas Day.

² Terminology varies by utility.

³ Times and dates vary for different utilities

Figure C-1. PG&E Time of Use Definitions Illustrated



TOU bills provide the total energy consumption during each time period (On-Peak, Partial Peak, Off-Peak) during the billing period. Some TOU meters also contain peak demand during each time period.

To analyze these bills, the first step was to spread total energy during the billing period to each day proportional to daily water flow using the method for kWh meters (steps 1-4). Most bills were set entirely in the summer or winter (“single season TOU bill”); however some bills have a start date in one season and an end date in another season (“multi-season TOU bill”). The subsequent analysis for these two different TOU bills varies. The general approach for both was to use the ratio of On, Partial, and Off-Peak energy consumption to spread daily energy use into 3 different times of the day.

C.4.3 Single Season TOU Bills

The following steps were taken to analyze bills that occur entirely in one season, either winter or summer.

Total energy used in each time period for the billing period is extracted: E_{ON} (On Peak), E_{PP} (Partial Peak), E_{OFF} (Off-Peak). Bill start and end dates are also determined

Daily energy use for in the billing period was determined following the method for Energy Meters (steps 1-4), i.e. allocating total energy proportional to daily water flows. Additionally, the day type (weekday, weekend, or holiday) is linked to each day, as illustrated in Table C-3.

Table C-3. Daily Energy Tied to Day Type Example

Day	EI	Water Flow	Daily_Energy	Day Type
1	EI _{Bill}	X	=X *EI _{Bill}	Weekend
2	EI _{Bill}	Y	=Y *EI _{Bill}	Holiday
3	EI _{Bill}	Z	=Z *EI _{Bill}	Weekday
4	...	...	...	...

All hours of the day on weekends and holidays were defined as off-peak times. Since there is no distinction between different time periods on these days, no additional granularity can be achieved. Thus, weekend and holiday 24-hour energy profiles are treated like energy meters: energy is spread evenly to all 24 hours.

Daily energy on weekdays was split into three different time periods using the ratio of On, Partial, and Off-Peak energy. Prior to calculating these ratios, the proper Off-Peak energy consumed on weekdays was first estimated (considerable off-peak energy is consumed on weekends and holidays).

The total energy consumption during weekends and holidays during the billing period was determined. All this energy consumption occurs during Off-Peak hours.

$$E_{OffPeak:WE/H} = \sum_{startdate}^{enddate} Daily_Energy_{WE_and_Holiday_Only}$$

The amount of Off-Peak energy consumption that occurs on weekdays is determined by subtracting weekend/holiday Off-Peak energy from total Off-Peak energy ($E_{Off_weekday}$).

$$E_{Off_weekday} = E_{OFF_Total} - E_{OffPeak:WE/H}$$

The ratio of energy used during each time period during a weekday was determined. This was calculated from the total bill energy consumption during On Peak (E_{ON}) and Partial Peak (E_{PP}) and the estimated weekday Off-Peak Energy. These ratios, A , B , and C , are defined in Table C-4.

Table C-4. On, Partial, and Off Peak Energy Ratios

Time Period	Monthly Energy Use	Percent of Weekday Energy Use
On-Peak	E_{ON}	$A = \frac{E_{ON}}{E_{ON} + E_{PP} + E_{Off_weekday}}$
Partial	E_{PP}	$B = \frac{E_{PP}}{E_{ON} + E_{PP} + E_{Off_weekday}}$
Off Peak Energy	$E_{Off_weekday}$	$C = \frac{E_{Off_weekday}}{E_{ON} + E_{PP} + E_{Off_weekday}}$

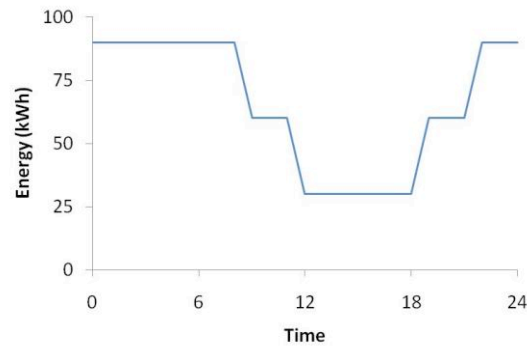
Daily energy (E_{daily}) used on weekdays was divided into the three time periods using the ratios A , B , and C . Within each time period the energy use was evenly spread among the hours of the day in which it was consumed, see Table C-5. For example, a summer weekday in PG&E territory has 6 On-Peak hours, 7 Partial-Peak hours, and 11 Off-Peak Hours. Peak energy used for a weekday is spread evenly over the 6 hours. Winter days have 13 hours of on-peak, 11 hours of off-peak, and no time On-Peak.

Table C-5. Hourly Energy Use Calculations

Time Period	Daily Energy Use for Weekday	Hourly Energy Use During Time Period
On-Peak	$A * E_{Daily}$	$\frac{A * E_{Daily}}{\text{On Peak Hours}}$
Partial	$B * E_{Daily}$	$\frac{B * E_{Daily}}{\text{Partial Peak Hours}}$
Off Peak Energy	$C * E_{Daily}$	$\frac{C * E_{Daily}}{\text{Off Peak Hours}}$

The 24-hour energy profile was developed using the hourly energy use within each time period bound by the start and end of each time period. An illustrative 24-hour energy profile for a facility with a TOU meter is shown in Figure C-2.

Figure C-2. Illustrative 24-hour Energy Profile for a TOU Meter



Demand information was sometimes available for facilities with TOU meters. If it was available, it reported the peak demand (in units of kW) that occurred during each time period (On, Partial, and Off-Peak) during the billing cycle.

When demand information was available, the Study Team estimated the demand of each hour during each time period to be equal to the peak demand reported for that time period. Thus the 24-hour demand profile for each day within a billing period was identical.

When demand information was unavailable, the Study Team estimated the magnitude of demand by applying a 55 percent load factor to the hourly energy profile.⁴

$$Demand = \frac{Energy}{.55}$$

C.4.4 Multi-Season TOU Bills

Multi-Season TOU bills are those bills that have a start date and end date in different seasons. For example, a PG&E bill that starts on April 15 and ends on May 15, bills for time in both winter and summer. There are no On-Peak hours during the winter season though considerably more partial peak hours to compensate. To analyze these bills, the Study Team effectively split a bill into two different bills, one that represents energy consumption only during the summer, while the other only represents winter. Once this is done, the process for a Single-Season TOU Bill was used.

To split the Multi-Season TOU Bills, the Study Team calculated how much energy is consumed in each time period for each season. This required populating a table similar to Table C-6.

⁴ Based on the Study Team's internal expertise, a load factor of 55 percent is typical of water system infrastructure.

Table C-6. Bill Splitting Methodology

Time Period	Season 1 Within the Billing Period	Season 2 Within the Billing Period
On Peak (kWh)	A	F
Partial Peak (kWh)	B	G
Off Peak (kWh)	C	H
Total (kWh)	D	J

The steps carried out to split these were as follows:

Daily energy use for in the billing period was determined following the method for Energy Meters (steps 1-4), i.e. allocating total energy proportional to daily water flows.

Total energy used in each time period for the billing period is extracted: E_{ON} (On Peak), E_{PP} (Partial Peak), E_{OFF} (Off-Peak). The bill start date, bill end date, and date at which the season changes (*SeasonChange*) were determined

The total energy consumption in each season was calculated by summing the daily energy consumption of each day in each season

$$D = \sum_{StartDate}^{SeasonChange} E_{Daily_Energy}$$

$$J = \sum_{SeasonChange}^{EndDate} E_{Daily_Energy}$$

The number of hours of On, Partial, and Off Peak time was associated with each day during the billing period based on utility rules. This information was stored in a table along with the calculated daily energy use. Table C-7 illustrates this below with the season changing from summer to winter on the fourth day of the billing period.

Table C-7. Daily Energy Tied to Day Type Example

Day	Season	Daily_Energy	Day Type	On Peak Hours	Partial Peak Hours	Off Peak Hours
1	Season 1	E ₁	Weekend	0	0	24
2	Season 1	E ₂	Holiday	0	0	24
3	Season 1	E ₃	Weekday	0	13	11
4	Season 2	E ₃	Weekday	6	7	11
5	...	...	...	...	...	...

The ratio of On Peak energy use in each season is determined using a weighting of the total number of hours of On Peak hours in each season and the energy daily energy use on the days when on peak energy is used. $OnPeakFraction_{season1}$ represents the percent of total bill On-Peak energy used during season 1 while $OnPeakFraction_{season2}$ represents the percent of total bill On-Peak energy used in season 2. The weighing multiplies the number of On-Peak hours in a day by the total energy consumption that day and totals this value for all days as illustrated in the set of equations below.

$$OnPeakFraction_{season1} = \frac{\sum_{StartDate}^{SeasonChange} E_i * OnPeakHours_i}{\sum_{StartDate}^{EndDate} E_i * OnPeakHours_i}$$

$$OnPeakFraction_{season2} = \frac{\sum_{SeasonChange}^{EndDate} E_i * OnPeakHours_i}{\sum_{StartDate}^{EndDate} E_i * OnPeakHours_i}$$

$$OnPeakFraction_{season2} = 1 - OnPeakFraction_{season1}$$

Partial Peak energy use in each season is determined in a similar manner to the splitting of On Peak energy use. $PartialPeakFraction_{season1}$ represents the percent of total bill Partial Peak energy used during season 1 while $PartialPeakFraction_{season2}$ represents the percent of total bill Partial Peak energy used in season 2.

$$PartialPeakFraction_{season1} = \frac{\sum_{StartDate}^{SeasonChange} E_i * PartialPeakHours_i}{\sum_{StartDate}^{EndDate} E_i * PartialPeakHours_i}$$

$$PartialPeakFraction_{season2} = \frac{\sum_{Season\ Change}^{EndDate} E_i * PartialPeakHours_i}{\sum_{StartDate}^{End\ Date} E_i * PartialPeakHours_i}$$

$$PartialPeakFraction_{season2} = 1 - PartialPeakFraction_{season1}$$

Using the above-calculated fractions, the bills could be split into two seasons as illustrated in Table C-8.

Table C-8. Bill Splitting Equations

Time Period	Season 1 Within the Billing Period	Season 2 Within the Billing Period
On Peak (kWh)	$A = E_{ON} * OnPeakFraction_{season1}$	$F = E_{ON} * OnPeakFraction_{season2}$
Partial Peak (kWh)	$B = E_{ON} * PartailPeakFraction_{season1}$	$G = E_{ON} * PartailPeakFraction_{season2}$
Off Peak (kWh)	$C = D - B - A$	$H = J - G - F$
Total (kWh)	$D = \sum_{StartDate}^{Season\ Change} E_{Daily_Energy}$	$J = \sum_{Season\ Change}^{EndDate} E_{Daily_Energy}$

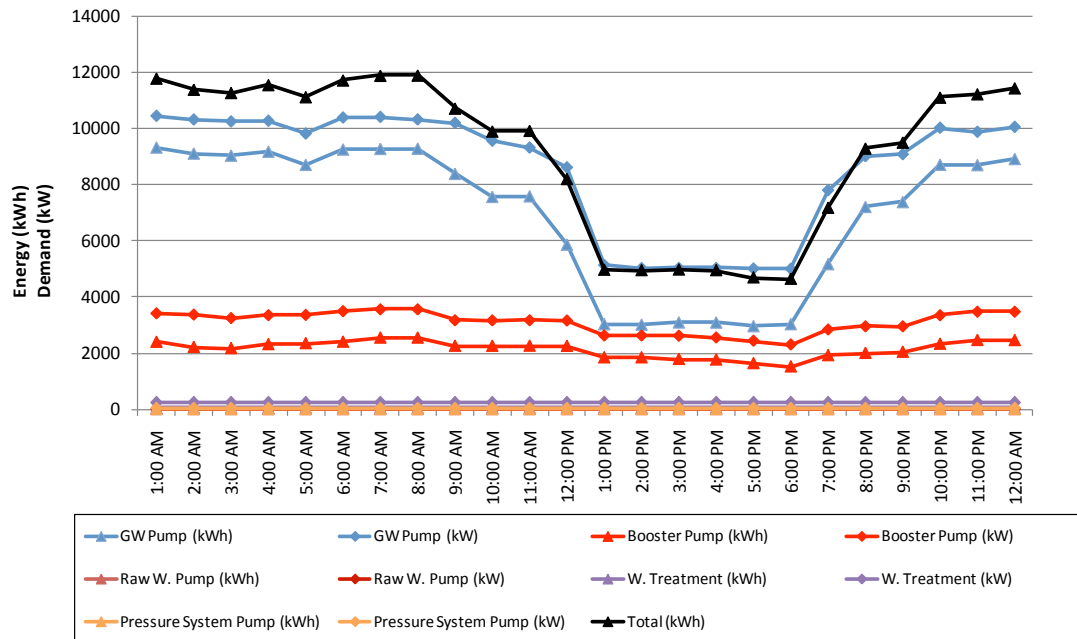
At this point, the bill was effectively split into two TOU bills that were each entirely contained in one season. The method for Single-Season TOU Bills was then followed to develop the hourly data.

C.5 Generating 24-hour Energy Profiles

Once all energy and water data was processed for all facilities within an agency, the 24-hour energy profile for any given day could be generated. The profiles presented in this report display the hourly energy consumption for all facilities operated by an agency in a given day.

Furthermore, each profile is segmented into the various facility types within an agency (groundwater pumps, water treatment plants, etc.) For example, the profile for groundwater pumps shows the combined hourly energy and demand for all groundwater pumps within the agency. An example 24-hour energy profile showing both energy and demand is shown in Figure C-3. The profiles for each facility type are independent from each other; the total profile is the sum of each facility type's 24-hour energy profile.

Figure C-3. Example 24-hour Energy Profile



Seven energy profiles for seven different days for each agency are contained in this report. These seven days are: Summer Peak Energy Demand Day, Summer High Water Demand, Summer Average Water Demand, Summer Low Water Demand, Winter High Water Demand, Winter Average Water Demand, and Winter Low Water Demand. The definitions of each are listed below.

Summer Peak Energy Demand Day – The day in summer on which the water agency’s energy service provider experienced its highest total system energy demand (this includes all of the energy use by all of the energy service provider’s customers). This date is specific to each energy service provider and has little to do with the water agency’s energy use or water deliveries. Information on when this day occurred was obtained from each energy service provider.

Summer High Water Demand – The day in summer where water demand by the water agency’s customers was at its highest. This day is obtained by analyzing the daily water demand of the agency during the summer months as defined by the agency’s energy service provider.

Summer Average Water Demand – The day in summer where water demand is closest to the average water demand for the entire summer season. This day is determined by calculating the average of the daily flows in each day during the summer. The database tool then identifies the day in summer that has the closest flow value to this average.

Summer Low Water Demand – The day in summer where water demand by the water agency’s customers was at its lowest. This day is obtained by analyzing the daily water demand of the agency during the summer months as defined by the agency’s energy service provider.

Winter High Water Demand – The day in winter where water demand by the water agency’s customers was at its highest. This day is obtained by analyzing the daily water demand of the agency during the winter months as defined by the agency’s energy service provider.

Winter Average Water Demand – The day in winter where water demand is closest to the average water demand for the entire winter season. This day is determined by calculating the average of the daily flows in each day during the winter. The database tool then identifies the day in winter that has the closest flow value to this average.

Winter Low Water Demand – The day in winter where water demand by the water agency’s customers was at its lowest. This day is obtained by analyzing the daily water demand of the agency during the winter months as defined by the agency’s energy service provider.

C.6 Peak Demand Calculation

The Study Team was asked to additionally calculate peak demand using methods outlined in the Database for Energy Efficient Resources (DEER).⁵

DEER defines peak demand as the demand that “...would be ‘seen’ at the electric grid level, averaged over the 9 hours, between 2pm and 5pm, during the three consecutive weekday period which contains the weekday with the highest temperature of the year.”⁶ The study team employed this method by averaging hourly energy consumption for the nine hours described. DEER provides documentation for which three-day series in 2005 should be used for calculations; however, such data and analysis for 2008 were not available. In the absence of this information, the Study Team employs this calculation method for each day of the year in 2008, calculating demand by using data from the given day and the following two days (regardless if any of the days are weekends or holidays). For example, when reporting the peak energy demand for July 8, 2008, calculations include data from July 8 through 10. When reporting the demand, the WELP Tool will also report the day of the week on which the 3-day period starts.

The peak demand by facility type (groundwater pump, water treatment plant, etc.) is accompanied with the 24-hour energy profiles presented in this report. Peak Demand is reported in kW and uses the data from the given day of the profile and the following two days for its calculation. Table C-9 shows an example output for peak demand results.

⁵ The DEER database and full documentation can be obtained at <http://www.energy.ca.gov/deer/>

⁶ For more details see: James J. Hirsch and Associates. *Definition of Demand (kW) Impacts Used in the DEER 2005 Update*. March 2006.

Table C-9. Example Peak Demand Results

Date	7/8/2008
Day	Tuesday
Peak Demand (kW)	
Groundwater	2,038
Booster Pumps	1,150
Raw Water Pump	2
Water Treatment	34
Pressure System Pumps	18

C.7 Energy Intensity Calculation

Energy intensity (EI) was calculated for each facility type within each agency using the database tool. Energy intensity in this document is reported, for example, as the agency-wide energy intensity of all groundwater pumps or all water treatment plants. The Study Team calculated EI on a daily and monthly basis, reporting monthly energy intensity in this document.

The calculation of EI (units of kWh/MGal) was calculated by dividing energy used at a facility by the water it pumped or processed with that energy.

$$EI = \frac{\text{Energy (kWh)}}{\text{Water Flow (MGal)}}$$

To calculate energy intensity for a facility type, the database tool adds all energy use by that facility type within an agency and divides it by the total water pumped or processed by that facility type. For example, when calculating EI for water treatment plants, the total energy used by all water treatment plants was divided by the total treated water production.

Total flow through each facility type was determined by the Study Team and entered as an input to the database tool. Total flow by facility type was obtained different ways for different facilities to ensure proper accounting. Special care was needed to obtain total flows for pump systems (booster pumps, wastewater pumps, recycled water pumps); the sum of the flows through each pump could not be used as pumps may be connected in series and water flow may be “double counted”. See Table C-10 for the definitions of total flow used by the Study Team. Total flow for each facility type was input to the database tool with a daily time stamp.

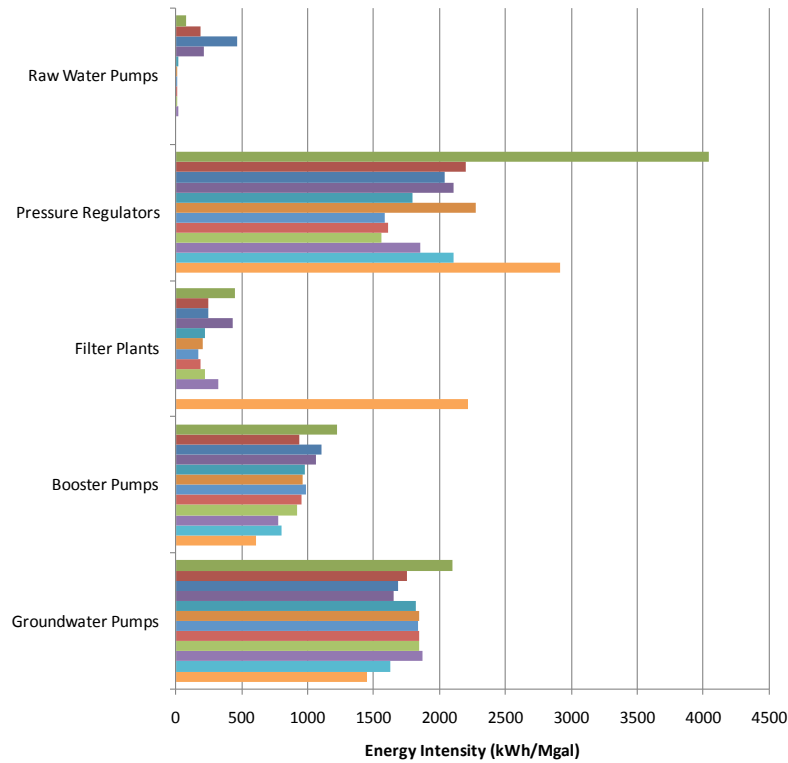
Table C-10. Total Flow Definitions

Facility Type	Total Flow Definition for Study Purposes
Groundwater Pumps	Total groundwater production by the agency
Water Treatment Plants	Total treated water production by the agency
Wastewater Treatment Plants	Total influent to all wastewater treatment plants
Recycled Water Plants	Total influent to all recycled water production plants
Booster Pumps	Total water entering areas served by booster pumps
Pressure System Pumps	Total water entering areas served by pressure system pumps
Wastewater Pumps	Total influent to all wastewater treatment plants served by wastewater pumps
Recycled Water Pumps	Total water entering areas served by recycled water pumps
Raw Water Pumps	Total raw water conveyance that is not gravity fed

Daily energy intensity was obtained by calculating the total energy consumption by a facility type for a given day and dividing it by the total flow for that day. The total energy consumption was obtained from the previously calculated 24-hour energy profiles; the hourly energy use was totaled within that day. Daily energy intensity is calculated and stored in the database tool for each facility type and each day in 2008.

Monthly energy intensity was obtained in a similar way to daily energy intensity. However, the facility type energy consumption represents the total energy consumption for a calendar month and is calculated referencing the 24-hour energy profile for each day of the month. Additionally, the total flow is the monthly sum of the daily total flow for the facility type. Monthly energy intensity is calculated and stored in the database tool for each facility type and each month in 2008. Monthly energy intensity is documented in this report, and example of which can be seen in Figure C-4.

Figure C-4. Example of Monthly Energy Intensity Results



C.8 Graphical User Interface

A simple and intuitive graphical user interface was developed to allow user to select processing options desired. Figure C-5 shows the layout and all possible selections for data processing. There are up to five categories of selections that can be used to retrieve the desired analysis results.

Figure C-5. Graphical User Interface (GUI)

Embedded Energy in Water Study 2: Water-Energy Load Profiling (WELP) Tool

Step 1: Choose Processing Option ☒ Load Profiles ☐ Energy Intensity ☐ Base Data

Step 2: Select Agency Agency:

Step 3: Select Day

Select Day By: ☒ Day Type ☐ Specific Day Day Type:

Step 4: Select Level of Detail

Option: ☒ 1 - Agency ☐ 2 - Agency Sub-Division ☐ 3 - Facility ☐ 4 - Facility Type

Export to Excel ☐

Step 1:

There are three processing options to choose from that determine what results are output by the WELP. Load Profile processing shows the 24 hour energy profile results. Energy intensity processing shows the energy consumption per water unit analysis. Base data processing runs the analysis algorithms and calculations (described in “WELP Tool Water and Energy Data Processing Algorithms”) for an agency and is only used when new agency data has been added to the WELP Tool.

Step 2:

Users select from a dropdown box the agency they want to view. The selection is used to determine which agency analysis results are displayed or data need to be analyzed. The database provided at the time this report was submitted comes pre-loaded with all the data from all the agencies mentioned in this report with the exception of Inland Empire Utilities Agency.

Step 3:

This step is only required for 24-hour load profile analysis. The user is presented two options for selecting the day that is processed. The Day Type option allows the user to select process based on seven predetermined day types: Summer Peak Energy (SPE), Summer Average Water Demand (SAW), Summer High Water Demand (SHW), Summer Low Water Demand (SLW), Winter Average Water Demand (WAW), Winter High Water Demand (WHW), and Winter Low Water Demand (WLW). The Specific Day option allows the user to select any day in 2008 that is desired. A calendar tool is available to select a day or the user can type a date in the text box provided. Figure C-6 shows available tools for specific day selection.

Figure C-6. GUI Day Selection

The screenshot displays a software interface for selecting a day and level of detail. It is divided into two main sections: Step 3: Select Day and Step 4: Select Level of Detail.

Step 3: Select Day

Select Day By:

- ☐ Day Type
- ☒ Specific Day

Date: 7/23/2008

Jul 2008 Jul 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

Step 4: Select Level of Detail

Option:

- ☒ 1 - Agency
- ☐ 2 - Agency Sub-Division
- ☐ 3 - Facility
- ☐ 4 - Facility Type

Step 4:

This step is only required for 24-hour load profile analysis. The WELP Tool has the ability to provide analysis results at four levels of detail ranging agency wide to a specific facility. For the agency sub-division level of detail there is an additional option that allows the user to select which summation is desired, meter type or facility type.

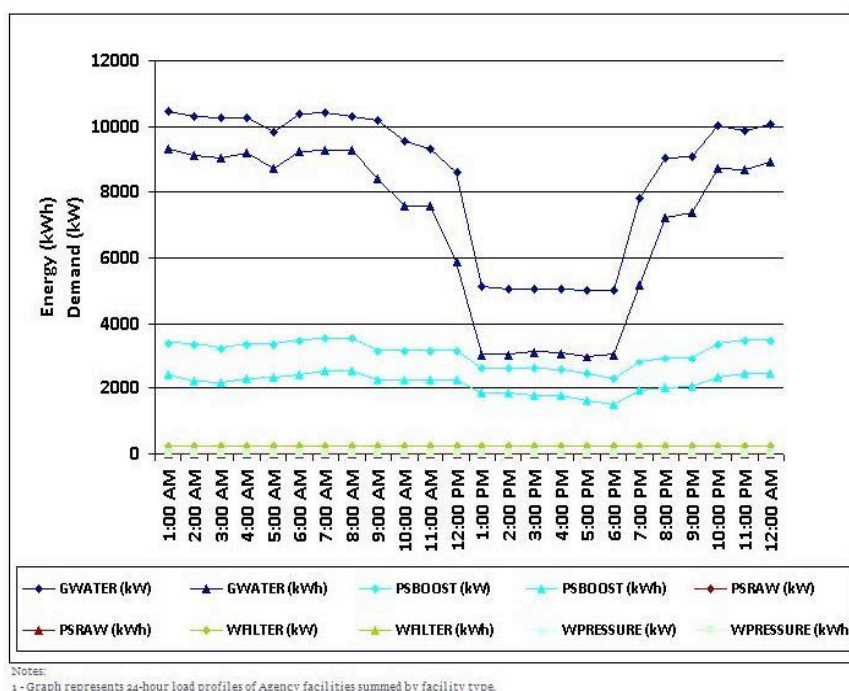
C.8.1 Load Profile Outputs

Load profile processing performs a series of queries that filter and sum data to the proper level of detail for the three reports that have been developed to display 24-hour load profile information. The three standard 24-hour load profile reports are Meter Type, Agency Sub-division, and Facility Type summations. Appendix A shows an example of each report. Users will most likely find the Facility Type graph of most use to them.

There are two additional reports that display meter level data for meters that are included in the load profiles and meters that were excluded from the load profiles. The process uses data calculated during base data processing, described later in this section, to create 24-hour load profiles for four levels of detail.

The Agency Report shows energy and demand totals for each facility type in the agency, it is most likely the graph users wish to view. This type of analysis is useful in determining which types of system components consume the most energy and which systems see variation in energy use throughout the day. As an example San Jose Water Company's agency report is displayed in Figure C-7. The facility type report shows the true energy and demand requirements of each facility type and is not stacked to represent total system energy consumption or demand.

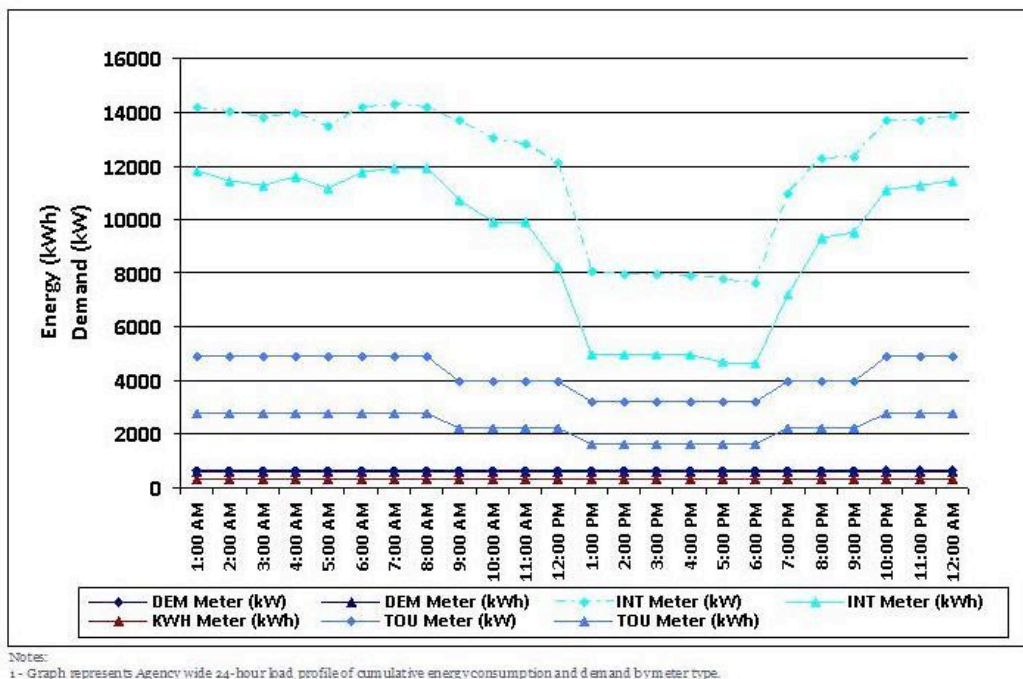
Figure C-7. Agency Report



The meter type report shows energy use for the selected agency separate by energy meter type. Figure C-8 shows an example of a meter type report. The graph associated with the meter type summation shows the cumulative or stacked energy consumption of the agency, while the tabular information shows the individual contributions of each meter type. The stacking order of the meters was chosen to maintain the load shape of each meter type. Simple monthly energy meter result in a flat line over 24-hour period and do not have a demand associated. Demand meters are then stacked on the energy only meters. Demand meters are also shown as flat line over the 24-hour period but do have demand associated with the energy. Time-of-Use (TOU) meters are then stacked on the demand meter. TOU meter data provides more detailed information and have a stepped load shape for both energy and demand. Interval meter energy and demand totals

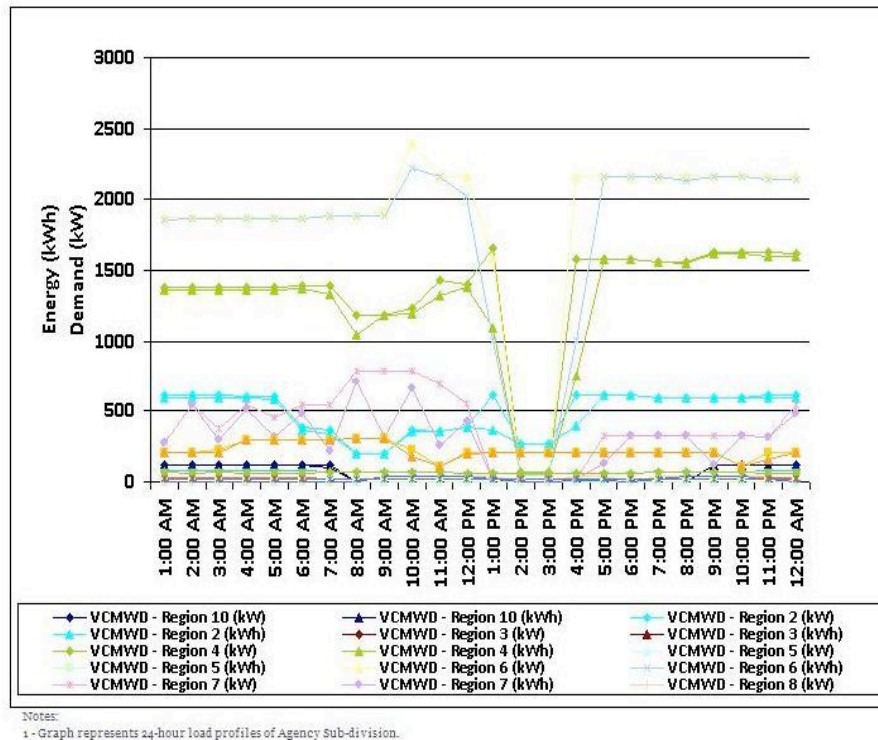
are then stacked on top of the TOU meter profiles providing the total system energy profile. Interval meter data provides an hourly detail for energy and demand, resulting in a unique load shape for each day.

Figure C-8. Meter Type Report



The agency sub-division report shows energy usage totaled by agency sub-division. Agencies may treat their network as a system of separate sub-divisions based on system pressure zones, regional supplies, or other criteria. This analysis can be useful in identifying which segments of the system have the highest energy requirements for water delivery. The sub-division report shows the true energy and demand for each system sub-divisions rather than stacking the energy and demand profiles. As an example, Valley Center Municipal Water District (VCMWD) has 11 sub-division based on the system pressure zones. The sub-division profile for VCMWD is shown in Figure C-9. From this graph you can see that there are two sub-divisions that have much higher energy consumption than the others. The sub-division profiles sums energy by sub-division which includes all system facilities within that sub-division, therefore the profile shapes are a mix of all meter types. Subdivision graphs are only presented for the few agencies that provided information on segmenting their system.

Figure C-9. Sub-Region Report



Along with the output graphs, meter inclusion and meter exclusion reports are generated.

The meter inclusion report shows meter level detail of the information included in the 24-hour load profiles. This report is available in tabular format only. The meter inclusion report is sorted by facility type, then by meter type, then by meter number. The report contains the facility energy intensity, the facility's assigned sub-division number, and an energy (kWh) value for each hour.

The meter exclusion report contains information about the meters that were not included in the 24-hour load profile reports. The report is sorted by meter number and includes the meter type and the reason for exclusion. The main reason for excluding a meter from the reports is that there were no flow or energy data for the date in question.

Agency Sub-division level processing outputs reports for a selected sub-division. A drop down list of agency sub-divisions shows the division number and a brief description of the region. For this report there is an option of outputting the analysis results using the meter type report or the facility type reports. The meter inclusion and exclusion reports are also included in this level of processing.

Facility type level processing displays analysis of a specific facility type for the selected agency. Facility type level processing results in a facility type 24-hour load profile report for the facility type selected from the drop down list. The data are shown as cumulative sum of energy and

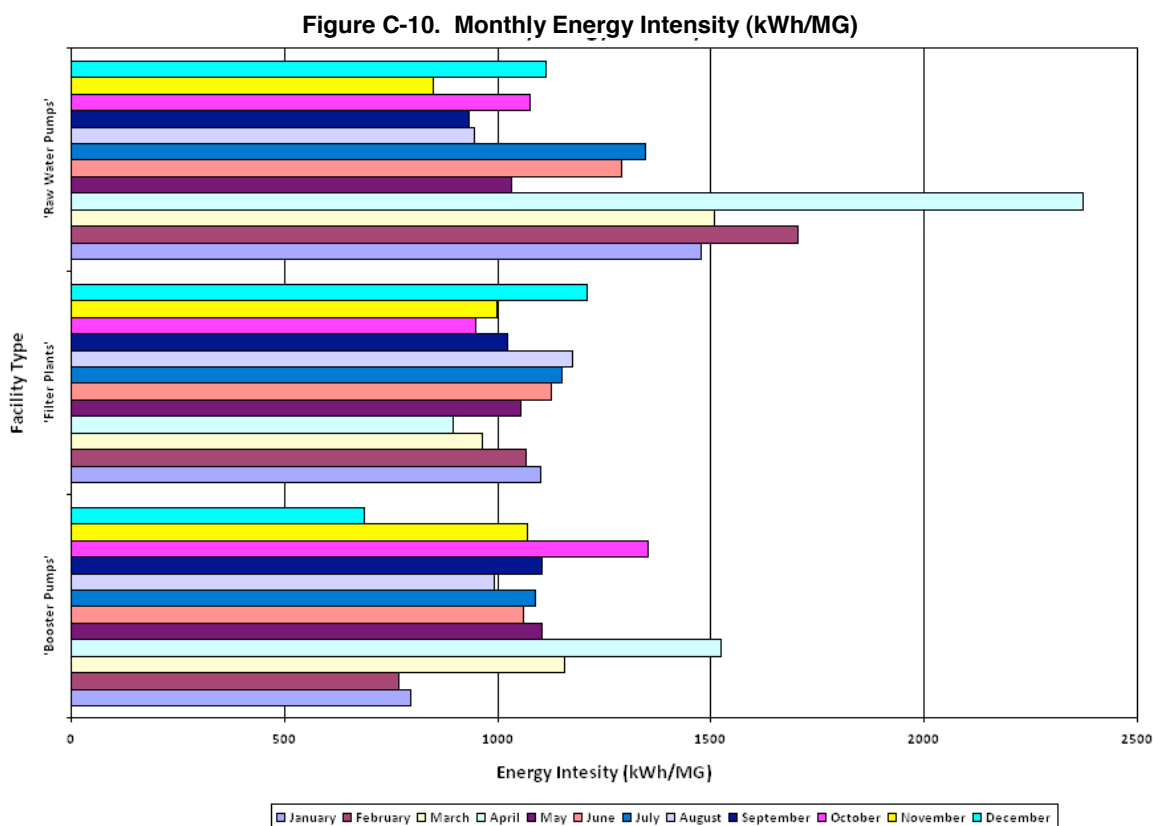
demand by meter type. The meter inclusion and exclusion reports are also available. This allows further analysis into specific facilities in a system.

Facility level processing allows analysis of a single facility in an agency's system. This level of processing uses the meter type report to display to energy and demand for the facility.

C.8.2 Energy Intensity

Energy Intensity processing analyzes the system facility types in groups, resulting in an energy intensity by facility type in two formats. The analysis results in both graphical and tabular monthly energy intensity and daily energy intensity.

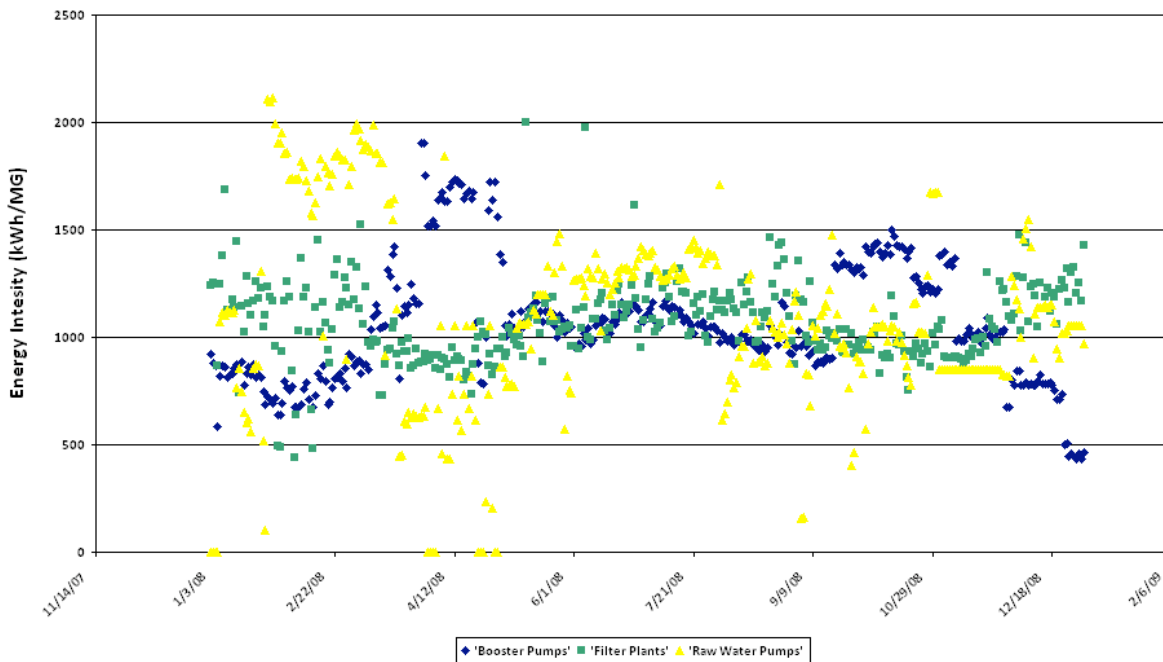
The monthly energy intensity analysis uses total energy and total flow by facility type to develop energy intensity values in units of kWh/MG. The monthly energy intensity report provides the user with a graphical look at the adjustment in energy intensity over time and allows for further investigation if a value seems out of line for the typical values for that type of facility. The graph is grouped by facility type and sorted by month. As an example the monthly energy intensity report for is included as Figure C-10.



Daily energy intensity analyzes the energy intensity of an agency by day. A daily energy intensity graph has been included as an example in Figure C-11. The daily energy intensity

graph also allows the user to view when system components are operational throughout the year; however daily data must be used with caution. Daily flow and energy is not always available for each agency. If this level of data is available it leads to a much larger scatter and a lower accuracy in estimating energy intensity due to numbers sources of variance and error in the raw data. A single day's data point is not always an accurate read of a facility's energy intensity, monthly averages are better suited.

Figure C-11. Daily Energy Intensity (kWh/MG)



C.9 Base Data

The base data processing option is used to build the daily energy data for each meter. The processing is documented in the “WELP Tool Water and Energy Data Processing Algorithms” section. The data processing can take several hours for agencies with a large number of facilities, while the database is processing data other features of the tool cannot be accessed.

C.10 Importing New Data

This section discusses the data types, for key elements of the database and the table relationships in the WELP Tool that pertain to importing data.

Steps for entering new data into the database:

- Check the Energy Service Provider index table for applicable IOU – tbl_Elec_Priv
- Add the agency to agency table – tbl_Agency

- Add Agency Sub-divisions to the sub-divisions table – tbl_Dist-region
- Note – There must be at least one sub-division per agency

Format Data

- Add energy meters to the energy meter index table – tbl_Emeter
- Add flow meters to the meter index table – tbl_Fmeter
- Add monthly energy data to the energy data storage table – tbl_Elec_Mtr_Data
- Add energy interval data to the interval data storage table – tbl_Emtr_Int
- Add flow data to the flow data storage table – tbl_Flw_Mtr_Data
- Add total flow data to the total flow storage table – tbl_Flw_Mtr_Data2

The first step to importing new data into the database is to make sure that the Energy Service Provider is included in the index table. Each agency must have a unique ID number that must be included in the energy meter index table. This number is used to assign an energy meter to an energy service provider. The other key information needed for this table is the summer peak energy day, which is specific to each provider, and the summer and winter season start dates. Typically the hour classifications used by the energy service providers change from summer to winter as energy use trends are different in each season. If the needed data from an energy service provider does not exist you must build an hourly classification and annual day type breakdown for the provider.

The next step is to add the agency to the agency index table. Each agency must have a unique identification number that will be used to assign water and energy meters to the agency. The agency code is also required, and is used to assign total flow values for facility types and agencies as needed. The primary energy service provider should be included in this table; from this number the database selects the appropriate Summer Peak Energy data for the energy service provider. The use water total check box should be used if total flow values are required for data analysis, in almost all cases this box should be checked. Total flow values were discussed in the water and flow processing section above.

After adding the agency to the database, you must add a minimum of one sub-division to the agency sub division table. Each sub-division is assigned two identifying numbers, the index table number and the agency region number. The index table number is used to assign flow meters to an agency sub-division and must be unique to the table, while the agency region number must be unique within the region. The agency identification number should be added to each sub-division added.

The energy meter index table contains all pertinent information for each agencies energy meters. Each meter must have a unique meter identifier, which can be a number, text, or any combination of the two. The items required for data analysis are the meter type, the facility code, the energy service provider, and the agency. The meter type correlates to the type of data

that are received for the meter and tells the database which processing routine to use. The facility code is required to assign the meter to a system component, this important for load profile and energy intensity analysis. The energy service provider is required so the system can look up the proper seasonal and hourly classifications for the meter and date that is being analyzed. The agency identification number is also required for each meter.

The flow meter index table contains all pertinent information about an agency's flow meters. Each record added to this table must have a unique flow meter identifier, associated agency, agency sub-division, and associated energy meter. The flow meter identification can be a number, text, or combination of the two. The agency identification number is used to assign the flow meter to an agency. The agency sub-division number is used to assign the flow meter to a sub-division, the number unique to the sub-division table must be used here not the number unique to the agency. The energy meter number field is used to link energy data to the flow for data processing.

The monthly energy data table contains the data for three of the four meter types. The table is setup to handle daily, monthly, or yearly billing information from the energy provider. Each record added to this table must have the energy meter number, meter read date, and number of days billed. The billing information available will dictate the other necessary information. For KWH type meters the billed kwh total should be added to the kWh total field. DEM type meters should provide the kWh total and the created and billed demand. Data for TOU type meters should provide on-peak, partial peak, and off-peak energy and demand numbers for the billing period.

The interval data table contains the data for the fourth meter type (INT). These data are usually available in electronic format from the energy service provider. Each record added to the table must have the energy meter number, the date, 24 hourly energy values, and 24 hourly demand values.

The flow data table contains the flow data associated with each flow meter. Flow data for the database must be in daily time-step. Distribution of monthly flow data was discussed in the water and energy processing section.

The total flow data table contains the daily total flow data for system facilities types. It can also hold an agency flow total that is used for determining the water demand day types. The flow meter identification string for total flow data must start with the agency code and finish with the appropriate suffix.

After new data is correctly imported, users should select the Base Data option in Step 1 of the GUI and the name of the new Agency in Step 2 and press the Execute button. This will process all the new imported data to allow it to be queried by the Load Profile and Energy Intensity features.

C.11 Database Field and Data Descriptions

Table C-11. Energy Service Providers Index (tbl_Elec_Priv)

Field Name	Data Type	Maximum Field Size	Notes
Esp_ID	Autonumber	Long Integer	This field contains the identifying number for each energy service provider. This field is the key for this table. The autonumber data type means that when a new record is added the database will automatically insert the next number in sequence.
Esp_Name	Text	50	This field contains the name or description of the energy service provider.
Esp_Symbol	Text	10	This field contains an acronym for the energy service provider.
Esp_PeakDate	Date/Time	-	This field contains the peak energy demand day that is associated with each energy service provider. The date was supplied by the IOU.
Esp_Summer	Date/Time	-	This field contains the date that starts the energy service provider's summer season.
Esp_Winter	Date/Time	-	This field contains the date that starts the energy service provider's winter season.

Table C-12. Agency Index (tbl_Agency)

Field Name	Data Type	Maximum Field Size	Notes
Adl_ID	Number	Long Integer	This field contains the identifying number associated with each agency. This field is the Primary Key for the table and must be a unique number. It used to associate system facilities with to an agency.
Adl_Name	Text	255	This field contains the name of the agency.
Adl_Code	Text	10	This field is an acronym or identifying text code for the agency. This field is used in the data processing to identify total flow values.
Adl_Location	Text	255	This Field contains some location or description information for the agency.
Adl_Type	Text	255	This field contains information on what type water services the agency provides.
Shd_ID	Number	Long Integer	Hydrologic region number. Links the agency to a hydrologic region. The number must correlate with the Primary Key of tbl_Hyd_reg.
Esp_ID	Number	Long Integer	Energy Service Provider ID number.
Srn_ID	Number	Long Integer	Study Region Number.
Adl_UseWatTot	Yes/no	-	This field must be selected if total water numbers will be used in processing.

Table C-13. Agency Sub-divisions (tbl_Dist_Region)

Field Name	Data Type	Maximum Field Size	Notes
Drn_ID	AutoNumber	Long Integer	Unique number used to identify each sub-division.
Drn_Num	Number	Long Integer	Agency Specific identifying number.
Drn_Desc	Text	255	Brief description of the sub-division
Adl_ID	Number	Long Integer	Number associated with agency of the sub-division

Table C-14. Energy Meter Index (tbl_Emeter)

Field Name	Data Type	Maximum Field Size	Notes
Emi_Num	Text	25	Unique Identifying Meter Number. This field is the primary Key for the table.
Emt_Code	Text	3	Field is linked to tbl_Emeter_Type. The meter type is assigned based on the type of data available for the meter. There are four options; KWH, DEM, TOU, and INT.
Fac_Code	Text	10	Field is linked to tbl_Fclty_Type. This field is used to assign the meter to a facility type. There are 11 options; GWATER, PSBOOST, PSRAW, PSRECYC, PSWW, WDADMIN, WFILTER, WIMPORT, WINTAKE, WPRESSURE, and WWTREAT
Esp_ID	Number	Long Integer	Field is linked to the Energy Service Provider Index table. Must contain the number associated with the energy service provider for the meter.
Emi_Tariff	Text	25	Contains the tariff for the meter.
Emi_Address	Text	255	Contains a description for the meter. Actual data does not contain physical addresses of system facilities.
Emi_Climate_Zone	Number	Long Integer	Linked to tbl_Climate. Contains the number associated with the DEER Climate Zone of the meter
Adl_ID	Number	Long Integer	Number associated with agency of the sub-division

Table C-15. Flow Meter Index (tbl_Fmeter)

Field Name	Data Type	Maximum Field Size	Notes
Fmi_Num	Text	25	Unique number or string of text that identifies the flow meter.
Fmi_Location	Text	255	Brief description of the flow meter's use and location. Data does not contain physical addresses of system facilities.
Drn_ID	Number	Long Integer	Linked to tbl_Dist_region. Assigns the flow meter to an agency sub-division.
Emi_Num	Text	25	Linked to tbl_Emeter. Associates Energy and flow data.
Adl_ID	Number	Long Integer	Linked to tbl_Agency. Assigns the flow meter to an agency.
Imp_Num	Number	Long Integer	Linked to tbl_ImpFac. Assigns the flow meter to an import source. Used to add embedded energy to flow through the facility. Functionality has been removed from data processing.

Table C-16. Total Flow Meter ID's

Facility Code	Suffix	Notes
GWATER	GW	This facility type is used for groundwater production or injection wells.
WFILTER	FP	This facility type is used for treatment plants. Total flow is may be required if data for individual components of a treatment plant are received.
PSBOOST	BP	This facility type indicates any pumps in a distribution system.
PSRAW	RAW	This facility type indicates raw water pumps that draw raw water from a surface supply or move water to a treatment plant.
WWTREAT	WW	This facility type is used for wastewater treatment plants. Total flow is may be required if data for individual components of a treatment plant are received.
PSWW	WS	This facility type is used for pumps that move water to wastewater treatment plants.
PSRECYC	WP	This facility type is used for recycled water distribution pumps.

Table C-17. Monthly Energy Data (tbl_Elec_Mtr_Data)

Field Name	Data Type	Maximum Field Size	Notes
Emi_Num	Text	25	Linked to tbl_Emeter. Assigns energy records to a meter
Emd_Date	Date/Time	-	Meter read date.
Emd_Days_Billed	Number	Long Integer	Number of days in the billing period.
Emd_Kwh_On	Number	Double	On-peak Energy Value
Emd_kwh_Partial	Number	Double	Partial Peak Energy Value
Emd_kwh_Off	Number	Double	Off-peak energy value
Emd_kwh_Total	Number	Double	Total energy value. Used for energy only meters and to check time of uses energy.
Emd_kw_On	Number	Double	On-peak demand value
Emd_kw_Partial	Number	Double	Partial peak demand value
Emd_kw_Off	Number	Double	Off-peak demand value
Emd_Dem_Created	Number	Double	Maximum demand. Information for DEM meters
Emd_Dem_Billed	Number	Double	Actual demand billed. Information for DEM meters only.
Emd_therms	Number	Double	Gas meter usage.

Table C-18. Interval Data (tbl_Emtr_Int)

Field Name	Data Type	Maximum Field Size	Notes
Emi_Num	Text	25	Linked to tbl_Emeter. Assigns energy records to a meter.
Int_Date	Date/Time	-	Date of records.
Int_100 - int_2400	Number	Double	Hourly energy values.
Int_kw_100 – int_kw_2400	Number	Double	Hourly demand values

Table C-19. Flow Data (tbl_Flw_Mtr_Data)

Field Name	Data Type	Maximum Field Size	Notes
Fmi_Num	Text	25	Linked to tbl_Fmeter. Assigns flow records to a flow meter.
Fmd_Date	Date/Time	-	Date of record.
Fmd_Flow	Number	Double	Daily flow

Table D-10: Total Flow Data (tbl_Flw_Mtr_Data2)

Field Name	Data Type	Maximum Field Size	Notes
Fmi_Num	Text	25	Linked to tbl_Fmeter. Assigns flow records to a flow meter.
Fmd_Date	Date/Time	-	Date of record.
Fmd_Flow	Number	Double	Daily flow