



**The  
California  
State  
University**  
Office of the Chancellor

# **Energy Metering For Utilities Management**

## Energy Metering for Utilities Management

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## 1.0 INTRODUCTION

The purpose of this Guide is to assist CSU campuses in how to collect and store metering data and how to analyze and visualize the data to improve energy efficiency and operations.

This Guide is the second of a two part series. This part covers:

- Sources of energy data and data acquisition.
- Management of Energy Data.
- Generating Reports from Data and Data Analysis.
- Using Data to Monitor, Manage, and Forecast Energy Use.

The companion to this guide is the CSU Metering Guide. The CSU Metering Guide covers utilities that should be metered, the devices that can be used for metering, and how the devices can be commissioned and calibrated to ensure accurate data.

## 2.0 SOURCES OF ENERGY DATA AND DATA ACQUISITION

### 2.1 Metering Devices

Metering devices should be intelligent micro-processor based controlled assemblies. The metering device should be capable of receiving the signal, data, or other inputs and communicating the accumulated data and information to building management systems (BMS) and centralized campus, web-based or system wide utility monitoring systems. Meters should use an Open Data Base Connectivity (ODBC) standard data base access method to make it possible for any database management system to access the data.

Each device should be able to store data for future acquisition and use. Data storage capacity should be specified based on the parameters to be recorded, duration that data will accumulate before downloading registers, number of programmed parameters, intervals, and event capture requirements. Metering device data storage capacity should be specified to exceed the polling time intervals and transfer of data to an external data storage device. Meters should have the capability to communicate and transmit information to a central data through a computer or server to a hard drive or other storage device for long term storage. Use of revenue-grade meters is recommended, especially for instances where billing or accounting for utility use is required. Metering device data storage and memory should be non-volatile and unaffected by loss of power.

For more information on typical metering devices, consult the CSU Metering Guide at [www.calstate.edu/CPDC/ae/gsf/guidelines.shtml](http://www.calstate.edu/CPDC/ae/gsf/guidelines.shtml). The CSU Metering Guide covers campus utilities that should be metered, the devices that can be used for metering, and how the devices can be commissioned and calibrated to ensure accurate data measurement.

### 2.2 Input and Submetering KYZ Pulse

When selecting a meter, consideration should be given to use of the meter to accumulate and transfer data from other utility meters to a PC Server or external storage device. For instance, a gas or water meter may be fitted with a pulse output accumulator to measure flow. The device used to measure flow produces a KYZ pulse output that can be read and measured by another building meter such as the power meter. The microprocessor based power meter can be programmed with any energy parameter and pulse value. The data is stored and accumulated in the power meter on a dedicated meter register and then transmitted with all other data to the PC Server and storage device. In this arrangement, one building power meter is used to accumulate and transmit data for multiple building utility meters. This arrangement could reduce the costs to install a building utility metering system.

## 2.3 Equipment Controls

Metering devices may also include control functions to provide supervisory control to initiate energy savings programs such as demand side management, load curtailment, operation and dispatch of distributed generation, and building or campus wide utility measurement. For example, to perform load curtailment the meter may send an output command directly or through an EMS interface to an air handling unit controller and a lighting control panel.

Metering devices used for supervisory control applications must be equipped with input and output terminals to receive or send signals to or from the equipment being controlled. The input or output may include communications protocols such as BACnet, MODBUS, Lonworks, contact closure, digital input/output or variable signal. The metering device may be required to be programmable to initiate a control for a pre-determined set point.

## 2.4 Energy Management Controls

Metering devices should be specified as open and non-proprietary for interoperability with third party energy management (EMS) and building management systems (BMS) as well as web-based controls. The EMS or BMS controller should be verified to be compatible with a metering device before the metering device is specified. Consult with both the meter manufacturer and energy management software publisher to confirm compatibility between the meter and software. Verify that database drivers exist for each meter/software application.

The specifier should understand EMS data requirements and limitations such as what data, data format and number of parameters the EMS can support. A BMS/EMS will make determinations regarding energy usage from the data received. Lighting and HVAC loads, if connected to the BMS/EMS, can be adjusted according to present usage, time of day, inside and outside air temperature, humidity, and demand response commands. Meters perform a vital and important function to the decisions made by the EMS, campus personnel, or third party service providers.

The metering system as a whole should be expandable and able to support a large quantity of meters without the need for extensive system upgrades, reprogramming or reconfiguration of the metering system.

## 2.5 Data Communication Protocol

Interoperability issues include communication protocols such as Ethernet TCP/IP, BACnet, ModBus, Profibus, Lonworks, as well as modem and signal converters. Meter communication protocols must be interoperable with EMS,

BMS and utility management programs. Communication data transfer rates must be supported by the cabling systems and data acquisition servers. Protocols should be object-oriented rather than flat, register-oriented where possible.

### **2.6 Device, Equipment and Control Software**

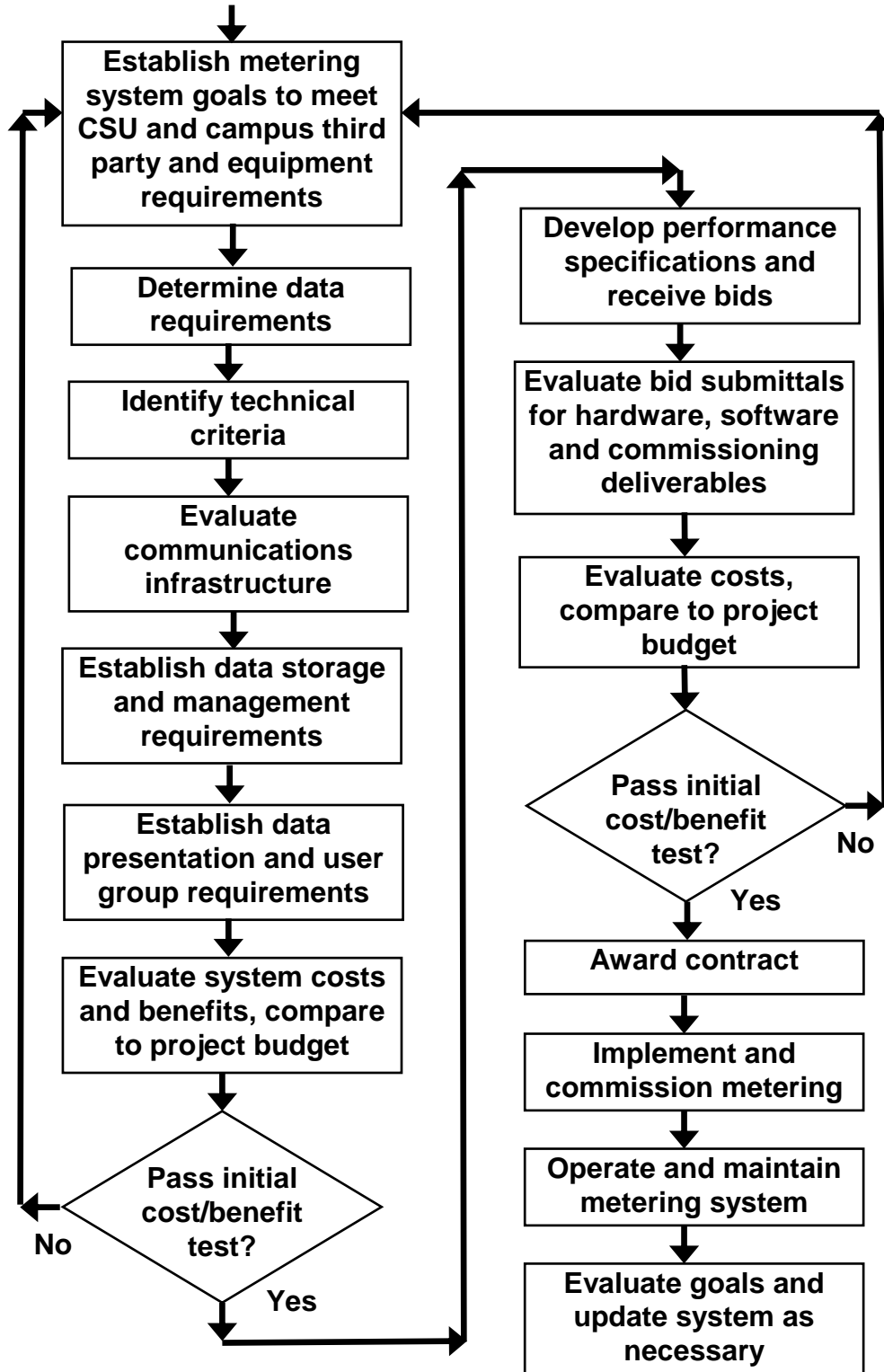
#### **2.6.1 Proprietary Software**

Programmable electronic metering devices will usually require software provided by the original manufacturer to access and read data. The software can be loaded on the meter, on a host personal computer, or on a server. Proprietary software is typically limited for use with the metering device(s) it is written for and may not be compatible with other devices, software or operating systems. Programming of meters will require use of a portable computer, device communications port, and may also require proprietary hardware, cables and connectors.

#### **2.6.2 Third Party Software**

Third party software is available to access and read meter data, and initiate supervisory controls. Standard protocols for metering devices, operating equipment and supervisory controls must be compatible for proper system operation. Information integration requires the selection and use of standard protocols within a building and preferably throughout the campus. The software should be written around open standards and web technologies and run on major operating systems. The software should also support commonly used data bases, support data exchange, support communication to field controllers and their web appliances. The software should support scheduling, alarms, trending, reporting and graphing applications.

2.7 Recommended Development Process for a Metering System



## **3.0 DATA MANAGEMENT AND STORAGE**

### **3.1 Central Data Server**

Metering device data must be stored for future reference and reporting. Metering devices have limited data storage capacity and will overwrite or stop recording data when the data registers are full. Data is lost with either outcome. Data from a meter can be uploaded to an EMS or BMS controller or to a central data server or web-based service. Information that is uploaded from a meter to server requires a data highway and also client-server architecture with compatible software and operating system between the server and meter or BMS/EMS.

### **3.2 Data Management**

Management of data for billing and planning purposes can be performed in-house by university staff, or by a third-party energy management provider. In-house management of data will require additional storage devices within a campus data center, or other location with uninterruptable power, to store accumulated data. Servers may require server-side data acquisition and energy management software, which may require periodic licensing fees. Reports of energy usage can be created for billing and planning purposes. Most manufacturers of revenue grade meters publish a software suite to support communications, billing, data analysis, energy management, graphics, and server operation.

Either the campus personnel or third-party providers will need to manage data acquisition and to be able to produce reports for utility billing, monitor energy efficiency of metered systems, and provide data for planning and audit purposes. The campus or third-party provider is responsible to collect, store and manage the data which can be made available to campus personnel and other interested parties through password protected access.

Whether a third-party or campus solution is selected, consideration must be given to data security and integrity. In-house campus systems must be audited regularly to avoid the risk of intruders compromising servers and systems. It is recommended that third-party providers submit guarantees of data confidentiality and security. It is also recommended that the contract between the campus and the third-party includes a provision that the data collected becomes the property of the campus upon termination of the contract or at any time the campus wishes to provide access to the data by third-parties. Third-party data base applications should use ODBC protocols.

Web-based data management for data acquisition, storage, and reporting is a viable option for data management, storage and presentation. The web-based

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service is capable of combining content from many different sources. Web services must have the capability to store and manage massive amounts of data in multiple directories for retrieval and use. If a web-based services architecture is being considered for utility data management, the information exchange protocols, such as XML (eXtensible Modeling Language) or SOAP (Simple Objective Access Protocol) must be supported by the BMS, EMS and metering devices.

## 4.0 DATA REPORTING AND ANALYSIS FOR ENERGY MANAGEMENT

After meters have been installed and tested to confirm their accuracy, the data collected from the meters can be reported in numerous ways. This section introduces examples of data reporting and graphing in order to identify utility saving and resource usage reduction opportunities. Refer to the Building Metering Guide for utilities and systems that should be metered.

### 4.1 Display of Energy Use

Data should be displayed graphically at user-selected intervals, including hourly, daily, weekly, and yearly. Shorter time intervals may also be desired or needed when evaluating data to detect operational problems. Power system harmonics and line distribution or faults are typical examples of where sub-cycle data is required. A meter with a fast sample rate must be specified for all applications where sub-cycle data is required.

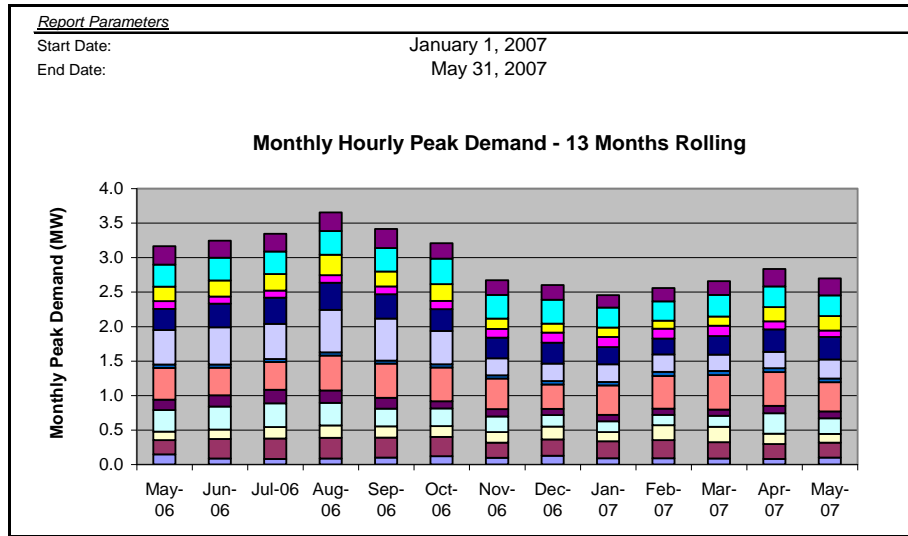
Whenever possible, meters should include an internal or external digital display to show measured values in real-time, as well as historical peaks in demand. A display will greatly enhance operations by allowing an operator to easily read data. As a cost saving measure, it is also feasible to purchase a limited quantity of external Human Machine Interface (HMI) display modules from meter manufacturers that can be used by field technicians and staff to “read” data locally from a black box or transducer-type devices.

### 4.2 Graphic Comparison of Energy Use

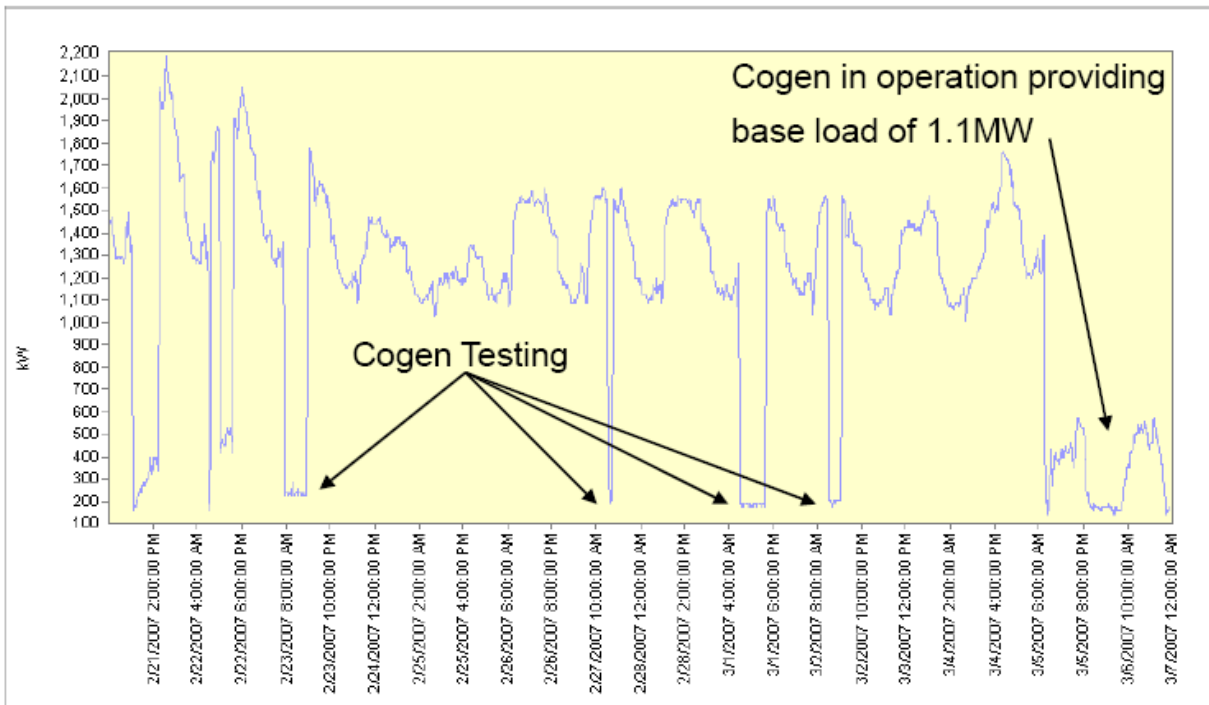
- **Campus**

Metering software should be capable of displaying data in various formats in order to meet the needs of various campus personnel (facilities management, facilities planning, energy manager, etc.). Examples of various data graphical formats are shown below.

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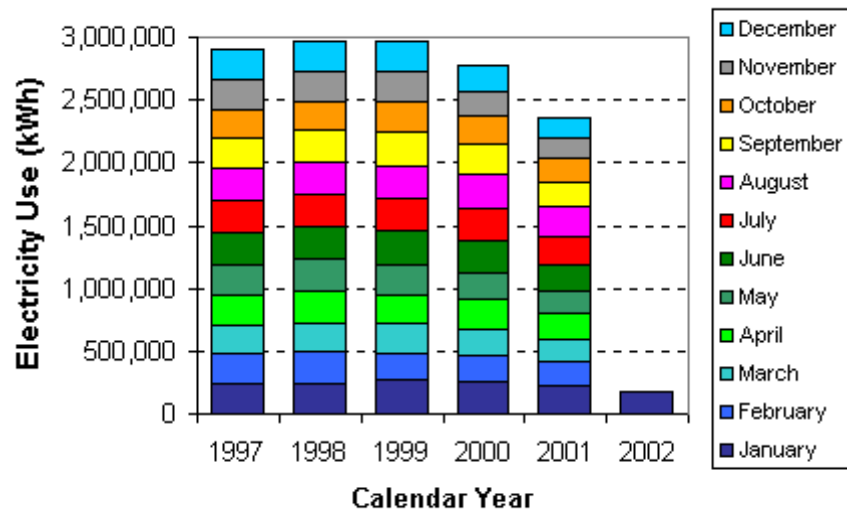


Stacked Bar Graph of Monthly Hourly Peak Demand-colors represent various campus buildings



Line graph of Utility import meter to display campus energy demand versus time-of-day to show reduction in purchased power to a “minimum import value” during cogeneration system testing and operation

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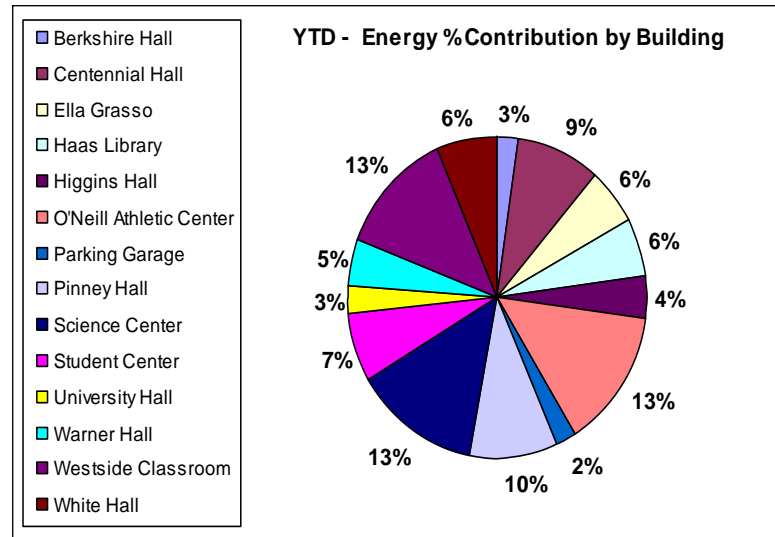
Stacked Bar Graph for Trend Analysis Comparison of Building Monthly Energy Consumption

### 4.3 Pie Chart Graphic Display of Campus Energy Use

Metering and energy management software should be able to make comparisons of energy usage based on baseline and future building growth, climate zones or daily high/low air temperatures, and building types.

The pie chart below is an example of a comparison of energy usage by building occupancy. Graphic presentation of data allows for quick visual recognition of where the most energy is being consumed on campus. When evaluating buildings for energy savings opportunities, this type of graphic is effective in identifying the best candidates.

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Pie Chart of Energy Usage by Building Type

- **Aggregate Load Profile Graphic**

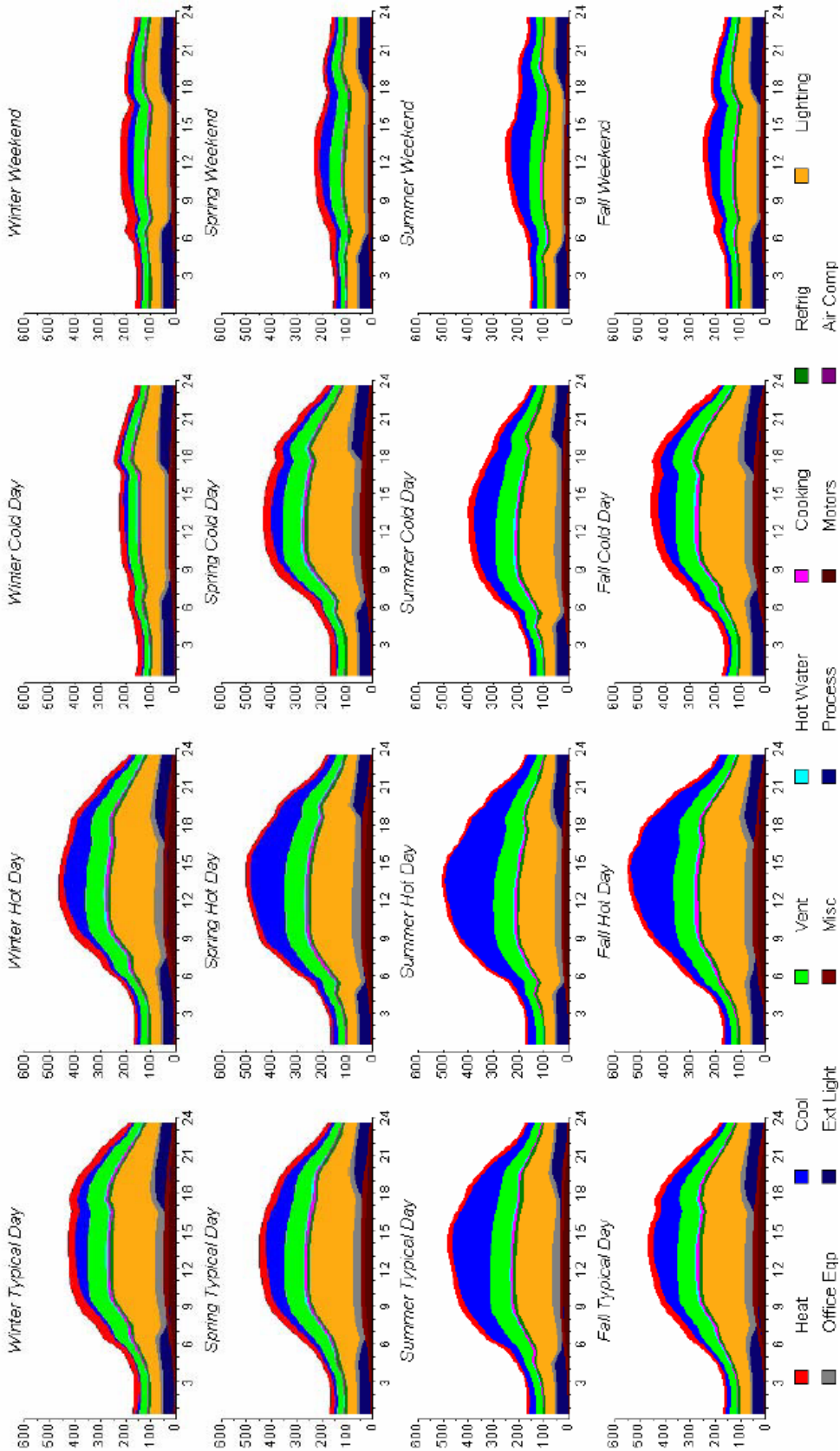
Equipment and system energy use within each building can be compared against national and state analyses of energy usage. The California Commercial End-Use Survey performed by the California Energy Commission offers data on energy usage for a college campus based on such parameters as time of day, season, and equipment (lighting, office machines, heating, cooling).

The survey included only areas serviced by Pacific Gas & Electric, Sacramento Municipal Utility District, Southern California Edison, and San Diego Gas & Electric. The following figure presents estimated aggregate energy usage for college campuses for sixteen 24-hour periods in each season. Energy usage by season as well as usage by type of equipment is shown.

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Segment Level Results  
 Analysis Year: 2002, Date: 12/21/2005

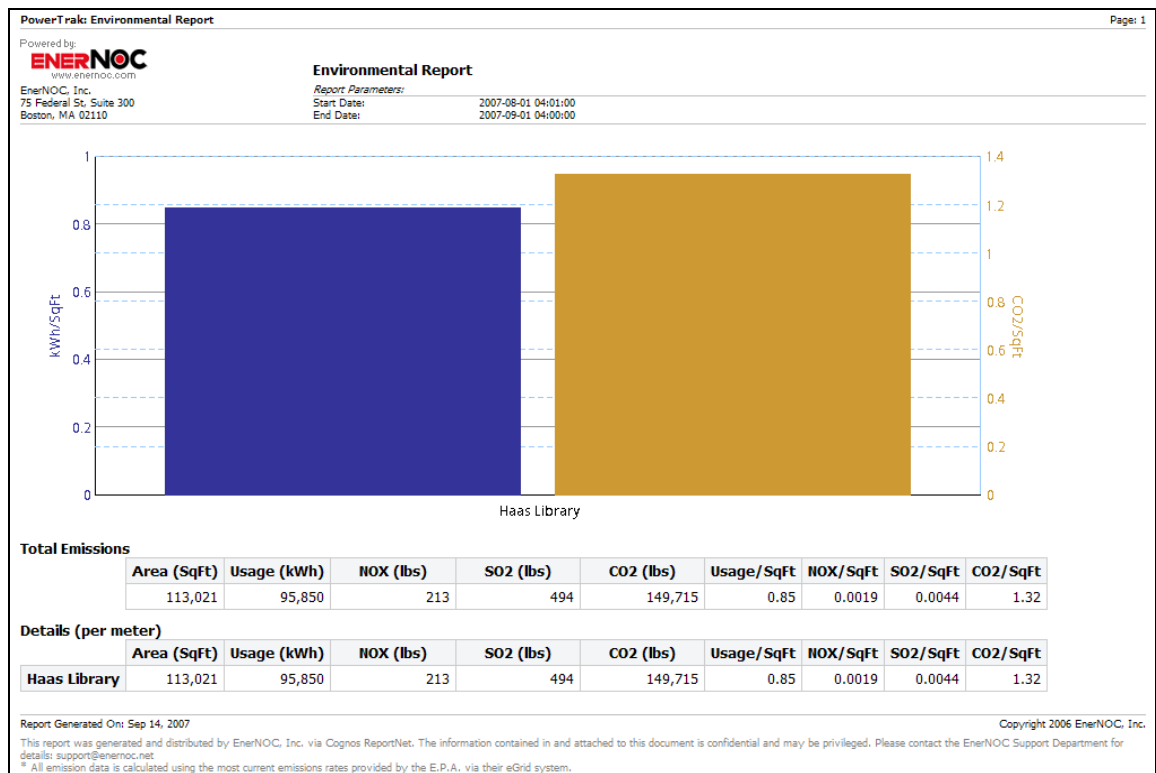
CA\_COLL - College  
 16-day End Use for Electric (MW)



Estimated Seasonal Aggregate Load for California College Campuses – 2002 Estimate

#### 4.4 Environmental Reports

A primary goal of campus energy management should include establishing a carbon (CO<sub>2</sub>) emission baseline measurement that can be used to document and show compliance in reducing the campus carbon footprint over time. Reports of building and campus energy usage can be combined with regional power generation emissions statistics, as reported directly from the Environmental Protection Agency (eGrid) as well as “power content” reports available from California utilities, to develop reports for campus facilities based on the amount of energy consumed and carbon produced. Buildings or certain facilities with a high carbon footprint can be readily identified and measures can then be taken to improve energy efficiency.



Sample Environmental Report for a library based on energy usage

#### 4.5 Variance Reports

Software selected for creation of metered data reports should be able to produce variance reports without extensive reformatting of data. Variance reports should include estimated energy usage and power demand, actual metered energy usage and demand, and variance for any user-selected time period and parameters.

#### **4.6 Cost Allocation Reports**

The metering system software should be able to produce cost allocation reports for purposes of accounting for cost allocation of energy use by non-state funded buildings. Each non-state funded building on the campus, such as housing, student union, recreation and dining facilities, should be metered with revenue-grade equipment in order to provide maximum accuracy and flexibility of data reporting. Reports should include total usage and maximum demand for each utility supplied during the billing period. Reports should be able to categorize metered data based on time-of-use periods in order to encourage energy usage during off-peak periods and implementation of energy saving and demand side management programs.

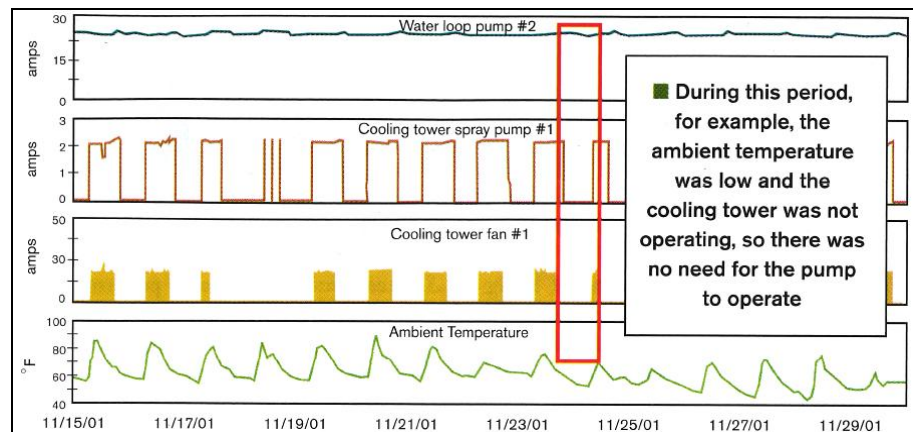
#### **4.7 Use of Meters to Identify Energy Savings**

- **Equipment Energy Use**

Equipment energy usage can be measured and graphed or displayed to show operating trends. When graphs of energy usage are plotted against time, it is possible to identify energy saving opportunities. This is accomplished by observing equipment operating hours based on energy consumption. In the example below, (see figure 4.3.1) a cooling tower pump (water Loop Pump #2), was shown to be running when the associated cooling tower was shut down and the subject building was unoccupied. In this example, the motor currents are plotted versus time-of-day to identify the energy saving opportunity.

The cost to identify the energy saving opportunity largely consists of the time to plot the data, analyze the data and then reprogram the building energy management control system. The payback for this effort can be a matter of days or weeks due to the low implementation costs.

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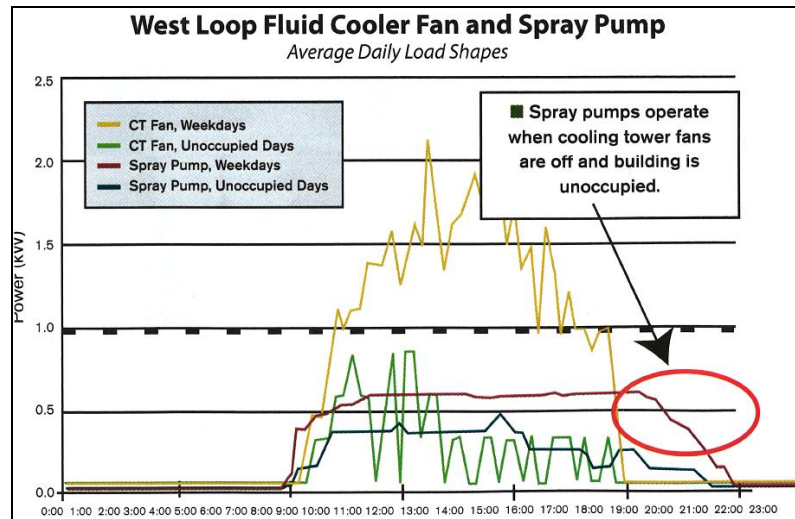
\*Figure 4.3.1

Example: Water Loop Pump in operation when cooling tower is off-line.

- **System Energy Use**

In the previous equipment example, a water loop pump was identified to be running when it should have been shut down. In this example of a system, (see figure 4.3.2) the cooling tower fans and spray pumps energy consumption (kW) plots are overlaid to show that the spray pumps continue to operate when the building is unoccupied. The spray pumps in this system should be shut down when the cooling tower fans are off. In this example, the EMS is reprogrammed to shut down the pumps when the building is not occupied, including holidays.

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\*Reprinted from Sustainable Facility Magazine

\*Figure 4.3.2

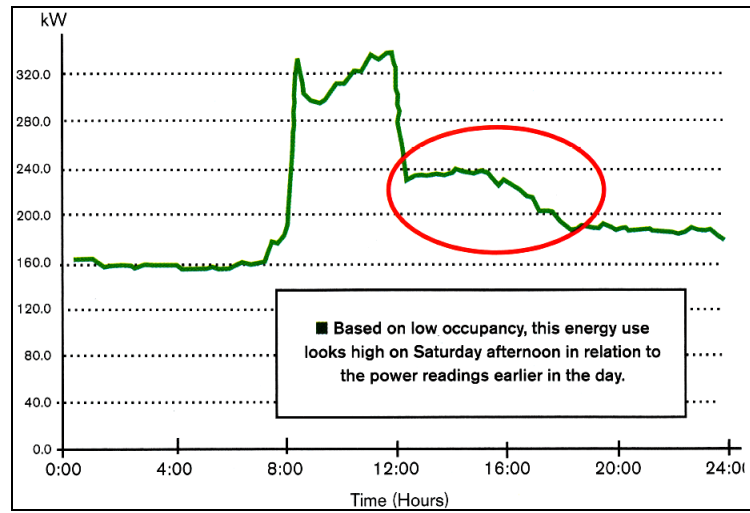
Example: Spray pump operation identified during periods when building is unoccupied and cooling tower fans are off.

- **Whole Building Energy Use**

The two previous examples of equipment and system operation identified excess energy use as a result of graphic analysis. A plot of the building electric power consumption versus days-of-the-week is shown below (see figure 4.3.3). Energy savings opportunities can also be identified by analyzing whole building energy use. Figure 4.3.3 shows the building load at a relatively high level when the building is unoccupied. This type of observation should lead to an analysis of building system and equipment loads to identify energy saving opportunities. In this example, the building conditioning and lighting system operation is modified through the EMS to reduce energy use on weekends and holidays.

In addition, comparison of previous records for the same building may show an unexpected increase in energy use, pointing to an operations or equipment issue requiring correction. The use of building benchmark data is also useful to understand if a building is using more or less energy than a comparable building with similar occupancy for a similar climate zone.

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\*Reprinted from Sustainable Facility Magazine

\*Figure 4.3.3

Example: Plot of energy use versus time and day-of-the-week reveals high energy use when building is unoccupied.

## 5.0 ENERGY MANAGEMENT

### 5.1 Analysis of Energy Consumption

- **Baseline Comparison**

Metering of utilities at the building level enables the establishment of building baseline conditions. A snapshot of energy use can be generated from the archived data to establish a baseline condition. The baseline data is then compared to real-time measurements when implementing a retro-based commissioning project (RBCx), monitoring based commissioning (MBCx), or other energy savings project such as a lighting replacement project or mechanical systems upgrade.

- **System Optimization**

Metering of all utilities can provide data needed to make decisions for demand reduction while minimizing the impact on the campus. For example, metering of building total energy and mechanical HVAC systems energy use may uncover opportunities for reduced operation of chillers while maintaining building ambient air temperatures at a comfortable range.

- **Trend Analysis**

Storage of data collected by meters will facilitate trend analysis, including weekly, monthly, or yearly trends in energy usage. Future building additions or renovations occurring on the campus can be analyzed using data collected to estimate future utility consumption when planning for utility expenditures in future budget years.

- **Monitoring Based Commissioning (MBCx)**

Reports generated by metered data should be configured in such a way as to aid MBCx efforts. Time-of-day, day-of-week, and monthly reports should be generated to ensure system changes implemented as part of the MBCx process are functioning as intended. Confirmation of reductions in energy use by new or modified system operation should be easily verified by data reported from the meters.

- **Utility Billing Validation**

Incoming utility services should be metered with campus owned revenue-grade equipment in order to provide the capability to validate utility metering and billing of usage.

Data gathered from campus meters placed at main utility service entrances should be able to be formatted in such a way to facilitate comparison against utility billing reports. Utility billing reports should include usage periods that match the utility's time-of-use period. Any discrepancies between the campus and utility meter should be easily recognizable to facilitate resolution.

## 5.2 Forecasting Energy Demand and Cost

- **Demand Side Management Control**

Meters that are in communication with the campus EMS can provide feedback in response to demand side management programs. For example, the building EMS controller may issue a command to reduce interior lighting energy usage by 20% through use of daylighting, occupancy, and scheduling controls. Building electrical meters can provide real-time measurements to the EMS controller as feedback, to ensure the goal of a reduction in energy usage is met. This is critical to the success of Utility sponsored load curtailment programs. In some cases, the load curtailment request may come directly from the utility.

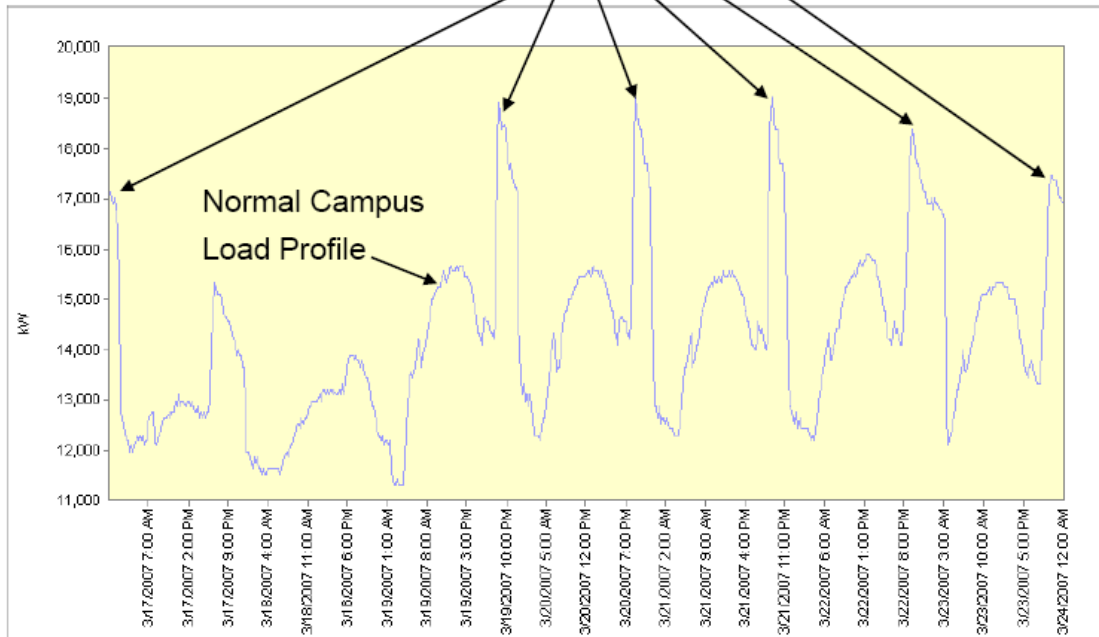
- **Peak Demand Control**

Use of campus wide metering will aid in management and limitation of electrical peak demand. Large electrical loads such as chillers can be operated during off-peak time intervals in combination with thermal energy storage tanks to minimize energy costs. Real time metering applications can be implemented to manage energy use and cost through algorithms that consider utility pricing, hourly temperature and humidity, hourly solar and wind profiles, operating costs, physical generating and load reduction assets available, and many other factors.

The graph below is an example of controlling peak demand. The 6MW of chiller electrical load is scheduled to be in operation between 9 PM and 6 AM. Electrical metering placed at both the chiller service and campus utility service will enable personnel to monitor the chiller operation and the effect of the additional load on the overall campus demand. Understanding campus electric power load profiles will assist energy managers in implementing demand side management programs with realistic objectives.

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Operation of 6MW of campus chiller load during off peak hours for thermal energy storage



- **Cost Control and Budgeting**

Implementing demand side and peak management controls will assist in the utility cost containment. Metering can identify loads that could be shut down when buildings are unoccupied. Metering of individual buildings will identify areas for improvement regarding energy efficiency. If a building is found to have higher energy usage than buildings with similar age, climate zone, and function, the cause of the higher energy usage and potential energy savings can be identified. Analysis of energy use reports will aid in identifying areas for improvement in energy efficiency and reprogramming of EMS load control.

- **Forecast Energy Costs and Generation**

The metering system should have the capability to produce reports displaying hourly, daily, weekly, monthly, and yearly energy usage. Data can then be sorted according to time-of-use periods used by the utility. With accurate meter records sorted by utility time-of-use periods, energy costs can be forecasted according to the various time-of-use utility rates.

The cost impact of changes in utility time-of-use rates can be calculated based on present energy usage gathered from the metering system. The addition of new building loads can be modeled. The installation of renewable energy sources such as photo-voltaic, wind energy or bio-mass generation and their impact to reduce utility energy purchases can be modeled as well. The size and operation of the renewable sources of

power can be modeled to optimize their payback and reduction in utility energy purchases. Another important issue is to understand the impact of new renewable generation sources on the existing campus electrical system. Valid meter data for switchgear, feeders, and buildings will allow for accurate load flow modeling to assure all system components are properly rated for all conditions of operation.

- **Utility Purchase Agreements**

Metering of all campus utilities will enable the campus to forecast future energy usage and demand for long-term purchase agreements. Accurate metering of utilities will avoid under-utilization of contracted energy, or expensive overage charges where estimates are below actual usage. Use of metered data to calculate net energy purchases resulting from a renewable energy project is essential when planning a project. The utility will require certain service equipment modifications depending on whether or not the campus will export any power to the grid.

### 5.3 Real Time Performance

- **Demand Response Measurement**

Demand Response programs offered by utilities can offer considerable savings to the campus. An effective and complete metering system for the campus is essential to ensure appropriate loads are reduced while minimizing the effect on the comfort of students and faculty. Once a command is sent from the utility to reduce demand, EMS controllers can make appropriate reductions in utility usage. Meters with real-time reporting of data can provide instantaneous feedback to the EMS controllers and campus energy personnel to ensure the required demand reduction mandate is achieved.

Several programs for demand curtailment are offered by the three California investor-owned utilities-Pacific Gas and Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E). The two most common programs are interruptible service and automated demand response programs.

The interruptible service program requires installation of an annunciator and dedicated telephone. When the utility issues a demand reduction mandate, the annunciator will sound an alarm, and/or the utility will call the dedicated telephone. The mandate must be acknowledged manually by personnel, and it is the responsibility of facilities personnel to reduce demand by a specified amount (e.g. 15%). Because there are no automatic controls in place, implementation of interruptible service programs are at a disadvantage compared to automatic methods of

demand reduction. The alarm or telephone must be supervised 24 hours a day, 7 days a week by personnel trained to acknowledge the alarm and implement immediate demand reduction procedures.

Automated demand response programs link the utility with the campus' EMS. An audit is first performed by utility personnel to identify specific demand reduction opportunities based on existing EMS controllers and controlled devices such as lighting and HVAC. A custom demand schedule is developed that is tailored to the EMS and the amount of demand that should be reduced. A predetermined schedule could include:

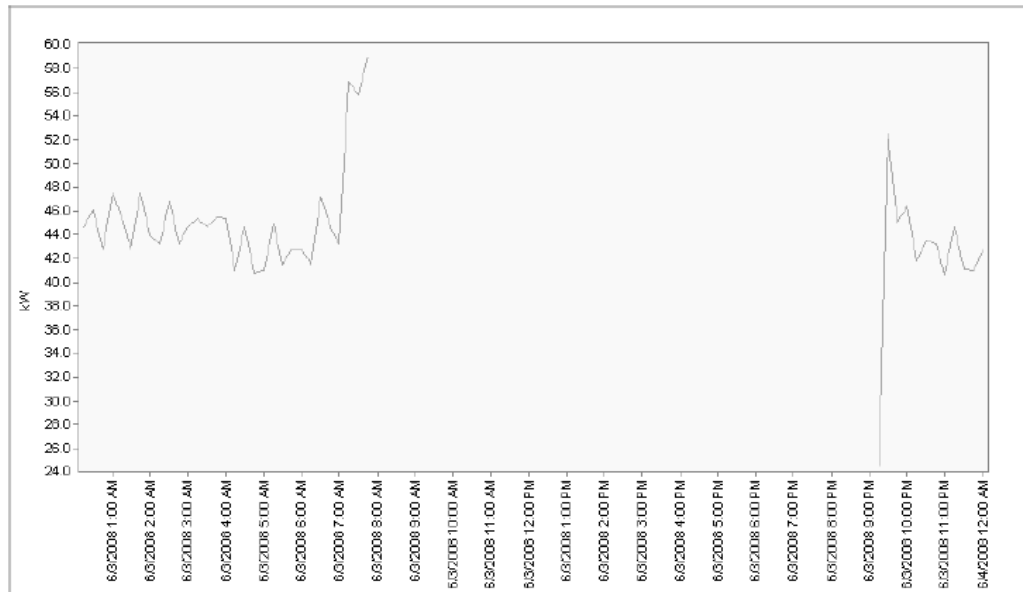
- Lighting reduction by dimming or switching off luminaires.
- Temperature increase in selected zones resulting in reduced cooling loads.
- Turn off non-essential pumps, such as irrigation, pool, and circulating pumps.

The utility then installs a control module that is connected to the Internet, and linked to the EMS controller(s). When the utility issues a demand reduction mandate, the mandate is sent via the Internet to the control module that commands the EMS to reduce load via the load reduction schedule that was developed during the audit. An automated demand response program offers flexibility in the amount of load curtailed, as well as the equipment or buildings included in the reduction of overall campus load. Since the load reduction is automatically performed by the EMS and utility control module, no personnel action is required beyond the initial utility audit and programming of the reduction schedule.

- **Threshold Alerts and Alarms**

Metering equipment should be configured to provide alarms regarding emergencies, such as a complete electrical outage of a building. The following graph illustrates metered data from a building that suffered a complete electrical outage. Immediately after receiving a zero reading from the meter, the EMS or metering software can notify campus facilities management via e-mail, pager, or other methods regarding the outage. Response time for maintenance personnel would be reduced. The system can send a second notification when power is restored. Facilities personnel would have accurate data regarding the time and duration of the outage. Individual building loads and critical systems can also be monitored in the same way. Water and gas meters should be capable of assisting with leak detection and should automatically sense and alarm for high flow conditions.

## Energy Metering for Utilities Management



Example of Power Outage Resulting in Notification/Alert

Metering devices and systems should be able to provide alerts in response to abnormal utility conditions, such as loss of power or flow, under/over voltage, or over/under frequency, low pressure, low flow, high or low temperature. Tolerances should be able to be user-selected. Real-time alerts of abnormal operating conditions will enable facilities management personnel to respond promptly, and will mitigate damage caused to equipment (e.g. motors) when operating under atypical conditions.

In addition, the metering system should be capable of generating a history report of past outages, either at the incoming utility or campus building level. Details such as the date and time of the outage beginning and end, as well as duration of the outage should be logged and included in an outage history report.

### 5.4 Smart Grid Application

The CSU is investigating the development of a Smart Grid that would involve all 23 CSU campuses. New advanced meters and energy use monitoring equipment known as “gateways” would be installed to capture real-time usage data from utility meters, building automation and control systems, and local generation resources. To develop the Smart Grid it will be necessary to meter and monitor every campus building and substation at each of the 23 CSU campuses. Data collected from the meters will be aggregated on a common energy management platform. The data that is collected can then be used to identify trends in energy use, perform demand-side management and monitoring-based commissioning at all CSU campuses, and provide

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information to each campus' facilities management to support energy efficiency in buildings. Real-time data will be used to identify outages or power quality issues.

The Smart Grid project will integrate metering systems, Enterprise Energy Information Systems, and campus information technology communication systems, both new and legacy systems, to a new Logic Terminal Unit (LTU). The LTU will provide two-way information exchange and control capability between each campus, Regional Utilities, the California Independent System Operator, Demand Response Aggregators, Energy Service Providers, and Monitoring Based Commissioning Service Providers. The LTU will integrate to new and legacy systems using open communication protocols currently available, including BACnet, LonWorks, Modbus/Modbus TCP/IP, and OPC.

A campus wide metering system network will facilitate the implementation of the Smart Grid data collection and control architecture. A campus wide metering system should be implemented to facilitate the development of the Smart Grid with particular attention to the use of open communication protocols. The Smart Grid will greatly enhance the effective use of metered data and improve the dispatch and operations of generation and loads. By specifying digital, networkable meters that use open communication protocols that are commonly in use in commercial applications, the integration of existing and new campus meters and LTU's into the data collection system will be greatly facilitated