DrCEUS: Energy and Demand Usage from Commercial On-Site Survey Data

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ABSTRACT

The California Energy Commission (Commission) is conducting on-site surveys of 3,000 commercial establishments throughout the service territories of the state's four investor owned utilities and one large municipal utility. This is a significant multi-year project that will provide data related to building characteristics, equipment operation and energy consumption. These data will be used for 1) the design, planning, measurement, and evaluation of energy efficiency initiatives; 2) development of energy end-use estimates and end-use load profiles by market segment; 3) input for the Commission's end-use forecasting models; and 4) development of a building energy demand analysis model (DrCEUS), which is capable of analyzing hourly energy use for user-defined market segments and hourly impacts of load management strategies and building standards.

This paper presents an overview of the study sample design, data collection efforts, DrCEUS model (input requirements and outputs), and describes the potential uses of the data resulting from this study.

Introduction

Over the past decade, the four major investor-owned utilities (IOUs) in California have undertaken commercial end-use surveys sporadically, using various survey methods and with varying levels of effort. Collecting these data is essential for supporting the evaluation of energy efficiency efforts in California. In particular, these data can be used to develop baseline shares of energy efficiency measures and practices, estimate end-use energy intensities, support the development of estimates of DSM potential and provide input assumptions for long-term end use forecasting needs. Viewed as a resource for these activities, the existing IOU-specific databases require considerable manipulation and application of simplifying assumptions in order to obtain a useful contemporaneous integrated database. Also needed is a single data processing and energy and demand simulation tool that translates these data into estimates of facility, segment, and system energy and demand usage.

This paper discusses the design and implementation of the commercial end-use survey, the development of an engineering simulation tool, the development of electric and natural gas end-use market profiles. Further, the paper will discuss how these data and simulation results can be used to support estimation of energy efficiency measure impacts as well as technical and economic potential for demand-side management,

Background and Study Approach

In response to the need for a commercial end-use survey, the California Energy Commission (CEC) was charged with implementing a statewide effort to collect data from buildings in the

commercial business sector using Public Goods Charges collected from California ratepayers. This effort involves on-site surveys of over 3,000 commercial facilities. The data collected will include detailed information relating to energy using equipment, business characteristics, operating schedules, and installation of energy efficient measures. The CEC also called for the development of a flexible building simulation tool to support the estimation of end-use load profiles as well as the evaluation of hourly impacts of energy efficiency measures, load management strategies, building standards, and other program policies. The tool, DrCEUS, is a site processing system that performs energy simulations using DOE 2.2 and the eQuest Quick Energy Simulation Tool. DrCEUS allows for easy weighting and aggregation of the site-level results via user-defined segments. Also designed into the system are procedures that allow for "what if..." scenarios, where energy efficiency measures can be substituted for installed equipment and results generated for comparison to baseline usage.

Data

Data for the CEUS sample frame were supplied by the three electric IOUs (Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric Company) and Sacramento Municipal District. These account level data were aggregated into just over 700,000 unique premises.[1] A modified stratified random sample was developed with a sample target of 3,000 completed surveys.[2] Stratification variables included utility service territory, CEC forecasting climate zones, building type and annual kWh usage.

The on-site surveys collect detailed information on premise characteristics. These characteristics include information on building shell (e.g. wall construction, window types and building orientation), energy using equipment features (e.g. equipment inventories, unit efficiencies and operating schedules), and business operating profiles. In addition, considerable effort was made to develop a survey instrument that adequately depicted the HVAC zoning schemes and activity areas used at each site. This was accomplished through the use of a component-based survey form and modeling approach that segments the premise into components and/or activity areas. Protocols for handling the surveying and simulation of multiple buildings and campus style buildings were also developed.

In addition to collecting information about building characteristics and operations, HVAC equipment and lighting were interval monitored for a minimum of two weeks in a subset of 1,000 premises. These data are used to inform and refine the HVAC and lighting simulations developed in DrCEUS, by offering insights into usage patterns for the monitored equipment.

As is the case for most detailed engineering simulation tools, DrCEUS requires detailed weather data. The development of the weather database represented a significant effort in this study. The major results of the weather analysis were detailed actual and normalized weather variables by representative weather station developed from the 16 CEC standards Climate zones.[3] The resulting set of weather stations represents 20 distinct zones across the state.

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[1] The sampling unit for this study is a "premise." A premise is defined as a collection of buildings and/or meters serving a unique customer at a specific location. Therefore, a premise may have several buildings occupied by the same customer, and each building may have several meters. Similarly, a premise may be a portion of a building such as one store in a strip mall, occupied by one customer and served by one meter.

[2] The sample was modified in the sense that a census was attempted for the 2% of buildings using the most annual kWh.

[3] For a discussion on the available data, weather normalization methodology and identification of representative weather stations see the CEC CEUS Weather Data report.

Building Simulation and Segmentation Tool – The DrCEUS System

The DrCEUS System is a building electric and gas energy use simulation tool that combines features of RER's SITEPRO software, eQUEST, and DOE-2.2. It also includes the ability to develop segment level profiles from the individual site-level data. Included in the system are error-checking procedures to debug common simulation problems and full color graphics to facilitate reporting of results at the site and segment levels. Input data are developed from site-level data, utility records, and other industry accepted sources. These input data include:

- **On-Site Survey Data.** Including building characteristics, equipment data, and operation schedules.
- **Technology Data Tables.** These tables provide default values when data are unavailable during data collection.
- **Weather Data.** DOE-2 actual and normal weather data.
- **Billing Data.** Utility billing data for electric and gas consumption, and electric demand.
- **Segment Weights.** Each site is assigned an expansion weight allowing for expansion to the population. These weights were developed when the sample was designed.

The DrCEUS System has two distinct modes of operation:

- **Site Processing Mode** entails the process used to create the calibrated premise-level building simulation models from the survey data. This mode can be run interactively, by single site, or in batch mode. It is also where measure assessment begins. In the site processor, measures are adjusted to represent the analysis goals and site-level results are generated for evaluation.
- **Segment Processing Mode** entails manipulation (i.e. expansion, aggregation, etc.) of the results from the calibrated models. In this mode segments are created by the user and viewed graphically or stored to Microsoft Excel Workbooks. The results can then be used for further analysis. It is in this mode that the user can aggregate results from any set of site-level data for the purposes of comparison.

Site Processing Mode

Figure 1 presents a flowchart of the DrCEUS site processing system. There are three major components of the site processing system, which are described briefly below.

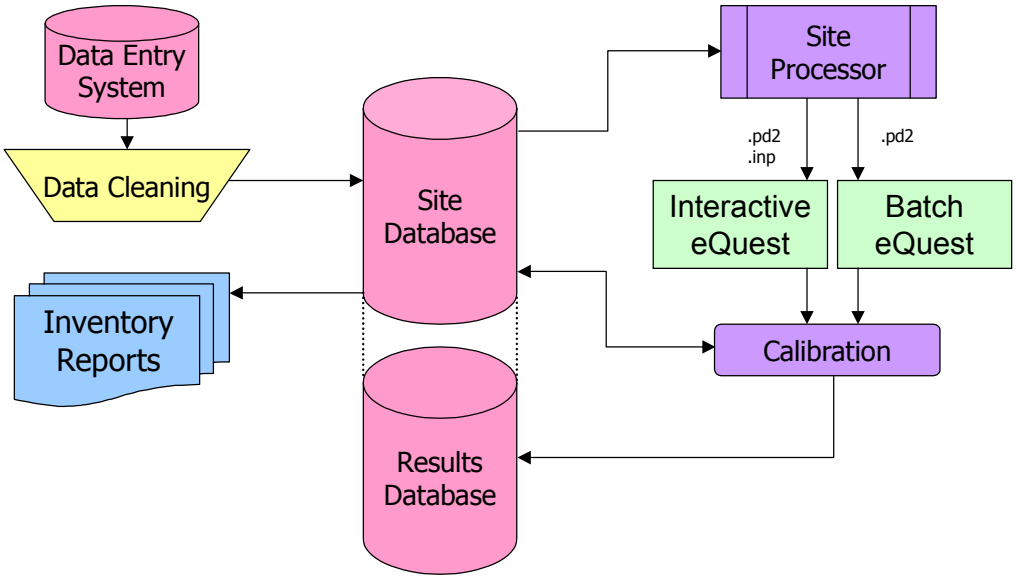


Figure 1: Site Processing Mode Flowchart

- **Survey Data Processing System** encompasses the Data Entry System, Data Cleaning, and Inventory Report elements on the left side of Figure 1. In this phase of processing, the survey data are entered, quality checked (QCed), and then printed in summary format.
- **Master (Site/Results) Database** encompasses the Site Database and Results Database elements in the middle of Figure 1. The concept is that all site data and simulation results are kept in a single "master" database.[4] These data are stored in a relational data management system (RDMS) and contain both the survey inputs after cleaning as well as the results from site processing.
- **Site Processing System** encompasses the Site Processor, Interactive eQUEST, Batch eQUEST, and Calibration elements on the right side of Figure 1. The site processing system consists of a set of programs designed to manage, process and review information about each site. DOE2 via eQUEST is the engine that is used to process the survey data and develop energy usage for the sites.

Site Processor Results

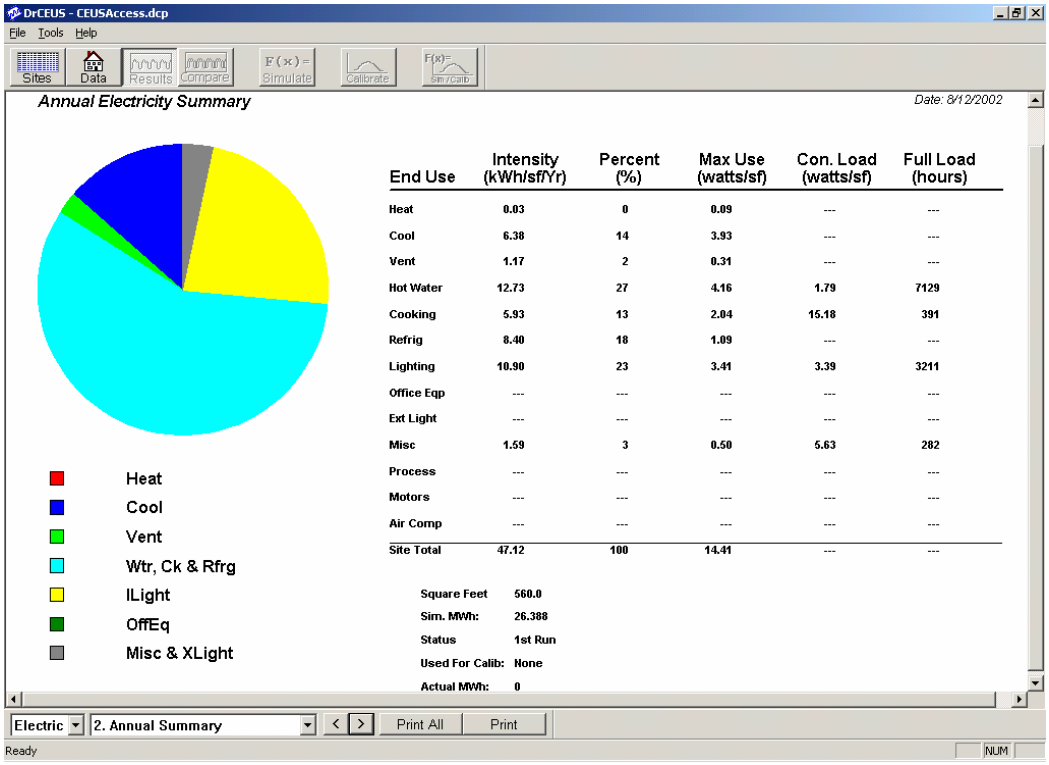
DrCEUS reports a number of useful simulation results, which can be displayed graphically or stored to files. These include the following:

- Annual end-use energy intensities,
- End-use peak load factors,
- 16-day results by end use,
- Monthly end-use peak loads, energy and gas usage,
- 365-day whole building gas use,
- 8760-hourly electric whole building energy usage, and
- Premise level schematic (viewable in eQuest).

[4] However, this concept is still being considered (as represented by the dashed lines in the figure) because results may be kept in a physically separate database if it makes more sense to do so.

Following are examples of the graphics available in the site processor and eQuest. Figure 2, Figure 3, and Figure 4 present examples of the graphical results from DrCEUS. Figure 5 provides an example of the premise level schematic produced by eQuest.

It should be noted that eQuest is available from the Site Processor and can be used to view information about the sites as desired. This allows the user to open eQuest and see how it simulates the premise and see changes in energy usage given changes made to the premise in the BDL directly or through the eQuest wizards. It must be noted, however, that changes made in the eQuest interface are not stored back to the Site Database. What this means is that changes made in eQuest are temporary in nature and do not change the survey data or results stored in the DrCEUS databases when the user returns to the DrCEUS interface. To make these changes permanent the user must change the survey data to reflect the changes made in eQuest and rerun the DrCEUS simulation.[5]



End Use	Intensity (kWh/sf/Yr)	Percent (%)	Max Use (watts/sf)	Con. Load (watts/sf)	Full Load (hours)
Heat	0.03	0	0.09	---	---
Cool	6.38	14	3.93	---	---
Vent	1.17	2	0.31	---	---
Hot Water	12.73	27	4.16	1.79	7129
Cooking	5.93	13	2.04	15.18	391
Refrig	8.40	18	1.09	---	---
Lighting	10.90	23	3.41	3.39	3211
Office Eqp	---	---	---	---	---
Ext Light	---	---	---	---	---
Misc	1.59	3	0.50	5.63	282
Process	---	---	---	---	---
Motors	---	---	---	---	---
Air Comp	---	---	---	---	---
Site Total	47.12	100	14.41	---	---

Figure 2: DrCEUS Results - Annual Electric Summary

[5] There is a facility within DrCEUS to allow the user to use changes made to the BDL through the eQuest interface if needed, but this should be considered a last resort when working with a site.

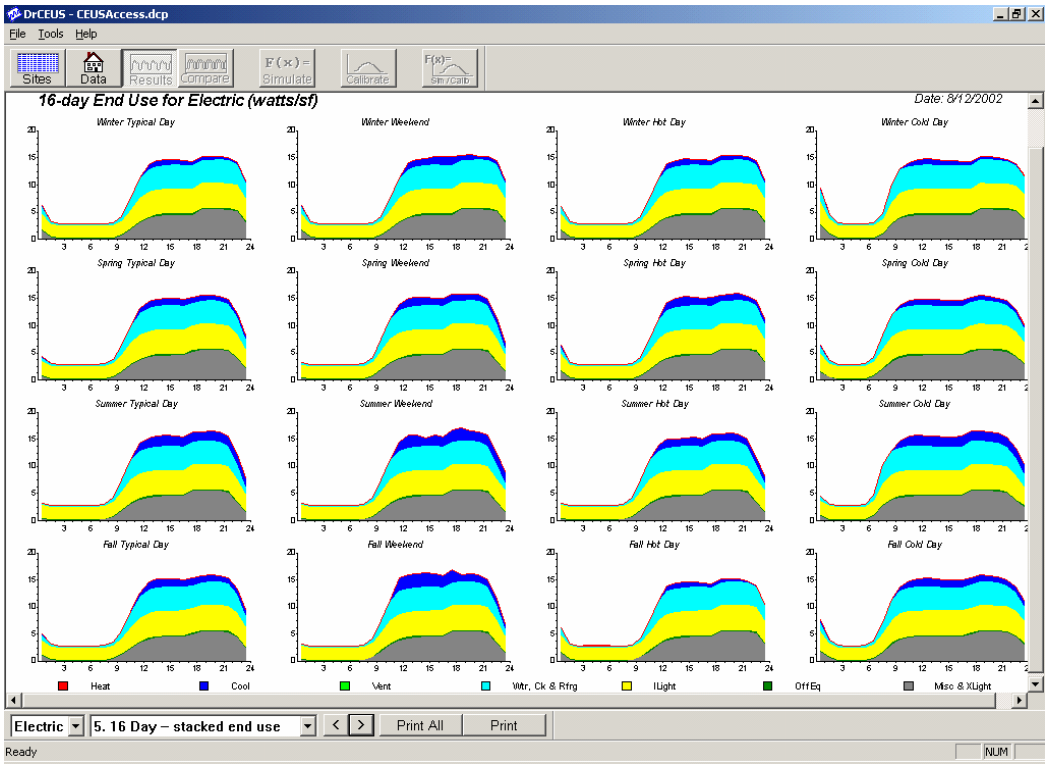


Figure 3: DrCEUS Results - 16-Day Hourly Electric End-Use (watts/sf)

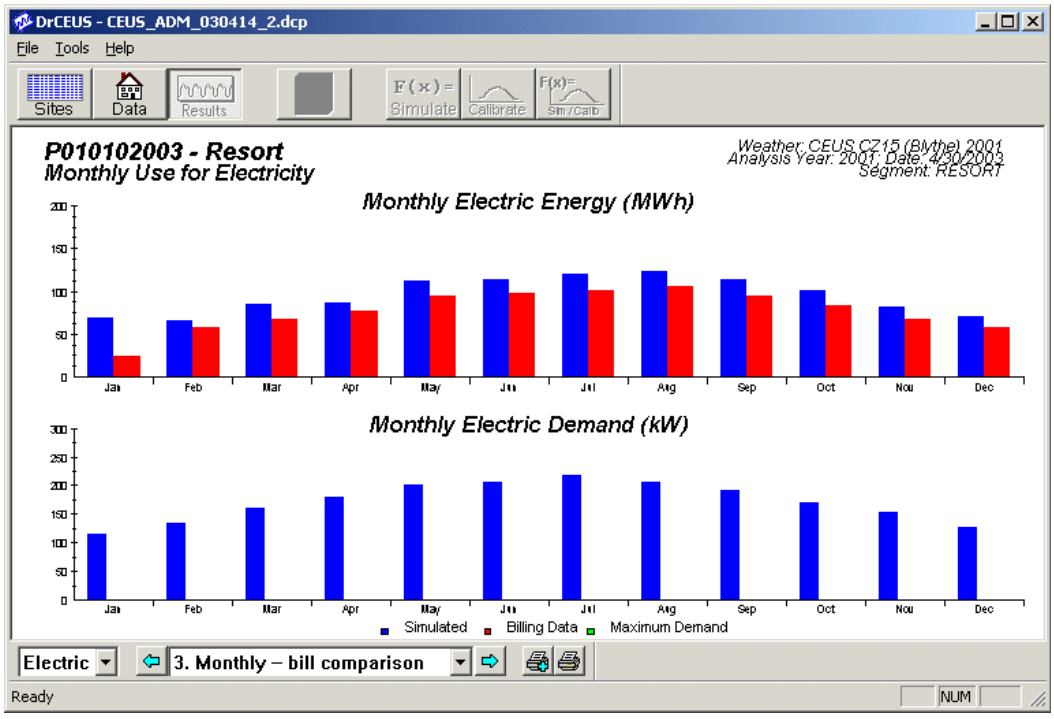


Figure 4: DrCEUS Results - Actual Billing verses Simulation

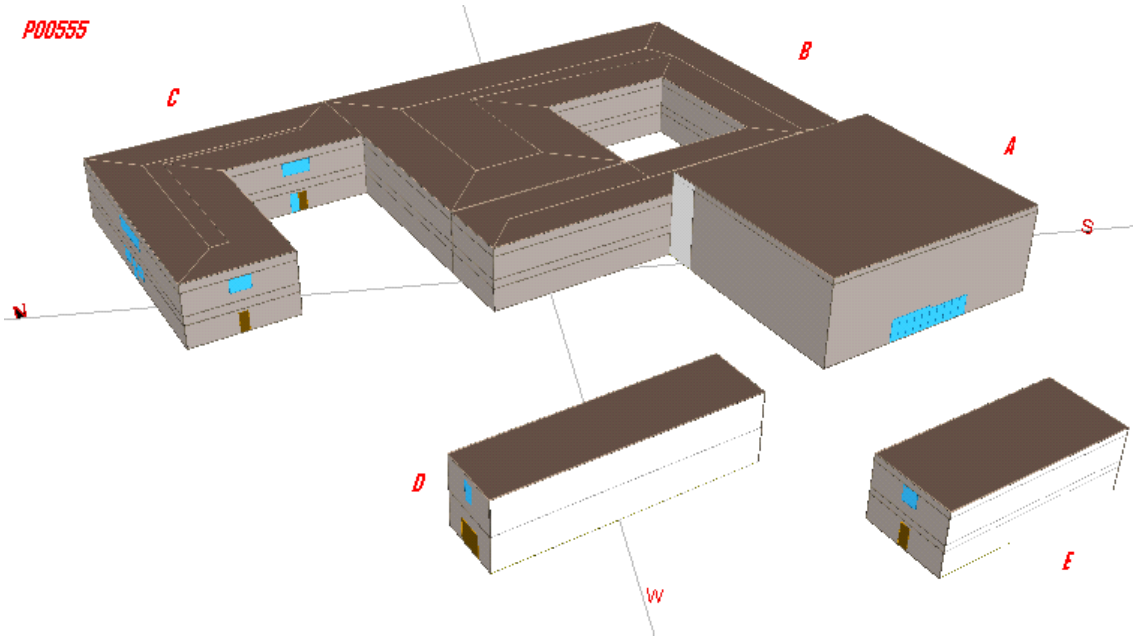


Figure 5: eQuest: Site-Level Schematic

Measure Analysis in the Site Processor

As can be seen in Figure 6, measure analysis uses the same tools as the Site Processor. The process entails modifying the Site Database so that the desired sites have installed the measures to be analyzed. Once this is done results are generated by the Site Processor using Batch eQuest[6] and can be view at the site level in the Site Processor. Further analysis can then be performed at the segment level, which will be described in the next section.

[6] Sites worked using Interactive eQuest should not be used in Measure Analysis. Since these sites have been altered outside of the DrCEUS system, they are no longer linked to the Site Database; hence changing the measures for these sites would have no affect on the results.

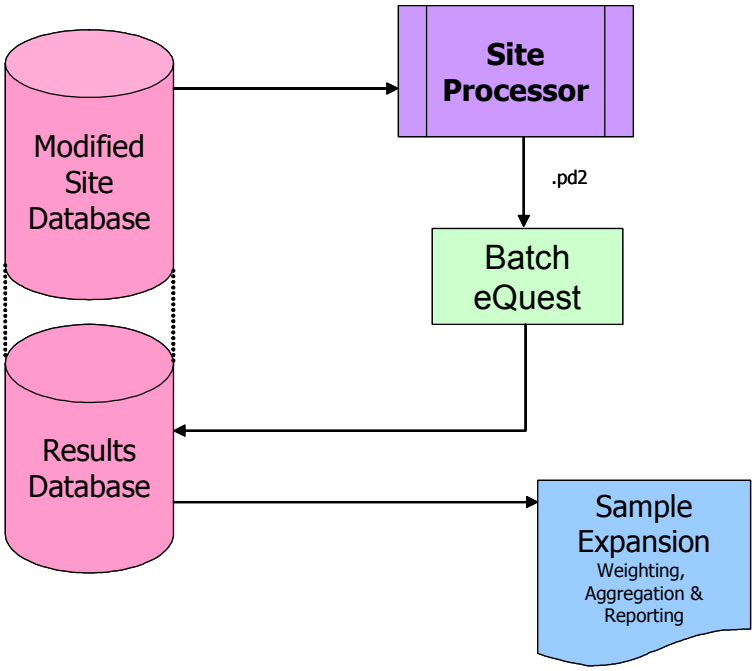


Figure 6: Measure Analysis Mode Flowchart

Segment Processing Mode

Segment processing entails manipulation (i.e. expansion, aggregation, etc.) of the results from the calibrated models and/or the sites where measures have been altered for the purpose of doing measure assessment.

The two major components of the Segment Processing mode are:

- **Master (Site/Results) Database** is the Site Database and Results Database elements in the middle of Figure 1 and/or Figure 6 as described previously.
- **Sample Expansion** is the module that is used to weight, aggregate, expand, view, and export the segment level results, whether from the baseline calibrated models or from measure runs.

There are many options that are presented in the user interface. The Segment Processor includes the ability to create segments from the list of sites in the database, add and remove sites from a specified segment, view results graphically, generate expanded results and export the results to a Microsoft Excel workbook. All data generated for the selected segment are exported to a tabbed workbook for easy access and further analysis by the user.

The following are figures showing some of the available graphics in the Segment Processor. Figure 7 shows an example of the Monthly Day Type chart that displays segment level results by the specified day types for each month of the analysis year. Figure 8 shows the chart that presents the electric 8760-hourly energy usage for the segment. Three monthly charts are displayed at a time and the user can scroll through the charts as desired.

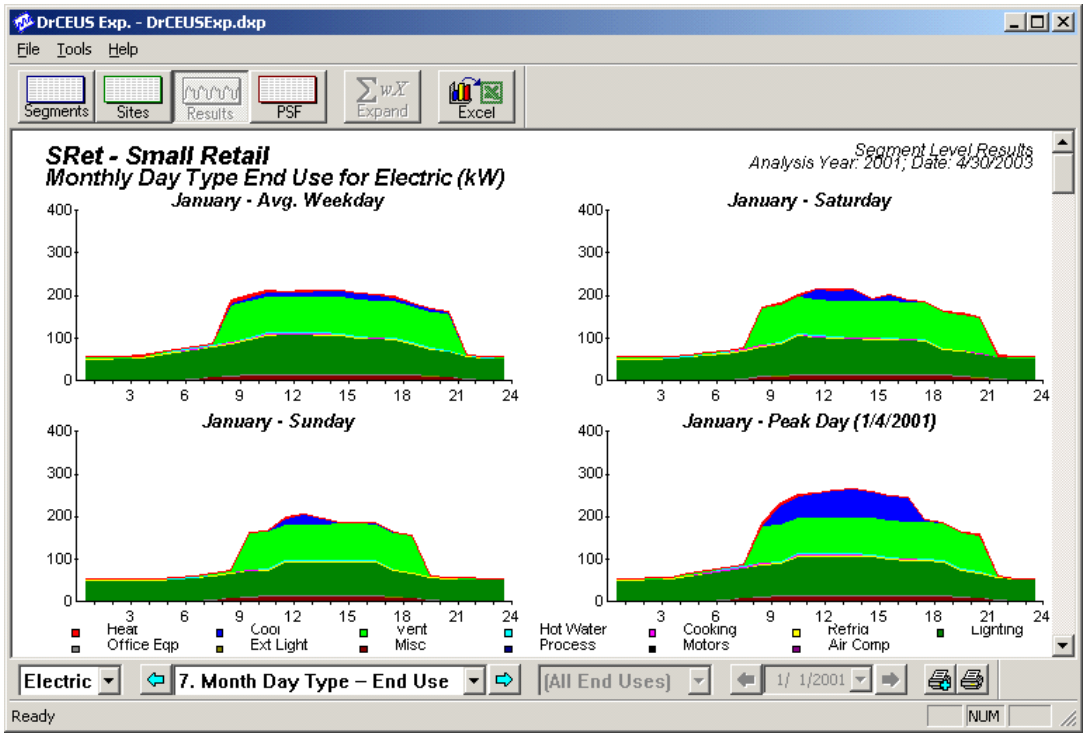


Figure 7: Segment Processor – Results Example

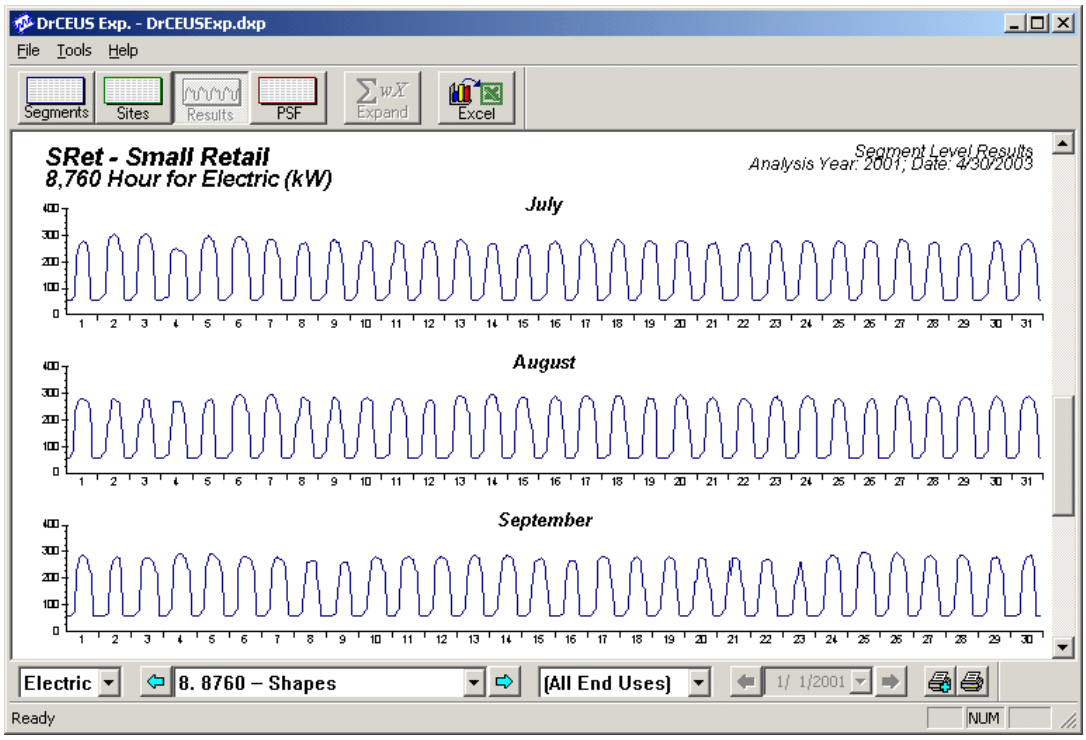


Figure 8: Segment Processor – Electric 8760 Usage Example

Applications of the CEUS Database and DrCEUS

The survey databases and DrCEUS framework developed for the CEUS study provide an integrated system that can support a variety of energy-related commercial end-use energy analysis. The following are some examples of the usefulness of these data and energy simulation capability of DrCEUS.

End-Use Demand Forecasting. The CEC's Commercial Sector Forecasting Model (CSFM) is a combined engineering and econometrically based end-use forecasting model that projects energy use by twelve building types, ten end-uses and, and three fuel types over sixteen climate zones. Much of the data needed to support this model is derived from the statewide CEUS, which has been periodically updated since the late 1970s.

The floor space portion of the CSFM utilizes the estimates of square footage by building type, vintage, and climate zone developed from the CEUS as a baseline from which future floorspace is estimated. The baseline square footage is utilized along with annual floorspace additions and economic and demographic drivers to estimate the future additions to floorspace. In addition to floorspace, the estimates of baseline fuel saturation and energy use at the end use level for each building type by vintage and climate zone used within the CSFM are developed from the data collected in the CEUS.

Energy Efficiency Measure Impact Analysis. The DrCEUS system is designed to support the analysis of the impact of installing high efficiency equipment and/or measures. The results from these analysis can be the per unit energy and demand savings per square foot or as total savings for a particular pre-defined segment.

Energy Efficiency Measure Potential Savings Analysis Support. California has recently completed a significant amount of work in the analysis of demand-side management technical, economic and market electric and gas savings potential for the commercial and residential sectors (KEMA-XENERGY 2003). These efforts are data intensive requiring baseline applicability, saturation and density information for each major end use equipment type and measure. In addition, these data need to include specific information on the presence, characteristics and per unit savings of high efficiency equipment and measures and the data needs to be assembled by building type and decision type (existing[7] and new construction).

The data collected from the CEUS study are a rich resource for a variety of these required data. For instance, the database contains data on end-use equipment saturations (e.g. percent of square feet cooled by packaged AC) as well as the presence of high efficiency measures (e.g., percent of chillers with EERs above a high efficiency threshold),. It also provides the ability to break out these features by building type and by segment (e.g. new construction)

As Needed Tailored Analysis and Market Profiles. Another potentially beneficial use of the DrCEUS and CEUS databases is the development of tailored market profiles on an as needed basis. For instance, the CEC staff often receives requests to develop energy use profiles for very specific market sectors (e.g. high schools in a specific geographical area), or "what if" scenarios relating to the installation of specific equipment in these market sectors (e.g. high efficiency air conditioning in middle schools). The CEC staff has tended to rely on judgmental estimates that rely on historic estimates. The availability of the DrCEUS system will allow the CEC staff to provide timely feedback to these requests with a level of precision dependent upon the number of premises fitting the specified market of interest.

[7] Existing buildings can also go through the retrofit, replace on burnout, and acquisition decision.

Conclusion

The California Energy Commission's commercial survey effort creates a current, consistent and comprehensive statewide database of energy using equipment in commercial buildings sector of California. This database allows for the evaluation of the inventory of equipment in commercial building with respect to energy efficiency measures as well as allowing the user to observe energy use patterns at the premise or segment level for the whole building or by end use.

The software gives the user the ability to graphically view energy patterns by user defined segments and makes available many statistics for use in future analysis of their choosing. Also available is the ability to export the information into a Microsoft Excel workbook for use in any sort of evaluation not available within the software.

References

KEMA-XENERGY, Inc. California Statewide Residential Sector Energy Efficiency Potential Study. Study ID #SW063. Prepared for Pacific Gas & Electric Company. Oakland, California. April 2003.