DRCEUS: COMMERCIAL SURVEY ANALYSIS TOOL FOR THE 21ST CENTURY

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ABSTRACT

Topic Area: Market Transformation and Energy Efficiency

The California Energy Commission (CEC) contracted with Itron (formerly RER) to implement a statewide effort to collect data from buildings in the commercial business sector. This effort involves on-site surveys of 2,800 commercial facilities. The data collected include detailed information relating to energy-using equipment, business characteristics, operating schedules, and stocks of energy efficient measures. The CEC also called for the development of a flexible building simulation tool to support the evaluation of energy use intensities, hourly end-use load profiles, and impacts of energy efficiency measures, load management strategies, building standards, and other program policies.

Objective. This paper will discuss the design and implementation of the commercial end-use survey, the development of the building simulation system, DrCEUS, and the linkages to eQuest and DOE 2.2 building simulation engine. It will also present results from the survey and simulation effort for the buildings surveyed at the time of the submission of this paper. More importantly, the paper will discuss how these data and simulation results can used to support estimation of long-term DSM potential and the impacts of energy efficiency measures in the commercial building sector.

Results/Achievements/Concepts. Results from the survey effort, coupled with the simulation system, can be used to support both end-use forecasting and the assessment of energy usage evaluation in commercial buildings. The data and simulation system can be also be used to evaluate the effects of energy efficient equipment installed in the various segments of the commercial sector.

Why This Paper is Valuable. The integrated commercial database will be one of the largest ever assembled. The software system, DrCEUS, comprises a technical innovation that provides a platform for producing building simulation results in a timely manner using data obtained from the current California commercial building stock. This paper shows how the system can be used in impact evaluations of energy efficient equipment and other energy efficiency measures in the commercial market place.

Introduction

Analyzing energy usage in commercial buildings has evolved a great deal over the course of the past few decades. In the 1980s surveyors would perform on-site surveys collecting data about energy-using equipment. The surveyor would bring the surveys back to the analyst and the analyst would enter the data into a SAS dataset. Basic statistics could be generated from the data, but with only SAS as the analysis tool, it was difficult to effectively analyze the data and draw conclusions about energy usage.

In the 1990s came the introduction of DOE 2 for the purpose of analyzing survey data from commercial buildings. In the early stages of using this model there were many problems with translating the survey data into BDL code for use by the building simulation model. The language was extremely complicated, but did enable the analyst to develop simulations of energy usage given the configuration of the equipment at the site. As DOE 2 became more mainstream, tools were developed that tried to make DOE 2 more user friendly by creating a user interface to the model, effectively insulating the user from writing BDL. This allowed the surveyor and analyst to generate the inputs to DOE 2 and view graphically the results generated from the simulations. Regional Economic Research's batch processing tool SitePro comes to mind as one of these tools.

Next came a site-processing tool called eQuest. Developed by J. J. Hirsh, this tool allowed the user to define a site in a graphical user interface. It presents a set of wizards for the analyst to use to define a building, allowing the user to easily specify the building footprint, the building shell characteristics and the HVAC. It also implements the concept of HVAC zoning which was previously very difficult to define using available tools. This tool has spawned the development of the batch-processing tool called The DrCEUS System (DrCEUS). This system utilizes the inherent characteristics of eQuest version 3, which used DOE 2.2 as its building simulation engine. It is designed to translate survey data collected in the field into BDL, which DOE 2.2 then uses to simulate energy usage for a wide variety of non-HVAC end uses as well as the typical HVAC end uses for which it is so well known.

DrCEUS includes a data entry system developed in Microsoft Access and a set of tools that facilitate the processing of sites using eQuest and DOE 2.2. It also includes the aggregation of results to Segment defined by the user based on demographic and characteristic data collected as part of the survey. The results of this process can be displayed graphically at both the site level, and the segment level and can compare sites graphically as well. The results can also be exported to a Microsoft Excel workbook for use with other tools available in the marketplace.

This paper discusses the development of the DrCEUS engineering simulation tool described above and the design and implementation of the commercial end-use survey currently being performed in California by Itron and its sub-contractors under the guidance of the CEC. Further, the paper will discuss how these data and simulation results will be used to support the estimation of energy efficiency measure impacts and help to create a benchmark for long-term energy use forecasts in the commercial sector in California.

Survey Design and Implementation

The California Energy Commission (CEC) was charged with the implementation of 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 2,800 commercial facilities. The data being collected includes detailed information relating to energy-using equipment, business characteristics, operating schedules, and installation of energy efficient measures.

Survey and Support Data

The data collection effort included support by the three investor-owned utilities in the state of California. These include Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric Company. Also joining the survey effort is the Sacramento Municipal District. Account-level records of electric and gas usage were received from the utilities on a monthly basis. These data were aggregated into just over 700,000 unique premises.[A] A modified stratified random sample was developed with a sample target of 2,800 completed surveys.[B] 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.[C] The resulting set of weather stations represents 20 distinct zones across the state.

There are two survey teams in the field at this time performing the on-site surveys. The surveys are split up between the two teams so that each has a number of sites in each service territory. Each team has been performing on-site surveys for a number of years and are both industry leaders in the field of commercial on-site surveys.

A 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.

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

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

Development of the DrCEUS System

As an accompaniment to the commercial on-site survey, the CEC specified 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, and building standards. The DrCEUS System is a site processing system that performs energy simulations using DOE 2.2 and the eQuest Quick Energy Simulation Tool. It performs analyses using the site-level survey data by translating the survey data into information that eQuest can read. Once the survey data have been translated, eQuest is started and signaled to perform a building simulation on the inputs supplied by DrCEUS. Once completed, the results are retrieved and stored in a database for further analysis.

Included in the system are a strong set of error-checking procedures to aid the analyst in debugging 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. They are as follows:

- **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.

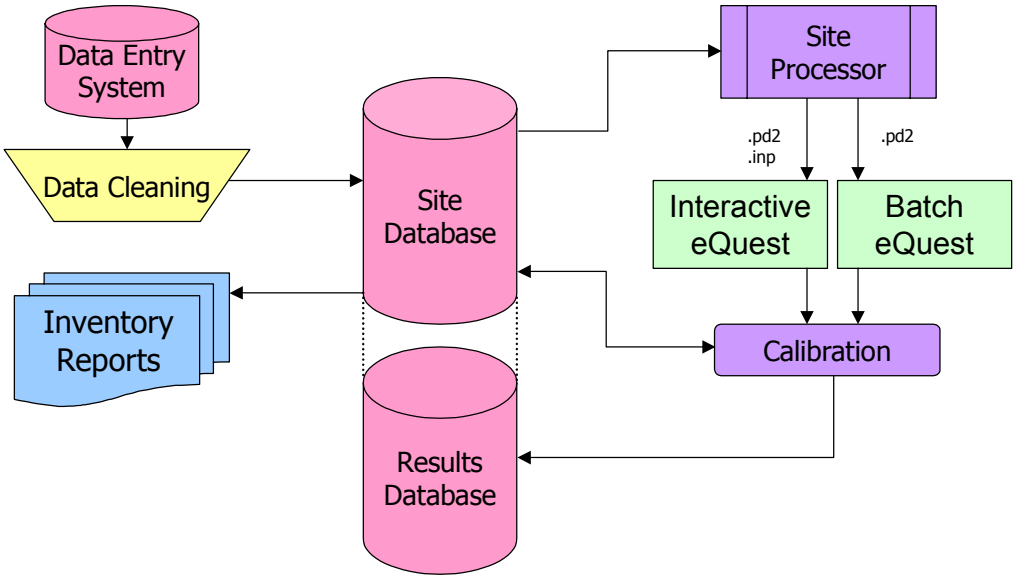


Figure 1: Site Processing Mode Flowchart

- **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.[D] 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 Graphics

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

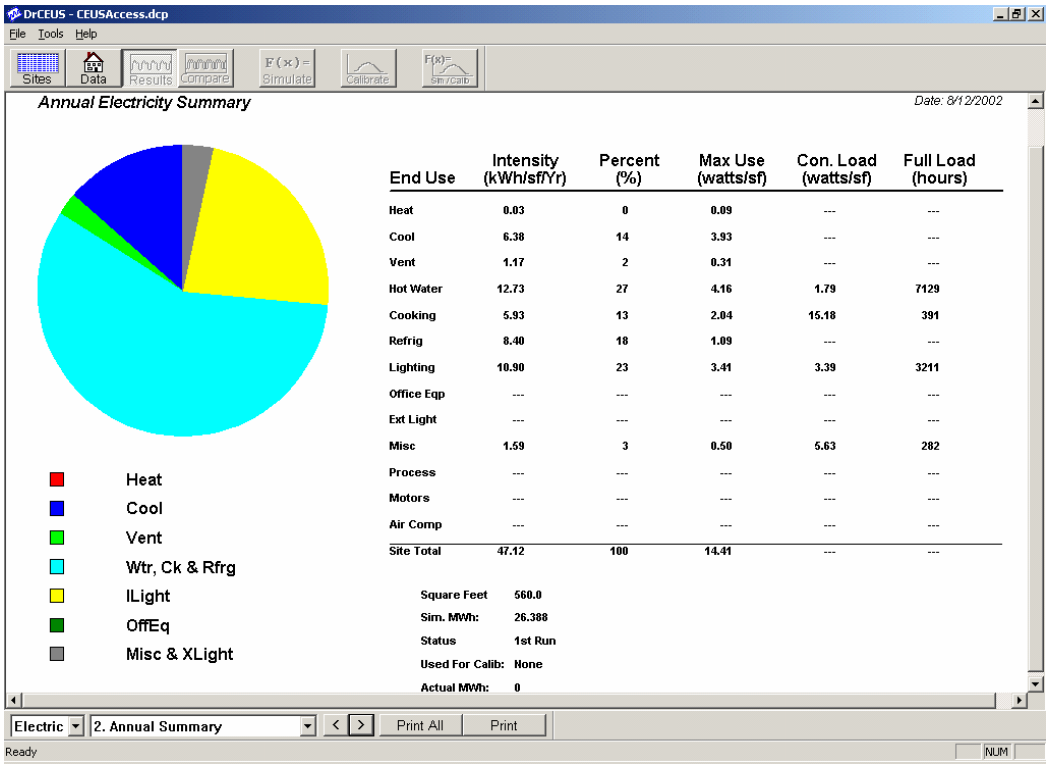
- Annual end-use energy intensities,
- End-use peak load factors,
- 16-day results by end use,

[D] 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.

- 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).

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, see how it simulates the premise, and view 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.[E]



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 Electricity Summary

[E] 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.

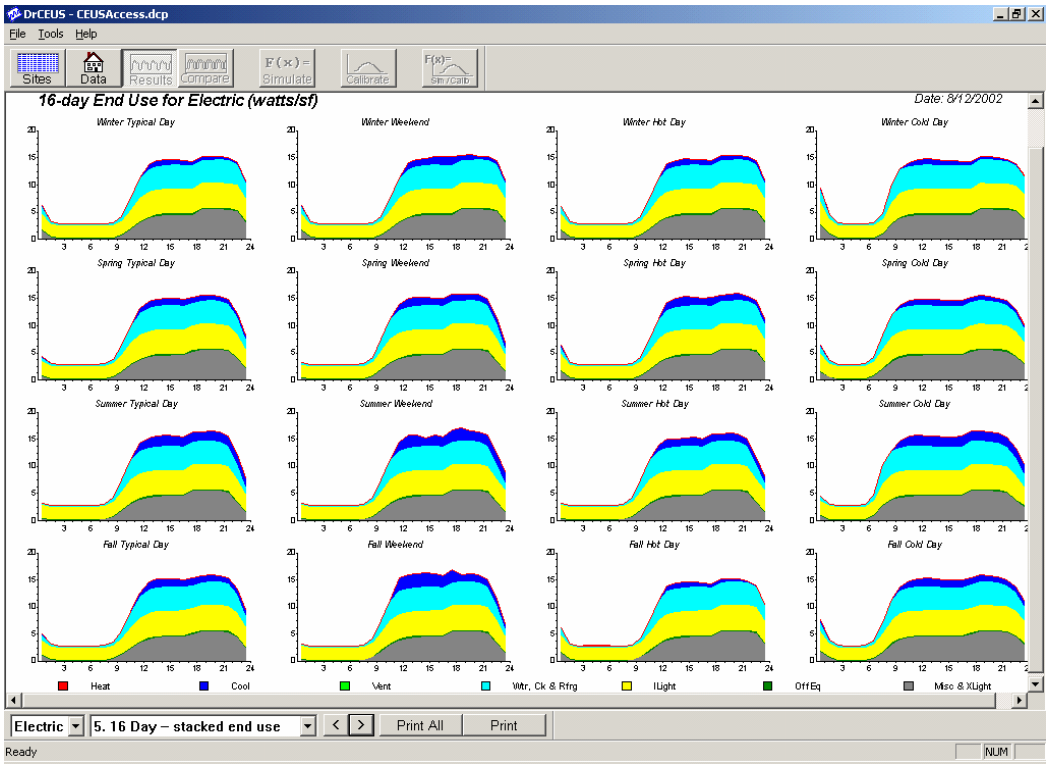


Figure 3: DrCEUS Results - 16-Day Hourly Electric End-Use (watts/sf)

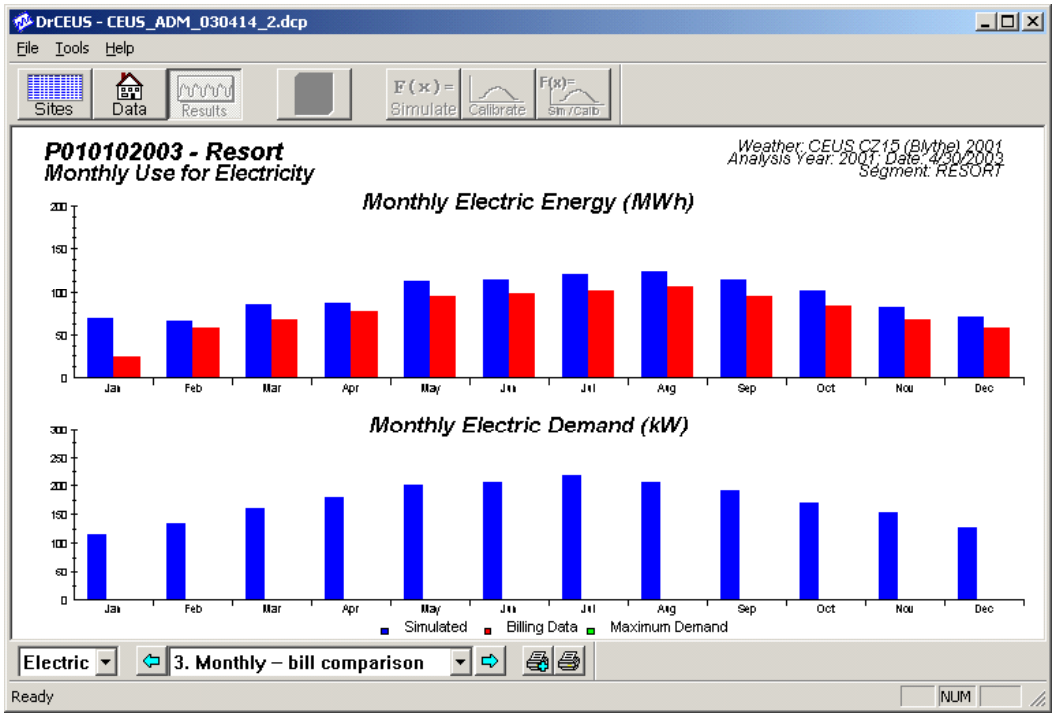


Figure 4: DrCEUS Results - Actual Billing verses Simulation

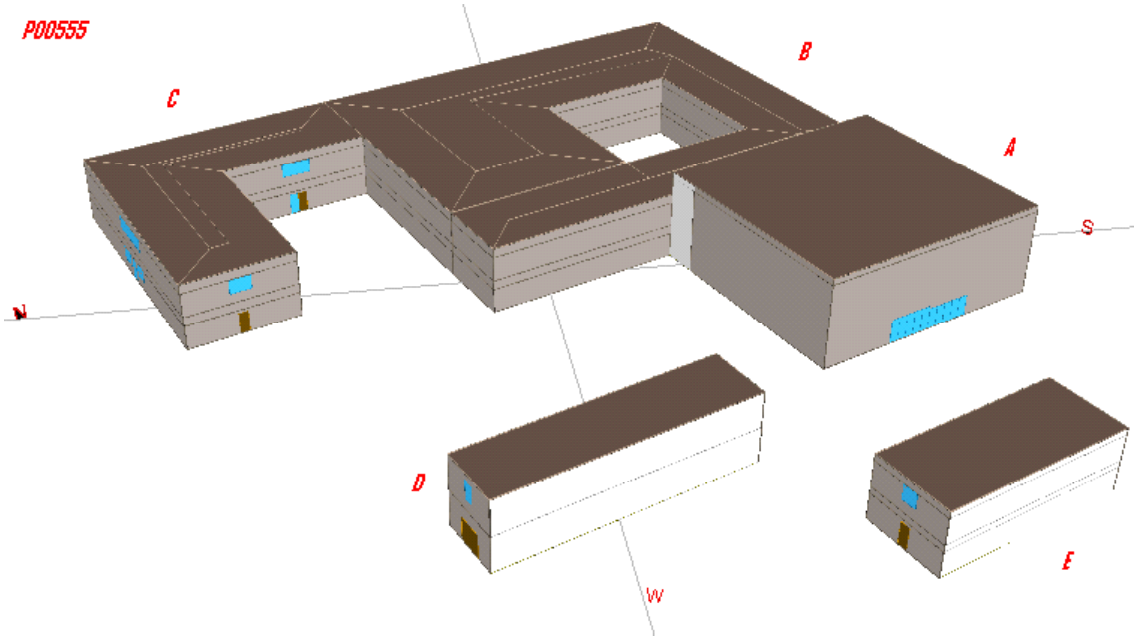


Figure 5: eQuest: Site-Level Schematic

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 doing measure assessment.

The two major components of the Segment Processing mode are as follows.

- **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.

Segment Processing Graphics

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.

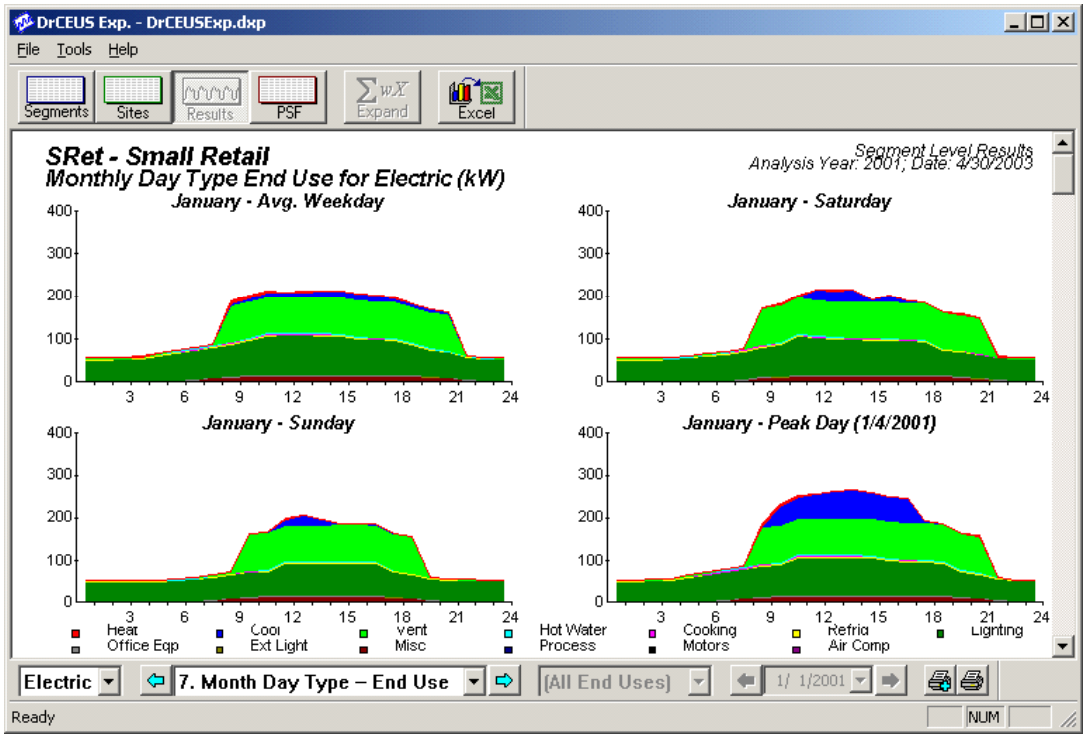


Figure 6: Segment Processor – Results Example

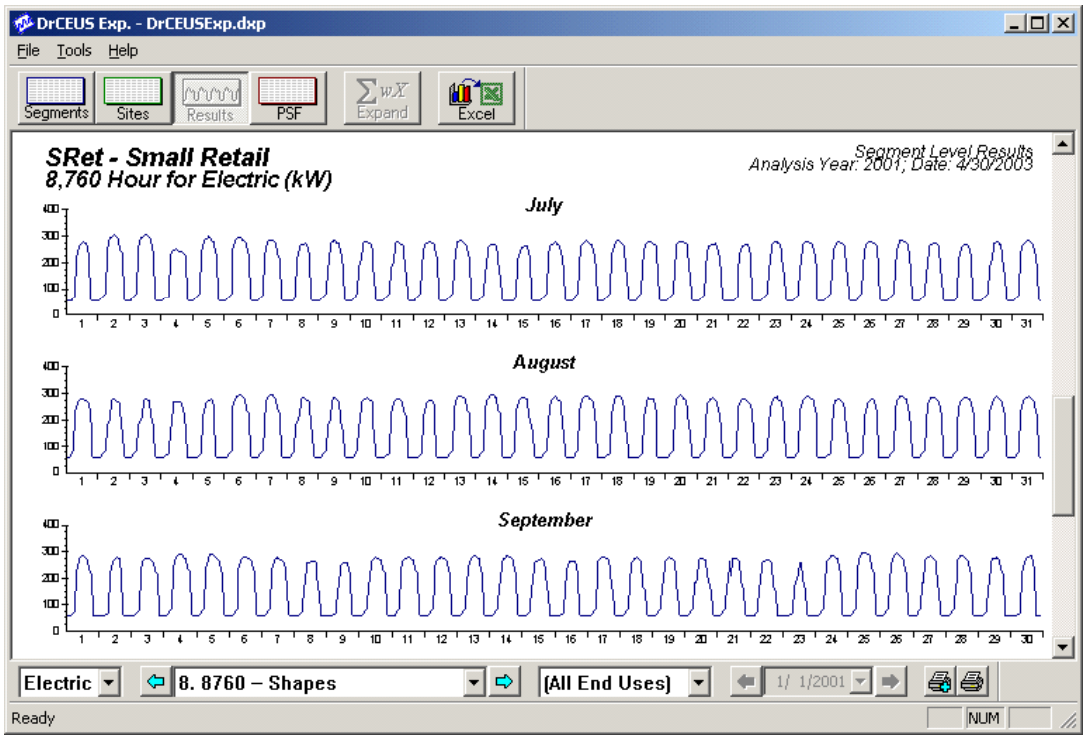


Figure 7: Segment Processor – Electric 8760 Usage Example

Results from the Survey and Simulations

As of the writing of this paper, the survey effort is approximately one third complete. There are two survey contractors in the field canvassing the state and they are expect to be out of the field by midyear 2004.

Results from the simulations at this point would be premature. With only one third of the sites surveyed any meaningful analysis cannot be performed. At the end of the project data will be developed from the complete database and will include saturations, intensities, EUIs peak loads, and many other statistics at both the state and utility service territory level. Also, complete building simulation results will be generated for the surveyed sites including whole building and end-use 8760 usage data, 16-day load profiles, and monthly usage.

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 analyses. The following are some examples of the usefulness of the data and energy simulation capability of DrCEUS.

Benchmark of the State of Commercial Buildings in California. The CEC commercial on-site database creates a perfect repository of the current state of commercial buildings in the State of California. This benchmark will allow for analysis in many disciplines like energy efficiency, long-term load forecasting and time-of-use rate analysis.

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 12 building types, 10 end-uses and, and three fuel types over 16 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 floor space is estimated. The baseline square footage is utilized along with annual floor space additions and economic and demographic drivers to estimate the future additions to floor space. In addition to floor space, 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 analyses can be the per unit energy and demand savings per square foot or 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 need to be assembled by building type and decision type (existing[F] 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. 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. In the future, The DrCEUS System could possibly be designed to help answer questions about demand response and real-time pricing as well.

Conclusion

The state of building equipment analysis and simulation has come a long way since the early 1980s. With the data developed for today's new tools, analysts will have available a timely snapshot of the commercial building sector from which to develop estimates of energy usage with respect to energy efficiency, energy usage patterns, and rate impacts based on current benchmark data.

The software developed as a part of the project allows for a graphical view and comparison of energy information by user-defined segments and makes available the entire database of results for uses in third party analysis tools of their choice. These data should provide a rich set of information for use in the analysis of energy usage for years to come.

References

1. KEMA-XENERGY, Inc., et all. California Statewide Commercial Sector Energy Efficiency Potential Study. Study ID #3346. Prepared for Pacific Gas & Electric Company. Oakland, California. July 2002.
2. KEMA-XENERGY, Inc. California Statewide Residential Sector Energy Efficiency Potential Study. Study ID #SW063. Prepared for Pacific Gas & Electric Company. Oakland, California. April 2003.

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