Action-oriented Benchmarking: Using the CEUS Database to Benchmark Commercial Buildings in California

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ABSTRACT

The 2006 Commercial End Use Survey (CEUS) database developed by the California Energy Commission is a far richer source of energy end-use data for non-residential buildings than has previously been available, and opens the possibility of creating new and more powerful energy benchmarking processes and tools. In this article—Part 2 of a two-part series—we describe the methodology and selected results from an action-oriented benchmarking approach using the new CEUS database. This approach goes beyond whole-building energy benchmarking to more advanced end-use and component-level benchmarking that enables users to identify and prioritize specific energy efficiency opportunities—an improvement on benchmarking tools typically in use today.

INTRODUCTION

Action-oriented benchmarking extends generalized whole-building energy benchmarking to include analysis of system and component energy use metrics and features. If coupled with the appropriate decision-tree logic, it thereby allows users to identify, screen, and prioritize potential efficiency opportunities, which in turn can be used to inform and optimize a full-scale audit or commissioning process (see Figure 1 in companion article [Mills et al. 2007]).

Action-oriented benchmarking extends traditional whole-building benchmarking in three important ways:

- End-use benchmarking, which shows the energy intensities and savings opportunities within each end use and its priority relative to other end uses.
- Features benchmarking, i.e. identifying the efficiency characteristics of specific systems, components, and operational conditions.
- Correlating features with end-use energy intensities, which can help assess the approximate savings potential from specific actions.

The CEUS database offers a rich source of data for action-oriented benchmarking, with energy use data and building characteristics for almost 2800 buildings representing a cross section of commercial buildings in California.

In this article, we first provide an overview of the CEUS database. Next, we illustrate the use of CEUS for action-oriented benchmarking (using offices and schools as examples). We conclude with some observations about the limitations and outlook for this type of analysis.

OVERVIEW OF CEUS DATABASE

The Commercial End Use Survey (CEUS) database was developed by the California Energy Commission (CEC) to support demand forecasting. For more detailed information on CEUS, see Ramirez et al. [2005] and the CEUS final report [Itron 2006]. Some of the key characteristics are summarized below:

- It involved a survey of about 2800 commercial buildings in four utility districts (PG&E, SCE, SDGE, SMUD) and seven major climate zones within California.
- The survey covered 12 major building types and 62 sub-types.
- The buildings were selected by modified stratified random sampling using four frames: building type, utility district, climate zone, and load. In selected cases, buildings were switched to allow for buildings that had interval metered data.
- A standardized survey tool was used to document over 100 physical and operational characteristics of the building. Energy use was obtained from utility bills.
- DOE-2 simulation models were developed for each building, based on the survey data. Simulation models were calibrated with monthly

utility data. Additionally, short-term metering and/or interval metering were used for calibration in a subset (~31 percent) of buildings. Calibration was to within 5 percent on annual energy use and 10 percent on monthly energy use [Ramirez 2007].

The CEUS survey represents the most comprehensive survey of this type ever done on commercial buildings at this scale. Nevertheless, it is important to recognize some important limitations:

- While the survey form was very detailed (elaborate enough to develop simulation models), there are gaps in data collection, as in any large survey.
- As noted earlier, the energy use and peak electric demand data in CEUS are from calibrated simulations.
- It is not truly representative of the entire state of California, because some utility districts are not covered.

These limitations notwithstanding, the CEUS database is still a remarkably rich source of data, and offers a unique opportunity for developing action-oriented benchmarking methods applicable to a wide range of commercial building types.

USING CEUS FOR ACTION-ORIENTED BENCHMARKING

End-use Energy Benchmarking

End-use energy benchmarking shows the overall potential for reductions in energy intensity within each end use and its priority relative to other end uses. The Carbon Trust in the UK [Action Energy 2003] has demonstrated the application of end-use benchmarking to identify efficiency opportunities in office buildings in the United Kingdom. Figure 1 shows the range of energy intensities for various end uses in large office buildings in the CEUS data set. All end uses show a wide range. Lighting has the highest median value, followed by cooling, office equipment, and ventilation. Users can plot their building's end use to identify and prioritize which end uses offer the greatest opportunity for savings. An additional way to analyze this is to compare the average end-use breakout to that of the user's building. Figure 2 shows the average end-use breakout for schools in various California climate zones.

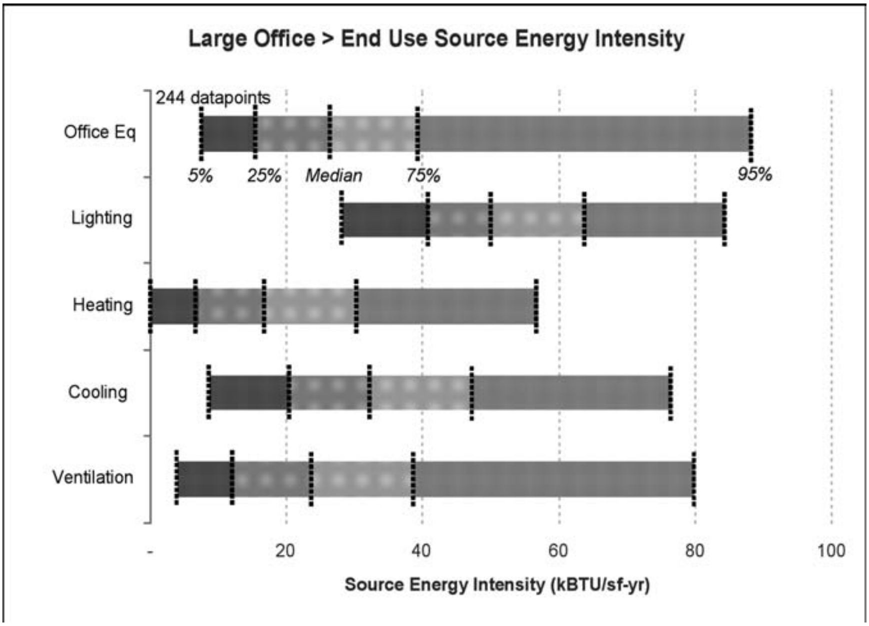


Figure 1. End use energy intensities for large office buildings in California. Source energy for electricity counted at 10.28 kBtu/kWh.

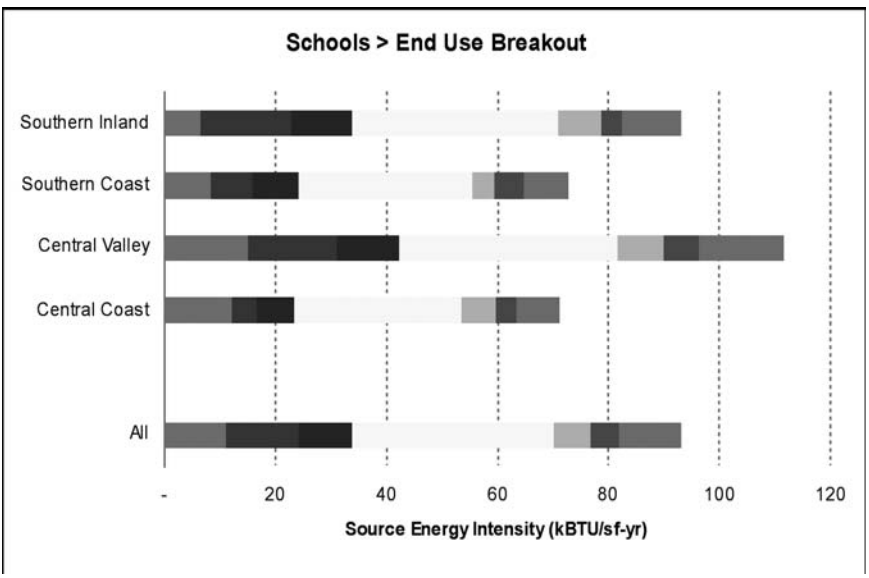


Figure 2. Average end use breakouts for schools in various California climate zones.

Features Benchmarking

The CEUS survey was remarkably detailed in documenting building features and operational characteristics (Figure 3 shows an illustrative selection).

Lighting	Lamp
	Ballast
	Control
	Hours of use
Envelope	Roof insulation
	Wall insulation
	Glazing type
	Exterior shading
	Interior shading
Air Handlers	System type
	Age
	Hours
	Temp Control
	Optimal start/stop
	Economizer
	Supply Fan Motor Eff
	Supply Airflow Efficiency
	Cooling Type
	Cooling EER/SEER
	Heating Type
	Heating fuel
	Heating efficiency
	HP Soft Start

Chillers	Type
	Fuel type
	Heat rejection type
	Age
	Efficiency
	Chilled Water Reset
	VSD compressor
	Cooling Lockout
	Water side economizer
Chilled Water Pumps	Age
	Motor type
	Motor efficiency
Cooling Towers	Type
	Temp control
	Age
	Fan type
	Fan control
	Fan motor eff
	Pump type
	Pump motor eff

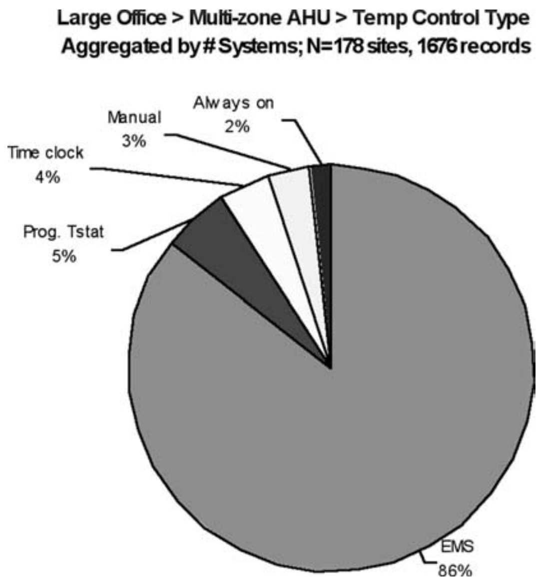
Figure 3. A selection of features documented in the CEUS database

Statistical distributions of these features allow users to "benchmark" the presence or absence of energy efficiency features in their building, relative to the prevalence of these features in the peer dataset. For example, Figure 4 shows the prevalence of different types of temperature controls for schools and large office buildings. While energy management systems (EMS) are very dominant in large office buildings, there is a wider range system types in schools, with only about 24 percent having EMS.

Component and system efficiencies such as HVAC power density [Kavanaugh et al. 2006] are another form of features-based benchmarking. Figure 5 shows the range of fan efficiency for various types of multi-zone air handlers in large office buildings. Note that although there is a wide range (factor of two) within each type, the medians for each type are very similar.

Correlation between Features and End Use Energy Intensities

Correlating building features with end use energy intensities can, in principle, provide an indication of potential savings from different types of energy-efficiency improvements. However, it is important to note at the



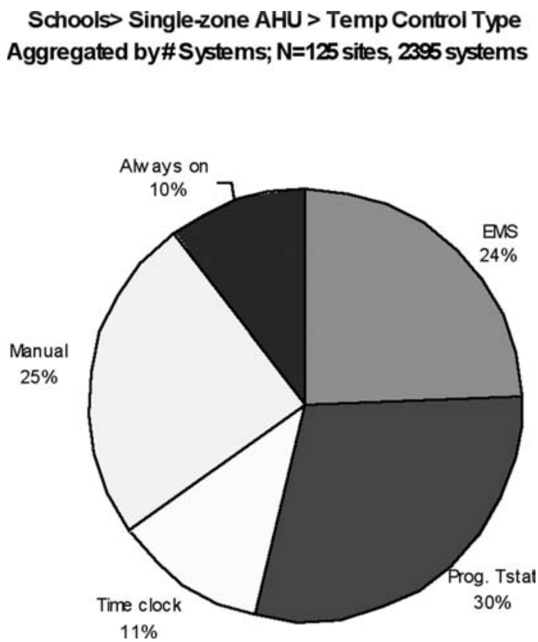


Figure. 4 Prevalence of different types of temperature controls for schools and large office buildings.

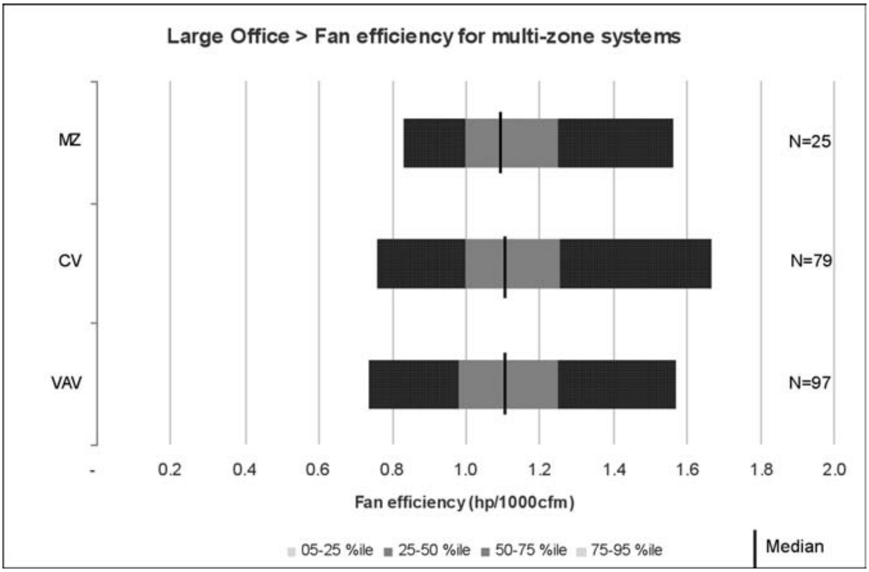


Figure 5. Range of fan system efficiencies for various types of multi-zone air handlers in large office buildings.

outset that there are two key limiting factors for this type of analysis:

- End-use energy intensity is not equivalent to energy efficiency, and is invariably a function of multiple features with interrelated impacts on energy use. Therefore, it is difficult to isolate the impact of a single feature—and the absence of a correlation does not necessarily imply that the feature has no impact.
- End use energy intensities are only available at the building level, whereas a feature may not be uniform across a given building. For example, there may be different types of lighting fixtures or different types of HVAC systems within a given building. Therefore correlating a given feature to an end use energy signature may be feasible only in cases where the feature is largely uniform across the building.

These caveats notwithstanding, such correlation analyses can provide useful information for the action-oriented benchmarking process. For example, Figure 6 shows the correlation between lighting energy intensity and two lighting features: lamp power density and lighting control type. As expected, lighting energy intensity is positively correlated with lamp

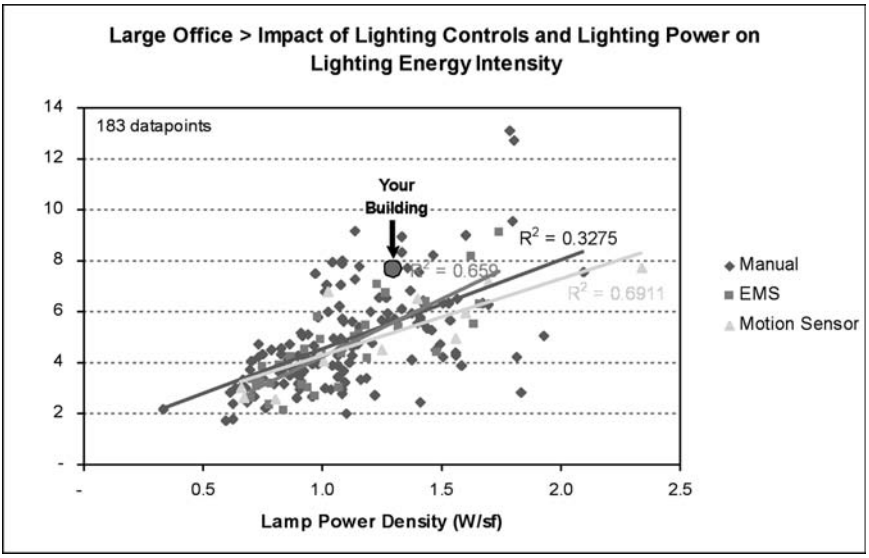


Figure 6. Correlation between lighting energy intensity and lamp power density for various control types in large office buildings. Includes only buildings where one control type predominates (>95 percent of lighting kW).

power density. The chart also shows that the linear regression lines for the three control types largely overlap. However, there is a much wider scatter for manually controlled systems than for the other two control types. (Note that even with automated controls, lights are left on when not needed because of false triggering and the delay effect. Therefore, in buildings where occupants are conscientious about turning off lights, manual controls may be more effective than automated controls.)

As another example, Figure 7 shows the correlation between ventilation energy intensity and HVAC system type in large office buildings. As expected, the median intensity for buildings with VAV systems is lower than the medians for buildings with multi-zone and constant volume systems. But here again, there is a wide range for each system type, reinforcing findings from other studies [e.g. Johnson 2002] that the presence of energy efficient features in and of itself does not guarantee a low energy building, and that building commissioning and operation are critical to achieving low energy intensity. The variance of median and minimum values between the three system types in Figure 7 also shows that features-based peer groups can help improve the relevance and meaning of action-oriented benchmarking.

Providing Guidance on Potential Actions

Collectively, the three types of benchmarking analyses discussed above can be used to provide guidance on actions to reduce the energy use. Of course, such guidance cannot be specific enough to substitute for a full energy audit. Rather, the approach used here is to work from a predefined list of actions, and then assess the relevance and impact of each of these actions for the given building using benchmarking-level data:

- "Relevance" in this context simply indicates how likely the action is to be applicable to the building being benchmarked. It is largely determined by the presence or absence of a feature. For example, the relevance of the action "install EMS lighting controls" would be relevant if the building currently has only manual controls.
- "Impact" indicates the effect of this action in reducing overall energy use. Note that an action with high relevance may not necessarily

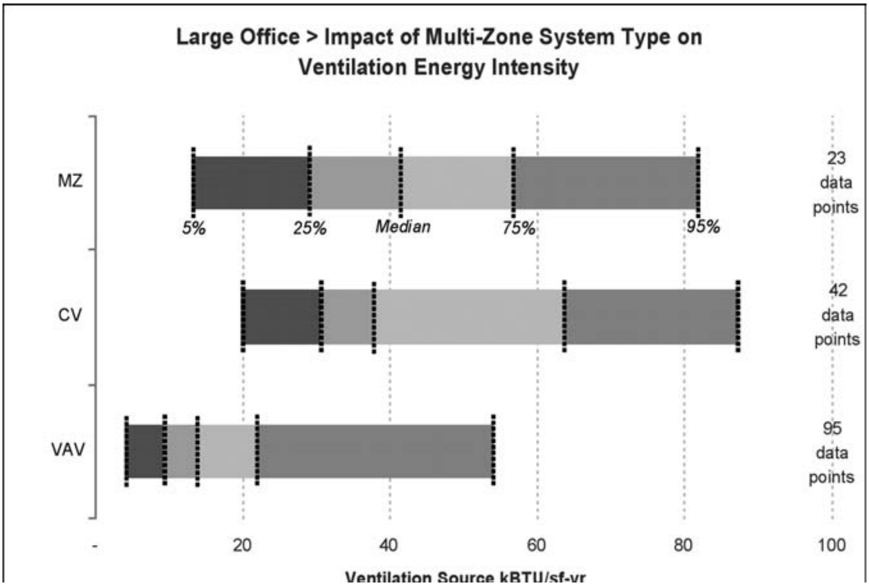
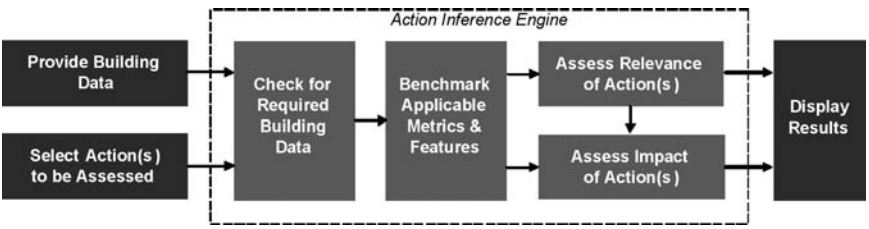


Figure 7. Correlation between ventilation energy intensity and various HVAC system types in large office buildings. Includes only buildings where one system type predominates (>95 percent of units).

have high impact. For example, in a laboratory building with standard fluorescent lamps, switching to energy efficient lamps may have a high relevance, but a low impact because lighting is a small percentage of total energy use.

The degree of specificity in assessing relevance and impact for each action is a function of the depth and detail of the database and availability of data for the individual building being benchmarked. In the *EnergyIQ* tool and its underlying web-based Action-Oriented Benchmarking system (described in the companion article [Mills et al. 2007]), both relevance and impact are rated in qualitative terms (e.g. high, medium, low). Figure 8 provides illustrative examples of the criteria for determining the relevance and impact of selected actions in *EnergyIQ,* using applicable metrics and features. Additionally, the tool will indicate the typical cost-effectiveness of each action, i.e. based on current practice, but not specifically for the given building.



	Assessment Criteria	
Actions	Relevance of Action	Impact of Action
Install efficient lamps	Benchmark *Installed W/sf* and calc percentile; If > 50% : High If < 50%, > 25% : Medium If < 25%, > 5% : Low If < 5% : N/A	Calc ratio of *Lighting Source EI* to *Total Source EI* If >= 0.3 : Same as Relevance If < 0.3, >= 0.1 : One level lower than Relevance If < 0.1 : Low
Install efficient ballasts	Benchmark *Ballast Type* ; If 'Magnetic' : High If Std electronic, high eff magnetic : Medium If Adv electronic : Low	Calc ratio of *Lighting Source EI* to *Total Source EI* If >= 0.5 : Same as Relevance If < 0.5, >= 0.3 : One level lower than Relevance If < 0.3 : Low
Improve fan efficiency	Benchmark *Installed hp/cfm* and calc percentile; If > 50% : High If < 50%, > 25% : Medium If < 25%, > 5% : Low If < 5% : N/A	Calc ratio of *Vent Source EI* to *Total Source EI* If >= 0.3 : Same as Relevance If < 0.3, >= 0.1 : One level lower than Relevance If < 0.1 : Low

Figure 8. Conceptual illustration of action inference mechanism (top), with illustrative examples of how benchmarking metrics and features are used to qualitatively rate ("high-medium-low") the relevance and impact of energy efficiency actions in EnergyIQ.

CONCLUSION AND OUTLOOK

This article provided illustrative examples of "action-oriented" benchmarking using the CEUS database. Specifically, building owners and managers can benchmark various end uses as well as system and component features, which in turn makes it possible to identify and assess the potential for various actions. However, it is also important to note that action-oriented benchmarking is not an "audit in a box." It cannot provide the level of specificity and depth of an on-site audit. Rather, it can improve significantly on first-generation benchmarking to help identify opportunities and prioritize potential actions for more detailed assessment. Additionally, it can be used to improve building operations by incorporating the metrics and benchmarks into the continuous commissioning process.

From a policy perspective, the effectiveness and widespread application of action-oriented benchmarking is contingent on the availability of reliable end-use data for buildings, availability of information-rich databases such as CEUS, and development of tools and user interfaces that adequately facilitate access to the benchmarking process and development of recommended actions. Currently, end-use metering is still relatively rare, and no other states have databases like CEUS. However, the growing momentum for voluntary and mandatory benchmarking in buildings may motivate a positive change on both these fronts.

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