

Update on California Commercial Building Benchmarking

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ABSTRACT

This paper discusses the history of benchmarking tools, current benchmarking activities, and the development of an advanced action-oriented benchmarking tool for California's non-residential buildings. Building energy benchmarking can help a building owner or operator determine how well their building is performing, compare their building's energy consumption to that of similar buildings, set and track performance targets, facilitate assessments of property values, and gain recognition for exemplary achievement. While existing simple benchmarking tools can help identify high-energy buildings, these tools do not provide enough feedback to identify the specific building systems or end-uses that may explain high energy use. Benchmarking can provide building owners and operators with the information necessary to make decisions regarding the pursuit of cost-effective energy efficiency improvements.

New action-oriented benchmarking tools are being developed to expand the capability of building energy benchmarking practices. The web-based action-oriented benchmarking tool will be based on the building and end use characteristics and energy consumption data from approximately 2800 commercial buildings from the California End Use Survey (CEUS). Surveyed end use characteristics, end-use energy use from simulations using developed prototypes, and computed energy savings from a standard set of retrofits will be used to provide users with building-specific benchmarks and feedback on energy saving potentials. The tool will allow users to benchmark their building's end use energy consumption against typical and good practice buildings. Based on the end use benchmarking results, the model will lead the user through a series of building and end-use specific questions and suggest possible retrofits or operational changes to reduce energy use. The tool will offer a layered approach to benchmarking, with initial inputs linked to existing whole-building energy use tools such as EPA's ENERGY STAR[®] Rating.

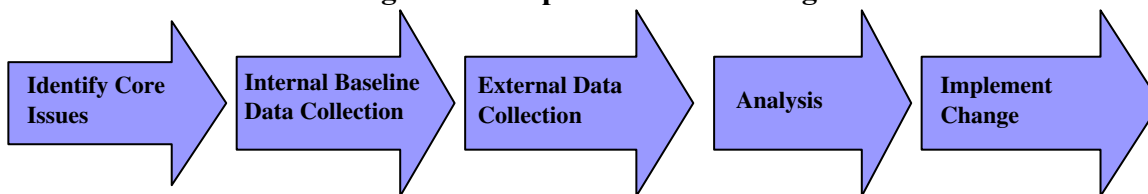
Introduction

Benchmarking Context

Historically, the activity of benchmarking and comparing business processes was part of the Total Quality Management (TQM) movement that assisted in identifying actions to improve process management. Benchmarking is also part of "learning processes" that provide a framework for evaluating how one organization's business process compares with others. The five steps in Figure 1 illustrate a generic representation of energy benchmarking. We can use this graphic to represent building energy benchmarking, which begins with an assessment of core issues, followed by collecting data on the subject facility (internal baseline) and comparing it with others (external data). The final two steps include analysis to compare internal and external data, and identification of actions to take to implement improvements. The final and critical step to identify potential actions to reduce energy use in a facility is left out of many of today's

building energy benchmarking approaches. However, this final step is being considered in the design of future action-oriented, advanced benchmarking tools.

Figure 1. Steps in Benchmarking



Building Energy Benchmarking

The purpose of whole-building energy benchmarking is to compare a given building's energy performance to that of similar buildings. Whole-building energy benchmarking can help a building owner or operator determine how well their building is performing, compare their building's energy consumption to that of similar buildings, track and set targets for improved performance, facilitate assessments of property values, and gain recognition for exemplary achievement. ENERGY STAR and Cal-Arch provide a framework for evaluating building energy consumption and can lead to further exploration and implementation of energy efficiency improvements. Web-based benchmarking tools, such as ENERGY STAR and Cal-Arch, allow for dissemination of building energy comparison data in ways that were not possible before the Internet. Correspondingly, benchmarking methods can also be used to evaluate the performance of building sub-systems and components.

The concept and practice of benchmarking the energy performance of buildings is a growing area of interest for building owners, utilities and state and federal agencies (Kinney and Piette 2003, CEC 2005). Benchmarking can be used to motivate building owners and operators to pursue cost-effective energy efficiency improvements. Guiding the work reported in this paper is the current focus on expanding the use of benchmarking tools in the California public and private sectors. This focus emerges from two key activities in California related to benchmarking. One is the Governor's Green Building Executive Order S-20-04 (Schwarzenegger 2004). The EO states that "the CEC shall propose a simple building benchmarking system". The second is the AB 549 Report to the Legislature on Strategies to Reduce Energy Consumption in Existing Buildings. The California utilities are also evaluating the need for benchmarking tools to help them meet new aggressive utility-wide energy saving goals for their 2006-2008 DSM programs.

This paper mentions a number of benchmarking tools developed at LBNL; discusses current California benchmarking activities – including the expansion of the number of California K-12 schools in a benchmarking database, the collaboration between Cal-Arch and ENERGY STAR activities; and discusses the future development of an action-oriented benchmarking tool which will allow users to benchmark their building's end use energy consumption and obtain feedback on energy saving potentials.

Benchmarking Activities at Lawrence Berkeley National Laboratory

LBNL has been instrumental in developing a number of commercial and industrial benchmarking systems over the past few years. Tools currently being used in the residential, commercial and industrial sectors include:

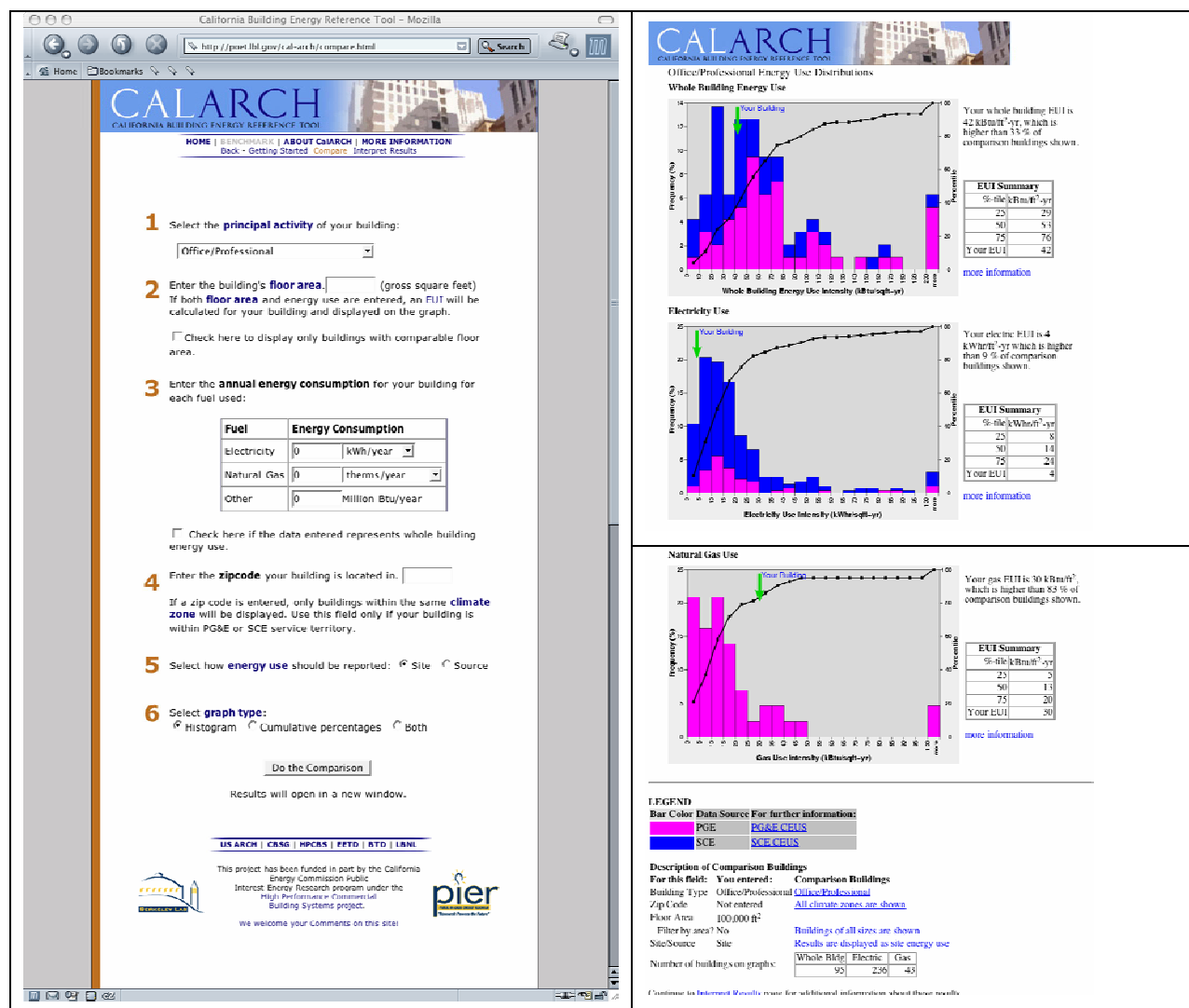
- **Home Energy Saver:** a tool to help consumers identify ways to save energy in their homes.
- **Cal-Arch:** a tool for benchmarking whole-building energy for California commercial buildings.
- **Labs 21:** a national database with whole-building and system-level energy use data for laboratories.
- **Cleanrooms:** Cleanroom level, system level, and selected equipment energy use data based upon measured performance.
- **Data Centers:** Data center, system-level, and selected equipment energy use data for California and New York facilities, based on measured performance.
- **BEST Winery:** a tool to evaluate the energy and water efficiency of a winery, and assess the environmental and financial impacts of improvement strategies.

Cal-Arch is of particular interest to this paper's discussion and is shown in Figure 2. Cal-Arch is a California-specific simple distributional benchmarking tool which is based on four key inputs: building type, location, floor area and building energy consumption (electricity and natural gas). This information provides a broad overview as to how their building compares to other buildings – further investigation is needed if a building's EUI is much greater than others...likewise, a low-EUI building should be reviewed to make sure all energy use is accounted for and the floor area is correct. LBNL's benchmarking website (<http://energybenchmarking.lbl.gov>) provides further information and links to each of the tools mentioned above.

Recent Benchmarking Activities

The second phase of the High Performance Commercial Buildings Systems (HPCBS) research program's benchmarking work is in process. This research is being conducted by LBNL for the California Energy Commission. The benchmarking research focuses on three areas – collaboration with the Collaborative for High Performing Schools, collaboration with EPA and ENERGY STAR, and developing plans for advanced benchmarking tools using the new California End Use Survey (2002 CEUS).

Figure 2. Cal-Arch Input and Results Pages

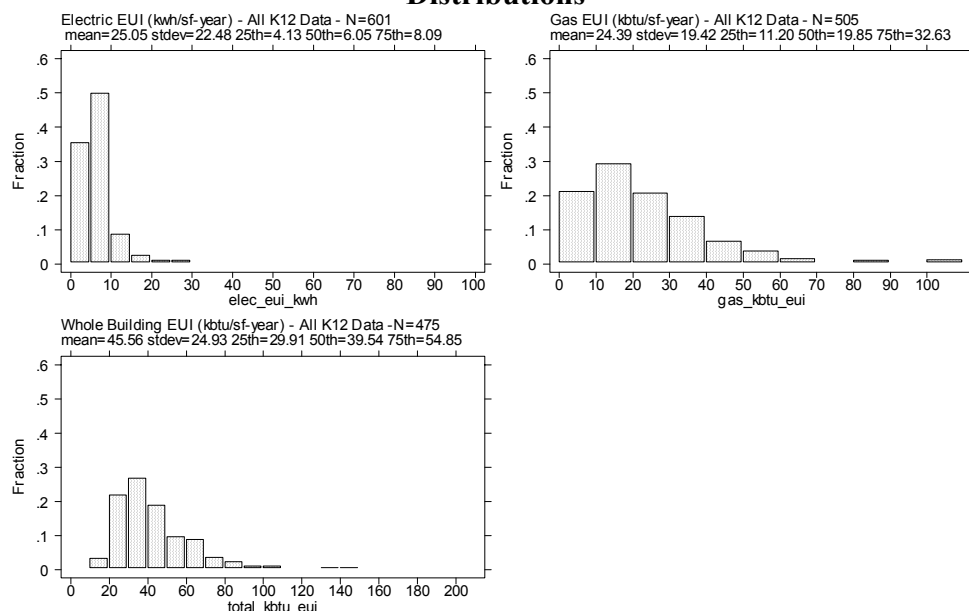


Collaboration with the Collaborative for High Performing Schools

In the first phase of the HPCBS program, we found that less than forty K-12 schools were included in the previous CEUS data set and therefore in Cal-Arch. There was interest in expanding the number of school benchmarking data points in order to provide a larger sample and better represent California schools. In the second phase of this work, we have expanded the schools database to include about 600 California K-12 schools through collaboration with the Collaborative for High Performing Schools, Pacific Gas & Electric, and the California Energy Commission's Bright Schools Program. Figure 3 shows the distribution of whole building energy use intensities (EUIs) for this expanded dataset. Matson and Piette 2006 provide a full analysis of this data. We found that the distributions of the EUIs within each data set have a normal distribution and are within the ranges of the distribution found for the CEUS data. As expected, we were able to denote clear ranges of EUI values for each educational level (elementary,

middle, high) and climate type. We anticipate that this data set will provide a rich basis for future schools-specific benchmarking tools.

Figure 3. New K-12 California Schools Data Set: Electric, Gas and Whole Building EUI Distributions



Collaboration with EPA and ENERGY STAR

The collaboration with EPA's ENERGY STAR focused on the discussions regarding benchmarking needs related to California's Executive Order and on evaluating how changes in the recent ENERGY STAR models affected the relative ENERGY STAR ratings for California buildings.

California's executive order: benchmarking. LBNL and EPA have been instrumental in the CEC and state agency discussions regarding how existing and future benchmarking tools and methods could be used or developed to serve the needs of California's Executive Order (CEC 2005). As part of these discussions, EPA and Oakridge National Laboratory will be developing new EnergyStar benchmarking models that will incorporate analyses of both the 2003 Commercial Building Energy Consumption Survey and the 2002 CEUS. To provide continuity with existing tools and other benchmarking systems, the EPA and the CEC will also collaborate on methodologies for data exchange between the national ENERGY STAR tool and future California-specific benchmarking tools.

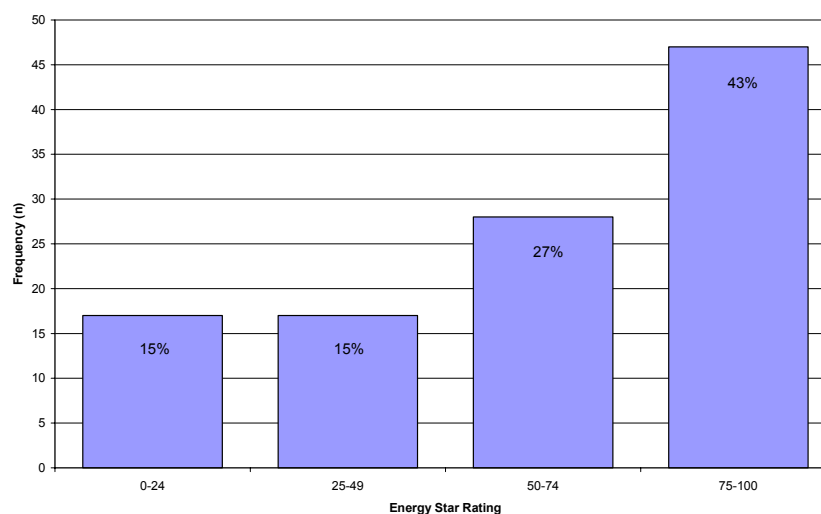
California building performance with Cal-Arch and new ENERGY STAR models. This section discusses the California-specific evaluation of the recent national ENERGY STAR models and how the results of the ENERGY STAR and Cal-Arch methods correlate to each other. Kinney and Piette (2002) had previously evaluated the performance of the California CEUS office and school buildings using the circa 2002 ENERGY STAR models. They found that the correlation between heating and cooling degrees for the Division 9 (California, Oregon, Washington, Alaska and Hawaii) CBECS offices was significantly different than that for the rest

of the country. As the ENERGY STAR office model only used cooling degrees in the weather-normalization procedure and the schools model only used heating degrees, there was concern that there was an upwards bias in the model that could play a significant factor in the higher scores found for California buildings. They also determined that the presence of pools significantly impacted the school ratings. EPA reviewed these issues and the current ENERGY STAR models include both heating and cooling degree days. They also added a pool attribute into the schools model. We have updated the Kinney and Piette evaluation and expanded it to include six building types (offices, K-12 schools, medical office buildings, hotel/motels, supermarkets and warehouses) using the corresponding current ENERGY STAR models. We found that the degree days changes and the addition of the pools attribute into the schools model reduced the school ratings to a more reasonable level. On average, the office building ratings changed only slightly. Matson and Piette (2005) provide further information regarding this analysis.

California CEUS Data – Office Buildings – Current ENERGY STAR Model Ratings

A subset of 109 California CEUS office buildings was evaluated with the current ENERGY STAR Rating tool. These buildings are also included in the Cal-Arch building database. The distribution of ENERGY STAR scores for the 109 office buildings are shown in Figure 4. The average ENERGY STAR rating is 61 – the floor-area weighted average rating is 68. 47 have ratings of 75 or greater (43% of sample) – this is significantly higher than the 25% predicted for the national stock.

Figure 4. CEUS Office Buildings: ENERGY STAR Ratings (n=109)



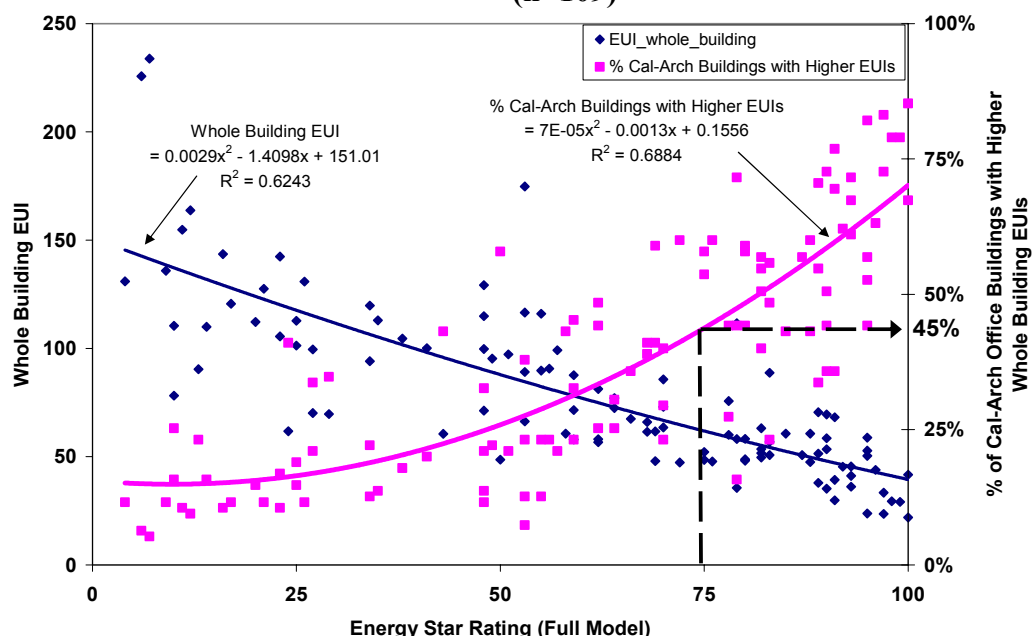
Correlation between ENERGY STAR Ratings and Cal-Arch Rankings

Cal-Arch and ENERGY STAR each provide benchmarking ratings for commercial buildings – Cal Arch based on the relative distribution of the overall building energy use/square foot (EUI), and ENERGY STAR based on a 1-100 scale determined from the buildings' EUI plus building and occupancy characteristics. Of interest is how well the ENERGY STAR rating and Cal-Arch rankings for individual buildings relate to each other. Cal-Arch currently reports

the percent of similar building types in the Cal-Arch database that have lower EUIs (less energy consumption per square foot per year), while ENERGY STAR reports the percent of similar building types nationwide that have higher EUIs. In order to compare the results of these tools directly, we have created a new metric – Relative Cal-Arch Ranking, which is the relative ranking of a building’s EUI within similar buildings in the Cal-Arch database. The relative ranking is the percent of buildings within the Cal-Arch database that have higher EUIs. This metric is easier to directly compare to the ENERGY STAR Scores, which also corresponds to the percent of buildings with higher EUIs.

The relative Cal-Arch rankings have been calculated for each of the 109 California CEUS office buildings. The whole building EUI and relative Cal-Arch are plotted against the ENERGY STAR Ratings (Figure 5). The building’s whole building energy use intensity (kBtu/ft²-year) is on the left axis. The building’s relative Cal-Arch ranking is on the right axis (% of Cal-Arch office buildings with higher whole building EUIs). We find that the trends between the Cal-Arch EUIs and Relative Cal-Arch Rankings are consistent – as ENERGY STAR Ratings increase, the Relative Cal-Arch Ranking also increases. As ENERGY STAR Ratings decrease, the whole building EUIs increase.

Figure 5. Comparison between ENERGY STAR Ratings (Full Model) and Whole Building Energy Use Intensity and Relative Cal-Arch Ranking: California CEUS Office Buildings (n=109)



Of significance is the relationship at an ENERGY STAR Rating of 75. As shown in Figure 4, we found that 43% of these 109 office buildings had an ENERGY STAR Rating of 75 or greater. Using the curve fit for the Relative Cal-Arch Ranking, we find that an ENERGY STAR Rating of 75 translates into 45% of office buildings in Cal-Arch having higher EUIs. These results are within bounds and are consistent with each other.

These results confirm that as the ENERGY STAR model is highly dependent on floor area and energy consumption, both of which are used to calculate EUI, the ENERGY STAR rating is roughly related to the whole building EUI. The consistent trend between the ENERGY

STAR rating and the relative Cal-Arch ranking points to how well the EUI distribution of the office buildings within the Cal-Arch database matches the distribution of ENERGY STAR ratings for the same dataset.

The Future: Action-Oriented Benchmarking Tools

While existing simple benchmarking tools can help identify high-energy buildings and can serve as a first look for building staff and decision-makers, these tools do not provide enough feedback to identify the specific building systems or end-uses that may explain high energy use. To address this problem, LBNL is working on the development of an advanced benchmarking tool. This “action-oriented” benchmarking tool is designed to drill down and take into account specific building and end-use characteristics to benchmark the performance of system components and sub-systems against those of similar typical and good practice buildings. There are a number of drill down benchmarking tools in use or under development today, such as the Nexus nationally-based *Business Energy Analyzer* used by the California investor-owned utilities, and Bill Bordass’s *Energy Assessment and Reporting Methodology (EARMTM)* used by the European Union – however, there are currently no California-specific benchmarking models that allow users to compare their building’s end use performance to that of similar California buildings. To meet this need, LBNL has developed a plan to develop a web- and California-based action-oriented benchmarking tool.

Typical and good practice simulation prototypes will be developed using building and end use characteristics and energy data from the 2700 buildings included in the 2002 CEUS. The 2002 CEUS will provide a far richer source of data than has previously been available and will open the possibilities of creating new and more powerful benchmarking process and tools. The 2002 CEUS end-use estimates should provide an important data set to explore evaluating the major drivers of the distribution of energy use intensities in California commercial buildings.

Issues that will be explored in developing the action-oriented tool include:

- Benchmarking model structure – simulation, distributional, regression, weather normalization.
- Scope – annual energy performance, seasonal energy performance, peak demand
- Comparison factors to consider – building type, characteristics, climate, vintage, levels of service, amount and types of miscellaneous loads, building systems, and efficiency levels.
- How to distinguish “efficient” buildings from those with missing data or low levels of service.

The tool will use a layered approach to evaluate energy performance by fuel and whole building. Note that whole building examples are shown here, though similar performance graphics and metrics would be provided by main fuel types. By entering basic building characteristics and energy data – or by transferring it automatically from other benchmarking tools such as ENERGY STAR, the user can quickly see how their building energy use intensity (EUI) compares to similar typical and good practice buildings as well as how it compares to the overall building stock (or CEUS) (Figure 6).

Moving to the end use level (Figure 7), the user can then identify their building’s unique end uses and see how their building’s overall energy consumption compares to a simulation of

the same end uses in a typical or good practice building. The user can then specify their building's end-use specific performance and operating characteristics, including sub-metered and actual performance data, so that the action-oriented tool can compare end use performance to that of the typical and good practice buildings. Based on this information, the tool would then lead the user through a series of questions and provide user-specific information on site-specific actions – ranging from operations to O&M to capital improvements – that the building staff should consider further to produce potential energy savings.

Figure 6. Energy Use Intensity (EUI) Compared to Building Stock (CEUS California Office Buildings)

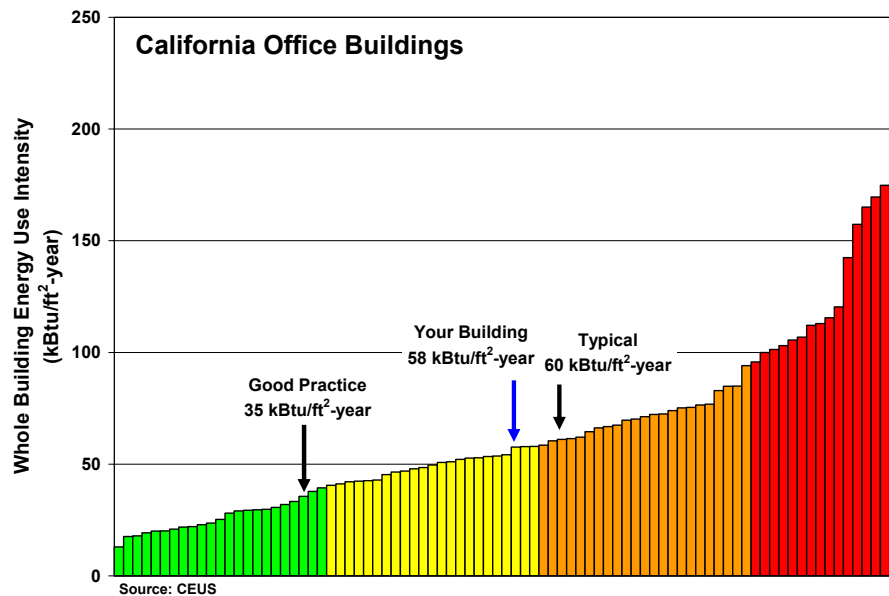
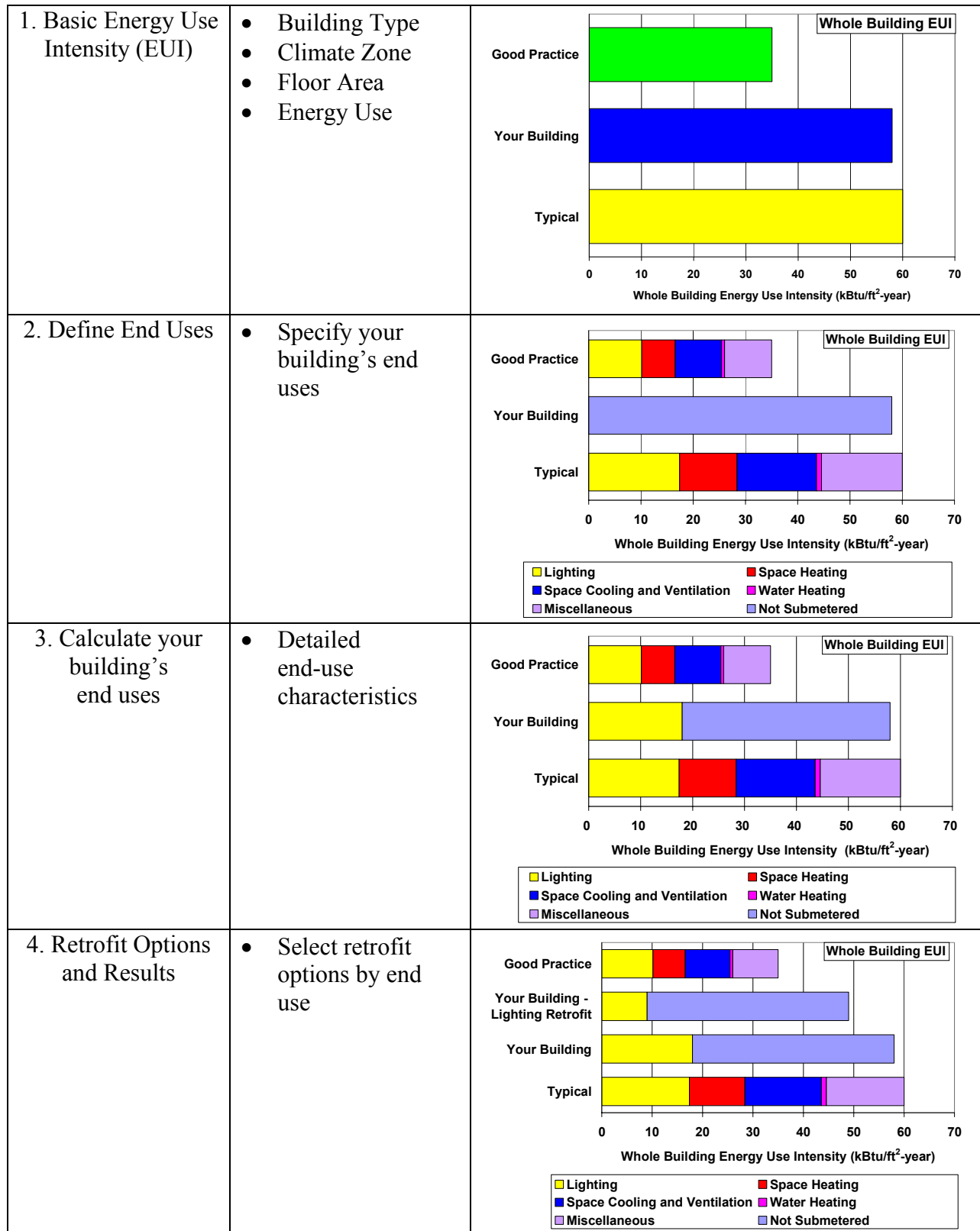


Figure 7. Building Blocks to Action-Oriented Benchmarking Method



Implementation Issues

While the action-oriented benchmarking tool will be able to provide results often found from a walk-through energy audit, it will not replace the analysis and conclusions typically found from an investment audit. Success of this tool will depend on how the layering is done – it is important to provide robust feedback and guidance at each level without overwhelming the user. Incremental steps between levels should be manageable and provide enough quality feedback so that the user is encouraged to go further through the tool, evaluate the applicability of specific retrofits and operational and performance improvements for their building, and implement activities that can improve their building's performance over the long term.

Web-based benchmarking methods have helped increase the implementation of simple and action-oriented benchmarking in the commercial building sector – more than 2500 buildings earned ENERGY STAR ratings in 2005 (EPA 2006). Interconnecting web-based benchmarking methods with each other, utility and energy agency programs, and energy information services can increase the accessibility and usability of these systems.

Conclusions

The development of and need for building energy and performance benchmarking tools has grown over the past several years. Building owners and managers want to know how their buildings perform and need tools that guide their operational changes and energy retrofits. The simple benchmarking tools (Cal-Arch, ENERGY STAR, etc.) discussed in this paper have started to meet this need. The creation of a California-based action-oriented benchmarking system may help California building operators hone in on and identify specific energy and performance improvements to maximize their building's performance.

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