

HPCBS

High Performance Commercial Building Systems

Review of California and National Benchmarking Methods

Task 2: Benchmarking California Buildings

Working Draft

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April 1, 2005



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1. Introduction

This report has been developed in order to support benchmarking planning and tool development currently under discussion by the California Energy Commission, Lawrence Berkeley National Laboratory and others in relationship to the Governor’s Executive Order. This report summarizes and compares two currently available building energy benchmarking tools – the U.S. Environmental Protection Agency’s Energy Star National Energy Performance Rating System regression-based model and Lawrence Berkeley National Laboratory’s Cal-Arch California-based distributional model. Prior to the time Cal-Arch was developed, there were several other benchmarking tools available to California consumers but none that were based solely on California data. The Energy Star and Cal-Arch benchmarking tools provide California with two unique and useful methods to benchmark the energy performance of California’s buildings. Correspondingly, the purpose of this report is not to determine which model is better, but to understand the underlying systems, assumptions, and outcomes of each model.

A Brief Benchmarking History

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 the graphic below illustrate a generic representation of benchmarking. We can use this graphic to represent building energy benchmarking, which begins with an assessment of core issues, followed by collecting data on your 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 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 benchmarking tools.

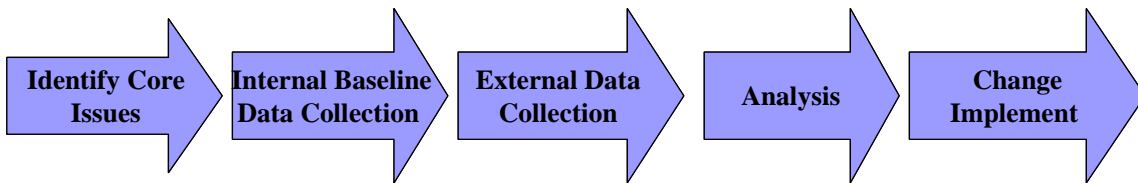


Figure 1-1 – Steps in Benchmarking

Building Energy Benchmarking

Building energy benchmarking is relatively new and web-based tools allow for dissemination of building energy comparison data in ways that were not possible before the Internet. The purpose of building energy benchmarking is to compare a given building’s energy performance to that of similar buildings. Benchmarking can help a

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building owner or operator determine how well their building is performing, compare their building's energy consumption to that of other similar buildings, set targets for improved performance, facilitate assessments of property values, and gain recognition for exemplary achievement. Energy Star and Cal-Arch both suggest that there is value in benchmarking California's buildings. Starting with basic building characteristics and energy use data, benchmarking forms a foundation for evaluating building energy consumption and can lead to further exploration and implementation of energy efficiency improvements.

Table 1-1 provides a brief summary of the Energy Star and Cal-Arch benchmarking systems. These benchmarking models can be used separately or together to evaluate the energy performance of a specific building. Both models are highly dependent on the accuracy of the floor area and energy consumption values – both of which are used to derive the building's energy use intensity (EUI, kBtu/ft²-year).

Table 1-2. Summary of Energy Star and Cal-Arch Attributes

	Energy Star	Cal Arch
Sources of Underlying Data		
Source of Data	Commercial Building Energy Consumption Survey (CBECS)	California Commercial End-Use Survey (CEUS)
Geographic Coverage	National	California
Type of Survey	Computer assisted phone survey	On-site survey
Scope of questions	Building and occupancy characteristics, energy consumption data	
Data quality issues	Floor area and energy consumption data for individual observations may be estimated or rounded	
Type of Statistic Model	Regression-based	Distributional
Level of Input Detail Required	Location, building type, building and occupancy characteristics, energy consumption data	Location, building type, floor area, energy consumption data
Normalization	<ul style="list-style-type: none"> – Energy consumption per square foot per year – Weather normalization of energy consumption data 	<ul style="list-style-type: none"> – Energy consumption per square foot per year – No weather normalization of energy consumption data – Comparison to energy use intensity for similar building types in similar climate zones or statewide
Output Metrics		
Graphics	Web-based Portfolio Manager with input screens and building performance results summaries for multiple buildings	Web-based tool with input screen and distributional histograms, cumulative percentages and statistical results
Scores	1 – 100 ranking compared to national dataset (75+ can apply for Energy Star label)	Percent of buildings with lower energy use intensities (EUIs)
Source vs. Site Energy	<ul style="list-style-type: none"> – Site energy inputs – Source energy used for rating calculations 	<ul style="list-style-type: none"> – Site energy inputs – Site or source energy results available

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Report Structure

This report discusses the following for the Energy Star and Cal-Arch benchmarking tools:

- Purpose of each model
- Sources of underlying data - geographic distribution, survey type, scope of questions, data quality issues
- Type of statistical methods used in each model and pros and cons of each method
- Level of detail required for data inputs - ease in collecting data inputs, data accuracy vs. robustness
- Normalization methods and impacts - weather, building area, other factors
- Output metrics – graphics, results, source vs. site energy

To provide a real world example, the application of the Energy Star and Cal-Arch benchmarking tools for two subsets of California commercial buildings is discussed. The data sets evaluated include the California Commercial End-Use Survey (CEUS) data and a subset of the California Department of General Services buildings.

Two appendices provide Energy Star model detail and further analysis results:

- Appendix A – Analysis of Current EPA Energy Star Models – CEUS Data
- Appendix B – Energy Star Regression Equations.

2. Overview of Two Benchmarking Models

This section discusses the various attributes of Energy Star and Cal-Arch. Energy Star is based on national commercial building data (www.energystar.gov) while Cal-Arch (<http://poet.lbl.gov/cal-arch/>) is based solely on California commercial building data.

2.A. Sources of Underlying Data

The Energy Star and Cal-Arch models are both based on data from building characteristics and energy consumption surveys. The Energy Star model is based on nationwide data from the DOE/EIA Commercial Buildings Energy Consumption Survey (CBECS) (DOE/EIA 1999), the Hospitality Research Group's Trends in the Hotel Industry Database (HRG), and EPRI's Energy Benchmarking Survey (Hospital Data). The Cal-Arch model uses data from the 1992 California Commercial End Use Survey (CEUS) – a proprietary survey conducted by California's investor-owned utilities.

Types of Surveys. All of these surveys are questionnaire-based surveys. Prior to 1999, the CBECS surveys were conducted by personal interviews of building owners or facility staff. The 1999 survey was conducted using a computer-assisted telephone interview, which provides interviewers with the ability to compare responses to those from previous surveys of the building and to run data accuracy checks on the responses. The CEUS surveys were conducted through on-site interviews and surveys.

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Scope of Questions. The CBECS and CEUS surveys are comprehensive building surveys that include numerous questions about building size and dimensions, occupancy and operational factors, building facilities, systems and equipment, and building energy consumption. The HRG and EPRI surveys include a much smaller number of variables specific to the hotel and hospital industries, including building characteristics, type of facility, facility amenities and services, occupancy, and energy consumption. Rather than building floor areas, these surveys report number of rooms and number of beds.

Data Quality Issues. The methodologies for CBECS and CEUS include varying levels of data quality checks. The accuracy of the data included in these surveys is dependent on how well each survey data point agrees with the underlying definition of each variable, the building science knowledge and capabilities of the surveyors and interviewees, the ability of the surveyor to accurately survey the building characteristics, and the interviewee's knowledge regarding building floor area, building characteristics and occupancy factors.

The two most important factors affecting building energy benchmarking are building floor area and annual energy consumption values. Accuracy of these values is essential in calculating realistic Energy Star scores and in comparing the user's building energy use intensities to that of similar buildings in Cal-Arch. Inaccurate building floor areas and/or incomplete energy consumption data can skew the calculated energy use intensity, and can result in an inaccurate comparison to other buildings.

Floor Area. Building floor area can be defined in a multitude of ways, including rentable space, conditioned floor area, gross floor area as shown on the plans, and rounded to the nearest hundred, thousand or million.

CBECS defines the building floor area as the gross or total square footage of all spaces in the building, both finished and unfinished, including basements, indoor parking levels, hallways, lobbies, stairways and elevator shafts (CBECS 1999). The CBECS interviewer asks the building owner to specify the actual building floor area or specify which floor area range the building fits into. If the owner doesn't know, the interviewer asks a series of relative questions ("is the building smaller than or larger than a book or music superstore, which is about 25,000 square feet?") to hone in on the building's floor area range. Some additional data rounding within square footage categories is done during analysis of the raw CBECS data – this can increase the overall error (Sharp 1996).

CEUS defines the survey floor area as the enclosed, normally occupied, square footage associated with a premise. A premise can be part of a building or include multiple buildings on a single site. Parking garages are not included if it is on a separate meter. The CEUS survey obtains building floor area by measuring, from drawings (blueprints, leasing documents, etc.), or as reported by the facility contact. Additional data (length, width, footprint, height) is collected and is used to double check total building areas and provide inputs for simulation models.

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Energy Consumption. Annual energy consumption (electricity, natural gas, other fuels) is needed to calculate a building's Energy Star rating and energy use intensity – this may require adding up energy consumption from multiple meters, making sure that all meters serving the building are counted, and checking that other facilities and purposes (outdoor lighting, etc.) are not being served by meters included in the calculation.

The majority of the CBECS energy consumption values are as reported by the building owner or interviewee. Utility company energy consumption data is requested only for those buildings where the interviewee was not able to supply this information. As such, there is no verification of the interviewee-supplied energy consumption data against the Utility-supplied data.

Prior to the CEUS on-site surveys, a list of gas and electric meters and accounts serving the surveyed premises is developed and provided to the on-site surveyor. During the on-site survey, the CEUS surveyor lists the utility meters found – noting whether the meter has been verified, added, deleted, not found, etc. The utility meter list is then used to obtain the energy consumption data from the utility. Errors in total energy consumption can occur if the surveyor is not able to identify all of the meters serving the premises or if meters serve more than the premise surveyed.

2.B. Type of Statistical Models

Both models are based on statistical analyses of building characteristic and energy consumption data. The Energy Star model is based on regression analyses whereas the Cal-Arch model is a distributional benchmark with quantitative statistics guiding the building evaluation.

Energy Star Model – Synopsis

The Energy Star model is based on building-type specific regression analysis, where annual source energy consumption is predicted based on building characteristics and occupancy factors. The Energy Star methodology for office buildings is summarized here. Further details regarding the Energy Star methodology and the current regression analyses are provided in Appendix B of this report. Buildings that score 75 or higher and meet the current industry standards for indoor environmental quality are eligible to receive the Energy Star label. Following is a brief description of the Energy Star methodology:

Mapping of Building Energy Consumption (EUI) on 1-100 Rating Scale:

- The building-type specific regression model (based on the applicable CBECS, Hotel or EPRI Hospital data) is used to predict the Actual LnSource energy consumption (EUI) for each observation in the data set (CBECS, Hotel or EPRI data). Independent variables are described in Appendix B.
- After generating EUI histograms, the Actual LnSource EUI (kBtu/ ft²-yr) data is mapped on a 1-100 point scale, with the 75% percentile Actual LnSource EUI at

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the 75 point level. This data is then smoothed out by fitting the data to a gamma distribution (Fitted LnSource EUI, kBtu/ft²-yr).

Energy Star Rating Calculation:

- The regression model is used to predict a specific building's source EUI.
- The Customized Source EUIs are calculated by multiplying the Fitted LnSource EUI data by an adjustment factor ($[\text{predicted building Source EUI}]/[\text{mean model Source EUI}]$).
- For the hotel and supermarket models, the Customized Source EUI values are calculated by applying the adjustment factor to the Fitted LnSource EUI data and then dividing the exponent of the adjusted Fitted LnSource EUI data by the building floor area.
- The building source energy consumption (Source EUI) is weather normalized based a 30-year average weather year (See Section 2.D).
- The weather-normalized building source energy consumption is compared to the Customized Source EUI values to determine the building's Energy Star rating.

EUI Adjustments for Secondary Uses. The Energy Star model adjusts the building energy consumption to take into account computer data centers, garages and parking lots, and swimming pools. EPA 1999 describes the derivation of these adjustments: for computer data centers, 359.5 kBtu/ft²-year is subtracted from the building energy consumption total (no operating hour adjustment); for parking facilities, a lighting and ventilation energy consumption value is multiplied by the number of operating hours per year and subtracted from the building total. The swimming pool model, developed by EPA staff based on a swimming pool model developed by LBNL, calculates swimming pool annual energy based on pool size and number of months operating per year.

Cal-Arch Model - Synopsis

Cal-Arch, a distributional benchmarking tool developed by LBNL, is based on existing survey data from California's 1992 Commercial End Use Survey (CEUS). Cal-Arch is a distributional benchmarking tool. Distributional benchmarking allows the user to determine the percent of similar buildings that use more or less energy than their building. The distribution of EUIs for comparison buildings is displayed graphically in a histogram and summary statistics are provided for each quartile. The data displayed are actual EUIs and are not adjusted for weather or any other factors. The user can compare their building's EUI to that of similar buildings in the same climate zone or statewide.

2.C. Model Inputs

Base Data

Energy Star. In developing the Energy Star building-specific models, EPA evaluated the data quality of each potential variable and used a data filter on the observations in the raw data sets to develop the data set used to develop the regression models.

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In order for Energy Star's regression models to be used effectively to estimate predicted energy use intensities, EPA requires that model inputs be within certain bounds. Buildings that fall outside of these bounds (such as small and very large buildings, buildings with shorter operating hours, etc.) are not able to obtain an Energy Star rating. The primary reason is because the Energy Star regression equations were derived based on a given dataset – accuracy of predicted source energy use intensities for buildings with characteristics outside the bounds of the original regression dataset would be suspect.

Appendix B includes the raw data input filters and the analysis tool input bounds.

Cal-Arch. Cal-Arch is a distributional benchmarking tool based on climate, building type and energy consumption data from the California Commercial End-Use Survey (CEUS). Theoretically, there are no restrictions regarding whether or not a given building can be benchmarked against the Cal-Arch dataset. A given building or premise's energy use intensity – regardless of number of buildings, building size, operating hours and unique characteristics – can be compared to the Cal-Arch database of building energy use intensities. After evaluating the relevance of the position of their building's EUI within the Cal-Arch distribution, the user can then independently review their building's operational and performance issues which may affect their building's energy use intensity.

Accuracy and Robustness

Energy Star. The Energy Star model calculates an Energy Star rating based on three main inputs (zip code for location, floor area, and monthly energy consumption data) plus a number of occupancy and use characteristics specific to each building type (number of occupants, operating hours, number of months per year, number of computers, percent of building floor area air conditioned, percent of building floor area heated, use of mechanical ventilation, cooking facilities, refrigeration, lighting, etc.). Table 2-1 summarizes the types of data inputs for each building type. Model-specific input assumptions and valid data value ranges are shown in Appendix B.

Zip code is used to pull heating and cooling degree data from the nearest weather station – the weather data is used to perform weather normalization on the energy consumption data.

Energy Star's building *floor area* input is the gross interior area of the building, including hallways, lobbies and ancillary services (stairways, elevators, janitor closets, mechanical rooms, etc.) (EPA 2003). In developing the Energy Star models, EPA looked at the correlation of building energy consumption to a number of building characteristics. They found that building floor area was the most significant input to the Energy Star regression models and provided a good fit as seen in the "Floor Area Only" R^2 values in Table 2-2. Additional inputs, such as occupancy, operation hours, computers, etc. added to the full model and increased the model's R^2 and robustness, but were individually not as significant a factor as the building floor areas were.

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Table 2-1. Required Information – Energy Star Models

	<i>K-12 Schools</i>	<i>Office</i>	<i>Hotels</i>	<i>Medical Offices</i>	<i>Supermarkets</i>	<i>Warehouses</i>	<i>Hospitals</i>	<i>Dorms</i>
<i>Zip Code</i>	X	X	X	X	X	X	X	X
<i>Year Built</i>	X	X	X	X	X	X	-	-
<i>Area</i>	X	X	X	X	X	X	-	X
<i>Number of Floors</i>	-	-	-	-	X	-	X	-
<i>Number of Rooms</i>	-	-	X	-	-	-	-	X
<i>Hours of Use</i>	X	X	-	X	X	X	-	-
<i>Number of Occupants</i>	X	X	-	X	X	X	-	-
<i>Tertiary Care</i>	-	-	-	-	-	-	X	-
<i>Above Ground Parking</i>	-	-	-	-	-	-	X	-
<i>Number of Personal Computers</i>	X	X	-	-	X	-	X	-
<i>On-site Cooking</i>	X	-	X	-	X	-	-	-
<i>On-site Laundry</i>	-	-	X	-	-	-	-	-
<i>%Floor area air conditioned</i>	X	-	-	X	-	X	-	X
<i>% Floor area heated</i>	X	-	-	X	-	X	-	X
<i>Mechanical Ventilation</i>	X	-	-	-	-	-	-	-

Table 2-2. Energy Star Model R²

Building Type	Model R²	
	Floor Area Only	Full Model
K-12 Schools	0.85	0.87
Offices	0.91	0.93
Hotels / Motels	not provided	0.60 to 0.88
Medical Offices	0.91	0.93
Supermarkets	0.63	0.79
Warehouses	not provided	0.80
Dorms	0.86	0.88
Hospitals	not provided	0.83

Cal-Arch. Cal-Arch requires four inputs: building type, floor area, energy consumption (electricity, gas, other), and zip code. For comparison, Cal-Arch provides an un-weighted distribution of EUIs for similar buildings in the same climate zone or statewide. Using an un-weighted distribution reduces the overall impact of high end use intensity buildings. Small sample sizes and extreme values are less apt to skew the distribution, but the middle portions of the distribution must be well defined with a good level of accuracy as a small change in EUI can shift the percentile ranking on a cumulative distribution substantially (Sharp 1998).

The *building type* is used to pull similar buildings from the Cal-Arch database to be used in the distributional comparison and it is important that the building be defined correctly

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and that the building type specified is the predominant building activity. Unlike Energy Star, Cal-Arch does not currently have the capability to calculate composite building energy use distributions for buildings with multiple building uses (for example, a building with 50% office space and 50% K-12 classrooms). Cal-Arch's building type definitions were designed to correspond roughly to the CBECS categories (Table 2-3) (Kinney and Piette 2003). The Energy Star model development also uses the CBECS categories. Using similar building type designations allows one to look at Cal-Arch and Energy Star results for similar building types.

As discussed previously, *floor area* and *annual energy consumption* values are used to calculate building or premise energy use intensities (EUIs). The survey units in CEUS are "premises" and can include multiple buildings. As such, Cal-Arch users can enter gross floor areas and annual energy consumption values for a single building or set of buildings as long as all floor areas and energy consumption values are accounted for. Inaccurate building floor areas and/or incomplete energy consumption data can skew the calculated EUI and can result in an inaccurate comparison within the EUI distribution.

Zip code is used by Cal-Arch to determine in which of the four California climate zones (North Coast, South Coast, Central Valley and Desert/Mountain) a building is located (Figure 2-1). These four climate zones were created by mapping the CEC's sixteen climate zones into four zones – doing so allowed Cal-Arch to provide larger climate-based sample sizes for each building type. By designating their building's zip code, the user is able to compare their building to similar buildings in a similar climate.

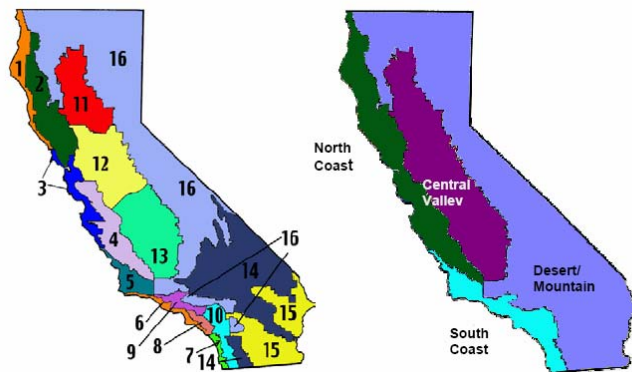


Figure 2-1. CEC California Climate Zones Mapped to Four Main Climate Zones

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Table 2-3. Building Type Correlation (Kinney and Piette 2003)

CBECS Category	CEUS Category	Title 24 (RLW survey)
Agricultural	Agricultural	
Education	Daycare or Preschool Elementary/Secondary College or University Vocational or Trade School	School
Enclosed Shopping/ Mall	Shop in Enclosed Mall	
Food Sales	Supermarket Convenience Store Other Food Store	Grocery Store
Food Services (Restaurant)	Fast Food or Self Service Table Service Bar/Tavern/Club/Other	Restaurant
Health Care (Inpatient)	Hospital	
Health Care (Outpatient)	Medical Office Clinic/Outpatient Care	Medical Clinic
Industrial Processing/Mfr	Assembly/Light Manufacturing Med/Heavy Equip. Mfg Food/Beverage Processor	
Lodging (Hotel/Motel/Dorm)	Hotel Motel Resort	Hotels/Motels
Nursing Home	Nursing Home	
Office/Professional	Administration & Management Financial/Legal Insurance/Real Estate Other Office	Office
Public Assembly	Recreation or Other Public Assembly	Religious, Auditorium Theater Community Center Gymnasium Libraries
Public Order & Safety		Fire/Police/Jail
Religious Worship	Church	Religious, Auditorium
Retail (except mall)	Department/Variety Store Other Retail	Retail & Wholesale
Service (except food)	Gas Station/Auto Repair Repair/Non-Auto Other Service Shop	
Warehouse (non-refrigerated)	Warehouse (non-refrigerated)	C&I Storage
Warehouse (refrigerated)	Warehouse (refrigerated)	C&I Storage

2.D. Normalization

Energy Star. Building energy usage is normalized per square foot per year. The Energy Star methodology includes *weather normalization* of the monthly energy consumption data. The weather normalization method used is based on E-Tracker, a software tool developed by Dr. Kelly Kissock (University of Dayton). The building's monthly electricity consumption data is regressed against the location's monthly average daily temperatures. Individual month's data must be within 50% of the building's average monthly consumption to be included in the model. Based on the regression analysis, historical 30-year average monthly temperatures are used to normalize the building's actual 12-month electricity consumption up or down. The same method is used for gas and district steam energy consumption, but all months are included in the normalization step (EPA 2005).

Cal-Arch. Building energy usage is normalized per square foot per year. While no weather normalization of energy consumption is used, users can compare their building's energy use intensity to that of similar buildings in the same climate zone as well as statewide.

2.E. Output Metrics

Energy Star

Graphics. Energy Star (www.energystar.gov) uses a web-based portfolio manager to input, calculate and present Energy Star ratings and data for multiple facilities. Users can also submit data for multiple buildings using an Excel-based import template. To input a new building's data directly into the portfolio manager, users are led through a series of input screens (one of which is shown in Figure 2-2). The portfolio manager performs a basic data check as the user enters data.

The My Portfolio page (Figure 2-3) provides summary performance information for all buildings included in the user's portfolio. The Portfolio Manager provides a choice of standard portfolio views, including building data (floor area, actual annual energy intensity) and performance data (energy star rating, environmental performance, energy costs, and comparisons to baseline energy consumption). The user can also specify custom summaries. The user can organize facilities into smaller groups of facilities and export performance data to Excel.

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PORTFOLIO MANAGER

ACCOUNT INFORMATION CONTACTS CONTACT US HELP LOGOUT

Home > My Portfolio > New office building > Add a Facility Space

Add a Facility Space: New office building

Values entered are used to generate a 1-to-100 rating of the facility's energy performance. As a convenience to Portfolio Manager users, default values for certain Facility characteristics which may not be known are provided. This feature enables estimated energy performance ratings to be calculated.

Please note: Using default values will not overwrite data that you have entered, however, while using the default values, your data will not be used in Space Use and Facility Performance calculations.

REQUIRED

Space Name:

Space Attribute	Value	Use Default Value	Units	Effective Date (when this Attribute Value was first true) <small>What is this? (MM/DD/YYYY)</small>
*Gross Floor Area	<input type="text"/>	N/A	Sq. Ft. ▾	<input type="text" value="01/01/2000"/>
*Occupants	<input type="text"/>	<input type="checkbox"/>	No Units	<input type="text" value="01/01/2000"/>
*Number of PCs	<input type="text"/>	<input type="checkbox"/>	No Units	<input type="text" value="01/01/2000"/>
*Operating Hours/Week	<input type="text"/>	<input type="checkbox"/>	Hours ▾	<input type="text" value="01/01/2000"/>

Figure 2-2. Energy Star Portfolio Manager – Building Input Screen

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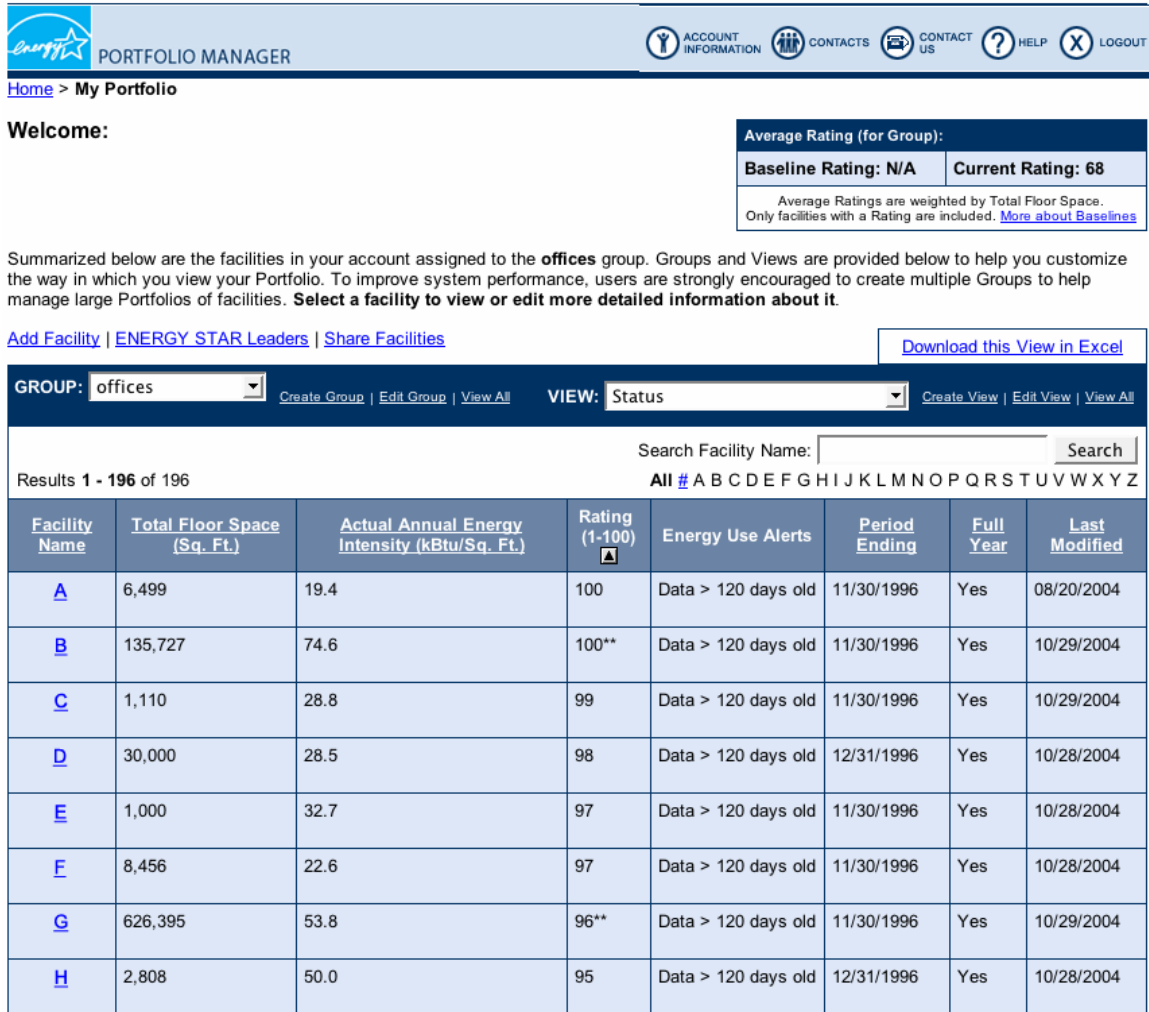


Figure 2-3. Energy Star Portfolio Manager – My Portfolio Results Summary

Results. The primary Energy Star result is the Energy Star rating. A building with a score of 75 or greater can obtain an Energy Star label if the building also meets current indoor environmental quality standards. Average ratings for all buildings in the Portfolio Manager, or for a smaller group of facilities, is available and can be compared to a average baseline rating.

Site vs. Source Energy. Energy Consumption data is entered as site energy, as provided on the building’s energy bills. In order to provide a fuel-neutral rating, Energy Star converts the site energy to source energy when determining the building’s Energy Star rating.

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Cal-Arch

Graphics. Cal-Arch is a web-based tool (<http://poet.lbl.gov/cal-arch/>) which includes an input page, results page, and supporting documentation. Figure 2-4 and Figure 2-5 show the input and results pages. To input their building's characteristics, users select their building type and input floor area, energy consumption, and zip code data. Their building can be compared to buildings with similar floor areas by checking a check box. By leaving the zip code input blank, their building can be compared to all similar CEUS buildings statewide. Users can also select output options, including site or source energy and type of distribution (histogram and/or cumulative percentage).

Results. The Cal-Arch results page (Figure 2-5) provides histograms showing how the evaluated building's energy use intensity compares to that of similar buildings. The EUI of the building being evaluated is identified with an arrow on the graph. Text is given summarizing the evaluated whole building, electric and gas EUIs – for example: “Your whole building EUI is 42 kWhr/ft²-yr which is higher than 9% of comparison buildings shown.” Summary quartile statistics are provided for the buildings included in the comparison building data set. The results page includes:

- Statewide or climate-zone specific whole building, electricity and gas EUI distributions by building type
- Position of building EUIs on EUI distributions
- Statistics (building EUI, % of buildings with lower EUIs, quartile EUI statistics)
- Description of comparison and evaluated buildings:
 - Building Type
 - Zip Code or climate zone
 - Floor area
 - Evaluated building floor area
 - Whether comparison building data is filtered by size
 - Site or source energy units
 - Number of comparison buildings on graphs (whole building, electric, gas)
- Links to more information

Site versus Source Energy. The Cal-Arch database includes site energy consumption values for each of the CEUS buildings. Similarly, the user inputs their building's annual energy consumption totals in site energy units, as provided on their energy bills. The user can view the results and graphics in either site or source units (kBtu/sf-year), where the site electricity data is converted to source energy using a factor of 2.7.

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California Building Energy Reference Tool - Mozilla

http://poet.lbl.gov/cal-arch/compare.html

HOME | BENCHMARK | ABOUT CalARCH | MORE INFORMATION
Back - Getting Started Compare Interpret Results

1 Select the **principal activity** of your building:

Office/Professional

2 Enter the building's **floor area**. (gross square feet)
If both **floor area** and energy use are entered, an EUI will be calculated for your building and displayed on the graph.

Check here to display only buildings with comparable floor area.

3 Enter the **annual energy consumption** for your building for each fuel used:

Fuel	Energy Consumption	
Electricity	0	kWh/year
Natural Gas	0	therms/year
Other	0	Million Btu/year

Check here if the data entered represents whole building energy use.

4 Enter the **zipcode** your building is located in.

If a zip code is entered, only buildings within the same **climate zone** will be displayed. Use this field only if your building is within PG&E or SCE service territory.

5 Select how **energy use** should be reported: Site Source

6 Select **graph type**:
 Histogram Cumulative percentages Both

Do the Comparison

Results will open in a new window.

US ARCH | CBSG | HPCBS | EETD | BTD | LBNL

This project has been funded in part by the California Energy Commission Public Interest Energy Research program under the High Performance Commercial Building Systems project.

We welcome your Comments on this site!

ENERGY STAR

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PIONEERING ENERGY RESEARCH
Research Powers the Future

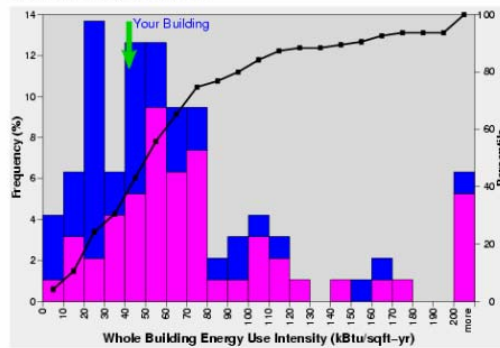
Figure 2-4. Cal-Arch Input Page

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Office/Professional Energy Use Distributions

Whole Building Energy Use

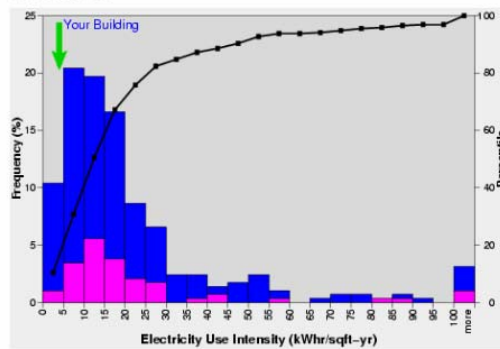


Your whole building EUI is 42 kBtu/ft²-yr, which is higher than 33 % of comparison buildings shown.

EUI Summary	
%-tile	kBtu/ft ² -yr
25	29
50	53
75	76
Your EUI	42

[more information](#)

Electricity Use

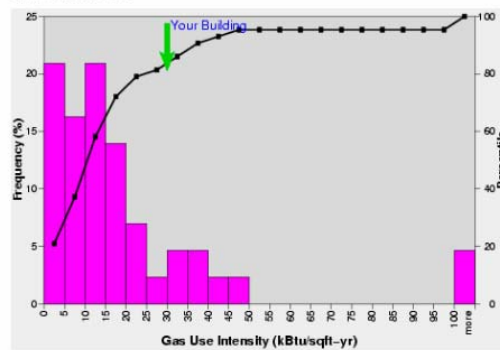


Your electric EUI is 4 kWh/ft²-yr which is higher than 9 % of comparison buildings shown.

EUI Summary	
%-tile	kWh/ft ² -yr
25	8
50	14
75	24
Your EUI	4

[more information](#)

Natural Gas Use



Your gas EUI is 30 kBtu/ft², which is higher than 83 % of comparison buildings shown.

EUI Summary	
%-tile	kBtu/ft ² -yr
25	5
50	13
75	20
Your EUI	30

[more information](#)

LEGEND

Bar Color Data Source For further information:

	PGE	PG&E CEUS
	SCE	SCE CEUS

Description of Comparison Buildings

For this field: You entered: Comparison Buildings
 Building Type Office/Professional [Office/Professional](#)
 Zip Code Not entered [All climate zones are shown](#)
 Floor Area 100,000 ft²
 Filter by area? No [Buildings of all sizes are shown](#)
 Site/Source Site [Results are displayed as site energy use](#)

Number of buildings on graphs:	Whole Bldg	Electric	Gas
	95	236	43

Continue to [Interpret Results](#) page for additional information about these results.

Figure 2-5. Cal-Arch Results Page

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3. Evaluation of Energy Star and Cal-Arch Models for California Buildings

National Performance – Energy Star

A number of papers have discussed the Energy Star model. Several of these have evaluated the characteristics and performance of Energy Star rated buildings compared to the national CBECS data. Others have evaluated how geographic-specific sets of buildings rate using the Energy Star model. Of these, Von Neida and Hicks (2001) show that the Energy Star offices' performance correlates well with that of the top 25% of the CBECS offices (Table 3-1). Hinge et al. (2002) used Energy Star to evaluate the performance of a subset of New York schools and found that the results seemed reasonable, though the impact of changes in facility maintenance and upkeep significantly affected Energy Star ratings over time.

Table 3-1. Comparison of 2001 Energy Star Office Buildings to CBECS Office Buildings (Von Neida and Hicks, 2001)

	Site Energy Intensity (kBtu/ft ² -year)	Source Energy Intensity (kBtu/ft ² -year)	Energy Cost Intensity (\$/ft ²)*
Energy Star Offices	61.4	166.2	1.23
CBECS Average	101.1	261.8	2.03
CBECS Top 25%	48.2	113.9	1.02
CBECS Bottom 25%	217.0	511.0	3.51
BOMA EER	-	-	2.11

California Performance – Energy Star

Kinney and Piette (2002) evaluated the performance of California CEUS office and school buildings using the previous 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 (Figure 3-1). As the office model used cooling degrees only and the schools model used heating degrees only, there was concern that there was an upwards bias in the model that could play a significant factor in scores. EPA reviewed this issue and now includes both heating and cooling degree days in the current models. Matson and Piette have updated this evaluation and expanded it to include six building types (offices, K-12 schools, medical office buildings, hotel/motels, supermarkets and warehouses) using the current Energy Star models. They found that the degree days changes and the addition of the pools model into the schools model reduced the school ratings to a more reasonable level. On average, the office building ratings changed only slightly. The Matson and Piette results are summarized below and the full memo is included as Appendix A of this report.

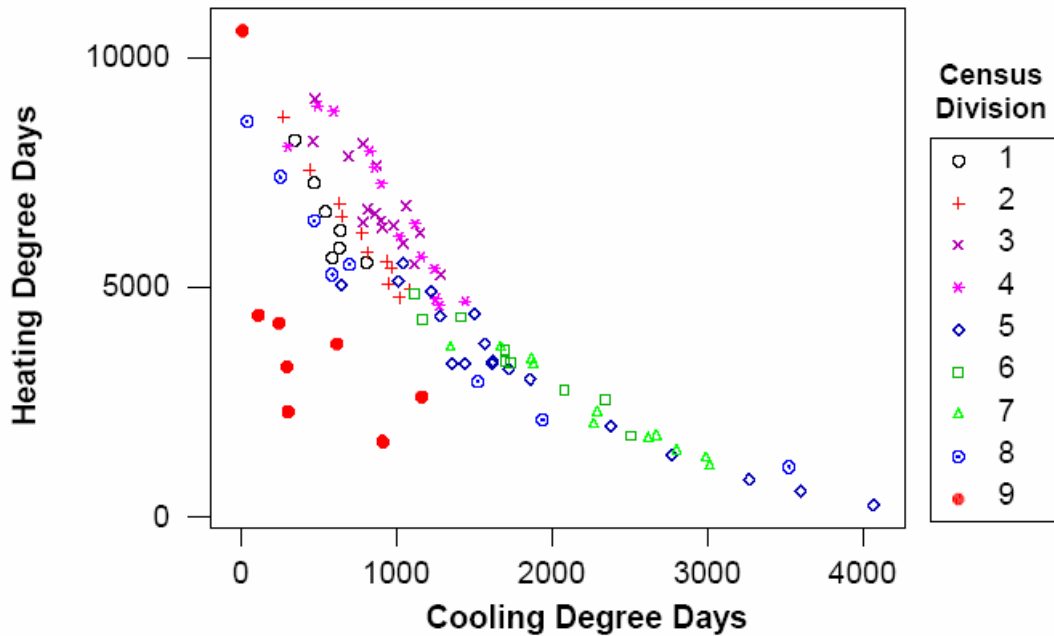


Figure 3-1. Heating Degree Days vs. Cooling Degree Days for CBECS Offices (Kinney and Piette 2002)

California CEUS Data – Current Energy Star Model Ratings

A subset of 224 California CEUS buildings was evaluated with the current Energy Star Rating tool, including six building types (K-12 Schools, Offices, Hotels, Medical Offices, Supermarkets and Warehouses) (Matson and Piette 2005 - See Appendix A). These buildings are also included in the Cal-Arch building database. Table 3-2 summarizes the results for each building type. It also includes a comparison between the earlier and current model results for the K-12 Schools and Offices. The average Energy Star rating for the full data set (n=224) is 59. Forty-one percent of the full data set's buildings have Energy Star ratings of 75 or greater – this is significantly higher than the 25% expected for the national stock.

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Table 3-2. Summary Statistics – Energy Star Ratings of California CEUS Buildings

Building Type	N	Un-weighted Average Rating		Floor-Area Weighted Average Rating		Percent of buildings with 75+ rating	
		Earlier Model	Current Model	Earlier Model	Current Model	Earlier Model	Current Model
K-12 Schools – Same Inputs as Earlier Model	32	75 ±24	67 ±25.6	61	63	69%	56%
Offices	109	-	61 ±28.3	-	68	-	43%
Offices Subset – Same Inputs as Earlier Model	54	65 ±25.5	66 ±25.2	70	69	48%	46%
Hotels	18	-	76 ±30.1	-	45	-	82%
Medical Offices	5	-	51 ±6.8	-	51	-	0%
Supermarkets	16	-	52 ±32.5	-	62	-	38%
Warehouses	44	-	46 ±33.8	-	40	-	27%
All Buildings	224	-	59 ±30.2	-	60	-	42%

The distribution of Energy Star scores for the 109 office buildings are shown in Figure 3-2. The average Energy Star rating is 61 (floor-area weighted is 68). 47 have ratings of 75 or greater (43% of sample) – this is significantly higher than the 25% predicted for the national stock.

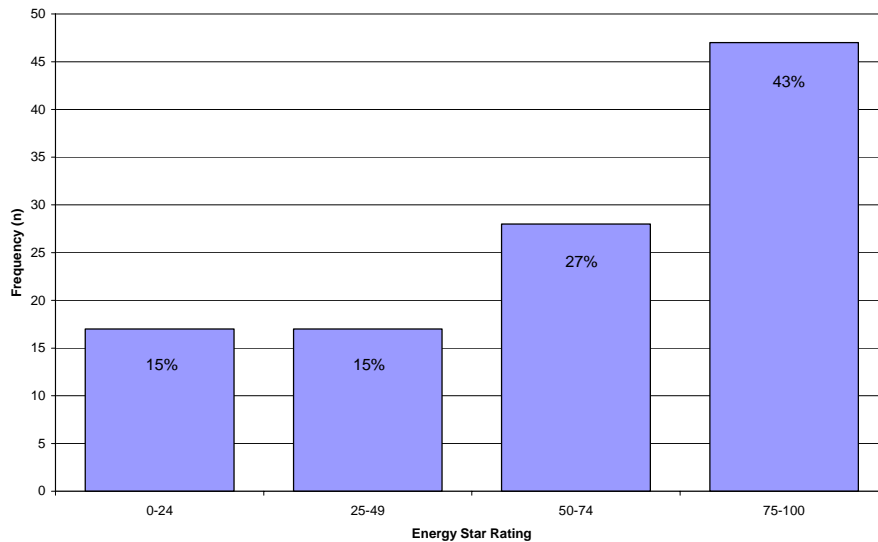


Figure 3-2. CEUS Office Buildings – Energy Star Ratings (n=109)

California Department of General Services Buildings

Nineteen California Department of General Services buildings have been rated using circa 2002 and 2003 Energy Star Office models. Of these, seventeen have ratings of 75 or

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greater, signifying that these buildings are eligible for an Energy Star if they meet the indoor environmental quality requirements. Table 3-3 shows the distribution of scores.

Table 3-3. California Department of General Services Buildings – Energy Star Ratings

Energy Star Score	Number of Buildings
50 – 74	2
75-79	1
80-89	4
90-100	12
Total Rated	19

Cal-Arch Performance

The current Cal-Arch model allows the user to compare one building’s energy use intensity against the distribution of energy use intensities for selected buildings from the Cal-Arch database (similar building types or all buildings, same climate zone or statewide). Figure 3-3 shows the distribution of whole building EUIs for the CEUS office buildings.

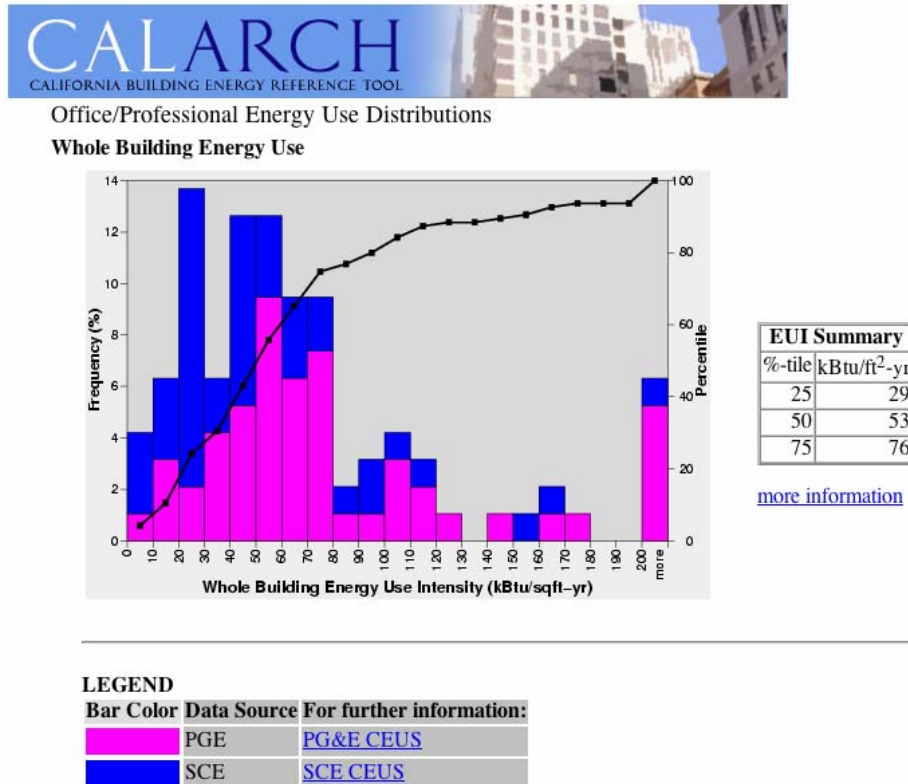


Figure 3-3. Whole Building EUI Distributions – CEUS Office Buildings in Cal-Arch

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Correlation between Energy Star Ratings and Cal-Arch Rankings

Of interest is how the Energy Star ratings and Cal-Arch rankings correlate for specific buildings. We have compared the scores and rankings for three CEUS office buildings having low, typical and very high whole building energy use intensities (EUIs) in the same climate zone (Table 3-4). Currently, Cal-Arch reports the percent of buildings that have lower EUIs (more efficient). To compare the Energy Star and Cal-Arch results on a more level playing field, this Cal-Arch statistic has been converted to be the percent of office buildings in the Cal-Arch database that have *higher* whole building EUIs (less efficient) than the building evaluated. Similarly, the Energy Star rating is a predictor of the percentage of office buildings nationwide that have lower energy performance. From this small sample, we can see that the building with a relatively low EUI is able to achieve a 98 Energy Star rating. This rating correlates well with the percent of office buildings in the Cal-Arch database that have higher whole building EUIs, 79% within the same climate zone and 88% statewide. This trend is also reflected in the results for the mid-range and high-range EUI buildings. The mid-range EUI building obtains an 82 Energy Star rating and the percent of Cal-Arch office buildings with higher whole building EUIs is 54% in the same climate zone and 70%, statewide. The high-range EUI building receives a poor Energy Star rating (23) and only 10% of Cal-Arch office buildings in the same climate zone and 8% statewide have higher whole building EUIs.

**Table 3-4. Energy Star Ratings and Cal-Arch Rankings
Three California CEUS Office Buildings - North Coast Climate zone**

	Building A	Building B	Building C
Floor Area (ft ²)	30,000	505,000	296,448
Whole Building Energy Use Intensity (EUI)	29	52	143
Energy Star Rating	98	82	23
Percent of Cal-Arch office buildings with higher whole building EUIs			
North Coast Climate Zone	79%	54%	10%
Statewide	88%	70%	8%

4. Summary

The Energy Star and Cal-Arch tools are tools for the buildings community to provide information on a building's relative energy performance. We have found that there is a strong correlation between relative Energy Star and Cal-Arch ratings which helps advocate a two-step process. The level of detail and inputs required is a significant factor in the use of these models. As such, these tools can be used separately or together. Cal-Arch can be used as a first step to perform a basic analysis, using minimal data to achieve a quick answer for one or more buildings. Using additional building and occupancy

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characteristic data, Energy Star can be used as a tool for further comparison with the national building stock.

To improve the accessibility of these tools, they have both had prototypes linked to web-based energy information services and energy information systems. Implementation of these tools into existing web-based systems can result in widespread access to benchmarking tools by building owners, staff and decision makers. Future tools under consideration, such as action-oriented advanced benchmarking, could provide initial feedback and recommendations on which building systems or operational strategies may reduce a building's energy use. Incorporating these types of features into benchmarking tools may improve the value of benchmarking, help motivate actions to reduce energy use, and broaden the use of benchmarking in the buildings marketplace.

5. Acknowledgements

We would like to thank Martha Brook and Nancy Jenkins (California Energy Commission), Bob Rose and Tracy Narel (U.S. Environmental Protection Agency), and David Casentini (D&R International) for their support in this effort. We would also like to thank Satkartak Kinney (Lawrence Berkeley National Laboratory) for her assistance on this project. This work was supported by the California Energy Commission, Public Interest Energy Research Program, under Contract No. 500-03-022 and by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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Appendix A: Analysis of Current EPA Energy Models CEUS Data

High Performance Commercial Buildings II Task 2.3 Develop Dr. CEUS Collaborative Plan Analysis of Current EPA Energy Star Models – CEUS Data January 28, 2005

Nance Matson and Mary Ann Piette
Lawrence Berkeley National Laboratory

Overview

This document summarizes results of a recent analysis by LBNL to evaluate the energy performance ratings of typical California commercial buildings. The analysis was performed as part of the PIER High Performance Commercial Buildings Program, Phase II. The objective of the Energy Star analysis is to assist LBNL, the California Energy Commission and the US EPA in evaluating how California buildings perform using current and earlier versions of Energy Star benchmarking tools. The Energy Star Energy Performance Rating tools determine the relative ranking of a given building's energy performance based on the building's operating characteristics and energy consumption.

This document is based on analysis of 224 buildings from California's Commercial End Use Survey (CEUS) evaluated with the Energy Star Rating tool, including six building types (K-12 Schools, Offices, Hotels, Medical Offices, Supermarkets and Warehouses). Table A-1 summarizes the results and includes a comparison between the earlier and current model results for the K-12 Schools and Offices. The average Energy Star rating for the full data set (n=224) is 59. Forty-one percent of the full data set's buildings have Energy Star ratings of 75 or greater – this is still significantly higher than the 25% expected for the national stock.

Table A-1. Summary Statistics

Building Type	N	Un-weighted Average Rating		Floor-Area Weighted Average Rating		Percent of buildings with 75+ rating	
		Earlier Model	Current Model	Earlier Model	Current Model	Earlier Model	Current Model
K-12 Schools – Same Inputs as Earlier Model	32	75 ±24	67 ±25.6	61	63	69%	56%
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All Buildings	224	-	59 ±30.2	-	60	-	42%

Schools and Office Buildings - Comparison to Earlier Analysis

Analyses of the Energy Star ratings of CEUS buildings using the earlier K-12 school and office building Energy Star models was conducted by LBNL in 2002. These analyses found that California buildings tended to have higher

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scores than the national averages. This difference was most prominent with the school buildings, although there was concern from EPA that the CEUS occupant densities were erroneous and problematic. As discussed below as well as in the detailed results sections of this memo, EPA has since revised the K-12 schools and office building models and we have compared the new and old ratings for these buildings. Detailed results of this analysis are provided in the results section of this memo.

Schools Model

The earlier Energy Star schools model included location, floor area, hours of operation, number of students, number of computers, heating degree days, presence of on-site cooking facilities, and the percent of school floor area that is air conditioned. The current model includes these inputs, though the number of students variable has been redefined - it is now the number of students at classroom capacity (design conditions), rather than the average number of students over the school year. This difference can impact the rating score if average capacity is significantly different than design capacity. The current model also includes both heating and cooling degree days, percent of school heated, and presence of mechanical ventilation. Based on LBNL's previous analysis that schools with swimming pools had higher end use intensities (EUIs) and corresponding lower ratings, the current model takes into account energy use from swimming pools as well as energy use from garages and data centers.

Compared to the earlier model, the average schools ratings have decreased significantly (from 75 to 67) and there is a broader distribution of ratings. The percentage of schools with a 75 or greater rating has dropped from 69% to 53%. This reflects the influence of including heating and cooling degree-days and the pools model in the school Energy Star model.

Office Building Model

The earlier Energy Star office model included location, floor area, hours of operation, number of occupants, number of computers and cooling degree days. During our previous analysis, we noticed that the distribution of California climate zone heating and cooling degree days is significantly different from that for the National Data, possibly resulting in higher than expected Energy Star ratings for California office buildings. EPA's current office model now takes heating and cooling degree days and office type (banking and finance, courthouse, and general office) into account. It takes into account the impact of parking garages and data centers on the Energy Star rating.

With the current office model, the average office building rating is 70, about the same as with the earlier model. Using the current model, the percent of office buildings with a 75 or greater rating has decreased slightly (48% to 43%). The average office building rating is still significantly higher than the ratings calculated in the EPA's analysis of the 1995 and 1999 California Commercial Building End-use Consumption (CBECS) office data - using the current model, the California CBECS office buildings' average ratings were 53 and 55, respectively.

Hotels, Medical Offices, Supermarkets and Warehouses

There are a high percentage of hotels with 75 or greater ratings (82%) - reflecting that the California hotels may not be well modeled using the national model, although this is a small sample (n=18). The ratings of the five medical offices rated are tightly grouped in the 40-60 range. This small sample size is not sufficient to determine whether the model serves California medical offices well. 38% of the supermarkets and 25% of the warehouses have 75 or better ratings, which may be more reasonable in terms of the national model.

Energy Star Model - Synopsis

The Energy Star model is based on building-type specific regression analysis, where annual source energy consumption is predicted based on building characteristics and occupancy factors. The regression analyses for the K-12 schools, office buildings, medical office buildings and warehouses are based on the 1999 CBECS data. The grocery and supermarket regression analysis is based on the 1992 and 1995 CBECS data. The hotel/motel regression analysis is based on data from The Hospitality Research Group's (HRG) *Trends in the Hotel Industry database*. Table A-2 summarizes the building-specific input assumptions. The detailed results sections further discuss these inputs.

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The Energy Star rating of a given building is determined as follows:

- The building-type specific regression model, based on the applicable CBECS or Hotel data, is used to predict the Actual LnSource energy consumption (EUI) for each observation. Independent variables are described in the building-specific results section.
- After generating EUI histograms, the Actual LnSource EUI (kBtu/yr) data is mapped on a 1-100 point scale, with the 75% percentile Actual LnSource EUI at the 75 point level. This data is then smoothed out by fitting the data to a gamma distribution (Fitted LnSource EUI, kBtu/yr).
- The regression model is used to predict a specific building's source EUI.
- The Customized Source EUIs are calculated by multiplying the Fitted LnSource EUI data by an adjustment factor ($[\text{predicted building Source EUI}]/[\text{mean model Source EUI}]$).
- For the hotel and supermarket models, the Customized Source EUI values are calculated by applying the adjustment factor to the Fitted LnSource EUI data and then dividing the exponent of the adjusted Fitted LnSource EUI data by the building floor area.
- The building source energy consumption (Source EUI) is weather normalized based a 30-year average weather year.
- The weather-normalized building source energy consumption is compared to the Customized Source EUI values to determine the building's Energy Star rating.

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Table A-2. Energy Star Model Building-specific Input Assumptions

	<i>K-12 Schools</i>	<i>Office</i>	<i>Hotels</i>	<i>Medical Offices</i>	<i>Supermarkets</i>	<i>Warehouses</i>
<i>Zip Code</i>	required	required	required	required	required	required
<i>Year Built</i>	required	required	required	required	required	required
<i>Area</i>	School building floor area, less garage and data center area	Office building floor area, less garage and data center area	Floor area, number of rooms, % occupancy	Floor area	Floor area, number of floors or levels	Floor area
<i>Hours of Use</i>	Operating hours per week	Operating hours per week	-	Operating hours per week	Hours at full staffing level	Hours at full staffing level
<i>Number of Occupants</i>	Number of students at classroom capacity	Number of Employees	-	Number of employees	Main shift staffing - number of employees	Main shift staffing – number of employees
<i>Number of Personal Computers</i>	Total number of personal computers and servers	Total number of personal computers and servers	-	-	Number of registers and personal computers normally in use	-
<i>On-site Cooking</i>	Dedicated facilities for food preparation and serving	-	Dedicated facilities for food preparation and serving	-	Dedicated facilities for food preparation (bakery, restaurant, etc.)	-
<i>On-site Laundry</i>	-	-	Laundry facilities to wash hotel linens	-	-	-
<i>%Floor area air conditioned</i>	required	-	-	required	-	required
<i>% Floor area heated</i>	required	-	-	required	-	required
<i>Mechanical Ventilation</i>	Yes/No based on economizer or system type	-	-	-	-	-

Table A-2(cont.) Energy Star Model Building-specific Input Assumptions

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	<i>K-12 Schools</i>	<i>Office</i>	<i>Hotels</i>	<i>Medical Offices</i>	<i>Supermarkets</i>	<i>Warehouses</i>
<i>Type of Facility</i>		General, Bank Branch, Financial Center, Courthouse	Economy, Mid-Scale, Upscale, Upper Upscale	-	-	Refrigerated, Unrefrigerated
<i>Swimming Pool</i>	Size (Olympic, recreational, short course), months open per year	-	-	-	-	-
<i>Garages</i>	Floor area, operating hours/week, number of employees, floors above/below ground	Floor area, operating hours/week, number of employees, floors above/below ground	Floor area, operating hours/week, number of employees, floors above/below ground	Floor area, operating hours/week, number of employees, floors above/below ground	Floor area, operating hours/week, number of employees, floors above/below ground	Floor area, operating hours/week, number of employees, floors above/below ground
<i>Data Centers</i>	Floor area, operating hours/week	Floor area, operating hours/week	Floor area, operating hours/week	Floor area, operating hours/week	Floor area, operating hours/week	Floor area, operating hours/week
<i>Warehouse Lighting</i>	-	-	-	-	-	Yes/No
<i>Refrigerated Cases / Walk-ins</i>	-	-	-	-	Number of refrigerated & freezer cases, number of walk-in coolers & freezers	Number of walk-in coolers & freezers

Source: EPA Import Templates (<https://www.energystar.gov/istar/pmpam/#> - Import Facility Data)

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Energy Star Results

K-12 Schools

There are 45 K-12 Schools in the CEUS database. Of these, 32 were able to be rated using the current model. The schools were modeled using the same inputs as used for the earlier model, allowing a comparison between the two models. For the new model, the average Energy Star rating is 66 (floor-area weighted is 63) (n=32). Seventeen schools have ratings of 75 or greater (53% of sample). Figure A-1 and Table A-3 show the distribution of scores for the new model, while Figures A-2 and A-3 compare the results of the two models. The distribution of scores is broader than found with the earlier model. The current model's scores are on average 9.75% lower than those from the earlier model. This reflects the impact of including both heating and cooling degree days, as well as the pool model, into the school Energy Star model.

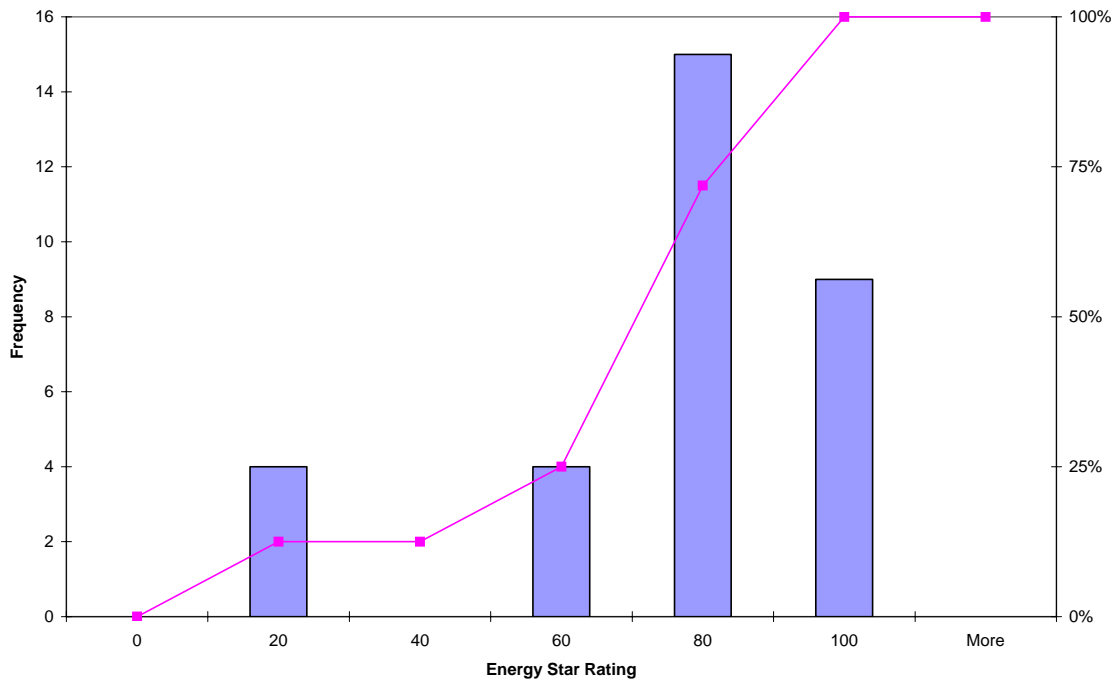


Figure A-1. School Energy Star Ratings (n=32)

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Table A-3. School Energy Star Ratings (n=32)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
0	0	0.00%
20	4	12.50%
40	0	12.50%
60	4	25.00%
80	15	71.88%
100	9	100.00%
More	0	100.00%

+75 Rating	17	53%
Total Rated	32	
Average Rating:		66 ±25.7
Average Rating: (Floor Area Weighted)		62

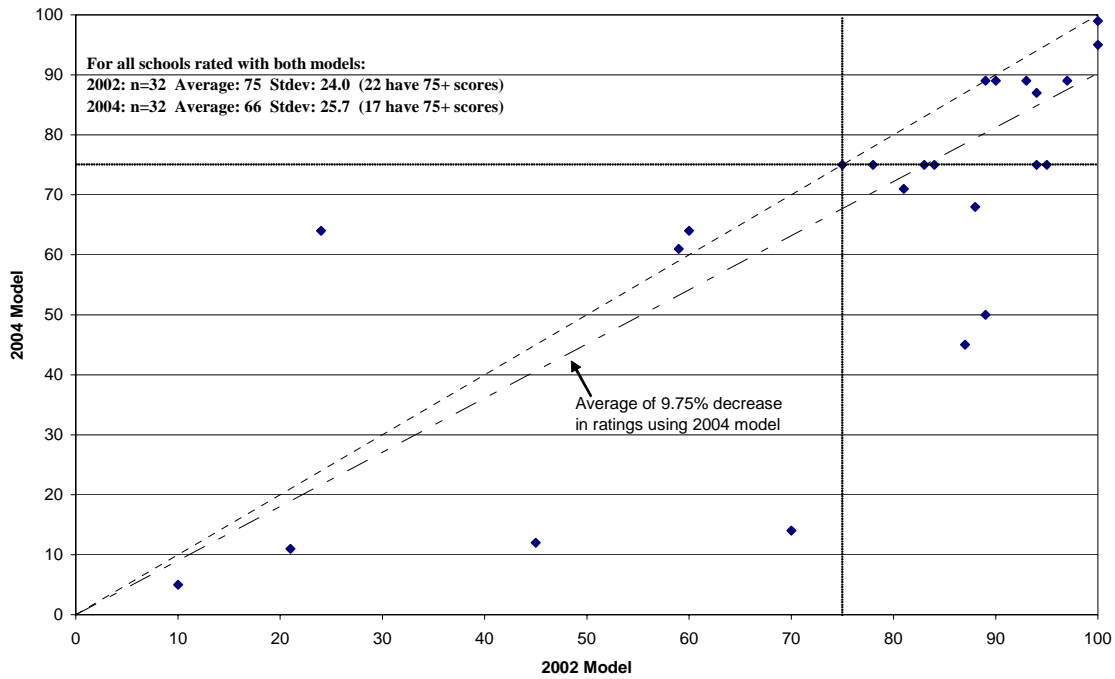


Figure A-2. Schools – Comparison between individual School Energy Star ratings using the 2002 and 2004 models (n=32)

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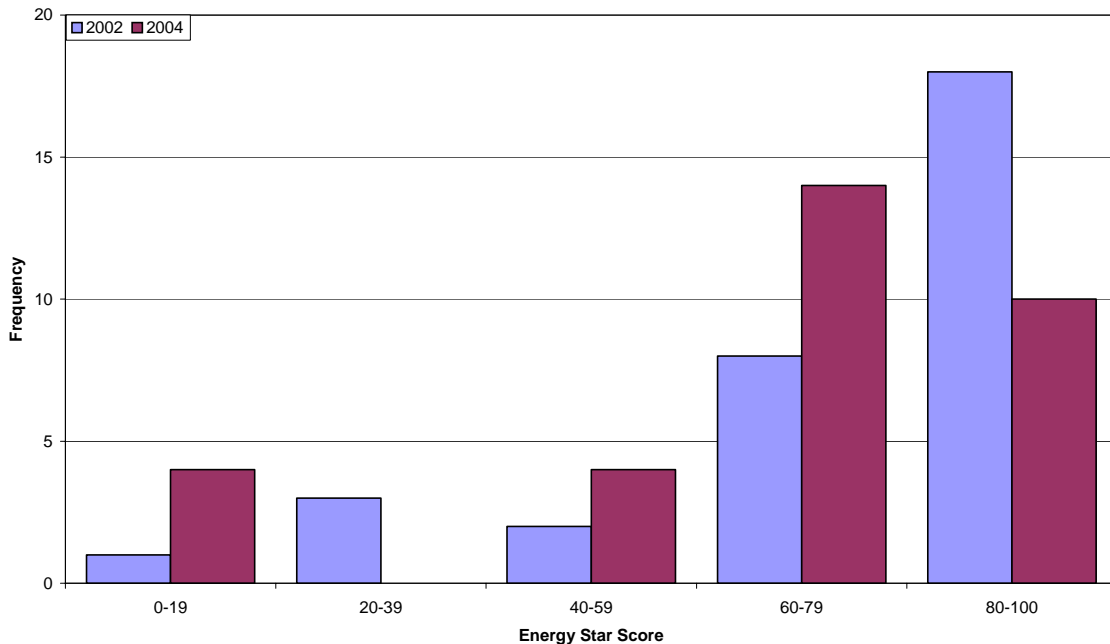


Figure A-3: 2002 and 2004 School Energy Star Ratings (n=32).

K-12 School Model

The K-12 School regression equation's independent variables include (EPA 2003a):

- floor area,
- number of students at classroom capacity
- presence of mechanical ventilation,
- number of computers,
- heating degree days times the percent of building area heated,
- cooling degree days times the percent of building cooled,
- occupancy hours,
- number of months used per year, and
- presence of cooking facilities.

During our previous analysis, we found that schools with swimming pools had higher EUIs and corresponding lower ratings. LBNL developed and provided a pool model to take into account the pool energy consumption. The pool model is based on pool size (Olympic, short course, recreational) and months in use per year. Note that LBNL's original research found that pool energy use may vary greatly whether the pool is covered or not. This variable is not required for the Energy Star pool analysis.

Three variables proved to be problematic with the schools model:

- number of students
- mechanical ventilation
- presence of cooking facilities

Number of Students. The number of students is defined as the school's classroom capacity – the number of students who can be seated in all classrooms at one time. The CEUS database does not report this number – the closest possible is the maximum number of occupants, which was used in this analysis.

WORKING DRAFT

Mechanical Ventilation. The mechanical ventilation flag (yes/no) definition is difficult to interpret: “Mechanical ventilation was defined to not exist ($VENT=0$) when heating-air furnaces, space heaters, district heating systems, or internal boilers were used for space heating in combination with no space cooling or the use of window or residential-type air conditioners. One variance from this definition was that mechanical ventilation was defined to exist ($VENT=1$) when variable-air volume (VAV) systems or economizers were present regardless of the type of space heating or cooling system or the presence of space cooling. Buildings with other space heating and cooling systems were defined as ventilated ($VENT=1$)” (Technical Description for the K-12 Model; July 31, 2003). The CEUS HVAC system descriptors, while providing a significant amount of information, did not provide enough information to use the first part of the definition ($VENT=0$) to discern whether mechanical ventilation was present. To determine whether a given school had mechanical ventilation, we calculated the percentage of cooling capacity with economizers. Heating capacity was used if the school didn’t have space cooling, and floor area was used if no space conditioning capacities given. The school was thus defined to have mechanical ventilation if greater than 50% of the school cooling capacity, heating capacity, or floor area had economizers. Any school with less than 50% economizer capacity was assumed to not have mechanical ventilation.

Presence of Cooking Facilities. The model defines the presence of cooking facilities as “dedicated facilities in which food is prepared and served to students. If the school has facilities in which food for students is only kept warm and/or served, or has only a galley that is used by teachers and staff,” the school does not have cooking facilities. The CEUS data includes three sets of variables which can be used to discern whether the school has cooking facilities – number of meals (breakfast, lunch, dinner) served per day, percent of space used for cooking, and an inventory of cooking appliances and the number of hours used per week. The number of meals served per day was used to determine the cooking flag, double-checked using the percent of space used for cooking and the number of hours cooking appliances are used.

WORKING DRAFT

Office Buildings

There are 196 office buildings in the CEUS database. Of these, 109 were able to be rated. The average Energy Star rating is 61 (floor-area weighted is 68) (n=109). 47 have ratings of 75 or greater (43% of sample). Figure A-4 and Table A-4 show the distribution of scores.

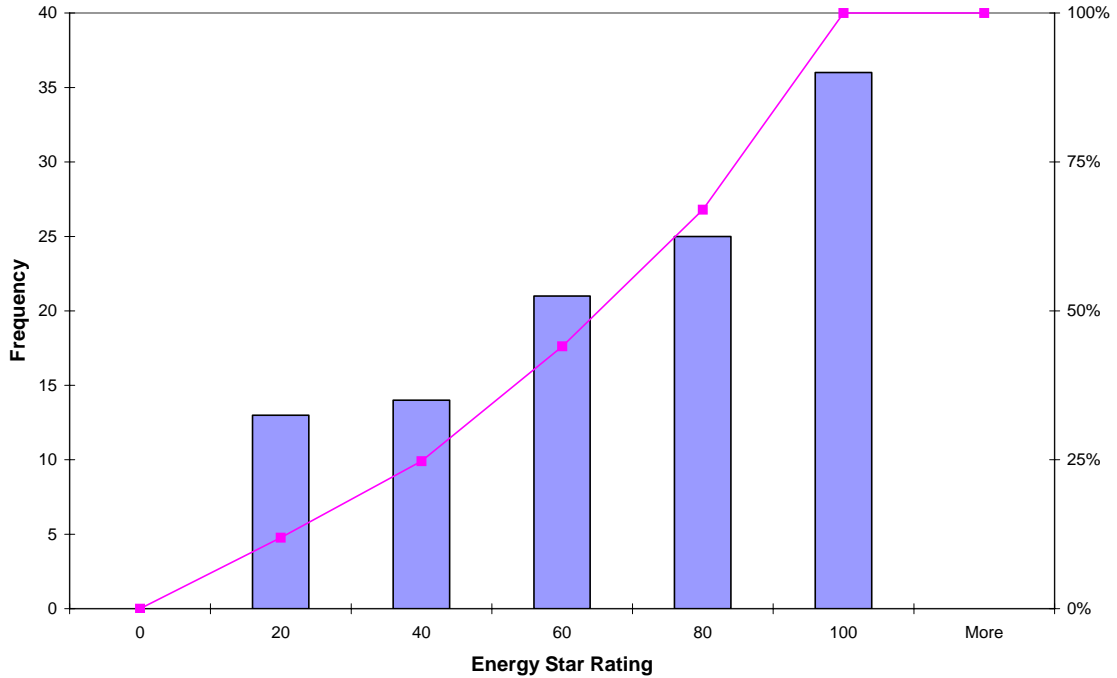


Figure A-4. Office Building Energy Star Scores (n=109)

WORKING DRAFT

Table A-4. Offices Energy Star Ratings (n=109)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
	0	0.00%
	20	11.93%
	40	24.77%
	60	44.04%
	80	66.97%
	100	100.00%
More	0	100.00%
+75 Rating	47	43%
Total Rated	109	
Average Rating:		61 ± 28.3
Average Rating: (Floor Area Weighted)		68

Comparison to Earlier Model (n=54)

A subset of the CEUS office buildings that had been rated with the earlier Energy Star model were rated using the current Energy Star Model. The inputs were used for both analyses. Figures A-5 and A-6 compare the results of the two models. The Energy Star scores and distributions did not change significantly between the two versions of the model. On average, the current model's ratings are two percent lower than that using the earlier model. The only significant difference between these two models is that both heating and cooling degree day are used in the current version's regression analysis.

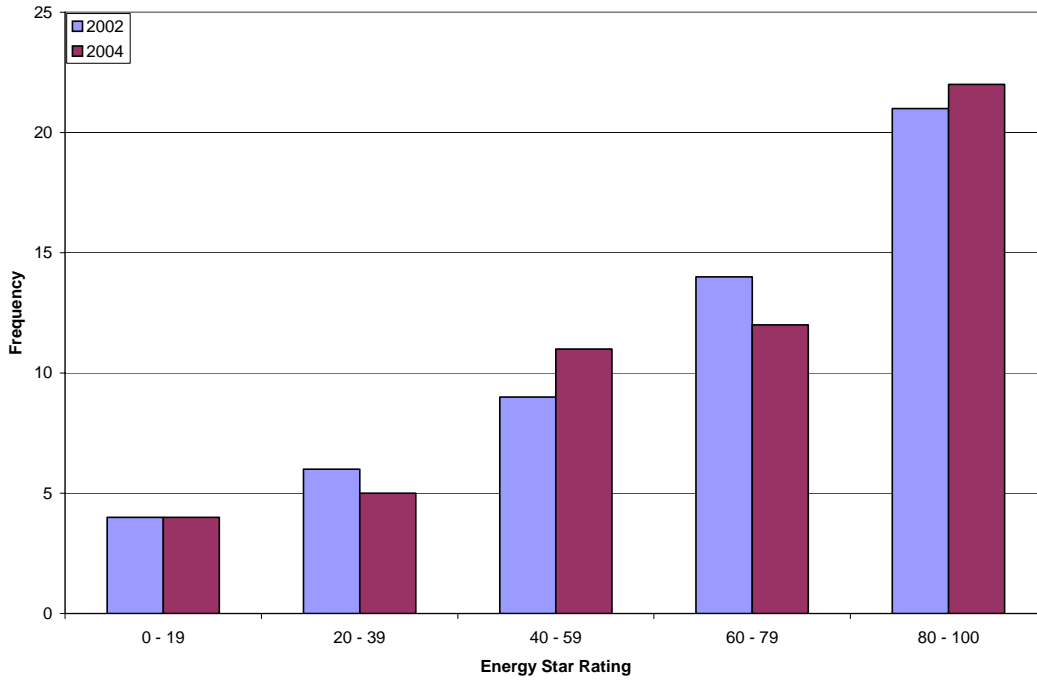


Figure A-5. Office Energy Star Ratings – Current and Earlier Model (n=54)

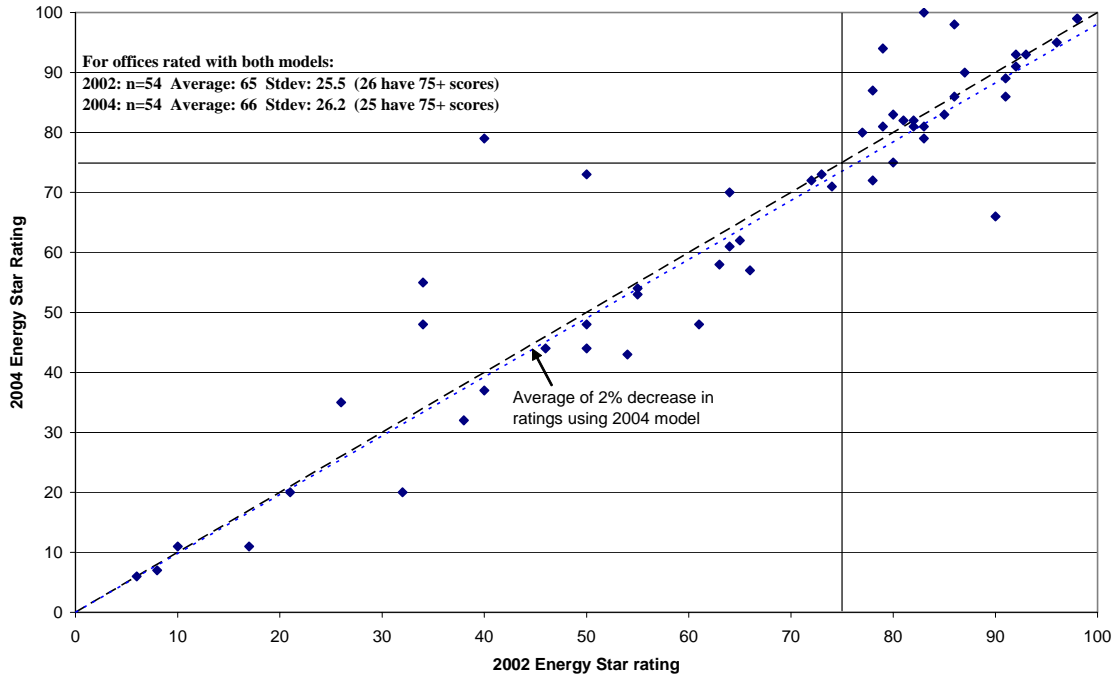


Figure A-6. Comparison of Current (2004) and Earlier (2002) Office Energy Star Ratings (n=54)

WORKING DRAFT

Office Model

The office building regression equation's independent variables include (EPA 2003b):

- floor area,
- number of computers,
- occupancy hours,
- number of employees,
- heating degree days,
- cooling degree days, and
- type of building (general, bank, financial center, and courthouse).

Other variables requested, but not used directly in the office regression model include the presence of garages and data centers – these inputs were used to take into account their impact on the Energy Star rating. The CEUS maximum building occupancy data was used for the number of employees. This may overestimate the number of employees, resulting in a slightly higher rating.

WORKING DRAFT

Hotels and Motels

There are 22 hotels and motels in the CEUS database. Of these, eighteen were able to be rated (5 economy, 6 mid-scale, 5 upscale and 2 upper upscale). Eleven have ratings of 75 or greater (61% of sample). The average Energy Star rating is 76 (floor-area weighted is 45) (n=18). Figure A-7 and Table A-5 show the distribution of scores.

Hotel and Motel Model

There are five regression equations, based on type of hotel (economy, midscale with food preparation, midscale without food preparation, upscale and upper upscale).

The independent variables for the economy, midscale and upscale hotels include (EPA 2001a):

- total degree-days (heating plus cooling degree-days, base 65),
- number of rooms, and
- presence of food preparation facilities.

The upper upscale hotel model is based on the number of rooms and presence of food preparation facilities only.

Other variables requested, but not used directly by the model include the floor area, occupancy rate, presence of laundry facilities, and garage and data center inputs. The garage and data center inputs were used to take into account their impact on the Energy Star rating.

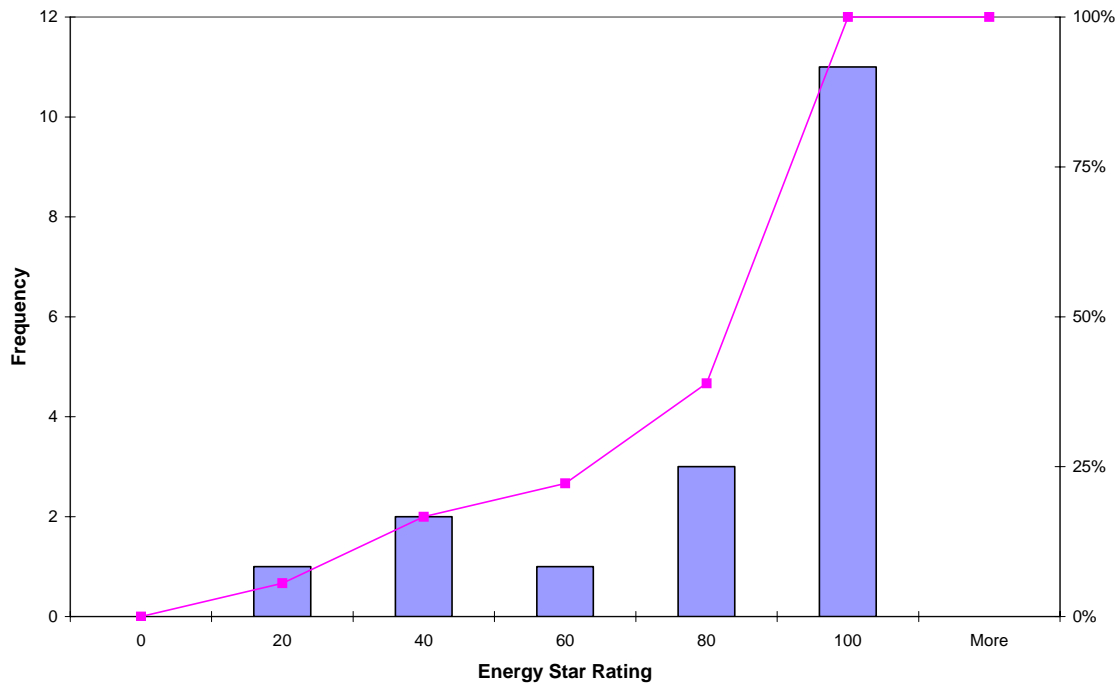


Figure A-7. Hotel Energy Star Ratings (n=18)

WORKING DRAFT

Table A-5. Hotel Energy Star Ratings (n=18)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
0	0	0.00%
20	1	5.56%
40	2	16.67%
60	1	22.22%
80	3	38.89%
100	11	100.00%
More	0	100.00%
+75 Rating	11	61%
Total Rated	18	
Average Rating:		76 ±30.1
Average Rating: (Floor Area Weighted)		45

WORKING DRAFT

Medical Offices

There are 18 medical office buildings in the CEUS database. Of these, five were able to be rated. Their scores were similar, ranging from 42 to 60. The average Energy Star rating is 51 (floor-area weighted is 52) (n=5). None have ratings of 75 or greater. Figure A-8 and Table A-6 show the distribution of scores.

Medical Office Model

The medical office regression equation's independent variables include (2004):

- floor area,
- number of workers,
- occupancy hours,
- heating degree days times the percent of building area heated, and
- cooling degree days times the percent of building cooled.

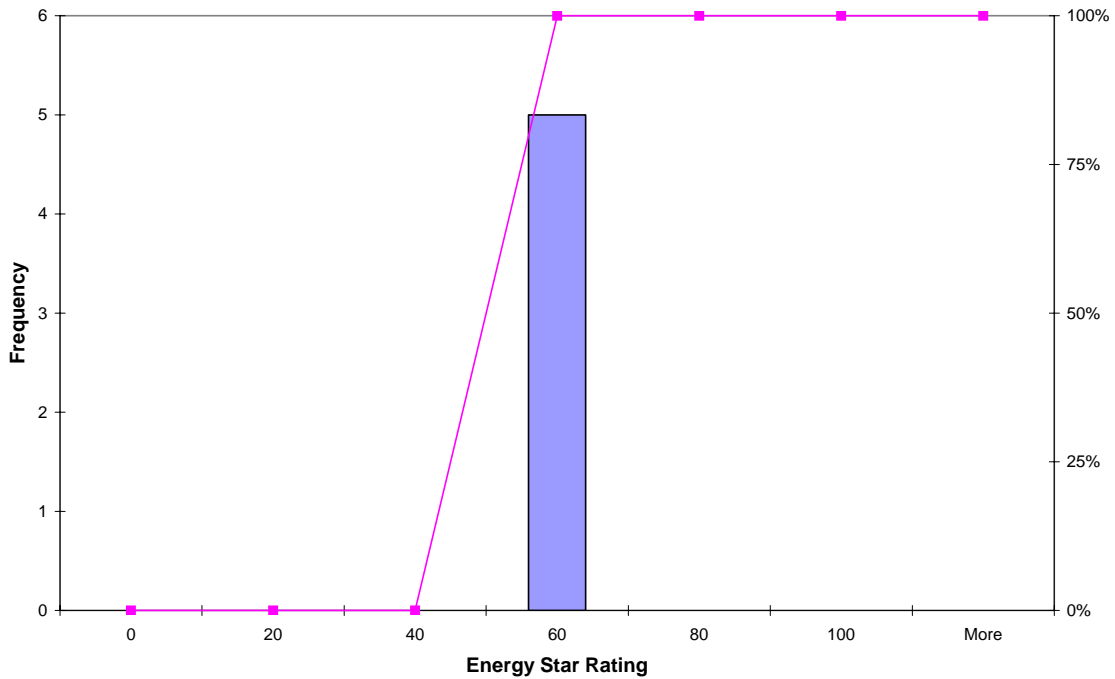


Figure A-8. Medical Offices Energy Star Ratings (n=5)

WORKING DRAFT

Table A-6. Medical Offices Energy Star Ratings (n=5)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
0	0	0.00%
20	0	0.00%
40	0	0.00%
60	5	100.00%
80	0	100.00%
100	0	100.00%
More	0	100.00%
+75 Rating	0	0%
Total Rated	5	
Average Rating:		51 ±6.6
Average Rating: (Floor Area Weighted)		52

WORKING DRAFT

Grocery Stores and Supermarkets

There are 21 grocery stores and supermarkets in the CEUS database. Of these, sixteen were able to be rated. The average Energy Star rating is 52 (floor-area weighted is 62) (n=16). Six have ratings of 75 or greater (38% of sample). Figure A-9 and Table A-7 show the distribution of scores.

Grocery / Supermarket Model

The grocery store/supermarket regression equation's independent variables include (2001b):

- floor area,
- occupancy hours,
- number of workers,
- number of refrigeration cases and walk-in units,
- number of floors,
- cooling degree-days, heating degree days,
- presence of cooking facilities, and
- number of computers or cash registers.

The last four variables (CDD, HDD, cooking and number of computers / cash registers) were included in the model, but were not found to be significant in the regression analysis.

The default (0.97 employees/1000 ft²) was used for the main shift staffing variable as it was difficult to determine from the CEUS occupancy and employee data.

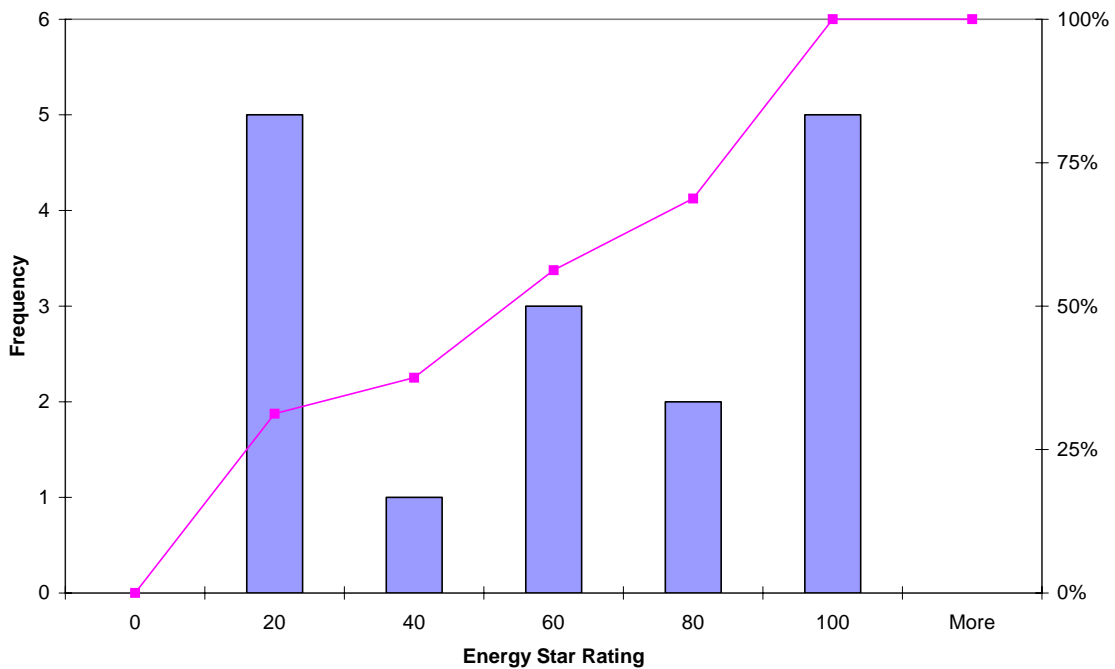


Figure A-9. Grocery Stores and Supermarkets Energy Star Ratings (n=16)

WORKING DRAFT

Table A-7. Supermarket Energy Star Ratings (n=16)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
0	0	0.00%
20	5	31.25%
40	1	37.50%
60	3	56.25%
80	2	68.75%
100	5	100.00%
More	0	100.00%
<hr/>		
+75 Rating	6	38%
Total Rated	16	
Average Rating:		52 ±32.5
Average Rating: (Floor Area Weighted)		62

WORKING DRAFT

Warehouses

There are 53 grocery stores and supermarkets in the CEUS database. Of these, 44 were able to be rated. The average Energy Star rating is 45 (floor-area weighted is 39) (n=44). Eleven have ratings of 75 or greater (25% of sample). Figure A-10 and Table A-8 show the distribution of scores.

Warehouse Model

The warehouse regression equation's independent variables include (2003c):

- whether the warehouse was refrigerated or un-refrigerated,
- number of walk-in refrigerators,
- floor area,
- heating degree days times the percent of building area heated,
- cooling degree days times the percent of building cooled,
- occupancy hours,
- number of workers, and
- whether or not the warehouse has lighting.

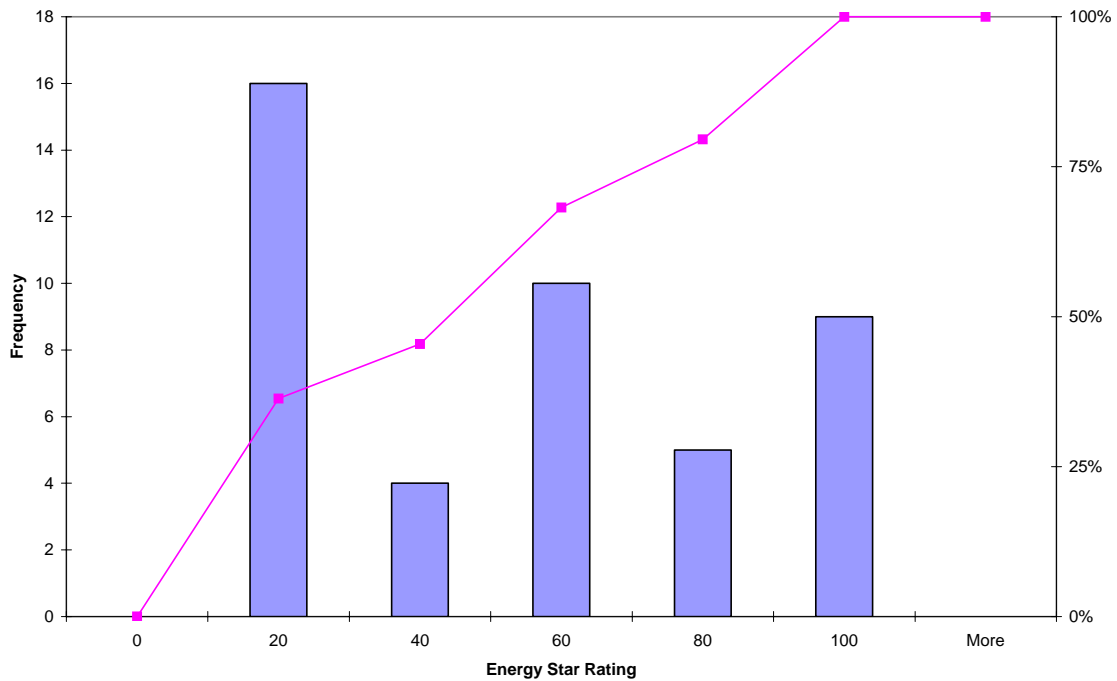


Figure A-10. Warehouse Energy Star Ratings (n=44)

WORKING DRAFT

Table A-8. Warehouse Energy Star Ratings (n=44)

<i>Bin</i>	<i>Frequency</i>	<i>Cumulative %</i>
0	0	0.00%
20	16	36.36%
40	4	45.45%
60	10	68.18%
80	5	79.55%
100	9	100.00%
More	0	100.00%
<hr/>		
+75 Rating	11	25%
Total Rated	44	
Average Rating:		45 ±33.6
Average Rating: (Floor Area Weighted)		39

Energy Star Portfolio Manager

The Energy Star Portfolio Manager provides a means to review inputs and results. Users can interactively change inputs and view the change in rating for a given building. We found the import tool easy to use and that it was easy to input data for a new building directly into the portfolio manager. However, changing a number of variables for a individual building requires going through a number of screens repeatedly to change values. It is impossible to look at all inputs for a given building at one time – when changing variables one must perform multiple clicks to change one input. One possible improvement would be for the portfolio manager to provide a single page with all input variables and outputs for an individual building. The user could review the buildings alert messages, determine what the problem may be, correct the inputs as needed, and view the revised score (or alert messages).

References

- US EPA, “Technical Description for the K-12 Model”, July 31, 2003.
- US EPA, “Technical Description for the Office, Bank, Financial Center, and Courthouse Model”, July 31, 2003
- US EPA, “Technical Description for the Hotel/Motel Model”, December 11, 2001
- US EPA, “Technical Description for the Medical Office Building Model”, January 14, 2004
- US EPA, “Technical Description for the Grocery Store/Supermarket Model”, December 11, 2001
- US EPA, “Technical Description for the Warehouse Model”, July 4, 2003.

Appendix B: Energy Star Regression Equations

B.1 Energy Star Regression Equations

The regression analyses for the K-12 schools, office buildings, medical office buildings and warehouses are based on the 1999 CBECS data. The grocery and supermarket regression analyses are based on the 1992 and 1995 CBECS data. The hotel/motel regression analysis is based on data from The Hospitality Research Group's (HRG) *Trends in the Hotel Industry database*. The hospital regression analysis is based on the 1997 EPRI Energy Benchmarking Survey.

K-12 Schools:

$$\begin{aligned} \text{Ln Source EU} = & 4.45 + 0.843 (\text{Ln}(\text{Sqft})) + 0.123(\text{Ln}(\text{Edseat})) + 0.149(\text{Vent}) + \\ & 0.08(\text{Ln}(\text{PCnum})) + 6.156\text{e-}5(\text{HDD}\times\text{heatp}) + 1.484\text{e-}4(\text{CDD}\times\text{coolp}) + 0.063(\text{Ln}(\text{Wkhrs})) \\ & + 0.057(\text{Monuse12}) + 0.098(\text{Cook}) \end{aligned}$$

Sqft	=	Gross building square footage
Edseat	=	Number of students that can be seated in all of the classrooms
Vent	=	Mechanical ventilation present (0=no, 1=yes)
PCnum	=	Number of personal computers
HDD	=	Heating Degree Days (Base 65 F)
Heatp	=	percent of the gross floor area that is heated
CDD	=	Cooling Degree Days (Base 65 F)
Coolp	=	percent of the gross floor area that is mechanically cooled
Wkhrs	=	average weekly hours when building is at least 50% occupied
Monuse12	=	year-round use (0=no, 1=yes)
Cook	=	Presence of an area dedicated to cooking and serving food (0=no, 1=yes)

N (adjusted)	=	400
R ²	=	0.8775
Adjusted R ²	=	0.8746

Floor area only		
R ²	=	0.85

Offices:

Current Model:

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$$\text{Ln Source (kBtu/year)} = 5.395 + 0.758 \text{ Ln(SqFt)} + 0.153 \text{ Ln(PCs)} + 0.194 \text{ Ln(WkHrs)} + 0.153 \text{ Ln(Nwker)} + 2.24\text{E-}5 \text{ HDD} + 6.96\text{E-}5 \text{ CDD} + 0.448 \text{ Bank} + 0.176 \text{ FinCtr} + 0.214 \text{ Courthse}$$

SqFt	=	Gross building or facility area
PCs	=	Number of Personal Computers
WkHrs	=	Weekly hours of use
Nwker	=	Number of workers
HDD	=	Heating Degree Days (Base-65F)
CDD	=	Cooling Degree Days (Base-65F)
Bank	=	Facility is a bank (0=No, 1=Yes)
FinCtr	=	Facility is a financial center (0=No, 1=Yes)
Courthse	=	Facility is a courthouse (0=No, 1=Yes)

N (adjusted)	=	910
R ²	=	0.9338
Adjusted R ²	=	0.9331

Floor area only		
R ²	=	0.91

Comparison to previous office model:

Previous Model:

$$\text{Source (kBtu/year)} = -42.215 + 14.967 \text{ Ln(Area)} + 0.012 \text{ CDD} + 0.517 \text{ Hours} + 16.766 \text{ OccDens} + 9.759 \text{ PCDens}$$

Hotel/Motels:

Upper Upscale:

$$\text{Ln Predicted Source EU} = 11.8784 + 0.942549 (\text{Ln(Rooms)}) + 0.633806 (\text{FoodFac})$$

N (adjusted)	=	102
R ²	=	0.8422
Adjusted R ²	=	0.839

Floor area only		
R ²	=	not provided

Upscale:

$$\text{Ln Predicted Source EU} = 8.034322 + 1.217668 (\text{Ln(Rooms)}) + 0.307686 (\text{Ln(DD)}) + 0.156245 (\text{FoodFac})$$

N (adjusted)	=	275
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R^2 = 0.8692
Adjusted R^2 = 0.8678

Floor area only
 R^2 = not provided

Midscale with Food and Beverage:

Ln Predicted Source EU = 8.598854 + 1.024112 (Ln(Rooms)) + 0.357193(Ln(DD))

N (adjusted) = 83
 R^2 = 0.689
Adjusted R^2 = 0.6812
Floor area only
 R^2 = N/A

Midscale without Food and Beverage:

Ln Predicted Source EU = 9.497230 + 1.121501 (Ln(Rooms)) + 0.15545 (Ln(DD))

N (adjusted) = 159
 R^2 = 0.6017
Adjusted R^2 = 0.5966
Floor area only
 R^2 = not provided

Economy:

Ln Predicted Source EU = 7.728508 + 0.933250 (Ln(Rooms)) + 0.448884 (Ln(DD)) + 0.466603 (FoodFac)

N (adjusted) = 86
 R^2 = 0.8793
Adjusted R^2 = 0.8749

Floor area only
 R^2 = N/A

Rooms = Number of hotel rooms
DD = Total heating and cooling degree days (base 65F)
FoodFac = Presence of revenue-generating food and beverage and/or Banquet facility (0=no, 1=yes)

Medical Offices:

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$\text{Ln Predicted Source EU} = 2.789 + 0.914 (\text{Ln}(\text{Sqft})) + 0.216 (\text{Ln}(\text{Nwker})) + 0.468(\text{Ln}(\text{Wkhrs})) + 5.32\text{e-}5 (\text{HDDxheatp}) + 2.01\text{e-}4(\text{CDDxcoolp})$

N (adjusted) = 82
 R^2 = 0.9336
Adjusted R^2 = 0.9292

Floor area only
 R^2 = 0.91

Supermarkets:

$\text{LnSource (kBtu/year)} = 6.235192543 + 0.5304121627*\text{Ln}(\text{Area}) + 0.1751649881*\text{Ln}(\text{Hours}) + 0.4197590116*\text{Ln}(\text{Workers}) + 0.08919559467*\text{Ln}(\text{CDD}) + 0.1510335536*\text{Ln}(\text{HDD}) - 0.4247541528*\text{Ln}(\text{Floors}) + 0.06842991077*\text{FoodRoom} + 0.01112991177*\text{PCs} + 0.25037737*\text{Ln}(\text{TotalRefrig})$

Area = Gross building square footage (ft²)
Hours = Average weekly hours when building is at least 50% occupied
Workers = number of workers during the main occupancy of the building
CDD = Cooling Degree Days (Base 65F)
HDD = Heating Degree Days (Base 65F)
Floors = Number of floors
FoodRoom = Presence of an area dedicated to cooking and serving food (0=no, 1=yes)
PCs = Number of PCs or electronic case registers
TotalRefrig = Total number of refrigeration cases and walk-in units

N (adjusted) = 88
 R^2 = 0.8118
Adjusted R^2 = 0.7901

Floor area only
 R^2 = 0.63

Warehouses:

$\text{Source (kBtu/year)} = 4.229 + 0.775(\text{RefWH}) + 0.088(\text{Walk-InRefs}) + 0.709 \text{Ln}(\text{Area}) + 1.273\text{e-}06 (\text{HDDxHeatPer}) + 1.936\text{e-}06(\text{CDDxCoolPer}) + 0.393 \text{Ln}(\text{Hours}) + 0.281 \text{Ln}(\text{Workers}) + 0.002 (\text{SumHID\&Halo})$

RefWH = Refrigerated warehouse (0=no, 1=yes)
Walk-InRefs = Total number of walk-in refrigerators
Area = Gross building square footage (ft²)
HDD = Heating Degree Days (Base-65F)
HeatPer = Percent of floor area heated
CDD = Cooling Degree Days (Base-65F)
CoolPer = Percent of floor area air conditioned

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Hours = Total weekly operating hours
Workers = Total employees on main shift
SumHID&Halo= Floor area % lit by high intensity discharge and halogen lights

N (adjusted) = 484
 R^2 = 0.8038
Adjusted R^2 = 0.8005
Floor area only
 R^2 = not provided

Dormitories / Residence Halls:

$\text{Ln Predicted Source EU} = 4.99455 + 0.91308 (\text{Ln}(\text{Sqft})) + 9.774\text{e-}5 (\text{HDDxheatp}) + 1.6279\text{e-}4 (\text{CDDxcoolp}) + 0.09455 (\text{Ln}(\text{Lodgrm}))$

Sqft = gross building square footage
HDD = heating degree day (base 65F)
heatp = percentage of the gross floor area that is heated
CDD = cooling degree days (base 65F)
coolp = percentage of the gross floor area that is mechanically cooled
Lodgrm = Number of guest/occupant rooms

N (adjusted) = 79
 R^2 = 0.8834
Adjusted R^2 = 0.8771
Floor area only
 R^2 = 0.86

Hospitals:

$\text{LnSource (kBtu/year)} = 7.50492 + 0.82798 \text{Ln}(\text{SqFt}) - 0.00002887 (\text{DD}) + 0.14794 (\text{Acute}) + 0.09278 (\text{Tertiary}) + 0.10439\text{Ln}(\# \text{ Beds}) + 0.11119\text{Ln}(\text{Max \# of Floors}) + 0.10534 (\text{Above Ground Parking})$

Sqft = gross building square footage
DD = Total heating and cooling degree days
Acute = Acute care / Children's Hospital facility (0=no, 1=yes)
Tertiary = Tertiary care provided (0=no, 1=yes)
Beds = Number of hospital beds
Max # of Floors= Maximum number of floors present
Above Ground
Parking = Above ground parking structure (0=no, 1=yes)

N (adjusted) = 493
 R^2 = 0.8322
Adjusted R^2 = 0.8293
Floor area only
 R^2 = not provided

WORKING DRAFT

Table B-1. Energy Star Building Characteristic Filters Applied to the Raw Data for Use in the Regression Analysis*

Variable	Description	K-12 Schools	Offices	Medical Offices	Supermarkets	Warehouses	Dorms
SQFT	Gross building or facility area (ft ²)	>4,999 & <900,000	>=5000 banks>= 1000	-	> 4,999 & < 1,000,000**	> 4,999 & < 1,000,000	-
WKHRS	Weekly Hours of Use	>30 & <168	> 30	>30 & <168	> 29	> 35	-
MONUSE	# of Months in Use out of past 12	> 8	> 10	-	> 10	> 10	-
NWKER / (SQFTX1000)	Occupant Density		>0.3 & <10.0	> 1	-	-	-
EDSEAT	Classroom seating capacity	< 10,000	-	-	-	-	-
PCNUM	# of Personal Computers	-	>= 0	-	-	-	-
Source EUI	Source energy use intensity (kBtu/sqft)	>37.3 & <314.8	>42.67 & <731.2	>38 & <575	-	-	> 40 & < 425
ELUSED	Electricity Used	-	-	-	-	>0	-
calculated	Total energy cost per MMBtu	> \$1.5	-	-	-	-	-
ELBTU	Annual Electricity Consumption	-	-	-	>0 & < 1 quad (10 ¹⁵ Btu)	-	-
HDD65 + CDD65	HDD+CDD	-	-	-	>0	-	-
FDSLSP	Food Sales Percentage	-	-	-	> 89%	-	-
PBA	Principal Building Activity	-	-	-	Food Sales	refrig / non-refrig	-
PBAPLUS	Principal Building Activity PLUS	-	-	-	-	refrig / non-refrig	dorm / fraternity / sorority

*Hospitals require complete records. Hotel/Motels require complete records for non-extended stay facilities.

**Grocery stores with less than 5000 square feet usually are convenience stores and have different usage patterns from supermarkets.

B.2. Energy Star Input Requirements

Following are the information required for each of the eight Energy Star models. Where applicable, the valid input values ranges are provided in parentheses following the input variable. The following four requirements also apply to all building types:

- 50% or more of gross area (not including Garages and Parking Lots) must be designated as primary use (e.g., office for office rating)
- Computer Data Center floor area cannot be greater than 10% of the facilities gross floor area (not including Garages and Parking Lots)
- Garage floor area cannot be greater than 100% of the entire facility.
- At least 11 full consecutive months of energy consumption data, with a minimum of 10 meter entries between 15 and 45 days each over the 12 month evaluation period.

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K-12 Schools:

The following information is required for a K-12 School Space.

- Zip code
- Gross floor area (5,000 – 1,000,000 ft²)
- Weekly operating hours (35 or greater)
- Number of students (1- 1,000,000)
- Number of months in operation (8 or more in the past 12 months)
- Percent of the gross floor area of the facility that is air-conditioned
- Percent of the gross floor area of the facility that is heated
- Number of personal computers
- Presence or absence of on-site cooking facilities
- Presence or absence of mechanical ventilation

Offices:

The following information is required for an Office Space.

- Zip code
- Gross floor area
 - General Office: 5,000 – 10,000,000 ft²
 - Bank Branch: 1,000 – 20,000 ft²
 - Financial Center: 20,000 – 10,000,000 ft²
 - Courthouse: 5,000 – 10,000,000 ft²
- Weekly operating hours (35 or greater)
- Number of occupants (1 – 25,000)
- Number of personal computers (1 – 25,000)

Medical Offices:

The following information is required for a Medical Office Space.

- Zip code
- Number of workers (2 – 3,500)
- Weekly operating hours (35 or greater)
- Gross floor area (5,000 – 1,000,000 ft²)
- Percent of the gross floor area of the facility that is air-conditioned
- Percent of the gross floor area of the facility that is heated

Hotel / Motel:

The following information is required for a Hotel Space.

- Zip code
- Number of rooms
 - Upper Upscale: 20 – 2,500
 - Upscale: 30 – 2,000
 - Midscale (w/food): 50 – 665
 - Midscale (no food): 40 – 320

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- Economy: 20 - 700
- Gross floor area (5,000 – 10,000,000 ft²)
- Presence or Absence of On-site cooking

Hotel/Motel annual average occupancy must be 45% or greater.

Supermarkets and Grocery Stores:

The following information is required for Supermarkets and Grocery Store Spaces.

- Zip code
- Gross floor area (5,000 – 250,000 ft²)
- Weekly operating hours (35 or greater)
- Main shift staffing (1 – 400)
- Presence or absence of on-site cooking facilities
- Number of registers/PCs (no more than 100)
- Number of walk-in freezers/coolers (1 – 350)
- Number of refrigerated/freezer cases (no more than 35)
- Number of floors (no more than 3)

Warehouses:

The following information is required for Refrigerated and Un-refrigerated Warehouse Spaces.

- Zip code
- Gross floor area (5,000 – 1,000,000 ft²)
- Number of walk-in coolers and refrigerators (no more than 35)
- Weekly operating hours (40 or greater)
- Total number of workers on main shift (no more than 4,000 workers)
- Presence or absence of high-intensity discharge (HID) or halogen lighting systems that primarily light the facility
- Percent of the gross floor area of the facility that is air-conditioned
- Percent of the gross floor area of the facility that is heated

Dorm:

The following information is required for Residence Hall and Dormitory Spaces.

- Zip code
- Number of rooms (5 – 800)
- Gross floor area (5,000 – 1,000,000 ft²)
- Percent of the gross floor area of the facility that is air-conditioned
- Percent of the gross floor area of the facility that is heated

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Hospital:

The following information is required for a Hospital Space.

- Zip code
- Number of licensed beds (16- 1,510)
- Gross floor area (20,000 -5,000,000 ft²)
- Number of floors (no more than 40)
- Presence or absence of tertiary care
- Presence or absence of above ground parking facilities