Rethinking Percent Savings

The Problem with Percent Savings and
the New Scale for a Zero Net-Energy Future

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Disclaimer

ABBREVIATIONS AND ACRONYMS

ACM	Alternative Compliance Manual
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CBECS	Commercial Buildings Energy Consumption Survey
CEC	California Energy Commission
CEUS	Commercial End-Use Survey
CHPS	The Collaborative for High Performance Schools
COMNET	Commercial Energy Services Network
CPUC	California Public Utilities Commission
EPA	Environmental Protection Agency
EUI	Energy Use Intensity
HERS	Home Energy Rating System
IECC	International Energy Conservation Code
LEED	Leadership in Energy and Environmental Design
NREL	National Renewable Energy Laboratory
NRNC	Non-residential New Construction
PBA	Principal Building Activities
PRM	Performance Rating Method
PV	Photovoltaic
TDV	Time Dependent Value
USGBC	United States Green Building Council

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EXECUTIVE SUMMARY

Energy incentive programs, green building rating systems, and energy labeling programs are commonly based on percent savings past code minimum. This approach has worked reasonably well, but percent savings becomes confusing and unstable as policy makers set goals for zero net-energy buildings and as energy codes become more stringent.

Percent savings is confusing because the codes frequently change. California updated its energy efficiency standards in 2001, 2005, and 2008 and each time, energy use was reduced from between 5% to 8%. ASHRAE updated Standard 90.1 in 1999, 2001, 2004, and 2007. Early green buildings claimed savings of 40% or more relative to ASHRAE Standard 90.1-1999, but many of these buildings would fail to comply with the most recent ASHRAE and California codes.

Percent savings is also confusing because in many cases not all of the energy used in buildings is considered. With LEED 2.1 and other early programs, only regulated energy was considered, such as heating, cooling, ventilation, hot water, and interior lighting. Process energy, plug loads, commercial refrigeration, and other non-regulated energy uses were not included because the codes did not establish a baseline for these end uses. In some building types like supermarkets and restaurants, the non-regulated energy can represent two thirds of the total. Even in offices and schools; non-regulated energy typically represents approximately one third of total energy. Ignoring non-regulated energy in the percent savings calculations overstates the percent savings and provides a false perception to building owners on what the energy savings benefits will be.

This white paper proposes a more stable scale to replace percent savings. The scale can be used as the basis for incentive programs, green building rating systems, and energy labels. Updates to energy codes can be evaluated on the scale, as opposed to having code updates redefine the scale. The scale will work for all building types from offices and schools to energy intensive building types such as supermarkets and laboratories. The scale is technically consistent with the ENERGY STAR Portfolio Manager program and its use will help bridge the gap between energy simulations used in the design and construction phase and actual building operation. The scale can be used to specify targets for green building ratings and incentives, eventually eliminating the need to create and model a baseline building.

Zero net-energy is a pure goal. As used here, it means that for a typical year, a building will produce as much energy as it uses. The “net” part means that the building is using the utility grid as its “battery,” charging the battery when the building is producing more energy than it is using and drawing from the battery during the night and at other times when it is consuming more energy than it is producing. Zero net-energy is absolute. Zero net-energy represents a value of zero. On the proposed scale, less is better. With zero net-energy, a baseline is not needed. The baseline is only needed to measure how far a building deviates from zero net-energy.

It is proposed that 100 on the scale represent average energy consumption at the turn of the millennium[1] (See Figure 1). The average is for all buildings, not just new buildings, so new buildings complying with the latest energy efficiency standards would get a score less than 100. The average is adjusted for neutral variables like climate, building type, and hours of operation. Neutral variables should have little impact on where a candidate building falls on the scale, since they affect both the candidate building and the average energy consumption in the same direction. All energy use is included: regulated energy and non-regulated energy. Considering

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[1] The 2003 CBECS database would be used to represent the average energy consumption of buildings at the turn of the millennium.

the significant process and refrigeration loads in energy intensive building types will encourage focus on the strategies and the feasibility of getting these buildings to zero net-energy.

Buildings that use half as much as the average get a 50 on the scale. Buildings that use twice as much as the average get 200 on the scale. A zero net-energy building gets zero on the scale. A building that is a net producer could get a negative score. The scale is stable over time because the zero point is absolute and the 100 marker represents average energy use at the turn of the millennium (based on CBECS 2003), which does not change. Average energy consumption may be estimated either through empirical analysis or through simulation of an "average building". Using the empirical approach, average energy consumption would be determined from surveys of existing buildings but normalized for turn of the millennium and adjusted for neutral variables. At a national level, the CBECS database is the best source of information. This is updated about every four years and is adequate for most building types. Other databases such as CEUS would be used as needed to supplement the CBECS data (again these would be adjusted as needed for the turn of the millennium).

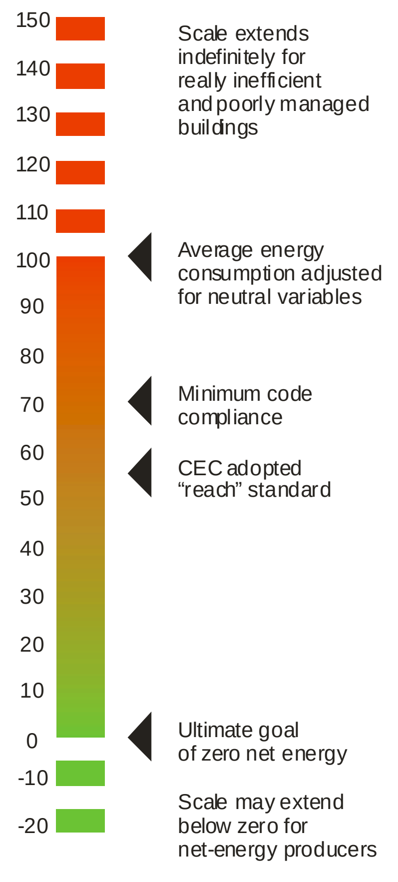

Figure 1 – The Recommended Scale

Moving to the recommended scale will enable the energy standards development process to become more of a top-down, goal oriented process to replace the current bottom-up process. The bottom-up process is characterized by measures that are individually evaluated and the ones that stick become mandatory or prescriptive requirements. The top-down process would set a goal on the scale and then prescriptive packages would be developed to achieve the goal. The prescriptive packages could capture the synergies between some measures and more closely approximate the integrated design process which is highly touted for new building design and construction.

As targets are set closer to zero on the scale, it should be feasible to abandon the current practice of creating a budget through the development of a standard design building. Compliance would be achieved by designing a building that achieves the specified target on the scale, say a 40. As the CEC and others develop beyond-code "reach" standards, these too can be pegged to the common scale.

IOU and other incentive programs as well as rating and labeling programs may use the scale directly as the basis for credit or monetary rewards. Green building rating systems would earn 2 points for instance for getting to 45, 4 points for getting to 40, etc. The points could be intelligently set considering the process and non-regulated energy uses for each building type. Likewise, performance oriented incentive programs could also be keyed to the common scale, for example $2.00/ft² for a 45 and $3.00/ft² for a 40.

The common scale would help the CPUC and other regulators measure the overall impact of their programs. If California buildings average an 80 on the scale with 100 as the national average, this is an important indicator of the effectiveness of all California programs and regulations in combination. As the CBECS average drifts down over the years, this too will be a measure of the effectiveness of our building energy efficiency and appliance programs.

The scale would enable all stakeholders to measure progress in the same terms and remove the frustration of percent savings past a moving target.

Median vs. Average. Several stakeholders in the development process for this white paper have recommended that 100 on the scale be the median energy use, as opposed to the average. This is still an open issue which is discussed later in the white paper.

1 BACKGROUND

1.1 DEFINITIONS

The following definitions will be useful to consider throughout this discussion:

Asset Rating. A rating that applies to a building independent of its operation. The Asset Rating is analogous to the EPA mileage rating for cars. It represents the inherent energy efficiency of the building, based on standard assumptions of occupant behavior or building management.

Operational Rating. A rating that considers not only the energy efficiency features of a building but how it is operated. ENERGY STAR Portfolio Manager is an Operational Rating. Using the car analogy, the operational rating is based on the actual electricity and other fuels used by the building and measured at the meter.

Regulated Energy. The portion of energy that is addressed by energy efficiency standards and generally includes heating, cooling, ventilation, water heating, and interior lighting. Exterior lighting may or may not be included.

Non-Regulated Energy. The remaining building energy use, consisting of:

- **Plug Loads.** Equipment that is plugged in to receptacles, including personal computers, printers, copiers, coffee machines, vending machines, residential refrigerators, etc.
- **Refrigeration.** Equipment that maintains the temperature of walk-in refrigerators, freezers, open refrigeration cases, and closed refrigeration cases.
- **Other.** Vertical transportation, cooking, fume hoods, and special equipment.

Neutral Variables. Factors such as climate, operating hours, etc. which should be the same for the baseline and the rated building.

Metric. The “currency” used to compare building performance such as site energy, source energy, Time Dependent Valuation (TDV) energy, or cost. The metric provides a means to combine different fuels such as natural gas and electricity.

California 2001, 2005, 2008. The update cycles of California Title 24, Part 6, Building Energy Efficiency code.

Zero Net-Energy. Achieved when a building produces as much energy on an annual basis (through PVs or other on-site generation sources) as is consumed on an annual basis. Since energy production at a building site is generally electricity, the choice of metric (see above) affects how much additional electricity needs to be produced to make up for natural gas and other energy uses.

1.2 THE PROBLEM WITH PERCENT SAVINGS

Percent energy savings calculations for new buildings and major modernizations present numerous difficulties from technical and strategic viewpoints.

The concept of percent savings and subsequent calculations presently have wide application in green building rating systems, utility programs, and federal tax deductions. Discussing building energy savings in terms of percentages is an easily understood approach. For example, stating “My building is 30% better than code” is a relatively simple way to describe energy savings. However, the inherent flaws of the percent savings concept become apparent when one considers exactly which code the building surpasses and what energy consumption areas that code takes into account.

PERCENT SAVINGS

In order to understand the problem presented by the percent savings approach, it is valuable to look at energy use in terms of a common metric. In California, this metric is TDV energy. Source energy is the metric used by the EPA ENERGY STAR program. Another national reference is simply cost, as used by the ASHRAE PRM calculations.

Following the precedent of the ENERGY STAR program, the energy metric depicted in Figure 2 represents total source energy use intensity (EUI) (Btu/ft^2-y), including non-regulated energy such as plug loads and refrigeration. Point A on the scale marks the average EUI for a group of about 1,000 California buildings.

Figure 2, Point B marks ASHRAE 90.1-1999, which represents the level of energy performance for the same 1,000 California buildings in minimum compliance with this standard (using the same operating assumptions). Point K, near the bottom of the scale marks a zero net-energy building. Point L represents net energy producers.

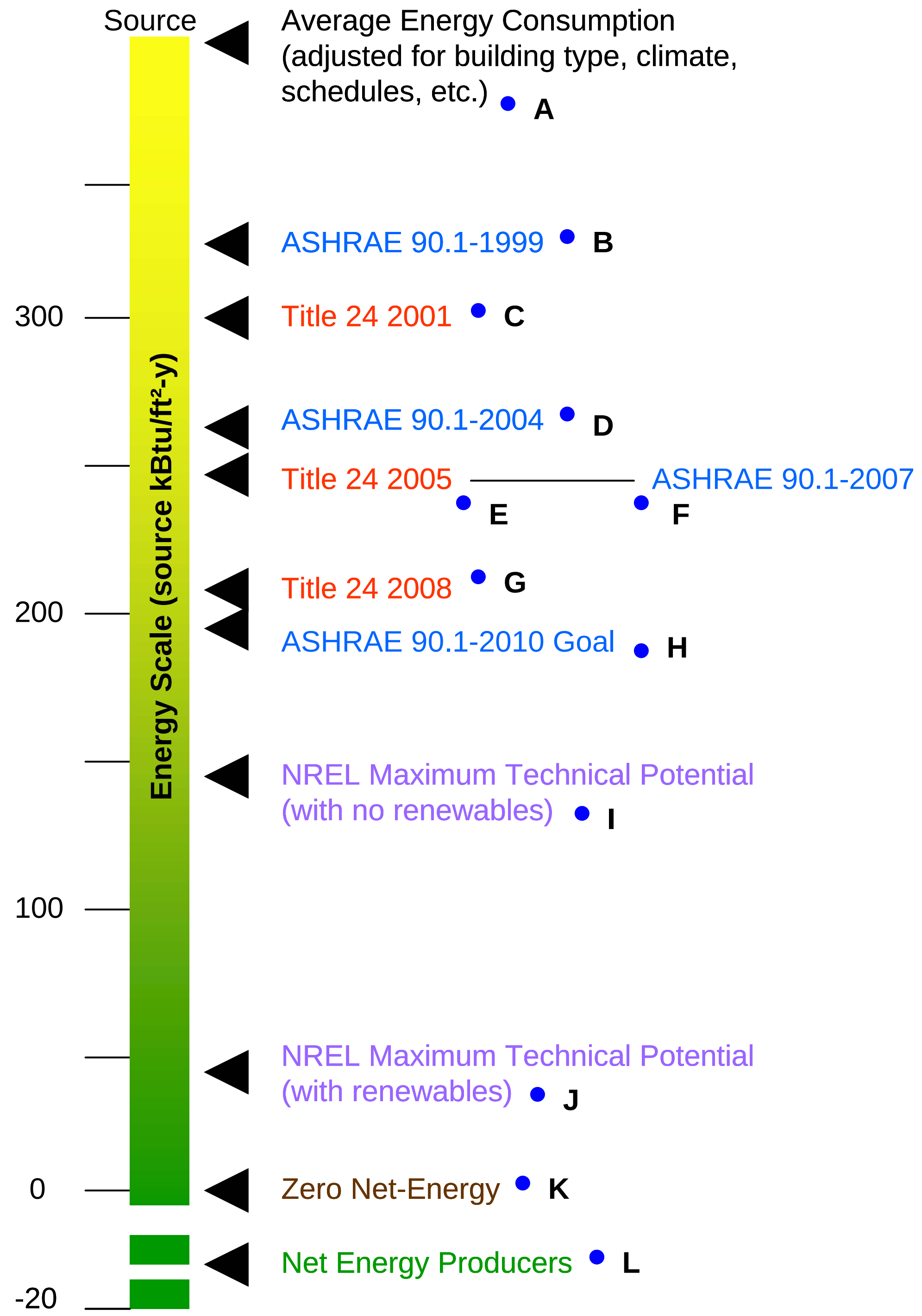

FIGURE 2 – CURRENT ENERGY METRIC

THE POINTS SHOWN IN THIS FIGURE ARE ESTIMATIONS BASED ON AVAILABLE DATA.

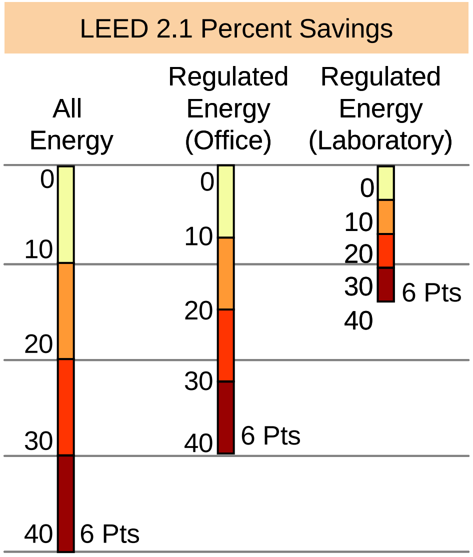

FIGURE 3 – LEED 2.1 PERCENT SAVINGS

LEED Version 2.1 used ASHRAE 90.1-1999 as its baseline and offered energy points based on percent savings past this baseline (See Figure 3). The percent savings calculations for LEED 2.1, however, only included regulated energy, so the marker on the scale of total energy use is shortened, depending on how much of the building energy is regulated. Offices have around 75% regulated (25% non-regulated) energy, so 40% regulated savings translates to about 30% total savings (see the center scale). For buildings like laboratories, or other energy intensive buildings such as supermarkets or restaurants, only about 30% of the total is regulated (with 70% non-regulated), so the 40% savings in regulated energy translates to about 25% total savings (see scale on the right).

Point C in Figure 2 indicates where California 2001 increased building energy efficiency stringency, for the same set of 1,000 buildings. This became the baseline for California's Savings By Design program at the time. The USGBC stated that if percent savings calculations are performed against the California 2001 baseline, 10% could be added and used as a basis of LEED points. The actual difference varies by building type, but the USGBC's ruling was easy to apply.

Subsequently, the release of ASHRAE 90.1-2004 (Point D) introduced changes, largely by lowering the lighting power limits. This became the baseline for LEED Version 2.2. LEED 2.2 also referenced the ASHRAE PRM (Appendix G), which defines percent savings in terms of all energy, not just regulated energy. The latter change made it more difficult for energy intensive buildings (like laboratories, supermarkets, or restaurants) to earn LEED energy points because no procedure was provided for claiming savings of non-regulated energy.

The California 2005 update (Point E) increased stringency again and this became the baseline for the CHPS 2006 Criteria and the new California Savings By Design programs. ASHRAE 90.1-2007, which is the baseline for LEED 2009, is represented by Point F. The California 2008 update (Point G) will take effect around the end of 2009 and is the baseline for CHPS 2009 Criteria. Point H represents the ASHRAE 90.1-2010 goal for a 30% reduction from ASHRAE Standard 90.1-2007.

The implications of measuring a building's energy efficiency against these standards can be illustrated in the following example. An office building calculated at 40% better than ASHRAE-

1999 would just barely comply with California 2005 and would fail to comply with California 2008. This office building, with significant energy efficiency relative to ASHRAE 1999, would only be about 12% better than ASHRAE 2004. This demonstrates the instability of percent savings in that the scale means something different depending on the baseline standard referenced and whether or not all energy consumption is included.

Points I and J in Figure 2 represent an estimate of NREL Maximum Technical Potentials. A recent NREL Technical Potential Study sets forth a benchmark for buildings, Point I on the scale, that incorporate all available technology feasible by the year 2025, excluding renewable energy. A second benchmark represents the NREL estimate (average) for buildings that incorporate PV systems or other renewable energy on-site sources. These markers on the scale are average. NREL concluded that many building types could reach zero net-energy, but that zero net-energy is not be feasible for many energy intensive buildings or towers in dense urban settings.

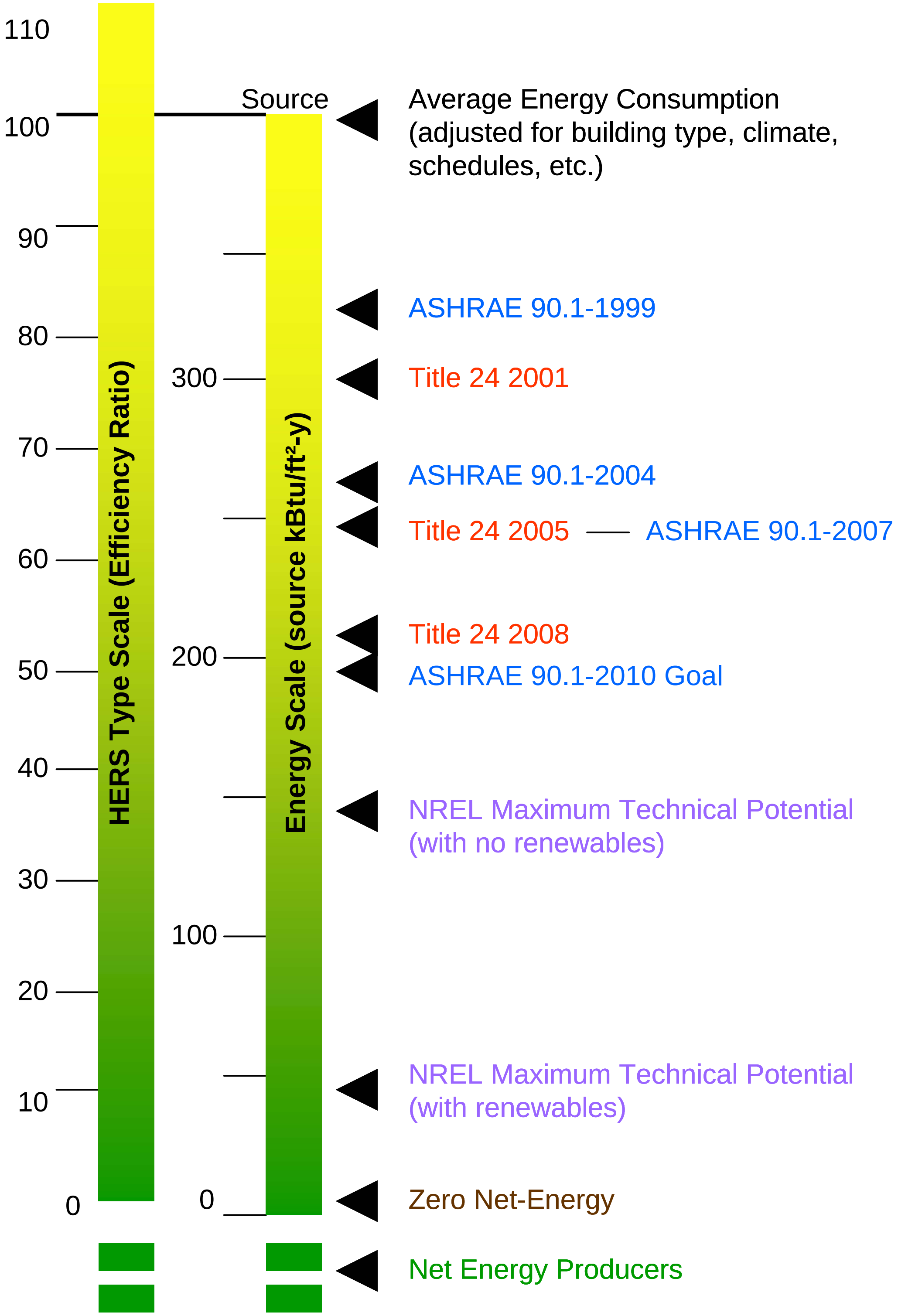

Figure 4 – HERS Style Scale Compared to Source Energy Metric

The points shown in this figure are estimations based on available data.

THE HERS STYLE SCALE

HERS uses a scale where zero net-energy is zero and 100 is the baseline. While the national HERS program utilizes the IECC 2006 as a baseline and California HERS uses California 2008 as a baseline, average energy consumption at the turn of the millennium (based on CBECS 2003) is recommended as a baseline for nonresidential buildings. The energy scale that has been evaluated in this discussion thus far would change with each climate zone, building type, and changes in operating hours, etc. An advantage of the HERS type scale is that 80 (roughly 20% better than the baseline) means roughly the same thing no matter the climate, the building type, or the operating hours. Another advantage of the HERS type scale is that energy codes can be pegged to it. On this scale, (in approximate terms), ASHRAE 90.1-1999 is about an 82, ASHRAE 90.1-2004, ASHRAE 90.1-2007, and California 2005 are about a 75, and California 2008 is about a 53. NREL maximum technical potential gets us to about a 35 without PVs and to about 10 with PVs.

The CBECS average energy consumption is also the baseline for the ENERGY STAR Portfolio Manager and Target Finder programs. Comparing the ENERGY STAR transformation curve with the HERS type scale, the 50th percentile hits at about 94 on the HERS scale. The 60th percentile hits at about 84; 70th percentile at about 74; 80th percentile at 64; and 90th percentile is at about 52. After that, the ENERGY STAR scale ceases to be useful as a tool to strive toward zero net-energy buildings since everything is around the 99th percentile.

The recommended HERS style scale would be stable over time, if the 2003 CBECS normalized average is used to define the top. This scale, which is technically consistent with the EPA ENERGY STAR scale, would reduce the confusion associated with moving baselines. Furthermore, an efficiency ratio scale is related to real-life energy consumption. It would provide a vital reference standard as goals are set towards zero net-energy.

1.3 VARIATION IN ENERGY CONSUMPTION BY BUILDING TYPE

It will be easier to achieve zero net-energy for some building types than others. Figure 5 shows source energy use on the vertical scale. Some common building types are shown in the left dimension. The colors represent compliance with California 2001 (in pale yellow), California 2005 (in magenta), and California 2008 (in blue).

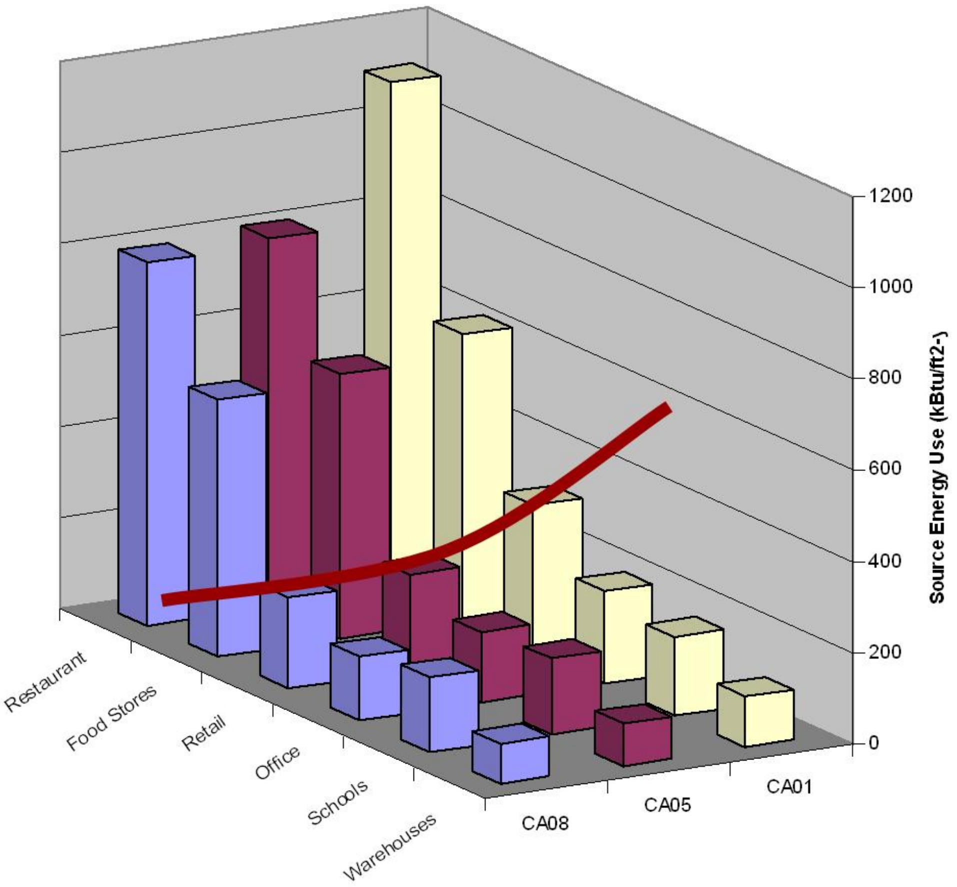

FIGURE 5 – AVERAGE SOURCE ENERGY CONSUMPTION BY BUILDING TYPE

SOURCE: ENERGY SIMULATIONS OF BUILDING SITES IN THE NRNC DATABASE

Of this group of buildings, restaurants have the most intensive energy use, followed by food stores, retail, offices, schools, and warehouses, the latter of which all have relatively small energy consumption. Shifting from yellow to magenta to blue, the savings resulting from the California code updates become evident.

As building codes are made more stringent for heating, cooling, ventilation, water heating, and lighting, the savings to be gained from these components are approaching their limits. To make the next advances in energy efficiency, non-regulated energy uses will need to be addressed. Or, alternatively, on-site renewable energy will need to be incorporated, and for some building types like supermarkets and restaurants, a lot of it is going to be needed.

Table 1 shows the savings in regulated energy use needed in order to achieve total energy savings, assuming that there are no opportunities to reduce non-regulated energy uses, which is now the case for many programs. For instance, if a building has 60% regulated energy and 40% non-regulated energy, then in order to achieve total savings of 35%, a reduction in regulated energy of 58.3% would be needed (cell shaded in gray). Similarly a restaurant with 40% regulated and 60% non-regulated would need a 35% reduction in regulated energy to achieve a total savings of 14% (also shaded in gray). For a building that is only 20% regulated energy, regulated energy could be eliminated altogether and the total savings would be only 20%.

TABLE 1 – REDUCTIONS IN REGULATED ENERGY USE NEEDED TO ACHIEVE TOTAL PERCENT SAVINGS

		SCHOOLS, OFFICES AND RETAIL		RESTAURANTS AND SUPERMARKETS		
Traditional Energy	100%	80%	60%	40%	20%	0%
Other Energy	0%	20%	40%	60%	80%	100%
TOTAL ENERGY SAVINGS DESIRED	REGULATED ENERGY SAVINGS NEEDED					
10.5%	10.5%	13.1%	17.5%	26.3%	52.5%	■
14.0%	14.0%	17.5%	23.3%	35.0%	70.0%	■
17.5%	17.5%	21.9%	29.2%	43.8%	87.5%	■
21.0%	21.0%	26.3%	35.0%	52.5%	■	■
24.5%	24.5%	30.6%	40.8%	61.3%	■	■
28.0%	28.0%	35.0%	46.7%	70.0%	■	■
31.5%	31.5%	39.4%	52.5%	78.8%	■	■
35.0%	35.0%	43.8%	58.3%	87.5%	■	■
38.5%	38.5%	48.1%	64.2%	96.3%	■	■
42.0%	42.0%	52.5%	70.0%	■	■	■

CALIBRATING MODELING ASSUMPTIONS TO CBECS/ENERGY STAR

The recommended approach provides a common scale for both Asset Ratings and Operational Ratings. The modeling assumptions that are currently used for performance calculations, as documented for instance in the California Alternative Calculation Methods (ACM) and in the ASHRAE PRM, need to be adjusted to produce results more consistent with the CBECS database and actual energy bills. Models may never improve to the point where actual energy consumption can be predicted down to the Btu, but they can be significantly enhanced and differences related to modeling assumptions can be lessened.

As part of their work related to the “Technical Potential” study, NREL developed procedures that set plug loads, refrigeration, process loads, and schedules to achieve better agreement between simulation models and utility bills. These algorithms offer an opportunity not only to better calibrate energy models to average operating conditions, but they also begin to provide a technical basis for crediting reductions in non-regulated energy. In collaboration with the New Buildings Institute, AEC is developing a national method for calculating energy savings. A significant portion of AEC’s work effort for the this project will be to recommend default schedules of operation, plug loads, and miscellaneous energy uses that bring simulation results into better agreement with CBECS and CEUS reported energy use. Some of these results are presented in the following section and laid out in more detail in the Appendices.

ENERGY STAR PROCEDURE TO ACCOUNT FOR “NEUTRAL VARIABLES”

The ENERGY STAR technical methodology has a procedure for “normalizing” average energy consumption. These procedures are documented in ENERGY STAR Performance Ratings Technical

Methodology.[2] The procedure results in the “predicted source EUI,” which is actually the normalized CBECS average EUI for a particular set of building conditions. The units are source kBtu/ft²-y. The dependent variable, source EUI, is normalized for climate, operating hours, building type, and other factors. These factors are termed ‘neutral variables’ in this discussion. A higher or lower score should not be given because a building is located in a cold climate or because it is operated for more hours during the week. EPA identified the neutral variables separately for each building type through a statistical analysis that identified significant factors. This procedure is discussed in greater detail in Section 2 and Section 3.1.

1.4 NON-REGULATED ENERGY IN ASSET RATINGS

In *How Buildings Learn*, Stewart Brand identifies the temporal nature of the building.[3] In reference to Figure 6, Brand observes that the site is eternal, the structure spans 30 to 300 years, the skin lasts about 20 to 50 years, the services are in place between 15 and 30 years, the space plan changes every 3 to 10 years, and the “stuff” inside the building is replaced as frequently as monthly. Brand’s concept of shearing building layers is helpful in discovering what should be considered in Asset Ratings.

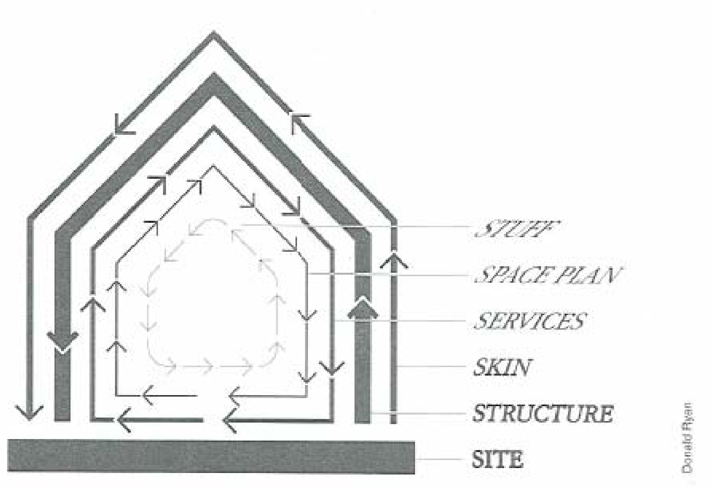

FIGURE 6 – STEWART BRAND’S CONCEPT OF SHEARING LAYERS

IMAGE COURTESY OF STEWART BRAND, HOW BUILDINGS LEARN

Much of the equipment that produces non-regulated energy use has a short lifecycle and is changed out frequently. Notebook computers, copy machines, and other equipment come and go with the tenants and is often leased. If a credit is offered, it should be discounted in some way to account for its temporal nature. Often, credits for reductions in non-regulated energy use turn into promises about future good behavior. For example, dictating that all future tenants will purchase ENERGY STAR office equipment. Similarly, stipulations could state that future tenants will purchase 20% of their power from Green-e certified sources or that they will power wash their cool roof every year to keep it white and performing well. If a credit is offered for Asset Ratings, it should be associated with some sort of binding commitment, like a tenant manual recorded with the deed.

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[2] ENERGY STAR Performance Ratings Technical Methodology. February 2009. Available Online at http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf.

[3] Brand, Stewart. How Buildings Learn: What Happens After They’re Built. New York: Viking, 1994.

2 MODELING ASSUMPTIONS

There is generally a significant gap between energy simulation results and actual building energy performance. Due to the nature of various capabilities in energy simulation programs, modeler experience, level of detail in architectural designs, assumptions about non-regulated energy, and other unknowns, energy model results vary, sometimes significantly, from actual energy consumption shown on utility bills. As a result, simulations can present the owner/tenant with a misconception about the building's actual energy use during its lifespan.

Bringing energy model simulation results closer to reality means calibrating modeling assumptions to empirical data from the CBECS database or other sources. The modeling assumptions used to calculate the Asset Ratings and to comply with codes should be reasonably consistent with the way the building will actually be operated. Integrating real world data for non-regulated energy drawn from CBECS and other sources into the simulation models will reduce differences and narrow the gap. This not only offers an opportunity to calibrate energy models to average operating conditions, but also begins to provide a technical basis for crediting reductions in non-regulated energy.

One of the goals of going to a stable and consistent scale for evaluating buildings at all phases of their life-cycle is to close the gap between the predictions of energy simulations and actual utility bills after the building is commissioned and started up. There are a number of reasons for the discrepancies between modeling results and utility bills and four of them are addressed in this section:

- Climate data on the weather file used for analysis may be different from the weather during the year when utility bills were accumulated.
- Assumptions about how the building was expected to be operated are different from how it actually was operated.
- Assumptions on the plug loads, process energy and other non-regulated energy uses are not properly represented in the simulation model.
- Major energy uses such as commercial refrigeration systems are not properly accounted for.

The recommended stable scale would apply to both Asset Ratings and Operational Ratings. Calibrating modeling assumptions will help to close the gap and create more consistency between energy modeling and Operational Ratings such as ENERGY STAR. Modeling assumptions currently used for performance calculations, as documented in the California Alternative Calculation Manual (ACM) and in the ASHRAE Performance Rating Method (PRM), are not currently consistent and should be better calibrated with information from the CBECS or other data sources, in order to improve agreement between the energy models and actual energy use.

2.1 CLIMATE ZONE

Energy simulations use hourly weather files to estimate energy use. Average energy consumption estimated from the ENERGY STAR regression equations use heating and cooling degree days at a base temperature of 65 F. The gap for weather differences may be reduced by deriving the inputs to the ENERGY STAR process from the weather files used in the energy simulations. Table 2 shows the degree days for the 16 California climate zones. These values may be used to normalize CBECS average energy consumption to the conditions that exist on the standard weather files. The Asset Rating would be calculated in this manner.

TABLE 2 – HEATING AND COOLING DEGREE DAYS FOR THE OFFICIAL CEC WEATHER FILES

CLIMATE ZONE	HEATING DEGREE DAYS (BASE 65)	COOLING DEGREE DAYS (BASE 65)
1	4085	0
2	2890	552
3	2541	101
4	2414	398
5	2277	100
6	1475	460
7	1344	629
8	1317	999
9	1260	1215
10	1637	1437
11	2656	1385
12	2649	1038
13	2228	1997
14	3113	1596
15	846	3906
16	5579	218

Neutralizing climate within energy simulations will ensure buildings are evaluated on their energy savings strategies alone, without a boost from temperate climates or a disadvantage from extreme temperatures.

2.2 SCHEDULES OF OPERATION

In the proposed scale and in ENERGY STAR performance ratings, hours of operation are considered a neutral variable. Using hours of operation as an equalizer within energy models can help create the same basis for comparison. Similar to climate, buildings should not be penalized or assisted based on their hours of operation. The CBECS weekly hours of operation are shown in Figure 7 and Figure 8. Figure 7 shows the range for the Principal Building Activities (PBA) tracked in the CBECS database and Figure 8 shows the same information for an expanded classification of building activities called (PBAPLUS). The black square represents the average for each group of buildings and the line represents plus or minus one standard deviation. For comparison, Table 3 shows the weekly hours of operation specified for nonresidential modeling purposes in the California ACM manual.

There is a large range in operating hours for different building types and even within a building type. Currently, energy simulations are dependent on this variable and if input incorrectly there can be significant variation in energy consumption versus actual hours. It is important that this value be as close to the actual operating schedule as possible in order to mimic real conditions. Since there is such a range in the offset of one standard deviation for most building types, it is hard to pinpoint the correct input without accurate information about the operations expected for a specific building. Since schedule information is hard to obtain during design and when it is obtained, it comes with uncertainty, it is recommended that likely minimum and maximum hours of operation be simulated to understand the impact on energy consumption results. This could result in a range of scores on the recommended scale, but this variation would be smaller since an increase or reduction in operating hours would affect the energy consumption in the candidate building and the average energy consumption in the same direction. Therefore, the recommended scale would negate some of the impact of being slightly off on the estimate of operating hours.

For California code compliance work, only four schedules of operation are permitted to be used: one for 24x7 occupancies like hotels and high-rise residential, one for hotel function rooms, one for retail, and one for all other nonresidential buildings. See Table 3 for a summary of the weekly HVAC hours. With the variation shown in Figure 7 and Figure 8, there would obviously be discrepancies between the California modeling assumptions and actual building use.

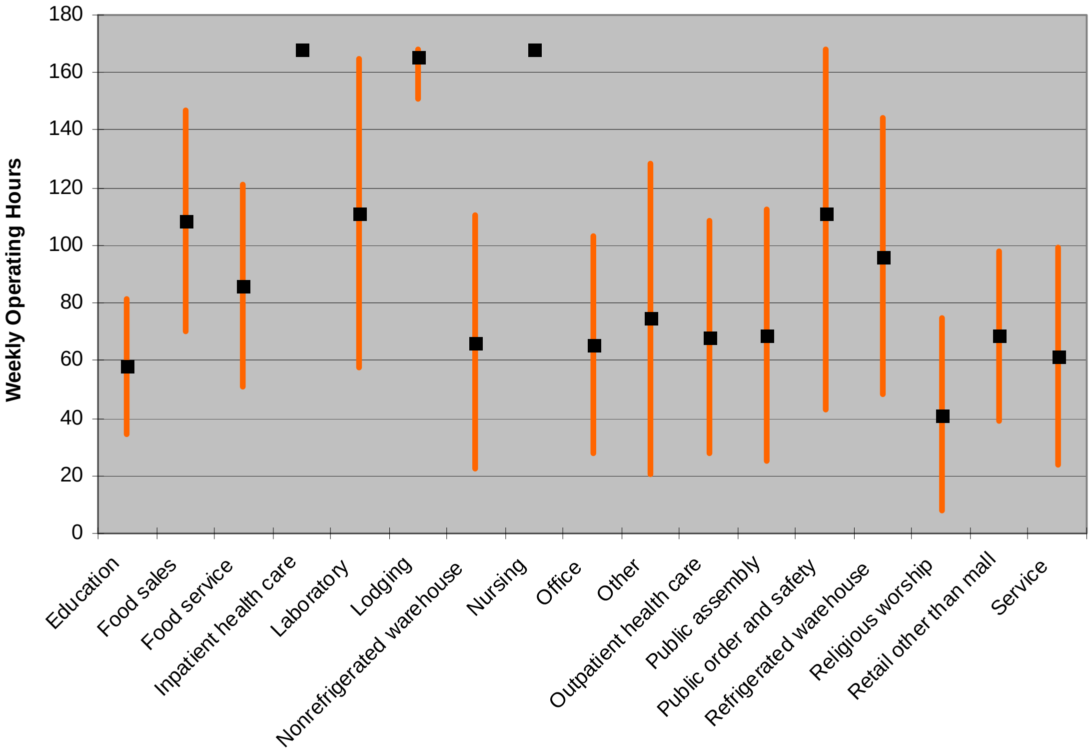

FIGURE 7 – PBA WEEKLY OPERATING HOURS

THE RANGE SHOWS PLUS AND MINUS ONE STANDARD DEVIATION. THE SQUARE IN THE MIDDLE IS THE AVERAGE.

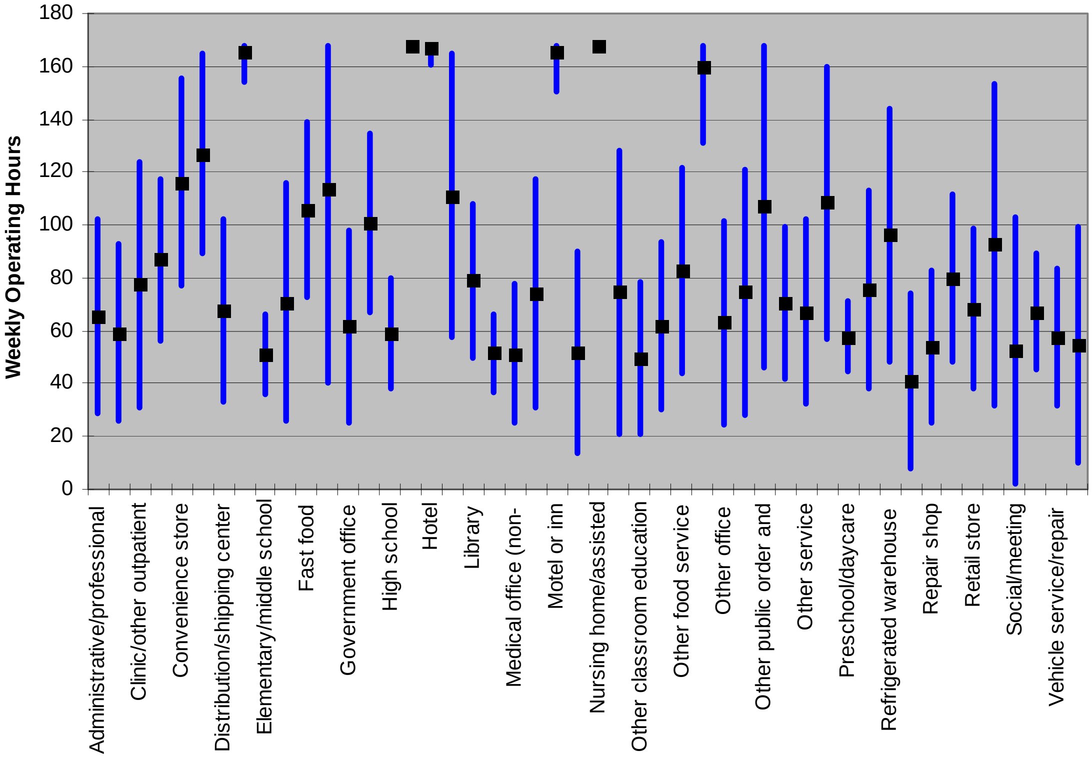

Figure 8 – PBAPLUS Weekly Operating Hours

The range shows plus and minus one standard deviation. The square in the middle is the average.

Table 3 – Weekly Hours of Operation Specified by California ACM Manual

These values are from the 2005 and the 2008 Nonresidential ACM Manuals (values the same in both cases).

Occupancy	Hours/Week of HVAC Operation
Nonresidential (other than Retail)	85
Retail	105
Hotel and Multi-Family	168
Hotel Function Areas	119

2.3 PLUG AND PROCESS LOADS

Plug and process loads are the largest non-regulated energy loads in many buildings. Since plug loads are determined by building users, they are extremely difficult to quantify. Using the NREL plug and process electricity intensity equations[4] and CBECS data, averages for selected building types have been calculated. The NREL procedure takes account of several office and telecommunications devices such as number of computers, flat screen and CRT monitors, servers, POS systems, laser and inkjet printers, copy machines, residential refrigerators, vending machines, escalators and elevators. Since this is not a comprehensive list of plug and process loads, the procedure includes a factor to pick up the missing components.

Figure 9 and Figure 10 show average power density in W/ft² (the black square) for the CBECS PBA and the expanded descriptions (PBAPlus). The bar represents plus and minus one standard deviation. These values include plug and process loads, but exclude commercial refrigeration.

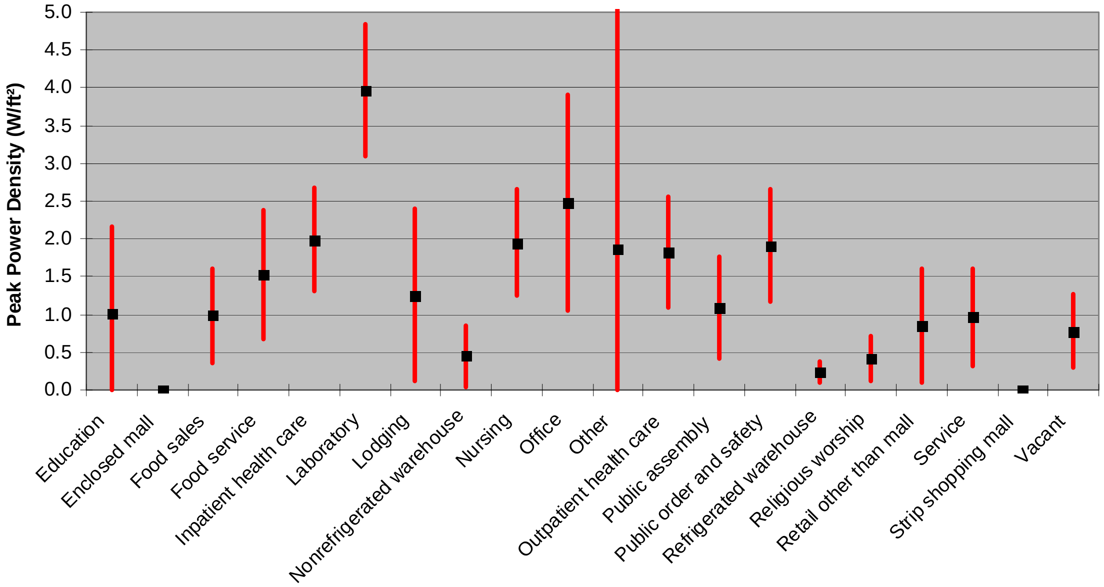

FIGURE 9 –PEAK POWER DENSITY (W/FT²) FOR PBA BUILDING TYPES

THE RANGE SHOWS PLUS AND MINUS ONE STANDARD DEVIATION. THE SQUARE IN THE MIDDLE IS THE AVERAGE.

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[4] See Appendix C of the Methodology of Modeling Building Performance across the Commercial Sector Technical Report. NREL developed algorithms to estimate plug load and miscellaneous power densities from CBECS data.

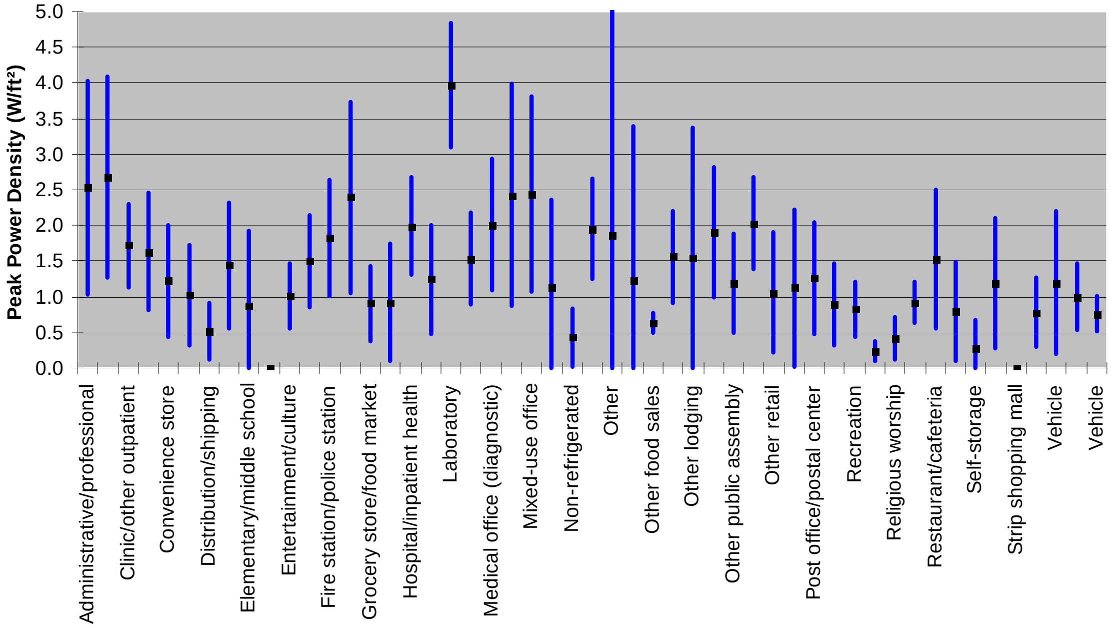

FIGURE 10 – PEAK POWER DENSITY (W/FT²) FOR PBAPLUS BUILDING TYPES

THE RANGE SHOWS PLUS AND MINUS ONE STANDARD DEVIATION. THE SQUARE IN THE MIDDLE IS THE AVERAGE.

Table 4 compares the CBECS based estimates to the assumptions prescribed by the California ACM manual. Figure 11 shows the same data in graphic form. For most common building types, California specified values are significantly lower than the average values from the CBECS analysis.

TABLE 4 – COMPARISON OF CBECS RECEPTACLE LOADS WITH ACM MODELING ASSUMPTIONS

	CBECS ESTIMATED PLUG AND PROCESS LOADS			
PRIMARY BUILDING ACTIVITY	HIGH	LOW	AVG	PLUG AND PROCESS LOAD FROM CALIFORNIA ACM
Education	2.2	0.0	1.0	1.00
Enclosed Mall	0.0	0.0	0.0	0.50
Food sales	1.6	0.4	1.0	1.00
Food service	2.4	0.7	1.5	1.50
Inpatient health care	2.7	1.3	2.0	1.50
Laboratory	4.8	3.1	4.0	n/a
Lodging	2.4	0.1	1.3	0.50
Non-refrigerated warehouse	0.9	0.0	0.4	0.20
Nursing	2.7	1.2	1.9	1.50
Office	3.9	1.0	2.5	1.50
Other	8.4	0.0	1.9	1.00
Outpatient health care	2.6	1.1	1.8	1.50
Public assembly	1.8	0.4	1.1	1.50
Public order and safety	2.7	1.2	1.9	1.50
Refrigerated warehouse	0.4	0.1	0.2	0.20
Religious worship	0.7	0.1	0.4	0.50
Retail other than mall	1.6	0.1	0.9	1.00
Service	1.6	0.3	1.0	1.00
Strip shopping mall	0.0	0.0	0.0	0.50
Vacant	1.3	0.3	0.8	1.00

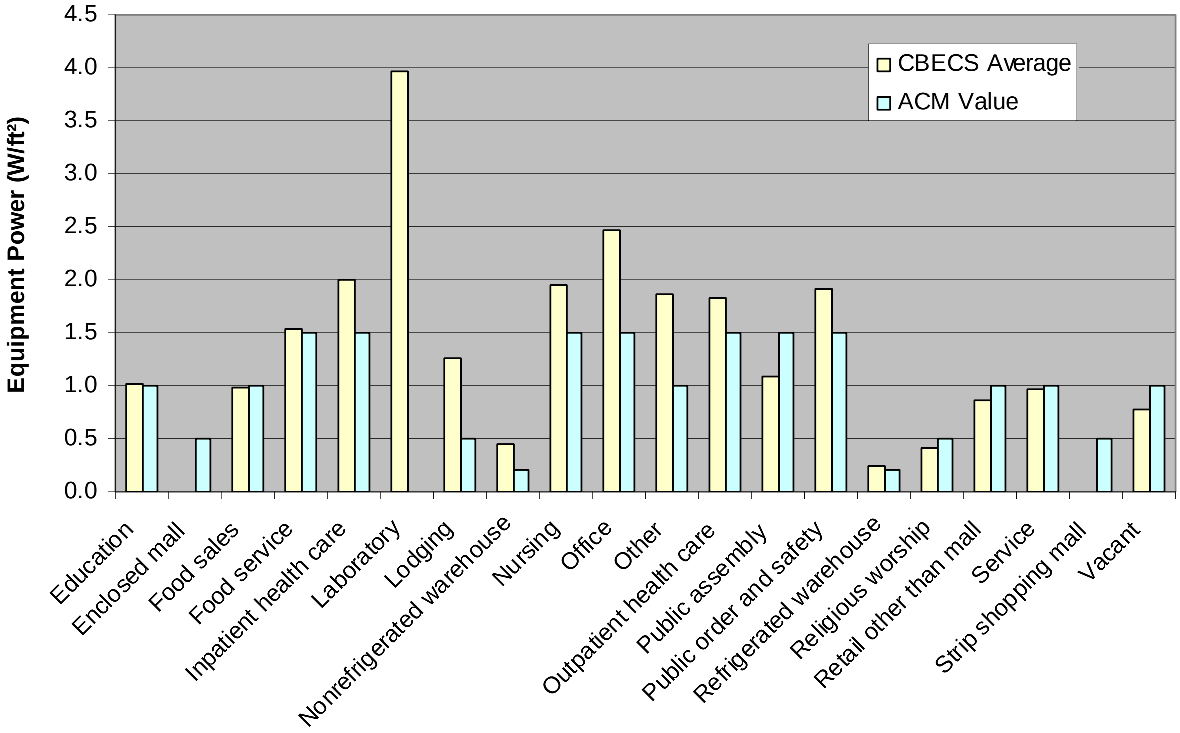

FIGURE 11 – COMPARISON OF CBECS AVERAGE AND CALIFORNIA ACM PLUG AND PROCESS LOADS

MALL DATA IS AVAILABLE FOR ACM, BUT NOT CBECS. LABORATORY DATA IS AVAILABLE FOR CBECS, BUT NOT FOR ACM.

2.4 REFRIGERATION

Refrigeration can account for a large portion of energy loads for certain building types such as food sales, food service, and refrigerated warehouses. Within energy simulations, refrigeration loads can be modeled in different ways, but are often ignored completely. This is a major source of inconsistency in energy consumption totals. CBECS data tracked the number of refrigeration equipment (not including residential refrigerators); closed refrigerated cases, open refrigerated cases, and walk-in refrigeration units.

By using this data collected in the CBECS and the simple conclusions made in the NREL study, typical refrigeration power densities can be used in energy simulations, eliminating assumptions made by the modeler. Table 5 shows refrigeration densities recommended by the NREL analysis for all CBECS PBA building types.

TABLE 5 – REFRIGERATED POWER DENSITY[5]

PBA CODE	PBA	REFRIGERATION POWER DENSITY (W/FT²)
1	Vacant	0.00
2	Office/professional < 30,000 ft²	0.07
2	Office/professional > 30,000 ft²	0.06
4	Laboratory	0.28
5	Non-refrigerated warehouse	0.05
6	Food sales	2.60
7	Public order and safety	0.06
8	Outpatient health care	0.08
11	Refrigerated warehouse	1.53
12	Religious worship	0.03
13	Public assembly	0.03
14	Education	0.06
15	Food service	1.12
16	Inpatient health care	0.08
17	Skilled nursing	0.08
18	Lodging	0.14
25	Retail	0.15
26	Service	0.12
91	Other	0.10

The NREL Technical Study assumes that refrigeration loads are year round, so estimates of annual energy consumption result from multiplying the power densities in Table 5 times 8,760 hours (365 days x 24 hours/day). The NREL Technical Study also modeled refrigeration as external equipment load which ignores the interactions with the space temperature and humidity.

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[5] Table C42 of NREL 41956

3 RECOMMENDATIONS

It is recommended that percent savings past code minimum be abandoned as the basis for incentive programs, green building rating systems and energy labels. The code-based baseline moves every three years or even more frequently as codes are updated, making the concept confusing and ambiguous. Additional confusion is engendered because significant components of energy use are often excluded in the percent savings calculations for federal tax credits and other programs. Percent savings has served its purpose, but as goals are set for zero net-energy; as codes become more stringent; and as non-regulated energy use becomes larger than regulated energy use, it is time to move on to a stable scale.

The recommended scale pegs 2003 average energy consumption at 100 and zero net-energy at zero. This scale is similar to the one used for HERS programs and is being implemented as part of the COMNET program for nonresidential buildings. The recommended scale overturns conventional American wisdom, presenting a less-is-good-and-more-is-bad approach, but this is a necessary viewpoint for energy consumption in buildings. The less-is-good-more-is-bad concept applies to consumer price indexes, construction cost indices, and HERS programs, so it is not entirely new to the American public.

Energy codes can be pegged to the scale and progress toward the California goals of zero net-energy can be evaluated. Incentive programs and green building rating systems may be pegged to markers on the scale in the same way that building codes are. The CBECS database provides an empirical basis for average energy consumption and this database is updated approximately every four years. The publicly available version of the CBECS database is for 2003 and the 2007 version is still being compiled and is not yet ready. Details of the next CBECS survey have not been released. It is recommended that the most recent and comprehensive version of the CBECS (or other) databases be used for normalization, but that the 2003 CBECS always be used to define 100 on the scale.

The recommended scale is shown in Figure 12 as a way to consistently measure energy performance. Periodic updates to the California energy efficiency standards and ASHRAE Standard 90.1 should be mapped against this scale, as opposed to letting code updates redefine the scale. Incentive payment levels should be targeted against this scale. Points in green building rating systems should be referenced to this scale. Energy labels and existing building recognition systems should be indexed to this scale (ENERGY STAR already uses a version of this scale).

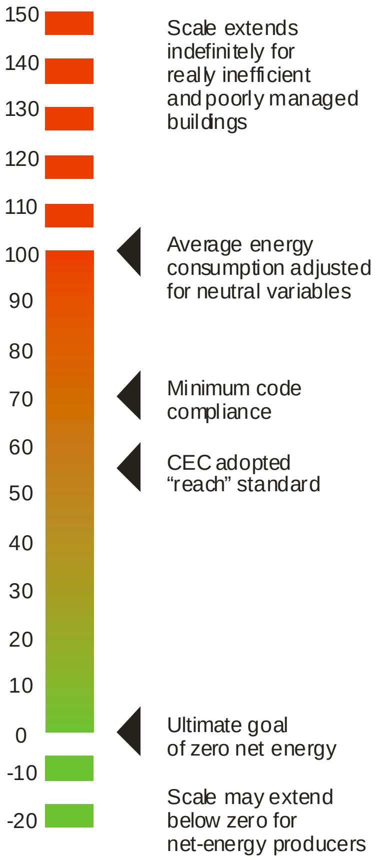

FIGURE 12 – THE RECOMMENDED SCALE

Buildings in the design or construction process would use energy simulations to find their place on the scale, but modeling assumptions need to be specified such that all energy use is included and such that modeling assumptions are set as close to reality as possible. In this way, the process of closing the gap between energy simulations and utility bills can begin. Both existing buildings and new buildings (in the design and construction phase) should use the same scale. After buildings are commissioned and started up, utility bills should be collected and an operational rating should be calculated and compared to the asset rating produced during the design/construction phase. Again, this will help close the loop.

The remainder of this section probes the details and implications of shifting to the recommended stable scale. The following topics or issues are addressed:

- How average energy consumption may be determined for various building types and how the EPA Source EUI metric might be translated to other metrics such as time of use (TOU) costs or TDV energy.
- How the code development update process might be shifted from the current bottom-up approach to a top-down approach that uses the scale to set targets, which are later verified through the development of prescriptive requirements.
- How utility incentive programs and other incentive programs could be modified to use the recommended scale.
- How to begin addressing components of energy use that are not currently addressed by building codes, such as plug loads, refrigeration systems, and other process energy uses.

Perhaps the most convincing argument for moving to the recommended stable scale is to support the California goals for zero net-energy by 2020 for residential buildings and 2030 for commercial buildings. To measure our progress toward these lofty goals, a scale is needed that considers all energy use and embraces the goal of zero net-energy. The recommended scale embodies this objective.

3.1 DETERMINING AVERAGE ENERGY USE (MARKING 100 ON THE SCALE)

One of the challenges of the recommended scale is determining the average energy consumption for a particular building type, climate, and set of operating conditions. The marker on the scale should not be a national average for all building types in all climates; that would be meaningless. The average should be adjusted for climate, building type, operating hours, and other neutral variables. The term *neutral variable* is used here to represent a factor that should not result in a higher or lower score on the scale, i.e. it should be neutral. For example, schools should not be compared to supermarkets, which are much more energy intensive. Buildings in hot humid climates should not be compared to buildings in mild climates. Buildings that are operated 24x7 should not be compared to buildings that operate on a normal weekday schedule. Average energy use, which pegs the 100 marker on the scale, needs to be adjusted for the neutral variables.

As part of its ENERGY STAR program, the EPA did a detailed analysis of the CBECS database. The technical underpinnings of the ENERGY STAR program are estimates of “Predicted Source EUI”. The process that EPA follows to determine the ENERGY STAR score is as follows:

1. **Calculate the Annual Source EUI of the candidate building.** For existing buildings, this is calculated from utility bills. Gas, electricity, and other fuels used in the building are converted to source energy, summed, and divided by the floor area of the candidate building. The units are source Btu/ft^2-yr. See Table 1 for the source-site multipliers used in the EPA program.
2. **Calculate the “Predicted Source EUI” for the building.** This is calculated from the procedure described later and is adjusted for the neutral variables. The EPA neutral variables are shown in Table 8. The “Predicted Source EUI” is the 100 marker on the recommended scale.
3. **Calculate the ratio of the Annual Source EUI to the Predicted Source EUI.** This is essentially the score on our recommended scale if you multiply this ratio times 100. EPA calls this the Energy Efficiency Ratio.
4. **Translate the Energy Efficiency Ratio to a percentile** through a transformation function based on the CBECS dataset for the building type being evaluated. The transformation function for offices is shown as Figure 13. Similar data is provided for other building types. This figure converts the Energy Efficiency Ratio to Cumulative Percent. The EPA ENERGY STAR score is one minus the Cumulative Percent.

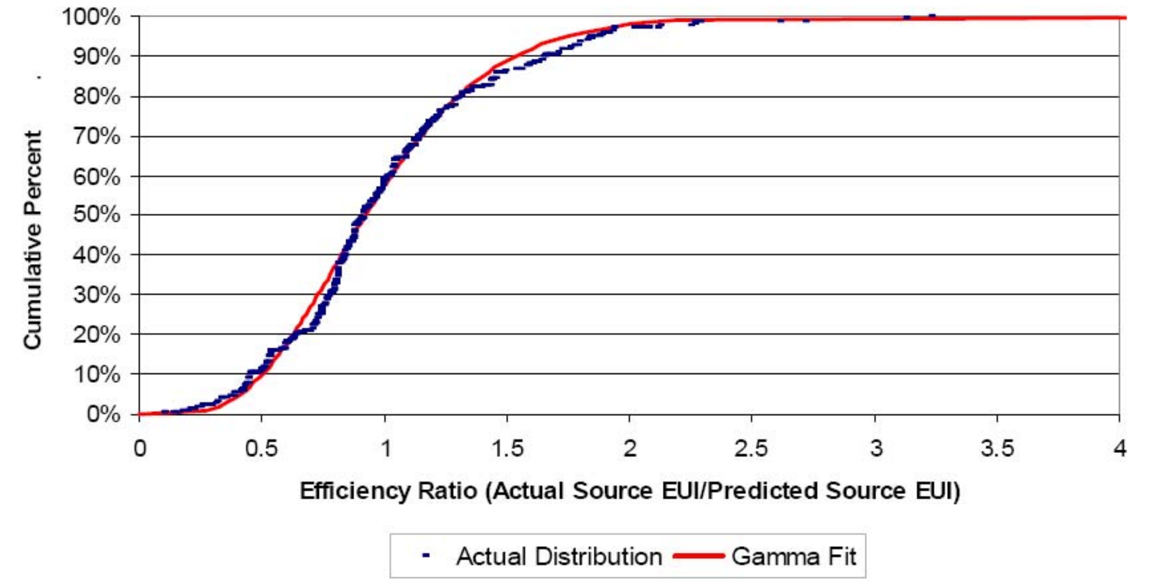

FIGURE 13 – CBECS CUMULATIVE DISTRIBUTION FOR OFFICES

For building types that are addressed by the ENERGY STAR program, a process for determining the average energy consumption and adjusting it for the neutral variables already exists. The EPA process works for common building types based on the neutral variable shown in Table 8. The equations and procedures for calculating the “Predicted Source EUI” were developed through regression analysis of the CBECS database. The process for each building type is described in greater detail in the “Technical Methodology” papers published on the ENERGY STAR website for each building type covered (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf). The process is fairly straightforward, but it does have some limitations for application wider than EPA intended.

The units returned are EPA source energy. Site energy is converted to source energy using the multipliers in Table 6. These are national average numbers. California abandoned its version of source energy[6] with the 2005 update to the standards and shifted its metric to time dependent valued (TDV) energy, which accounts not only for the efficiency of generation and distribution but also the time pattern of energy use. For typical building load profiles, EPA “Predicted Source EUI” can be converted to TDV energy through weighted average values. Such values were calculated for low-rise residential buildings as part of the research supporting the California HERS program. See Table 7. Similar translations could easily be developed for nonresidential building load profiles.

The COMNET project is developing time-of-use energy costs for use in calculating green building ratings and federal tax deductions. These may also be translated to and from EPA predicted source EUI. For most building types, the choice of the metric will not significantly impact the position on the scale. At this time, a specific metric is not recommended, although there are a lot of reasons to use EPA source energy to be consistent with the ENERGY STAR program.

Another issue is that the EPA empirical procedure is only applicable to common building types for which there is enough CBECS data. ENERGY STAR as a voluntary program can be selective, but

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[6] The California standards used a source multiplier of 3.0 for electricity and 1.0 for all fossil fuels. District chilled or hot water systems were not considered.

energy codes, publicly funded incentive programs, and energy labeling programs need to be more comprehensive. The same procedure does not need to apply to all building types, but the programs need to address all building types in an equitable way.

TABLE 6 –SOURCE-SITE RATIOS FOR ALL PORTFOLIO MANAGER FUELS

FUEL TYPE	SOURCE-SITE RATIO
Electricity	3.340
Natural Gas	1.047
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.01
Propane & Liquid Propane	1.01
Steam	1.45
Hot Water	1.35
Chilled Water	1.05
Wood	1.0
Coal/Coke	1.0
Other	1.0

TABLE 7 – RESIDENTIAL WEIGHTED AVERAGE ANNUAL TDV MULTIPLIERS FOR ELECTRICITY CONVERSION (KTDV/KWH)

SOURCE: THESE VALUES ARE PUBLISHED IN THE PHASE II HERS RESEARCH REPORT

CLIMATE ZONE	CONSTANT ON SCHEDULE	FSEC SCHEDULE	CEC 1999 LIGHTING SCHEDULE	1980 JASKE LIGHTING SCHEDULE	CEC EQUIPMENT SCHEDULE	CEC ACM INTERNAL GAINS SCHEDULE	EXTERIOR LIGHTS ON FROM 7-12 IN THE EVENING	EXTERIOR LIGHTS ON FROM 6-10 IN THE EVENING
1	13.93	14.31	14.17	14.26	15.13	14.49	12.90	14.71
2	13.94	14.30	14.08	14.18	15.14	14.40	12.88	14.46
3	13.97	14.31	14.20	14.29	15.07	14.45	13.11	14.75
4	13.96	14.29	14.11	14.21	15.10	14.42	13.00	14.56
5	13.95	14.29	14.23	14.29	15.05	14.55	13.00	14.86
6	14.00	14.34	14.25	14.31	15.09	14.59	13.09	14.79
7	17.64	17.99	17.75	17.78	18.96	18.24	16.02	18.28
8	13.98	14.30	14.15	14.24	15.10	14.51	13.08	14.61
9	13.95	14.28	14.12	14.21	15.10	14.44	13.02	14.59
10	13.92	14.26	14.07	14.16	15.08	14.39	12.96	14.49
11	13.93	14.32	14.08	14.21	15.20	14.43	12.74	14.48
12	13.94	14.32	14.09	14.21	15.17	14.42	12.84	14.47
13	13.97	14.34	14.22	14.34	15.11	14.48	13.08	14.76
14	13.92	14.30	14.14	14.26	15.11	14.45	12.96	14.66
15	13.92	14.27	14.08	14.19	15.11	14.41	12.94	14.51
16	13.93	14.29	14.10	14.20	15.16	14.41	12.84	14.65

Table 8 – ENERGY STAR Neutral Variables

	Office/ Bank Courthouse	Retail Stores	K-12 Schools	Supermarkets	Warehouses	Hospitals	Hotels	Dormitories
Climate	■	■	■	■	■	■	■	■
Floor Area	■	■	■	■	■	■		
Weekly Operating Hours	■	■	■	■	■			
Number of Occupants	■	■	■	■	■			
Number of Personal Computers	■	■	■					
Number of Walk-in Refrigeration Units		■		■	■			
Number of Refrigeration Cases		■						
Refrigerated Warehouse					■			
Number of Cash Registers		■						
Student Seating Capacity			■					
Mechanical Ventilation			■					
Seasonal Operation			■					
Lighting Density					■			
Acute Care						■		
Tertiary Care						■		
Number of Beds						■		
Number of Floors						■		
Above Ground Parking						■		
Number of Rooms							■	■
Food and Beverage Facilities			■	■			■	
Up-Scale vs. Economy							■	

As performance targets get closer to zero net-energy, the exact location of 100 on the scale becomes less significant. In fact, when the target becomes zero net-energy, the 100 marker is irrelevant. At this point, the only thing that matters is that reasonable assumptions are made about operating conditions, plug loads, etc. so that there can be confidence that the candidate building will really achieve zero net-energy. Baselines close to zero make the currently widely used percent savings metric unstable. Small changes in the baseline can result in amplified differences in outcome (as one divides by a small number). When the baseline is zero, then the system completely falls apart, because it is impossible to divide by zero.

The reason that ENERGY STAR addresses only common building types is that the CBECS data is limited. Data is available to make meaningful regressions for the building types addressed, but is inadequate for other building types. The 2003 CBECS data which is used by ENERGY STAR has information on 4,820 buildings. At a national scale, this is a pretty small sample. Consider, for instance, that the CEUS database has 2,800 buildings just for California. Extending the California sampling rate to the whole country would result in a data set of approximately 20,000 buildings, more than four times as many as the most recent publically available survey. With the renewed interest in energy independence and investment in green technologies, proposals are being made in Washington to expand the CBECS survey to more than 15,000 buildings. This could possibly provide the data necessary to extend the EPA's empirical approach to more building types. However, this is a long term solution because the next survey would likely include energy consumption for the year 2011 and it would be at least 2013 before the data would become available to the public.

Other approaches would need to be employed for non-ENERGY STAR buildings in the short term. The following are options that should be explored in subsequent research:

- Estimate average energy consumption by creating a baseline building representing typical or average conditions and modeling this building with an energy simulation program. This approach is similar to that currently used for percent savings calculations, except that the baseline would be defined as average or typical and not code minimum.[7]
- Use other databases such as CEUS[8] that are richer for some building types and use these datasets to produce national scope regression equations similar to what EPA has produced for the eight building types that they cover.

Some of the stakeholders who have been consulted in the development of this report have expressed a desire to use median energy use as opposed to average energy use to mark the 100 point on the scale. There are some issues. In order to know the median, empirical data will be needed on the distribution of energy use for the building type being evaluated. The EPA methodology papers have these curves. However, as evidenced by the limits on building types covered by the EPA program, this data (at least from CBECS) does not exist for all building types. For building types for which there is no empirical data, the average or the median will need to be estimated using some other technique. If the estimate is made with simulations with the "baseline" inputs set for average or typical conditions, no empirical data would exist. Such average or typical conditions have been developed for laboratories, for instance, by the Savings By Design program. The approach would be similar to our current compliance process, except that the "baseline" would represent average conditions, not code minimum. For these cases, it is uncertain how the median would be determined, other than just assuming a normal Gaussian distribution whereby the median and the average are the same.

3.2 ENERGY CODE IMPLICATIONS

Establishing a stable scale to measure our progress toward zero net-energy has implications for code development, because California's code goal is that the codes require zero net-energy buildings by certain target dates and it is highly questionable that the code development approach used in the past will enable the achievement of these goals.

A bottom-up process has been used for code development for decades. With this process, a myriad of code change proposals are offered by various stakeholders. Each code change is independently evaluated in terms of criteria for acceptability, including cost effectiveness,

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[7] The California IOUs have begun this process for hospitals, laboratories and some other building types to address gaps in the Savings By Design program.

[8] An issue is that the CEUS dataset is not publically available in raw form.

market maturity, energy savings, applicability, and scope and authority. The measures that pass the tests are incorporated into the standards as mandatory or prescriptive requirements. The ones that fail the tests are postponed until the next code update cycle, included as compliance options, or dropped altogether.

This process has worked reasonably well in the past, but as the CEC and CPUC goals for zero net-energy are embraced, new approaches need to be considered. The bottom-up approach is not goal-oriented. Going into each code update cycle, it is impossible to predict the overall impact of the code update cycle. It depends on which measures survive the vetting process and how the various remaining measures work in combination with each other.

A top-down approach, in contrast, would begin with an analysis of the current energy use in buildings and evolve into the setting of achievable top-down goals. The top-down goals would be established to achieve the ultimate goal of zero net-energy by the target date. For low-rise residential, there are four code update cycles likely to occur between now and the 2020 target for zero net-energy: 2011, 2014, 2017, and 2020. There are seven or possibly eight code update cycles prior to the 2030 commercial target for zero net-energy. If the present standing on a stable scale (such as that proposed in this paper) can be determined, then progressive increments can be established to get to the ultimate target. The increments may be aimed at certain technologies or design strategies at each level and, as result, may not represent equal steps.

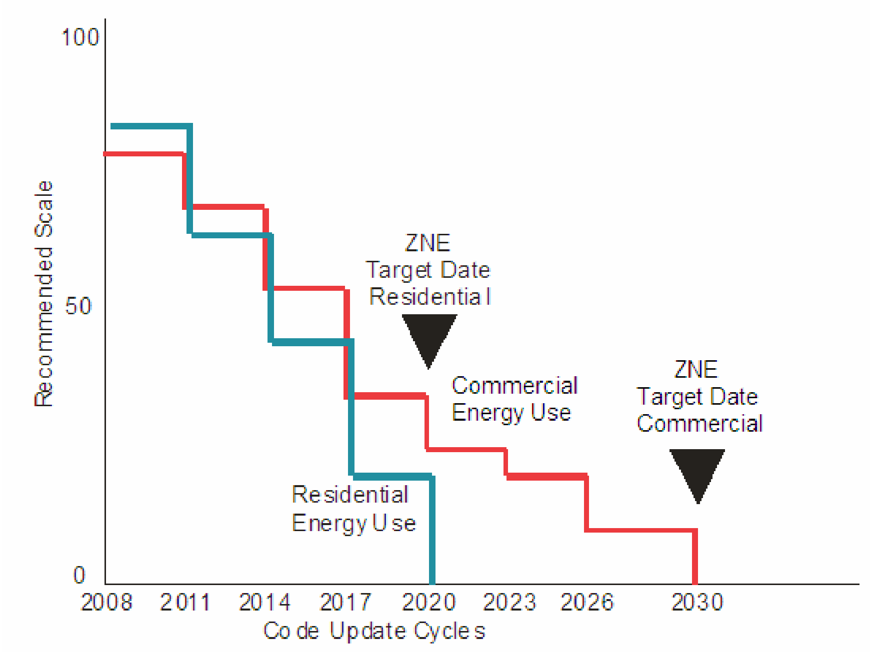

FIGURE 14 – CODE CYCLES TOWARD ZERO NET-ENERGY

The current paradigm is that the performance standards are derived from the mandatory measures and the prescriptive requirements. The energy budget is determined by upgrading or downgrading the proposed design to be in exact compliance with the mandatory measures and the prescriptive requirements. The standard design building is then modeled and the result becomes the energy performance target for the proposed design. This paradigm is consistent with the bottom-up approach that has been used for code development work for the last three decades.

With the top-down approach, the performance target would be developed first and then one or more packages of prescriptive requirements would be developed to achieve compliance with the target. Each package of prescriptive requirements could follow a different design approach or be specific to a particular building type. A prescriptive package for supermarkets would likely address the refrigeration systems in some meaningful way, while a prescriptive package for restaurants would likely focus on cooking as well as refrigeration. The prescriptive package for offices would address workstations and server rooms. The design and construction community would still have a choice between a performance approach and a prescriptive approach, but precedence would be reversed.

Use of the recommended 0-100 scale for setting the code compliance target, as opposed to TDV energy, source energy or some other metric has the advantage of allowing adjustments to the neutral variables such as hours of operation and outside air ventilation rates. As adjustments are made, for instance as hours of operation go up, the energy use of the candidate building would go up, but so would the average energy consumption. The increases are roughly proportional to each other, so a COMNET target of 35 would be valid for a range of variation in neutral variables. Making reasonable assumptions on operating hours, process loads, and plug loads will help close the gap between the reality of utility bills and energy consumption at the meter and what is predicted by the energy simulation models.

A pure performance standard was proposed by DOE in the late 1970s with their Notice of Proposed Rulemaking for the Building Energy Performance Standards (BEPS). The first and second generation California energy efficiency standards also used a pure performance approach. With a pure performance approach, there is no need to develop the standard design building. The target is determined from a table and one designs toward that goal. Both BEPS and the California fixed energy budgets were expressed in terms of Btu/ft^2-yr. Neither survived. In the late 1980s, California moved toward the current “custom budget” approach and so did ASHRAE with Standard 90.1-1989.

There were a number of problems with the early attempts at fixed energy budgets. The fundamental problem was that estimating absolute energy use through models presents a much greater challenge than making comparisons. The fixed energy budgets required an estimate of absolute energy use while the custom budget approach (or the standard design approach) only requires that two cases be compared. Both can be high or both can be low; the important thing for code compliance is that the estimate for the proposed design is less than the estimate for the standard design. Energy analysts have a lot more confidence in using simulation tools to make comparisons than to predict absolute energy use.

The interesting thing is that after 30 years of energy codes, it may be possible to come full circle and once again embrace a form of fixed energy targets, at first for energy labels and green building ratings but eventually for code compliance. This would be made possible through the use of the recommended scale for specifying the target and the goals for zero net-energy buildings within a reasonable timeframe.

3.3 INCENTIVE PROGRAM IMPLICATIONS

The California goals for zero net-energy have a number of important implications for utility and state incentive programs. The precedent for incentive programs has been to pay for measures or performance that exceed code minimum. The Savings By Design program, for instance, begins paying for performance that is 10% or more efficient than code minimum. The California Solar Initiative (CSI) pays for the installation of PV systems, but might not if they were already required by code. Another precedent for incentive programs is that the amount of the incentive shall not exceed the incremental first cost of the capital improvements.

The enabling legislation for the CEC, the Warren-Alquist Act, requires that the building standards be “cost effective when taken in their entirety and amortized over the economic life of the building”. For most code update cycles, the cost effectiveness requirement has been conservatively applied to mean that each measure or design strategy that is added as either a mandatory or prescriptive requirement is cost effective on its own. However, the CEC has contended (and it has not been challenged) that the cost effectiveness burden applies to the whole package of measures and not to each individual measure. With this interpretation, some measures may not be cost effective as long as the entire package is cost effective. The broader interpretation of the Warren-Alquist Act supports the top-down approach to code development discussed previously.

Even with the broader interpretation, the zero net-energy goals may be inconsistent with the requirement for cost effectiveness in the Warren-Alquist Act. As the target dates for zero net-energy near, more renewable production and more efficiency may be needed than is cost effective, even when the “taken in their entirety” clause is used. A situation could arise where the standards are cost effective as long as the rate payer incentives are in place, but as soon as the standards become mandatory and the incentives go away, the standards are no longer cost effective. If this were to occur, the purpose of incentive programs could shift from paying to exceed code to buying down the first cost of measures for new buildings so that the mandatory code is cost effective by the definitions of the Warren-Alquist Act. Such an incentive could be paid on a per square foot basis, perhaps by building type for each new project.

Another possible future scenario, and one that the CEC is considering, is to internalize externalities, such as carbon emissions, which are associated with energy consumption. This would cause the monetary benefits of energy savings to increase. The increased value assigned to the energy saving benefits would increase the likelihood that a zero net-energy package of measures would be cost effective.

3.4 ADDRESSING THE NON-REGULATED ENERGY USES

In most instances, the rating authority requires that the types and magnitudes of non-regulated energy be the same for both the standard design and the proposed design. If the non-regulated energy use is large, this makes it very difficult to achieve high levels of percent savings. As buildings move closer to zero net-energy, it is essential to find a way to reduce non-regulated energy use and take credit for these reductions. The appropriate approach will depend on the type of non-regulated energy use. In some cases, it may be possible to extend the scope of the standard to include the energy end use. Commercial refrigeration in supermarkets and restaurants is a good example. Other non-regulated energy uses, such as plug loads, are more temporal in nature and may be best addressed through other means. The following paragraphs discuss some of the issues and opportunities.

Refrigeration, plug loads, and process energy can represent as much as 65% of the energy use in some building types and this energy is not currently addressed by energy efficiency standards, e.g. they are non-regulated energy uses. To reach the goal of zero net-energy, these energy uses will have to be addressed by building standards or appliance standards. Some, such as refrigeration, can be included in the standards, but others like plug loads may be better addressed through programs that promote smart building maintenance and operation.

Commercial refrigeration is half of the total energy use in supermarkets and a significant share of energy use in other building types. Refrigeration is considered a component of process energy.[9] In general, process energy has not been addressed by energy efficiency codes, although refrigerated warehouses were added to the California 2008 standards, and the CEC intends to expand the scope even more in 2011 to address casework and refrigerated cabinets in

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[9] ASHRAE Standard 90.1-2007 defines process energy as “energy consumed in support of manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building”.

supermarkets. Steps are underway both in California and within ASHRAE to incorporate refrigeration equipment in the standards. As they are brought into the standards, modeling techniques will be refined so that energy use can be more accurately estimated by simulation programs.

Elevators, escalators, moving walkways, and other “people movers” within buildings are not currently addressed by energy efficiency codes. These systems are provided by just a handful of manufacturers and their design is dominated by life-safety issues. Some manufacturers have already incorporated energy efficiency measures such as motors that turn into generators when elevator cars are descending (sort of like a Prius going down hill). In Europe, moving walkways and escalators have been paired with occupant sensors that slow the machines down and save energy when they are not being used (as soon as someone steps aboard, they speed up). These and other technologies are already beginning to appear in the market. There is some question as to how to best address these specialized systems. Perhaps a voluntary approach like the ENERGY STAR program would work better. This would leave manufacturers with the freedom to innovate while providing strong incentives for them to do so.

Specialized laboratory and hospital equipment is also not well suited to regulation. New equipment is introduced at a high rate and any attempt at regulation would be several years behind the curve. Perhaps a better approach would be to require that equipment be labeled so that its energy use is known. Equipment that requires cooling could use central chilled water systems instead of local inefficient DX equipment.

Plug loads are perhaps the most difficult piece of non-regulated energy to address. One issue is that they are very short-lived. Another issue is that they are often not known with any certainty at the time buildings are being designed and constructed. Managing plug loads is more of an operations issue than a design issue. The architectural and engineering team makes assumptions about plug loads (usually with a safety factor) when sizing the cooling system and the electric circuits, but apart from that, plug loads receive little attention from the design team.

However, this does not mean that there are no opportunities for savings. There are. Notebook computers and flat screen monitors can reduce the power per workstation to less than 70 W. Thin client workstations can reduce power to less than 30 W. However, with this option more servers are needed to do the work, so in a sense the power is relocated from worker areas to server rooms. The advantage is that the servers can be more efficient and the temperature in server rooms can be higher. There are also opportunities with power management, whereby workstation monitors, hard drives, and even CPUs are shutdown after a period of inactivity and the power management system can be managed over a network, instead of by each individual user.

Within the server room itself, there are also many ways to reduce energy use. Configuring all of the equipment such that they draw air from a cool aisle and exhaust to a hot aisle improves the air conditioning efficiency of server rooms. Elevating the temperature to the 80s or even the 90s is also possible, since for the majority of the time the server room is unoccupied. Virtualization of servers and advanced server management can work like workstation power management to shut down equipment that is not needed, or at least place it in standby mode.

Plug loads also include copy machines, printers, fax machines, typewriters, coffee machines, microwave ovens, residential scale refrigerators, stereos, TVs, and many other types of equipment. The ENERGY STAR program applies to many of these equipment types and a purchasing program that requires ENERGY STAR equipment would have a significant impact. ENERGY STAR also has power management programs for IT professionals.

As buildings are designed for zero net-energy, what is important is that tools are made available to accurately and fairly account for non-regulated energy uses as well as the related energy savings opportunities. These loads will not be eliminated altogether, but if they can be identified, then the amount of on-site power generation needed to achieve zero net-energy can be determined.

3.5 ADDITIONAL RESEARCH

This white paper raises issues and proposes broad solutions, but additional research is needed to address the details. Some of these follow-up research efforts are discussed below.

ESTIMATING AVERAGE ENERGY CONSUMPTION

Two approaches have been identified to determine the average energy consumption and thereby set the 100 marker on the recommended scale: the empirical approach and the modeling approach.

- The empirical approach is used by the EPA ENERGY STAR program and represents an inverse modeling approach whereby statistical analysis of a database building energy consumption results in the identification of independent variables (or neutral variables) that explain a dependent variable, which in the case of the ENERGY STAR program is “Predicted Source EUI”.
- The modeling approach has been recommended by some reviewers of this white paper. With the modeling approach, energy efficiency features of the candidate building would be modified to represent average conditions and this baseline building would be modeled to yield an estimate of average energy consumption. The approach is similar to the custom budget approach that has been used by ASHRAE and California performance standards for the last two decades. The difference is that the candidate building is modified to represent average conditions, not code minimum.

The table below compares the advantages and disadvantages of the two approaches.

Approach	Advantages/Benefits	Disadvantages/Problems
Empirical	The method is consistent with the EPA ENERGY STAR Target Finder and Portfolio Manager programs, the most widely used operational ratings. Real consumption numbers, as measured at the utility meter, are used to determine average energy consumption. The CBECS database is updated every four years or so.	Some building types are not adequately represented in the CBECS database. Simulations must predict absolute energy use to compare against the average metered data, and modelers might be encouraged to find loopholes by choosing software that consistently under-predict consumption. Future CBECS or other databases would need to be adjusted to represent turn of the millennium buildings.
Modeling	The method is conceptually similar to the performance approach used by California and ASHRAE for two decades. Baseline energy use could be separated by end uses and each end use could be compared to the candidate building. This would enable a comparison of the energy efficiency of individual building systems, not just the whole building. Neutralizing the effect of climate, operating hours and other assumptions would be direct, since these assumptions would be	The CBECS and other databases have limited information at the system or component level which would be needed to determine the energy efficiency features of the baseline (average) building. It would be difficult to determine the average building, since there are many combinations of energy efficiency features that could result in the same energy consumption. The rules for developing the baseline (average) building could be quite complex

	used in both the candidate and baseline buildings. Energy simulation programs would only have to make a comparison instead of predicting absolute energy consumption.	with system maps and other details similar to the ASHRAE PRM (Appendix G of 90.1).

CONFIDENCE IN MODELING TOOLS AND RESULTS

The confidence we have in predicting absolute energy use with simulation tools is a major factor in comparing the empirical and modeling approaches. This shows up both as an advantage for the modeling approach in that it is only necessary to make a comparison, not to predict absolute energy consumption. It also shows up as a disadvantage of the empirical approach, because with this approach, it is necessary to predict absolute energy use and our confidence in simulation tools to do this is low.

Additional research is needed to develop methods to methodically test, calibrate, and assess the results of simulation tools so that the differences due to calculation methods are minimized and more accurately track metered energy use. Only simulation tools that predict results within a reasonable band of acceptance would be allowed to be used. ASHRAE Standard 140-2007 is a suite of tests to methodically make these comparisons, but the requirement is only to complete the suite of tests and to compare the findings to other software programs. However, the COMNET project[10] is adding acceptance criteria to the Standard 140 tests and expanding tests to include other aspects.

Research is also needed to constrain and inform inputs to the models, such as plug loads, operating schedules, and other factors. Incomplete or inaccurate inputs likely account for a larger variance with utility bills than the accuracy of the model. The energy modeler is often left to estimate or guess on inputs to the model and the guess can have a huge impact on the results. The recommended empirical approach self corrects for this to some extent because neutral variables such as climate, operating hours, etc. affect both the modeling results for the candidate building and the baseline (through the regression models) in the same direction. In other words, an increase in operating hours causes the EPA Predicted Source EUI to go higher and it also causes the modeling prediction for the candidate building to go higher. As both numbers move in the same direction, the ratio between them (which is the recommended score) is less affected. Research is needed to study these impacts in greater detail; verify the above intuitive argument on the canceling effect; and to establish acceptable ranges of inputs for those cases when little information is available.

CHALLENGES IN DEFINING THE "AVERAGE BUILDING"

For the modeling approach to work, a rule set must be created to define the "average building". When code minimum is used as the baseline, the rule set is easier to develop because it is more or less defined by the combination of prescriptive requirements and mandatory measures, as supplemented by the California ACM manuals and the ASHRAE PRM. The code minimum building is essentially defined by component performance. The "average building" is another matter. What we mostly know about the "average building" is how much energy it uses. Databases such as CBECS contain only high level information such as number of stories, floor area, and annual gas and electricity use. Detailed information needed for a model definition such as insulation

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[10] The COMNET project (AEC is the technical lead for this NBI project) will result in a set of modeling rules and procedures for calculating energy labels, green building ratings, and federal tax deductions. A number of acceptance tests are being developed that will need to be satisfied by software that is used for these purposes. These tests use the ASHRAE 140-2007 suite but are coupled with acceptance criteria.

levels, equipment efficiencies, and lighting levels is quite limited. Even if the detailed information were available, using it to define the average building would be challenging. If a sample of buildings consists of 50% rooftop DX packages and 50% chilled water systems, what is the average? A fairly complex rule set would need to be developed and a different rule set might be needed for different building types and climate regions.

The purpose of defining the “average building” is to be able to model it and have it predict the baseline “average” energy consumption. Building components and energy efficiency features of the average building would be set to values that will result in average energy consumption, as reported in the CBECS or other databases. The problem is that there are many different combinations of energy efficiency features that would result in the same average energy consumption. If you envision a console with a hundred dials each representing an input to the model and one digital output at the top of the console displaying the predicted energy consumption, you can begin to see the challenge. You know what the digital output should say and you play with the dials until you get it to agree, however, there are many combinations of dial setting that will result in the same output. Which one is right? Are any of them right? The choice could significantly affect the process and the modeling estimate of annual energy use.

With the modeling approach, a considerable research effort would be needed to develop and test the rule set for defining the average building. The paragraphs above illustrate the challenge.

COVERING ALL BUILDING TYPES

As noted in the table above, one of the problems with the empirical approach is that the CBECS database does not adequately represent all building types. Retail establishments in shopping centers, for instance, are not covered[11]. Neither are specialized building types such as laboratories or data centers. The modeling approach is one solution for these building types, provided a rule set can be developed to properly define the “average building”. More long term solutions, especially for retail, may be to expand the CBECS database for future surveys. In any event, research is needed to develop a methodology for estimating average energy consumption for these building types that take the appropriate neutral variables into account.

AVERAGE VS. MEDIAN

Some reviewers of this white paper recommended that the score represent the ratio of candidate building energy use to median energy use, as opposed to average energy use. The EPA ENERGY STAR Portfolio Manager and Target Finder programs are based on median as opposed to average, e.g. an ENERGY STAR score of 50 means that half the buildings like yours use less energy and half use more; it does not mean that your energy use is exactly at the average.

Basing the score on the median can most easily be achieved with the empirical approach. With the modeling approach, information about the statistical distribution of buildings around the median is not known. To use median energy consumption as the denominator in the ratio (score) would require a transformation function similar to the ones that EPA uses (see Figure 13 for an example for offices).

Additional research is needed to evaluate the pros and cons of using median or average energy consumption in the denominator of the energy efficiency ratio and if there are compelling reasons to use a median, then methods would need to be developed for estimating it.

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[11] The EPA ENERGY STAR program for retail stores excludes stores located in shopping centers because of this limitation.

4 APPENDICES

4.1 NONRESIDENTIAL NEW CONSTRUCTION (NRNC) DATABASE

The NRNC database consists of about 1800 sites of buildings constructed from about 1996 until 2004. Energy models have been developed for a subset of the sites (956 records) and used to compare the stringency of California energy code updates. This appendix presents the findings of some studies made with this database to understand the impact of standards updates for the recent cycles.

FILTERING NRNC DATABASE

The 956 records in the NRNC database used for code evaluation were screened to remove outliers and sites with incomplete information. A set of criteria were developed for filtering the database records after reviewing the data in the NRNC database in detail. Using the criteria listed in the table below, a total of 551 buildings were excluded from the analysis. Building types were limited to food stores, offices, retail, schools, and warehouses. These building types were selected for additional analysis because it is possible to make comparisons against the CBECS database.

TABLE 9 – SELECTION CRITERIA FOR NRNC DATABASE

NAME	DESCRIPTION	MATCHES
Source EUI	Criteria 1: Source Energy<20% or >500% of avg. source energy for bldg type	29
Fan/Pump EUI	Criteria 2: Fan/Pump Energy more than Half of Total	28
Process Load	Criteria 3: Process Load<5% or >60% of total (except for labs, supermarkets, restaurants)	108
Lighting EUI	Criteria 4: Sites with a lighting EUI > 25 kWh/ft²-yr	0
Floor Area	Criteria 5: Floor Area < 1,000 ft²	6
Cooling EUI	Criteria 6: Cooling energy < 0.2 kWh/ft²-yr	130
Low Source EUI	Criteria 7: Source energy < 0 kBtu/ft²-yr	0
EPD	Criteria 8: EPD=0	97
Bldg Type	Criteria 9: Building Type (limit to office, retail, schools, warehouses, and retail)	362
Any	Exclude Building if any criterion above are TRUE	551

The breakdown of the remaining data set by climate zone and building type is shown below. All climate zones except 1 and 16 are covered by the data set. The data is most limited for the food store and warehouse building types.

Table 10 – Filtered NRNC Data Set Used in Analysis

Building Type	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Grand Total
Food Store	1	1	3	1	2	-	2	2	2	3	5	3	-	2	27
Office	3	32	26	2	16	14	10	5	9	7	15	6	5	-	150
Retail	-	9	13	3	14	10	12	15	15	1	12	3	6	3	116
School	3	6	7	-	6	2	4	8	15	4	16	13	10	2	96
Warehouse	1	2	-	-	1	-	1	2	-	2	2	4	1	-	16
Grand Total	8	50	49	6	39	26	29	32	41	17	50	29	22	7	405

Findings

Table 12 through 15 show the estimated source energy consumption for the set of 405 buildings in minimum compliance with the last three code cycles and ASHRAE 2004. These estimates were made using the DOE-2.2 simulation engine, except for the 2001 dataset which was estimated using DOE-2.1E. The findings are summarized in Table 11. These values are presented in EPA source energy units for consistency with other studies.

Table 11 – Summary of Results

AEC Bldg Type	California 2001	California 2005	California 2008	ASHRAE 2004
Food Store	652	568	563	701
Office	183	135	121	140
Retail	290	194	181	289
School	181	93	92	108
Warehouse	118	84	78	96
Grand Total	242	169	159	211

Table 12 – Simulation Estimated Source Energy – Title 24 2001 Baseline

AEC Bldg Type	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Grand Total
Food Store	785	449	667	636	722	-	443	486	526	572	962	631	-	483	652
Office	142	177	241	132	133	202	143	169	233	192	141	150	209	-	183
Retail	-	280	306	330	248	289	268	258	364	293	328	267	239	259	290
School	184	144	153	-	189	200	192	149	180	166	229	175	174	189	181
Warehouse	29	65	-	-	54	-	202	72	-	279	123	100	123	-	118
Grand Total	224	192	272	315	211	235	224	219	276	269	296	216	197	303	242

TABLE 13 – SIMULATION ESTIMATED SOURCE ENERGY – TITLE 24 2005 BASELINE (2008 ANALYSIS)

AEC BLDG TYPE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	GRAND TOTAL
Food Store	1346	411	487	528	682	-	437	438	459	456	821	427	-	407	568
Office	115	145	161	125	110	150	110	108	154	122	111	102	174	-	135
Retail	-	181	208	227	174	211	175	187	211	229	212	205	162	173	194
School	78	95	92	-	98	108	104	80	97	91	77	97	105	133	93
Warehouse	20	60	-	-	42	-	167	33	-	233	100	41	97	-	84
Grand Total	243	148	183	243	159	170	161	154	169	193	195	136	136	228	169

TABLE 14 – SIMULATION ESTIMATED SOURCE ENERGY – TITLE 24 2008 BASELINE

AEC BLDG TYPE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	GRAND TOTAL
Food Store	1346	408	484	527	679	-	435	436	455	451	811	420	-	394	563
Office	95	128	146	116	98	137	99	100	137	104	95	93	156	-	121
Retail	-	170	198	204	165	193	163	172	197	194	198	187	147	162	181
School	79	93	90	-	97	106	101	80	95	91	76	96	104	129	92
Warehouse	19	57	-	-	39	-	153	32	-	216	98	39	83	-	78
Grand Total	236	134	173	228	150	156	151	145	159	181	185	130	127	219	159

TABLE 15 – SIMULATION ESTIMATED SOURCE ENERGY – ASHRAE 90.1-2004 BASELINE

AEC BLDG TYPE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	GRAND TOTAL
Food Store	1467	580	665	675	823	-	588	561	601	589	922	537	-	543	701
Office	114	146	167	128	120	161	118	105	157	121	115	105	177	-	140
Retail	-	278	300	334	271	311	283	262	328	319	284	314	258	237	289
School	96	107	99	-	113	123	122	95	115	109	90	109	126	153	108
Warehouse	24	80	-	-	49	-	167	46	-	244	128	51	101	-	96
Grand Total	265	171	223	322	208	216	221	201	226	227	229	166	172	300	211

4.2 COMMERCIAL END USE SURVEY (CEUS)

The CEUS database is very rich and is quite useful in evaluating energy end uses. Table 16 shows the EPA weighted source EUIs for each of the building types covered in the CEUS database. The end uses are broken into two categories: regulated energy uses and non-regulated energy uses. The regulated energy uses include heating, cooling, ventilation, hot water, and interior lighting. The non-regulated energy uses include all other energy sources.

On average, non-regulated energy use represents about 40% of the total for the 2,800 buildings in the database. However, for some building types, the non-regulated energy use is much higher: 65% for restaurants and 64% for food stores. It is 83% for refrigerated warehouses. For offices, the average non-regulated energy use is about 32%; for schools, it is 26%; for retail, it is 27%. Table 17 shows each of the end uses for this same set of building types.

Figure 15 through 21 show the breakout for food stores, restaurants, offices, retail, schools, and warehouses. The regulated pie sections are pulled away, while the non-regulated components are shown tight. It is apparent from these figures that dealing only with regulated energy is of limited use in reaching ambitious energy goals. Restaurants and food stores particularly run into the problem that dealing with only regulated loads limits the total savings achievable. For a goal of zero net-energy unregulated loads must be addressed for all building types, whether directly or through renewable energy production.

TABLE 16 – CEUS SOURCE EUI BY BUILDING TYPE (KBTU/FT²-YR)

	REGULATED SOURCE EUI (KBTU/FT²-YR)	NON-REGULATED SOURCE EUI (KBTU/FT²-YR)	TOTAL EPA SOURCE EUI (KBTU/FT²-YR)	PERCENT NON-REGULATED
All Commercial	109.45	73.36	182.81	40%
Small Office (<30k ft²)	104.03	56.29	160.33	35%
Large Office (>=30k ft²)	154.63	70.20	224.82	31%
Restaurant	239.97	438.17	678.14	65%
Retail	121.28	43.93	165.21	27%
Food Store	180.22	316.05	496.27	64%
Refrigerated Warehouse	39.98	194.10	234.08	83%
Non-refrigerated Warehouse	36.31	17.78	54.10	33%
School	75.23	26.56	101.79	26%
College	132.25	43.53	175.78	25%
Health	222.79	79.90	302.70	26%
Lodging	131.02	51.64	182.66	28%
Miscellaneous	72.09	64.36	136.45	47%
All Offices	136.82	65.22	202.03	32%
All Warehouses	36.79	43.60	80.39	54%

Table 17 – CEUS Source EUI End Uses by Building Type (kBtu/ft^2-yr)

	Heat	Cool	Vent	WH	Int. Ltg	Refrig	Cook	Ext Ltg	Office Eqp	Misc	Air Comp	Motors	Proc
All Commercial	12.5	23.7	18.6	10.1	44.7	20.9	12.7	9.1	11.1	9.6	0.5	6.5	3.1
Small Office (<30k ft^2)	11.3	29.8	14.7	4.6	43.7	6.6	1.2	10.8	25.0	8.9	0.0	2.5	1.2
Large Office (>=30k ft^2)	23.6	41.2	34.9	4.1	50.8	4.7	1.6	5.6	40.8	6.7	0.3	8.2	2.3
Restaurant	8.6	65.7	36.9	55.2	73.5	112.5	278.8	23.0	7.2	12.9	0.1	3.1	0.5
Retail	4.1	25.2	20.6	2.4	69.0	11.7	3.0	10.5	5.6	8.2	0.6	3.3	1.0
Food Store	10.9	32.8	29.4	9.7	97.5	255.6	31.9	10.8	4.2	10.8	0.1	2.1	0.6
Refrigerated WH	1.1	3.8	2.7	1.2	31.2	153.2	1.7	4.0	1.9	6.5	0.5	20.7	5.6
Non-refrigerated WH	3.3	3.8	3.2	0.9	25.2	3.2	0.2	3.0	2.7	4.4	0.2	3.3	0.7
School	12.0	13.4	10.9	6.1	32.8	5.7	3.2	8.4	5.2	2.8	0.0	0.9	0.2
College	29.5	25.4	23.4	10.2	43.8	5.2	4.9	10.4	8.2	6.5	0.1	6.6	1.6
Health	42.3	45.8	46.1	33.8	54.8	8.1	8.5	6.5	9.8	30.2	0.1	8.9	7.8
Lodging	12.4	27.6	20.4	30.7	39.9	10.3	12.4	7.0	1.9	14.1	0.0	5.5	0.5
Miscellaneous	8.4	13.0	9.8	11.2	29.8	9.8	4.0	12.2	4.0	12.4	1.4	12.3	8.2
All Offices	19.2	37.2	27.7	4.3	48.3	5.4	1.5	7.4	35.2	7.5	0.2	6.2	1.9
All Warehouses	2.9	3.8	3.2	0.9	26.1	25.2	0.4	3.1	2.6	4.8	0.2	5.9	1.3

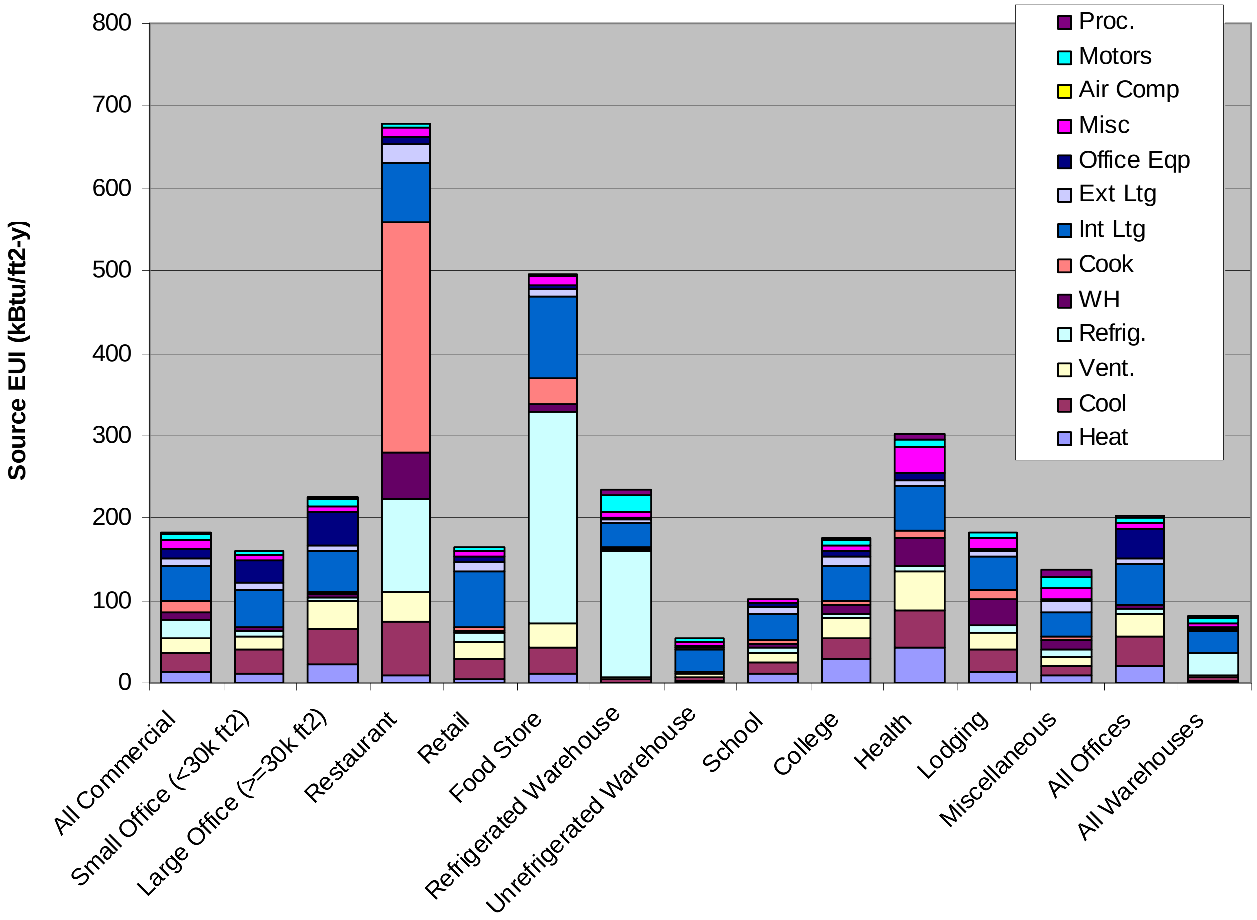

FIGURE 15 – CEUS EUI END USES BY BUILDING TYPE

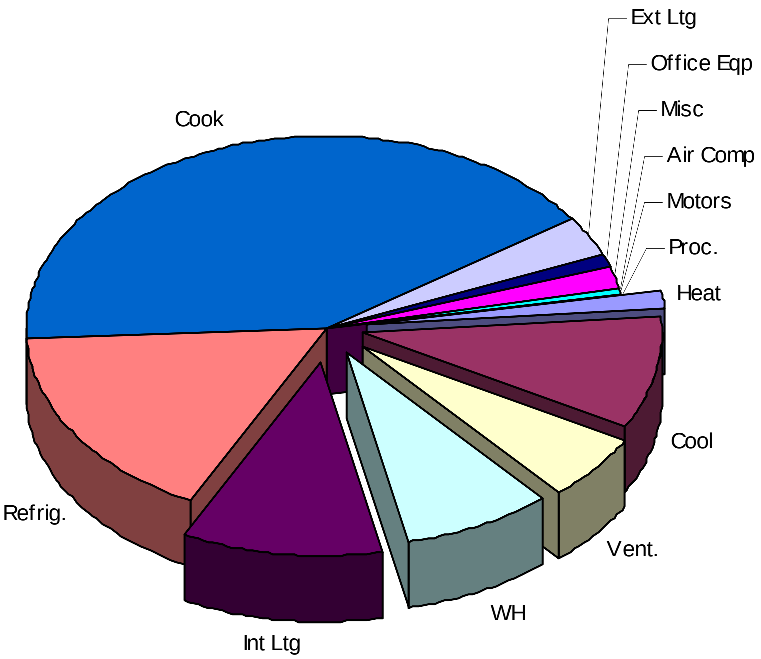

FIGURE 16 – CEUS RESTAURANT END USES

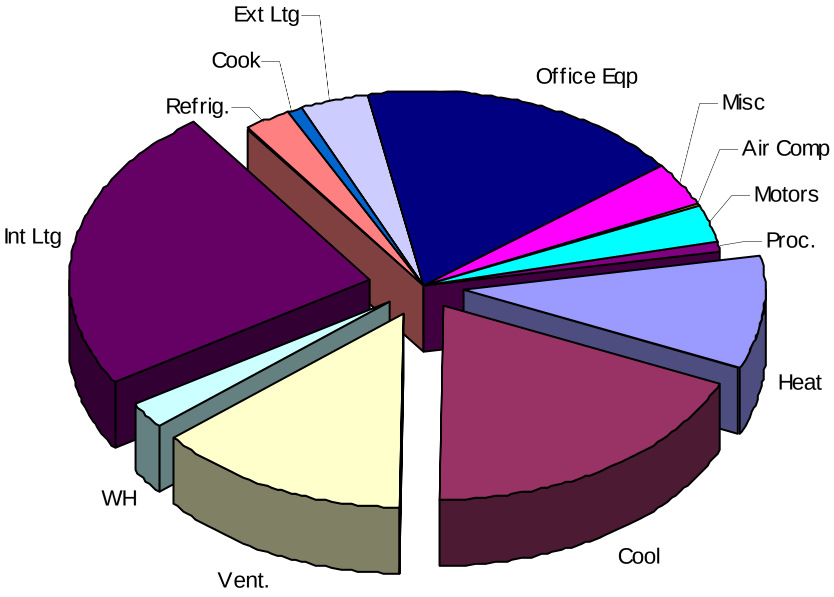

FIGURE 17 – CEUS ALL OFFICES END USES

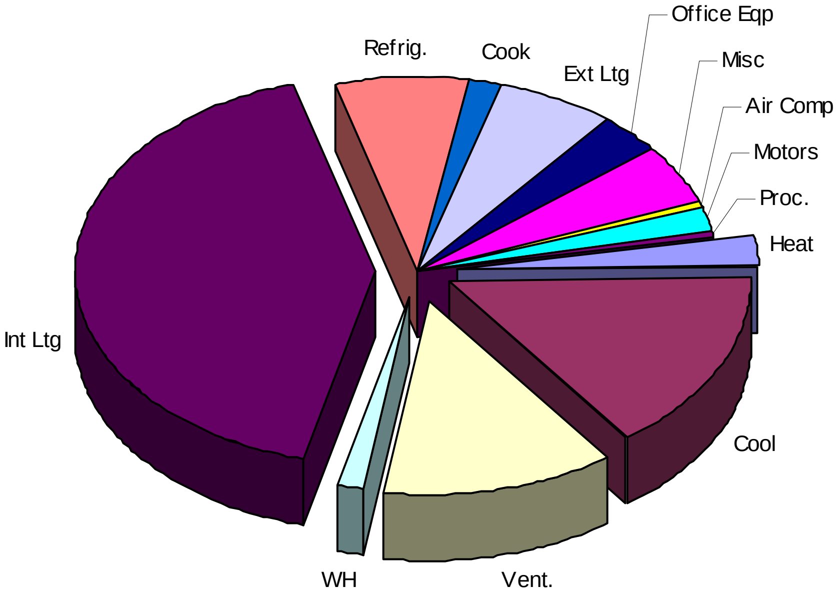

FIGURE 18 – CEUS RETAIL END USES

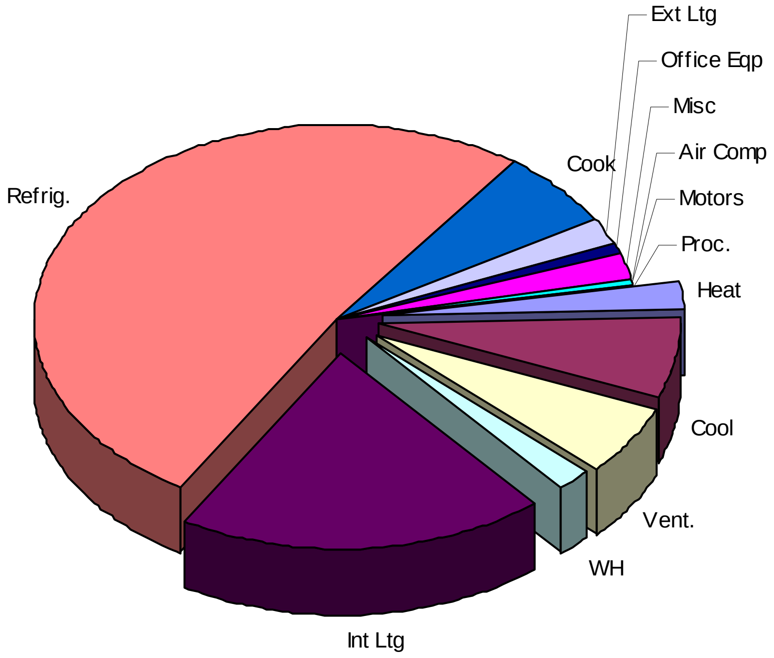

FIGURE 19 – CEUS FOOD STORES END USES

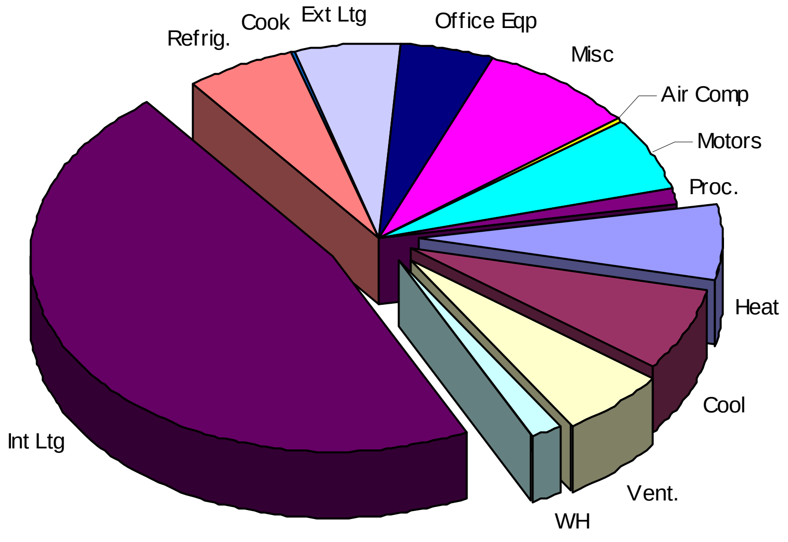

FIGURE 20 – CEUS UNREFRIGERATED WAREHOUSES END USES

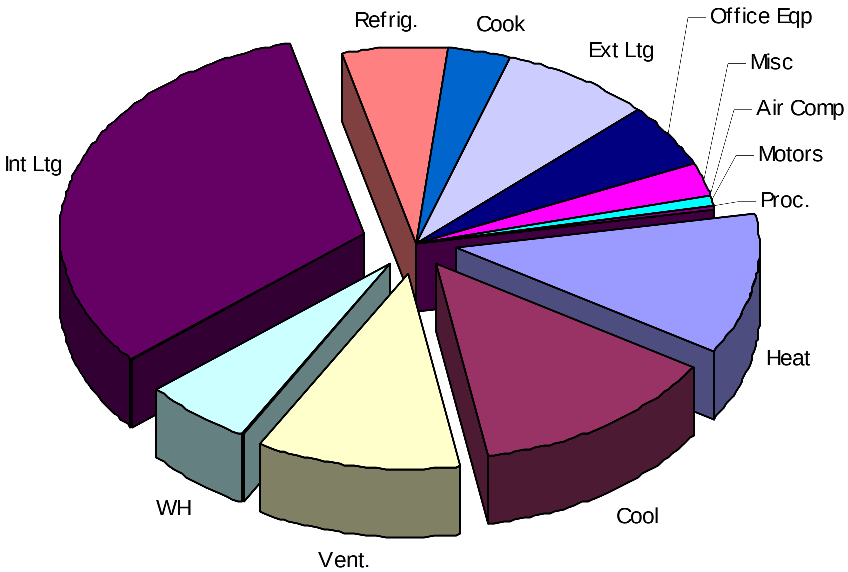

FIGURE 21 – CEUS SCHOOL END USES

4.3 ENERGY STAR PREDICTED SOURCE EUI

The United States EPA ENERGY STAR program is based on the ratio of the *Actual Source EUI* [12] for a building to the *Predicted Source EUI*. The *Actual Source EUI* is the total energy use of the candidate ENERGY STAR building converted to source units. The source-site ratio for electricity is 3.34; the ratio is 1.047 for natural gas.[13] The *Predicted Source EUI* represents the average energy use for a building like the candidate building, that is operated like the candidate building, and is located in a similar climate to the candidate building. EPA has developed a procedure for calculating *Predicted Source EUI*. The procedure takes into account the neutral variables shown in Table 18.

TABLE 18 – NEUTRAL VARIABLES USED TO CALCULATE EPA PREDICTED SOURCE EUI

	Hotels	Retail Stores	K-12 Schools	Supermarkets	Dormitories	Warehouses	Hospitals	Office/Bank/Courthouse
Climate	■	■	■	■	■	■	■	■
Floor Area	·	■	■	■	·	■	■	■
Weekly Operating Hours	·	■	■	■	·	■	·	■
Number of Occupants	·	■	■	■	·	■	·	■
Number of Personal Computers	·	■	■	·	·	·	·	■
Number of Walk-in Refrig Units	·	■	·	■	·	■	·	·
Number of Refrig Cases	·	■	·	·	·	·	·	·
Refrigerated Warehouse	·	·	·	·	·	■	·	·
Number of Cash Registers	·	■	·	·	·	·	·	·
Student Seating Capacity	·	·	■	·	·	·	·	·
Mechanical Ventilation	·	·	■	·	·	·	·	·
Seasonal Operation	·	·	■	·	·	·	·	·
Lighting Density	·	·	·	·	·	■	·	·
Acute Care	·	·	·	·	·	·	■	·
Tertiary Care	·	·	·	·	·	·	■	·
Number of Beds	·	·	·	·	·	·	■	·

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[12] EUI is energy use intensity and for the United States EPA program is expressed in kBtu/ft^2-y.

[13] ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use, December 2007.

	Hotels	Retail Stores	K-12 Schools	Supermarkets	Dormitories	Warehouses	Hospitals	Office/Bank/Courthouse
Number of Floors	·	·	·	·	·	·	■	·
Above Ground Parking	·	·	·	·	·	·	■	·
Number of Rooms	■	·	·	·	■	·	·	·
Food and Beverage Facilities	■	·	■	■	·	·	·	·
Up-Scale vs. Economy	■	·	·	·	·	·	·	·

Estimates for the NRNC Database Sites

The technical methodology to calculating predicted source energy (kBtu/ft^2) for Energy Star ratings was applied to the five building types studied. The *Predicted Source EUI* was calculated for each of the 405 buildings selected for the analysis. Summary statistics for predicted source energy use (kBtu/ft^2) for this dataset are presented in the tables below. EPA source energy multipliers were used to calculate source energy. See Table 119 through 21 below.

Table 19 – Average of EPA Predicted Source EUI

Building Type	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Grand Total
Food Store	1020	929	1006	967	916	-	957	1032	1023	1068	1016	1054	-	1233	1026
Office	256	229	240	276	193	221	236	182	266	188	247	222	213	-	228
Retail	-	419	377	368	379	379	408	390	429	534	372	436	393	339	394
School	103	88	96	-	87	94	86	95	105	115	100	110	115	152	103
Warehouse	78	106	-	-	78	-	118	100	-	221	117	132	250	-	134
Grand Total	272	255	303	437	278	272	332	306	304	350	302	268	219	541	295

Table 20 – Minimum of EPA Predicted Source EUI

Building Type	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Grand Total
Food Store	1020	929	895	967	915	-	866	988	999	1031	947	998	-	1188	866
Office	210	88	127	196	121	98	157	153	158	143	136	173	121	-	88
Retail	-	354	246	307	213	262	341	255	334	534	121	391	303	269	121
School	99	50	78	-	75	90	45	42	48	99	51	63	93	144	42
Warehouse	78	81	-	-	78	-	118	72	-	215	100	119	250	-	72
Grand Total	78	50	78	196	75	90	45	42	48	99	51	63	93	144	42

TABLE 21 – MAXIMUM OF EPA PREDICTED SOURCE EUI

BUILDING TYPE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	GRAND TOTAL
Food Store	1020	929	1191	967	918	-	1047	1076	1047	1091	1080	1112	-	1278	1278
Office	320	389	349	356	264	373	341	203	377	250	334	279	279	-	389
Retail	-	485	607	433	516	632	509	491	530	534	602	483	463	411	632
School	112	113	112	-	109	97	116	125	128	126	123	127	134	159	159
Warehouse	78	132	-	-	78	-	118	127	-	226	134	148	250	-	250
Grand Total	1020	929	1191	967	918	632	1047	1076	1047	1091	1080	1112	463	1278	1278

SENSITIVITY STUDIES

This section looks at the sensitivity of changing the neutral variable and how this affects *Predicted Source EUI*. For each building type, neutral variables were varied systematically to gain a picture of the effect of a single variable.

OFFICES

Figure 22 through 27 show the variations in Predicted Source EUI in offices. The variables not being tested in each graph are set to the EPA example office which is 200,000 ft^2 in climate zone 12, operating 80 hours per week. There are 1.25 workers per 1000 ft^2 and 1.25 computers per 1000 ft^2. 100% of the building is heated and cooled. The scales are set the same for easy comparison across variables

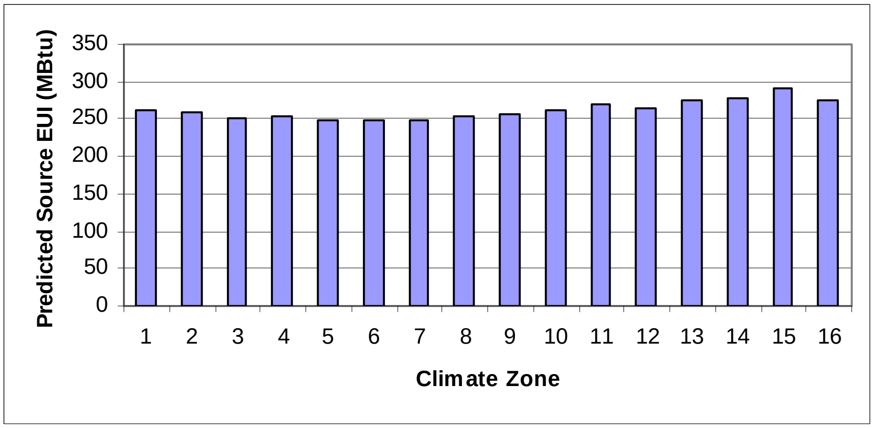

FIGURE 22 – OFFICE – CLIMATE ZONE VARIATION

200,000 FT^2 OFFICE, 80 HOURS/WEEK, 1.25 WORKERS/1000 FT^2, 1.25 COMPUTERS/1000FT^2, 100% HEATED AND COOLED

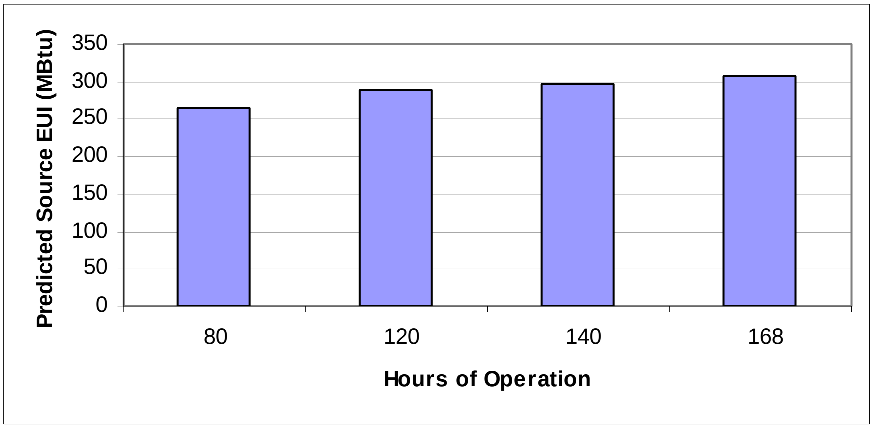

FIGURE 23 – OFFICE – HOURS OF OPERATION VARIATION

200,000 FT^2 OFFICE, CLIMATE ZONE 12, 1.25 WORKERS/1000 FT^2, 1.25 COMPUTERS/1000FT^2, 100% HEATED AND COOLED

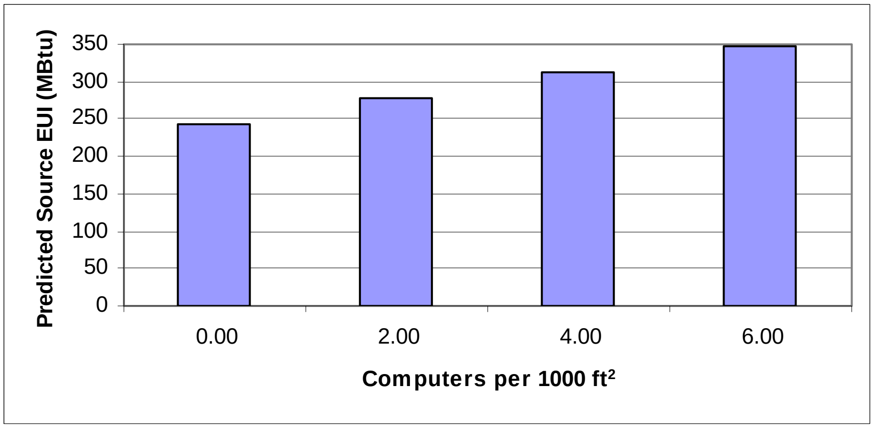

FIGURE 24 – OFFICE – NUMBER OF COMPUTERS VARIATION

200,000 FT^2 OFFICE, CLIMATE ZONE 12, 80 HOURS/WEEK, 1.25 WORKERS/1000 FT^2, 100% HEATED AND COOLED

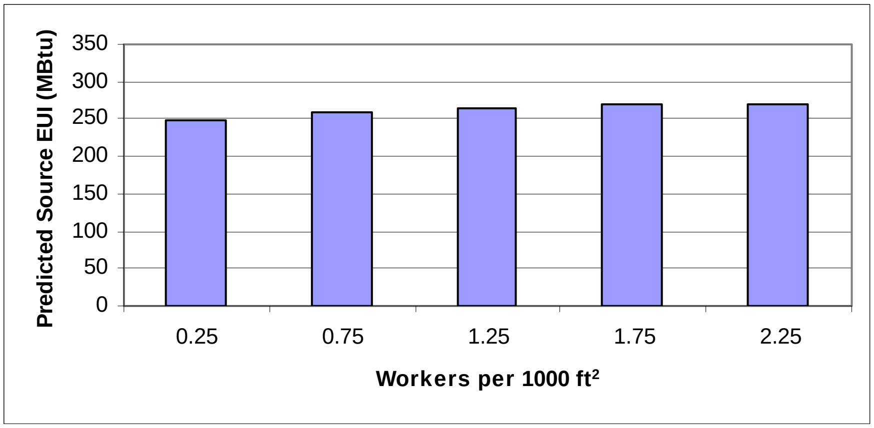

FIGURE 25 – OFFICE – OCCUPANT DENSITY VARIATION

200,000 FT^2 OFFICE, CLIMATE ZONE 12, 80 HOURS/WEEK, 1.25 COMPUTERS/1000FT^2, 100% HEATED AND COOLED

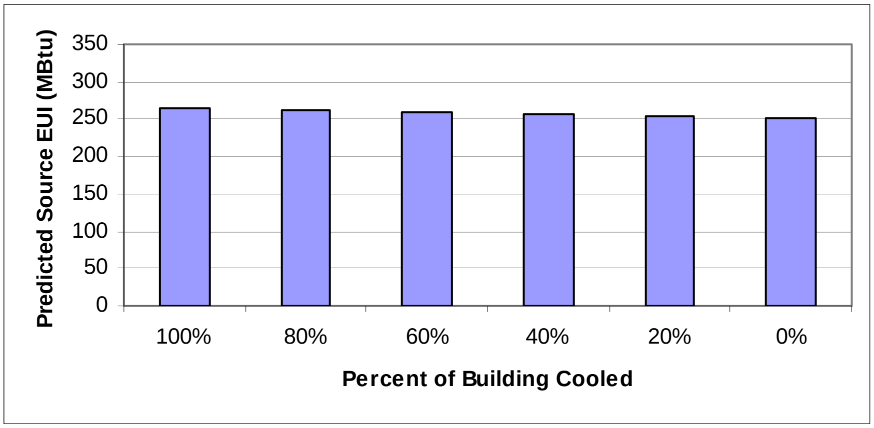

FIGURE 26 – OFFICE – PERCENT COOLING VARIATION

200,000 FT^2 OFFICE, CLIMATE ZONE 12, 80 HOURS/WEEK, 1.25 WORKERS/1000 FT^2, 1.25 COMPUTERS/1000FT^2, 100% HEATED

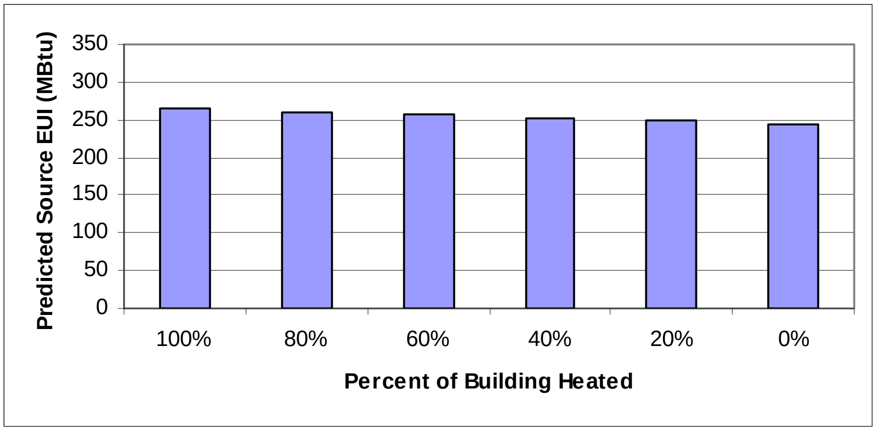

FIGURE 27 – OFFICE – PERCENT HEATING VARIATION

200,000 FT^2 OFFICE, CLIMATE ZONE 12, 80 HOURS/WEEK, 1.25 WORKERS/1000 FT^2, 1.25 COMPUTERS/1000FT^2, 100% COOLED

RETAIL

Figure 28 through 35 show the variations in Predicted Source EUI in retail buildings. The variables not being tested in each graph are set to the EPA example retail building which is 50,000 ft^2 in climate zone 12, operating 70 hours per week. There are 0.16 workers, 0.06 computers, 0.12 registers, and 0.14 refrigerator cases per 1000 ft^2. 100% of the building is heated and cooled. The scales are set the same for easy comparison across variables.

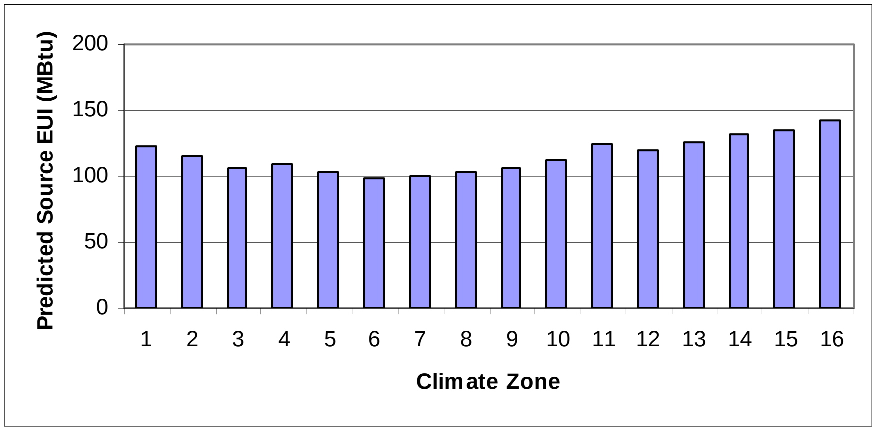

FIGURE 28 – RETAIL – CLIMATE ZONE VARIATION

50,000 FT^2 STORE, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

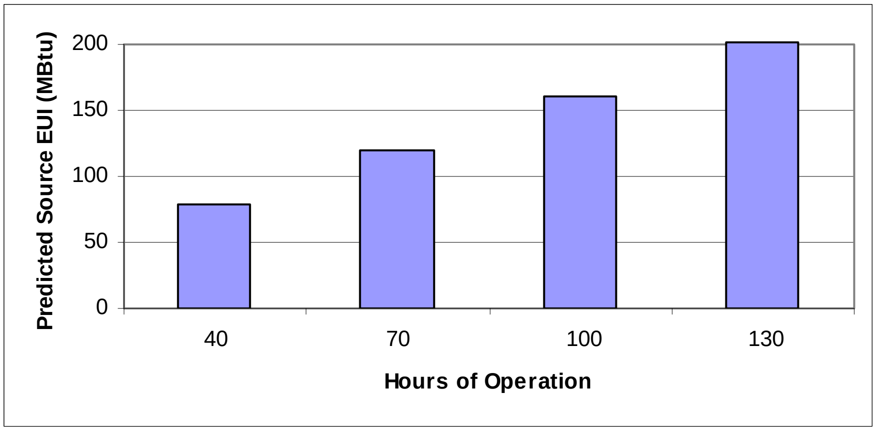

FIGURE 29 – RETAIL – HOURS OF OPERATION VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

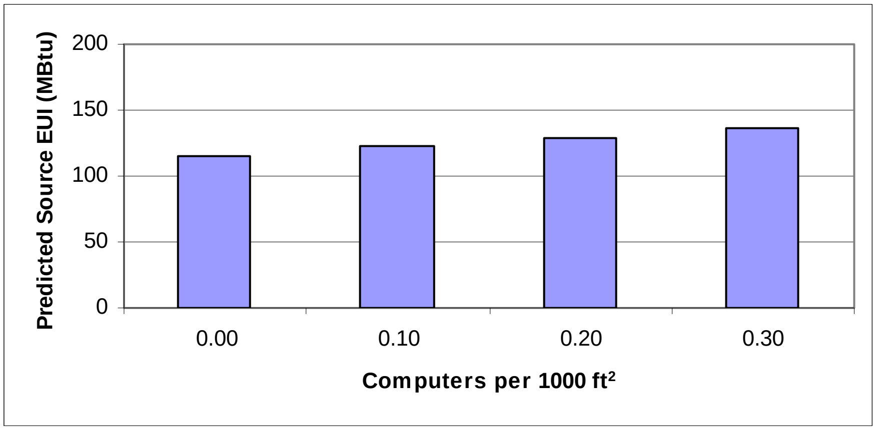

FIGURE 30 – RETAIL – NUMBER OF COMPUTERS VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

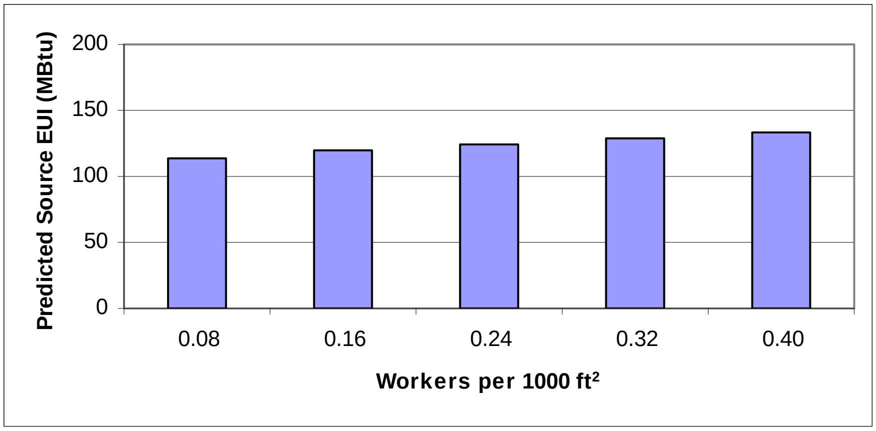

FIGURE 31 – RETAIL – OCCUPANT DENSITY VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

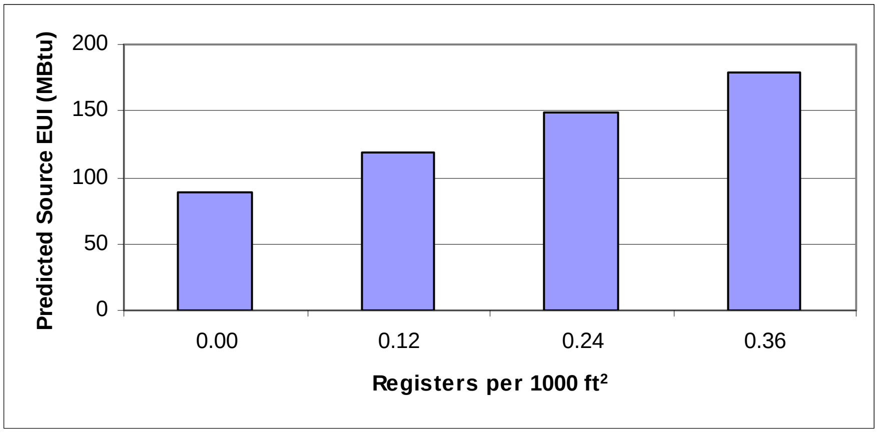

FIGURE 32 – RETAIL – NUMBER OF REGISTERS VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

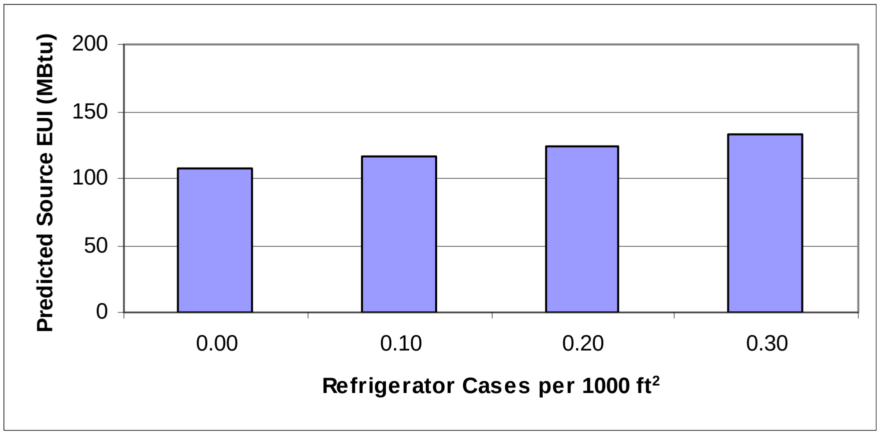

FIGURE 33 – RETAIL – NUMBER OF REFRIGERATOR CASES VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 100% HEATED AND COOLED

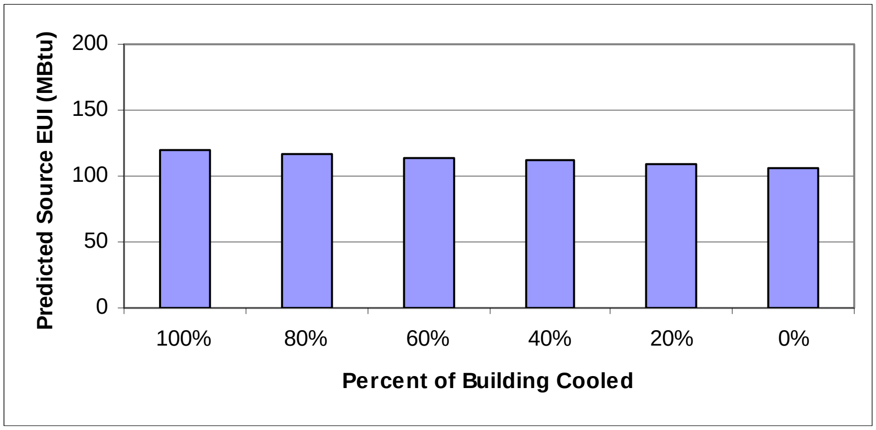

FIGURE 34 – RETAIL – PERCENT COOLING VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% HEATED

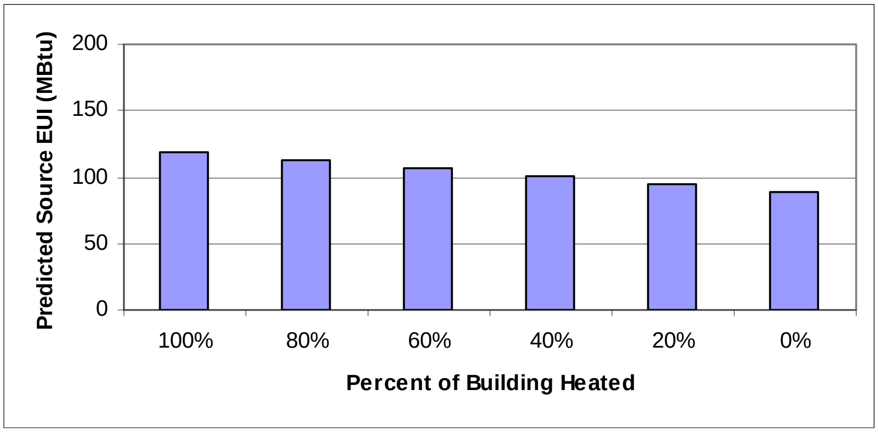

FIGURE 35 – RETAIL – PERCENT HEATING VARIATION

50,000 FT^2 STORE, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.16 WORKERS/1000 FT^2, 0.06 COMPUTERS/1000FT^2, 0.12 REGISTERS/1000 FT^2, 0.14 REFRIGERATORS/1000FT^2, 100% COOLED

SCHOOLS

Figure 36 through Figure 44 show the variations in Predicted Source EUI in schools. The variables not being tested in each graph are set to the EPA example school which is 50,000 ft^2 in climate zone 12, operating 70 hours per week. There are 0.80 computers per 1000 ft^2 and a student seating capacity of 400. The school is run on a traditional schedule, and has onsite cooking and mechanical ventilation. 50% of the building is heated and 50% is cooled. The scales are set the same for easy comparison across variables.

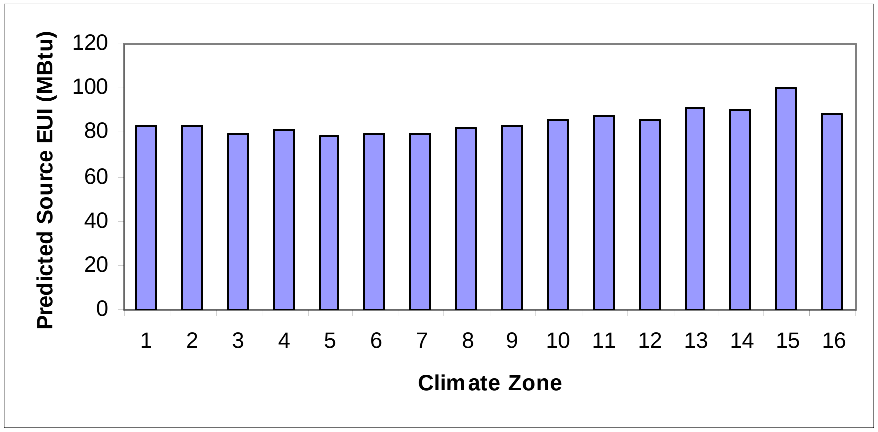

FIGURE 36 – SCHOOL – CLIMATE ZONE VARIATION

50,000 FT^2 SCHOOL, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

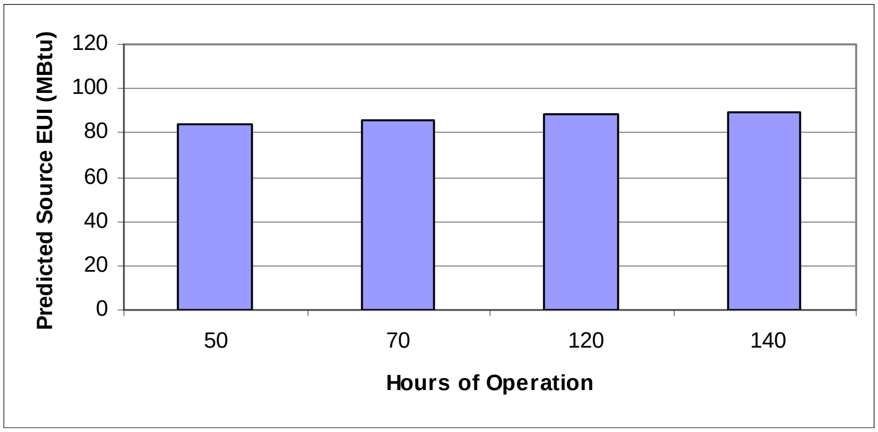

FIGURE 37 – SCHOOL – HOURS OF OPERATION VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

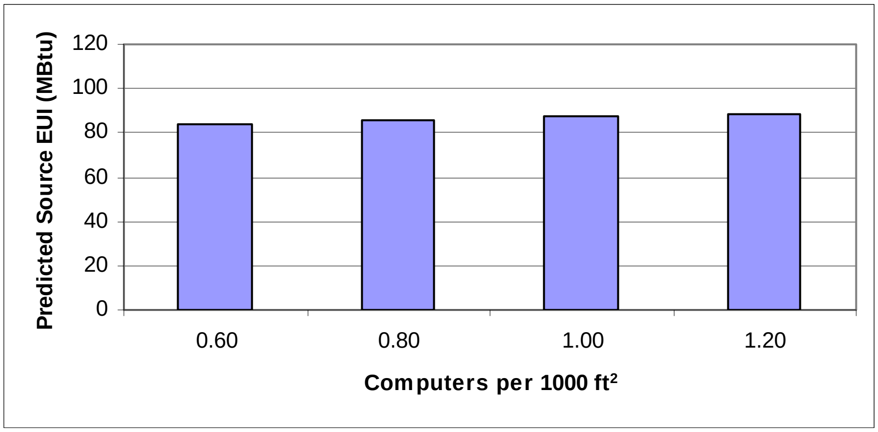

FIGURE 38 – SCHOOL – NUMBER OF COMPUTERS VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

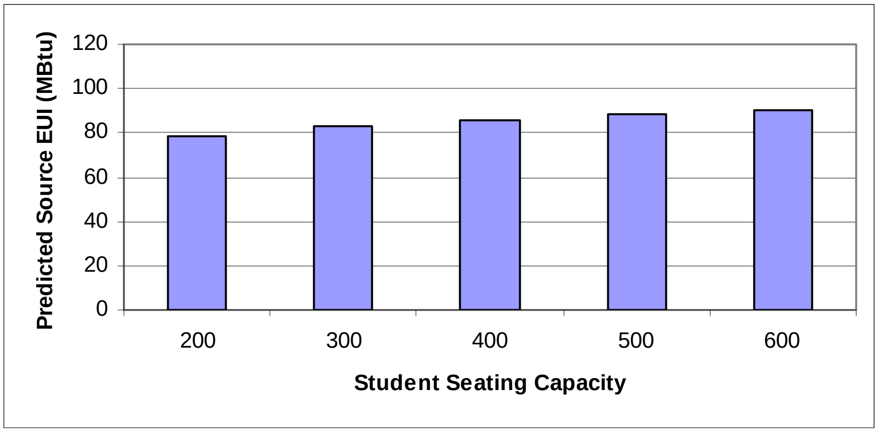

FIGURE 39 – SCHOOL – NUMBER OF STUDENTS VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

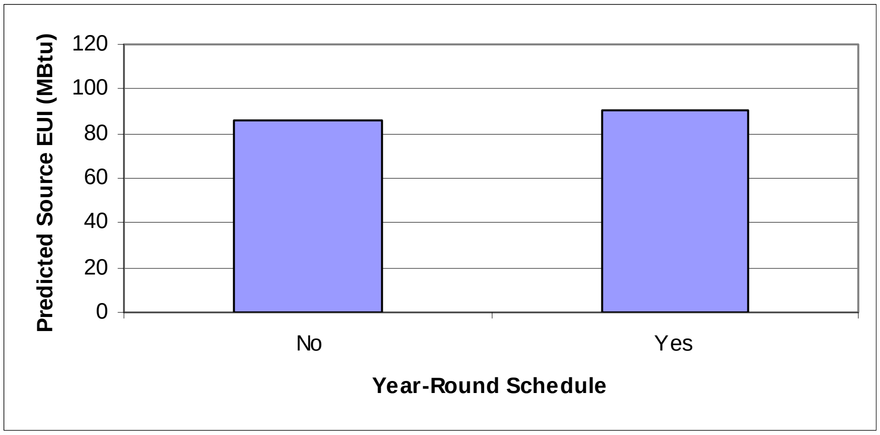

FIGURE 40 – SCHOOL – YEAR-ROUND VS. TRADITIONAL

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

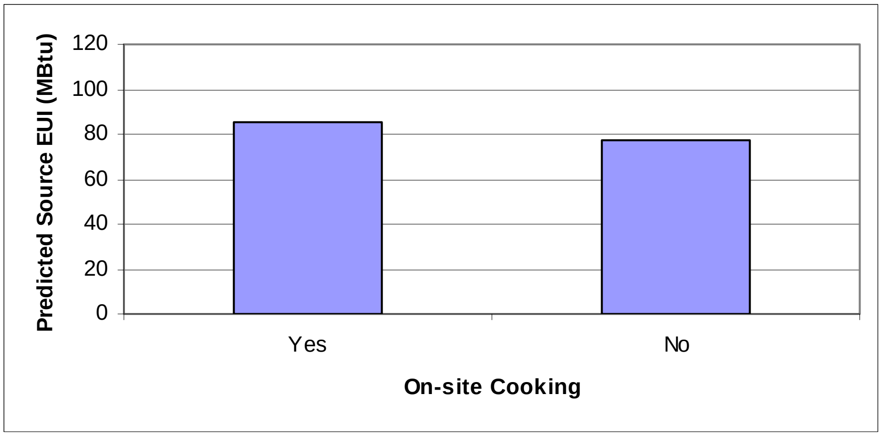

FIGURE 41 – SCHOOL – ON-SITE COOKING VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, MECHANICAL VENTILATION PRESENT, 100% HEATED AND COOLED

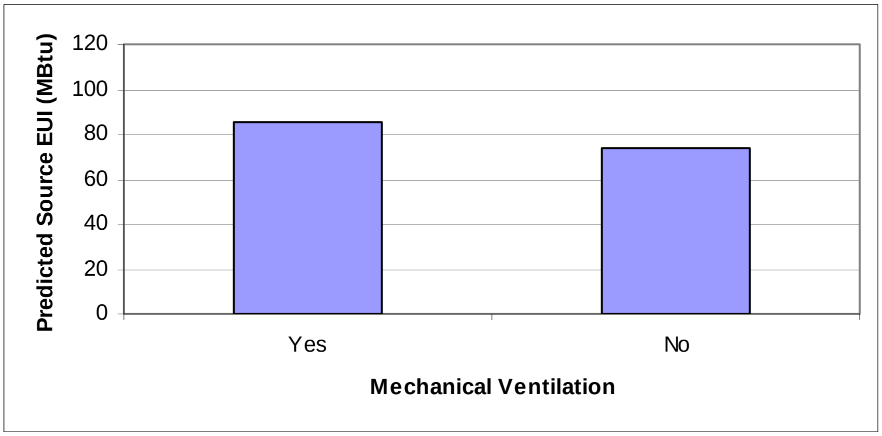

FIGURE 42 – SCHOOL – MECHANICAL VENTILATION VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, 100% HEATED AND COOLED

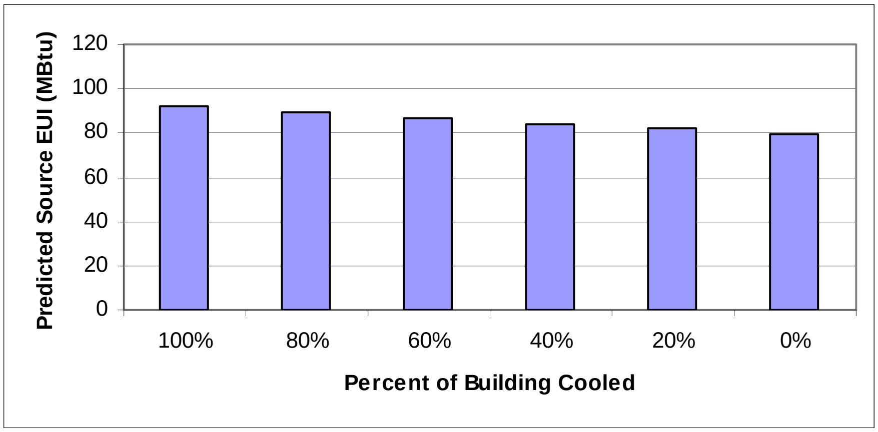

FIGURE 43 – SCHOOL – PERCENT COOLED VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% HEATED

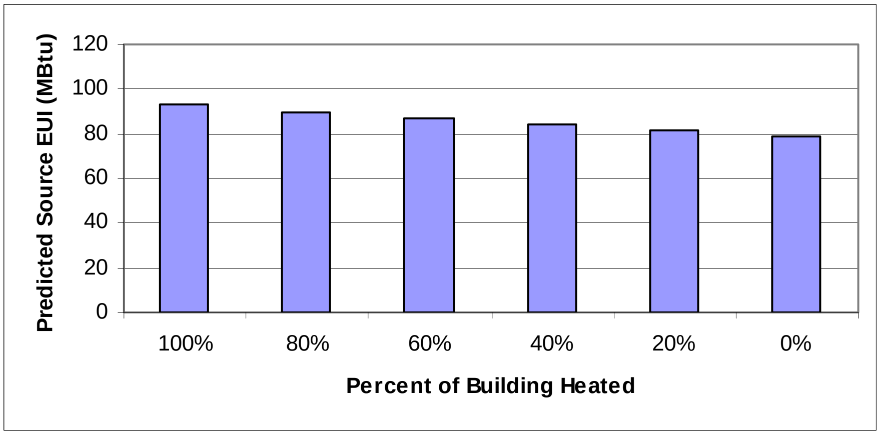

FIGURE 44 – SCHOOL – PERCENT HEATED VARIATION

50,000 FT^2 SCHOOL, CLIMATE ZONE 12, 70 HOURS/WEEK, 0.80 COMPUTERS/1000FT^2, 400 STUDENT CAPACITY, TRADITIONAL 9 MONTH SCHEDULE, ON SITE COOKING PRESENT, MECHANICAL VENTILATION PRESENT, 100% COOLED

FOOD STORES

Figure 45 through Figure 51 show the variations in Predicted Source EUI in food stores. The variables not being tested in each graph are set to the EPA example food store which is 42,000 ft^2 in climate zone 12, operating 168 hours per week. There are 0.48 workers, 0.24 walk-in refrigerators, and 0.02 on-site cooking units per 1000 ft^2. 100% of the building is heated cooled. The scales are set the same for easy comparison across variables.

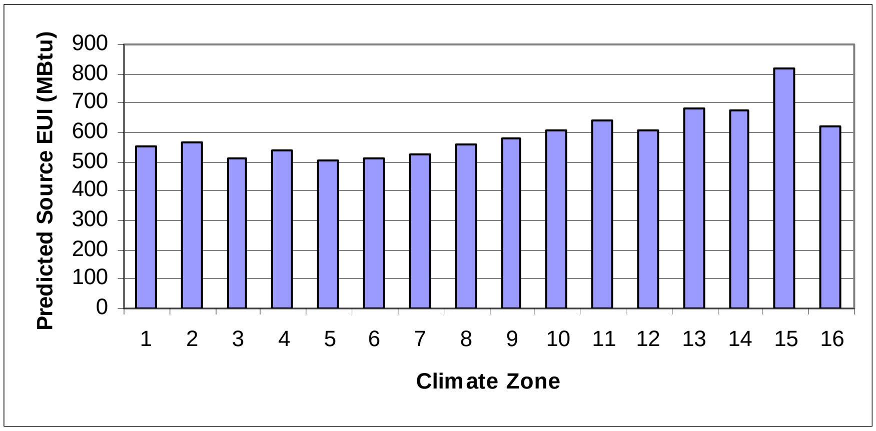

FIGURE 45 – FOOD STORE – CLIMATE ZONE VARIATION

42,000 FT^2 STORE, 168 HOURS/WEEK, 0.48 WORKERS/1000FT^2, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% HEATED AND COOLED

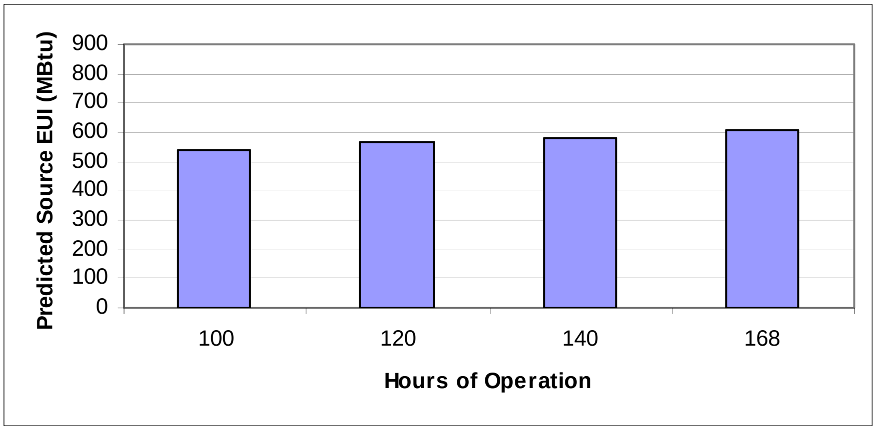

FIGURE 46 – FOOD STORE – HOURS OF OPERATION VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 0.48 WORKERS/1000FT^2, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% HEATED AND COOLED

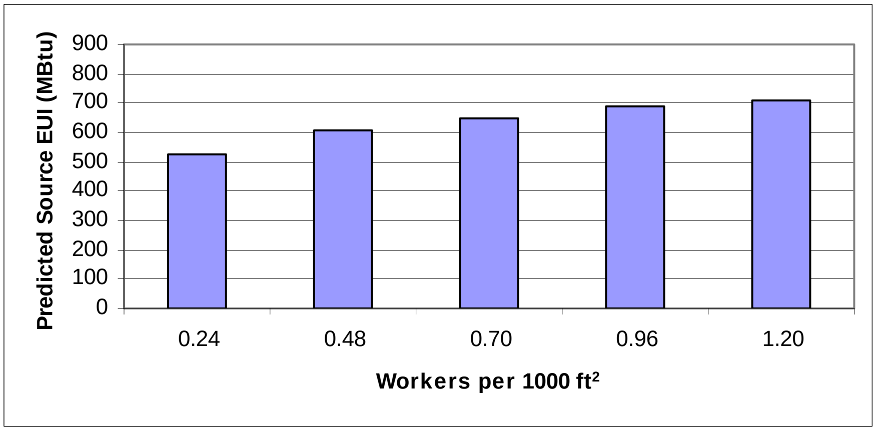

FIGURE 47 – FOOD STORE – OCCUPANT DENSITY VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 168 HOURS/WEEK, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% HEATED AND COOLED

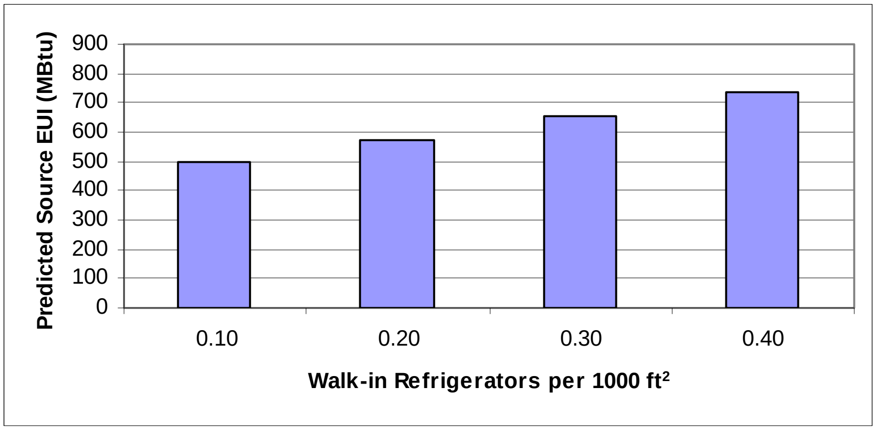

FIGURE 48 – FOOD STORE – REFRIGERATOR DENSITY VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 168 HOURS/WEEK, 0.48 WORKERS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% HEATED AND COOLED

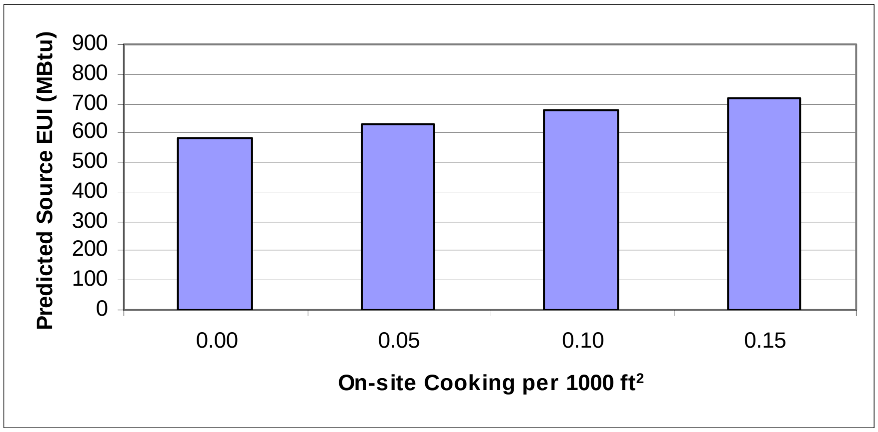

FIGURE 49 – FOOD STORE – COOKING DENSITY VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 168 HOURS/WEEK, 0.48 WORKERS/1000FT^2, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 100% HEATED AND COOLED

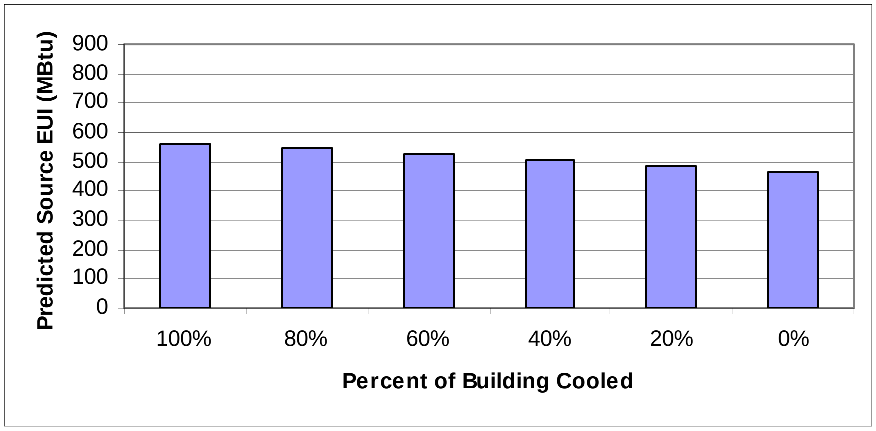

FIGURE 50 – FOOD STORE – PERCENT COOLED VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 168 HOURS/WEEK, 0.48 WORKERS/1000FT^2, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% HEATED

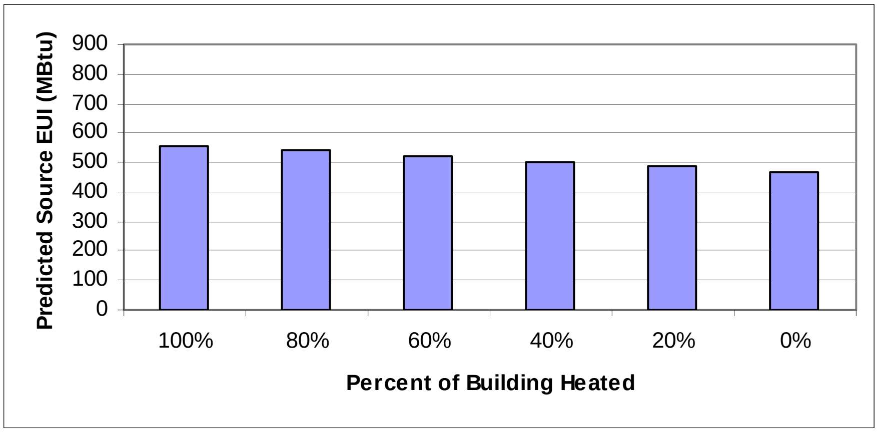

FIGURE 51 – FOOD STORE – PERCENT HEATED VARIATION

42,000 FT^2 STORE, CLIMATE ZONE 12, 168 HOURS/WEEK, 0.48 WORKERS/1000FT^2, 0.24 WALK-IN REFRIGERATORS/1000FT^2, 0.02 ON-SITE COOKING/1000FT^2, 100% COOLED

WAREHOUSES

Figure 52 throughFigure 59 show the variations in Predicted Source EUI in warehouses. The variables not being tested in each graph are set to the EPA example warehouse which is 200,000 ft^2 in climate zone 12, operating 40 hours per week. There are 0.06 workers, and no walk-in refrigerators per 1000 ^{ft2}. None of the lighting is HID or halogen. 100% of the building is heated and cooled, and the warehouse is not refrigerated. The scales are set the same for easy comparison across variables.

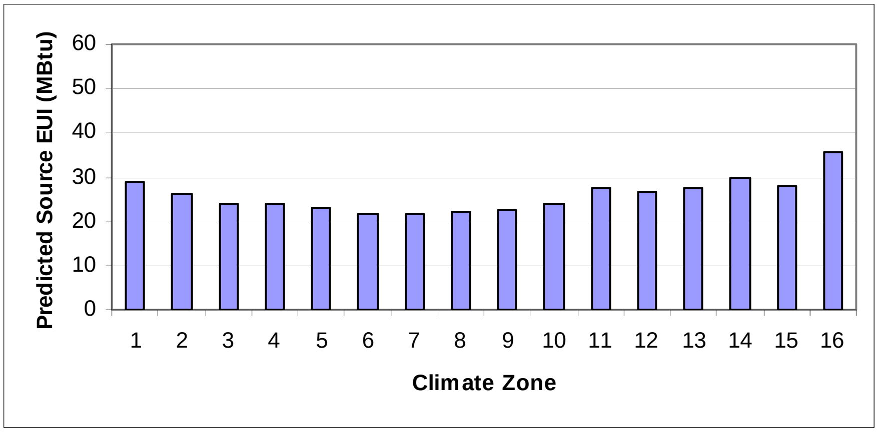

FIGURE 52 – WAREHOUSE – CLIMATE ZONE VARIATION

200,000 FT^2 WAREHOUSE, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 100% HEATED, 50% COOLED

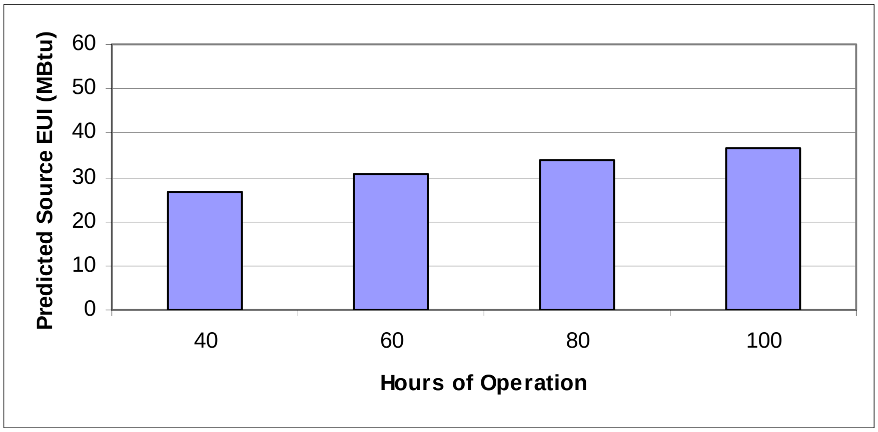

FIGURE 53 – WAREHOUSE – HOURS OF OPERATION VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 100% HEATED, 50% COOLED

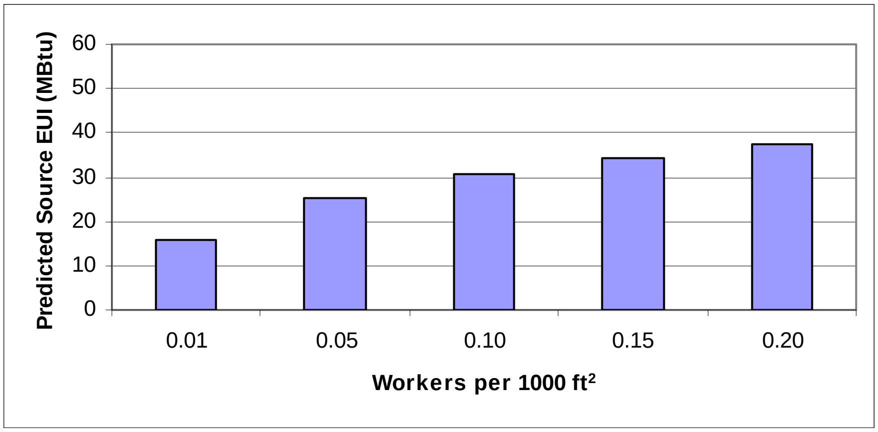

FIGURE 54 – WAREHOUSE – OCCUPANT DENSITY VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 100% HEATED, 50% COOLED

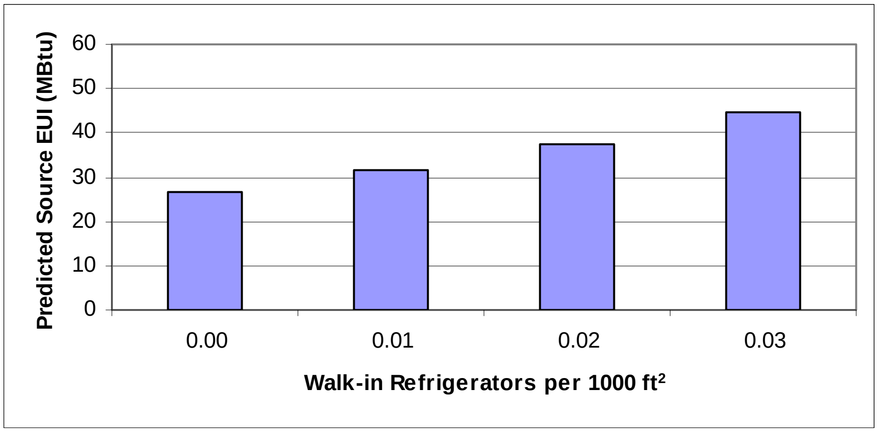

FIGURE 55 – WAREHOUSE – REFRIGERATION DENSITY VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 100% HEATED, 50% COOLED

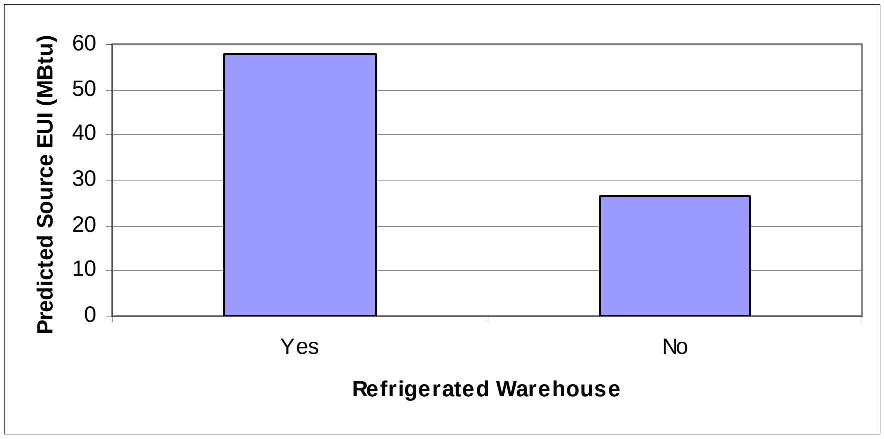

FIGURE 56 – WAREHOUSE – REFRIGERATED WAREHOUSE VS. NON-REFRIGERATED WAREHOUSE

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, 0% HID AND HALOGEN, 100% HEATED, 50% COOLED

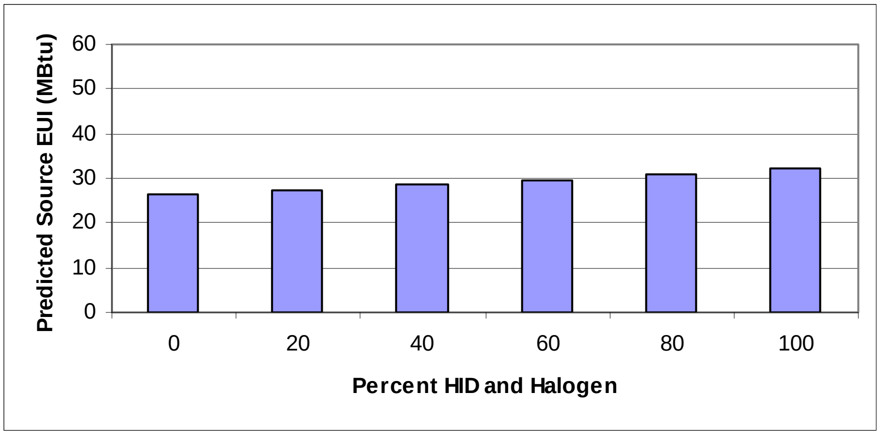

FIGURE 57 – WAREHOUSE – PERCENT HID AND HALOGEN LIGHTING VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 100% HEATED, 50% COOLED

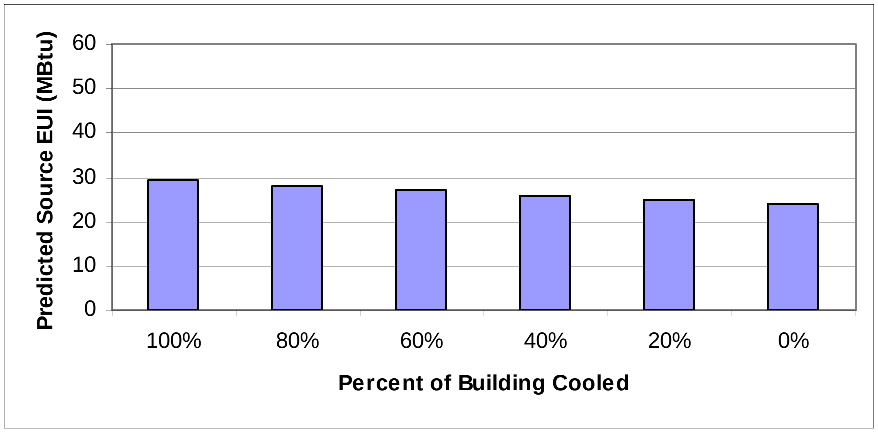

FIGURE 58 – WAREHOUSE – PERCENT COOLED VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 100% HEATED

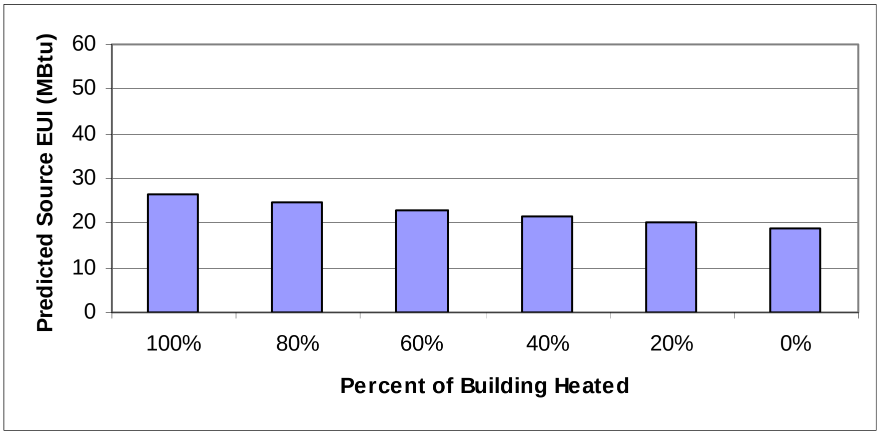

FIGURE 59 – WAREHOUSE – PERCENT HEATED VARIATION

200,000 FT^2 WAREHOUSE, CLIMATE ZONE 12, 40 HOURS/WEEK, 0.06 WORKERS/1000FT^2, 0.0 WALK-IN REFRIGERATORS/1000FT^2, UNREFRIGERATED WAREHOUSE, 0% HID AND HALOGEN, 50% COOLED

4.4 ENERGY STAR REGRESSIONS

The ENERGY STAR Performance Ratings are based on technical methodology, specific to each building type. This methodology provides a thorough list of key variables that relate to the source EUI which can assist in closing in on the variation between modeled and actual energy use. The program uses regression analysis to provide accurate and unbiased results with respect to important operational components, for example building square footage, computer density, density of occupants, and heating and cooling degree days for an office building. The raw data on which this analysis is based is also from the CBECS database.

The dependent variable in ENERGY STAR regression analysis is source EUI, with independent variables noted in the Technical Methodology descriptions for different building types. Variables are significant at the 95% confidence interval, making these variables directly connected to the source EUI of the building.

The resulting regression analysis is used to create gamma curves that relate the source EUI and cumulative percentages for the building. Using the curve to find the related percentage curve directly corresponds to the building's ENERGY STAR rating. Because this curve is dependent on a few independent variables, considerable effort should be made to correlate these independent variables with those input into energy simulations. This would effectively give the ENERGY STAR rating and the energy model results equivalent baselines, making them comparable in overall energy savings.

There are several characteristics identified as key variables that can estimate average source EUI in different building types. Below is an example of variables used for retail stores and office buildings. Similar variables are noted in the ENERGY STAR program for hospitals, hotels, K-12 schools, medical buildings, dormitories, supermarkets, warehouses, and wastewater treatment plants.

Retail Store:

- Natural log of gross square foot
- Weekly operating hours
- Number of workers per 1,000 square feet
- Number of personal computers (PCs) per 1,000 square feet
- Number of cash registers per 1,000 square feet
- Number of walk in refrigeration units per 1,000 square feet
- Number of open and closed refrigeration cases per 1,000 square feet
- Heating degree days times percent of the building that is heated
- Cooling degree days times percent of the building that is cooled

Office Building, Bank/Financial Institutions, and Courthouses:

- Natural log of gross square foot
- Number of personal computers (PCs) per 1,000 square feet
- Natural log of weekly operating hours
- Natural log of the number of workers per 1,000 square feet
- Heating degree days times percent of the building that is heated
- Cooling degree days times percent of the building that is cooled

Aligning these variables could eliminate discrepancies, allowing the energy simulation results to better model the actual activities that are occurring while the building is operational.