Rethinking Percent Savings—
The Problem with Percent Savings and zEPI:
The New Scale for a Net Zero Energy Future

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ABSTRACT

This paper proposes a stable metric for comparing the energy efficiency of buildings. The paper examines the problem of using “percent savings better than a given energy code” to appraise a building’s energy performance. The baseline for this metric, “a given energy code,” can vary greatly in its inherent efficiency. As an alternative, the paper recommends a new scale—the Zero Energy Performance Index (zEPI)—that can be used to evaluate buildings in a stable, elegant manner. A zEPI score of “0” would be a net zero energy building, while a score of “100” represents a building with average energy consumption as of the year 2000. The score for a given building will be higher or lower in linear relationship to the year 2000 benchmark. Finally, the benefits of zEPI are examined, including those for energy codes, building rating programs, incentive programs, and addressing non-regulated energy loads.

INTRODUCTION

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 net zero 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; each time, energy use was reduced from between 5% and 8% (CEC 2001, 2006, 2008a). ASHRAE updated 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 (USGBC 2002). 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 about 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 as to what the energy savings benefits will be.

This paper proposes a more stable scale to replace percent savings: the Zero Energy Performance Index (zEPI). This scale can be used as the basis for incentive programs, green building rating systems, and energy labels. Updates to energy codes can be evaluated using zEPI, as opposed to having code updates redefine the scale. zEPI will work for all building types from offices and schools to energy-intensive building types such as supermarkets and laboratories.

Net zero energy is a pure goal, needing no point of comparison. 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.

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than it is producing. On the zEPI scale, net zero energy represents a value of zero.

A baseline is needed, however, to compare how far buildings deviate from net zero energy. For that benchmark, it is proposed that a zEPI score of “100” represent average energy consumption for a given building type at the turn of the millennium (see Figure 1). The average is for all existing buildings of a given type, not just new buildings. Therefore, new buildings complying with the latest energy efficiency standards would achieve a score less than “100.” The average is adjusted for neutral variables like climate, building type, and hours of operation. Neutral variables are used in a similar manner for both the rated building and the baseline building, minimizing their impact on the zEPI score. All energy uses are included: regulated energy and non-regulated energy. Assessing process and refrigeration loads in calculating a zEPI score will encourage strategies for getting buildings with significant process and refrigeration loads to net zero energy.

Buildings that use half as much energy as the year 2000 average will obtain a zEPI of “50.” Buildings that use twice as much as the average will receive a zEPI of “200.” As noted, a net zero energy building gets zero on the scale, meaning that a lower score will be a better score under the zEPI system. A building that is a net producer of energy could even gain a negative score.

zEPI 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), which will not change (EIA 2003). 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 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 the California End-Use Survey (CEUS), would be used as needed to supplement the CBECS data (these would be adjusted as needed to reflect the building stock at the turn of the millennium; Itron 2006).

Moving to zEPI for marking a building’s comparative energy efficiency 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 with those that are deemed cost-effective becoming mandatory or prescriptive requirements. The top-down process would set a goal on the zEPI scale, and then prescriptive packages of energy efficiency measures would be developed to achieve the goal. Prescriptive packages targeted to meet a zEPI score could better capture synergies between efficiency measures and would more closely approximate the integrated design process, which is highly touted for new building design and construction.

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

Investor owned utility (IOU) incentive programs, as well as rating and labeling programs, can use the zEPI scale as the basis for credit or monetary rewards. For instance, green building rating systems would award two points for getting to “45,” four points for getting to “40,” etc. The points targets could be intelligently set for each building type, giving due consideration to the likely process and non-regulated energy uses for each building type. Likewise, performance-oriented incentive programs could be keyed to the common zEPI scale—for example, $2/ft² ($21.52/m²) for a zEPI of “45” and $3/ft² ($32.28/m²) for a zEPI of “40.”

The use of zEPI as a common scale would help the California Public Utilities Commission (CPUC) and other regulators measure the overall impact of their building efficiency programs. If California buildings average an “80” on the

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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.
scale while “100” is the national average, this is an important indicator of the combined effectiveness of California’s efficiency programs and regulations.

zEPI would enable all stakeholders in the building efficiency field to measure progress in the same terms and would remove the frustration of comparing percent savings past multiple moving targets.

BACKGROUND

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. The rating is based on the ratio of the predicted energy use of the building, through energy modeling, to the energy use of a reference or benchmark building. The rating can be a normalized score (such as the zEPI scale) or a letter grade.

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 (EPA 2007b). 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. The rating is a normalized energy use (unitless) applicable to existing buildings.

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

Nonregulated 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.


Net Zero Energy. Achieved when a building produces as much energy on an annual basis (through PVs or other on-site self-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.

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 presently has 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 a building’s relative energy efficiency. However, the inherent flaws of the percent savings concept become apparent when one considers exactly which code the building surpasses and which 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 (EPA 2007d). Another national reference is simply cost, as used by the ASHRAE PRM calculations (ASHRAE 2007a).

Following the precedent of the ENERGY STAR program, the energy metric depicted in Figure 2 represents the total source energy use intensity (EUI) (Btu/ft²·y [kWh/m²·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, representing the level of energy performance for the same 1,000 California buildings in minimum compliance with ASHRAE 90.1-1999 (using the same operating assumptions; ASHRAE 1999). Point K, near the bottom of the scale, marks a net zero energy building. Point L represents net energy producers.

LEED Version 2.1 used ASHRAE 90.1-1999 as its baseline and offered energy points for percent savings past this baseline (See Figure 3; USGBC 2002). The percent savings calculations for LEED 2.1, however, only included regulated energy, so the reference marker on the scale 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 in Figure 3). For buildings like laboratories, supermarkets, or restaurants, only about 30% of total energy use is regulated (with 70% non-regulated), so 40% savings in regulated energy translates to about 12% total savings (see scale on the right in Figure 3).
Point C in Figure 2 indicates where California 2001 increased building energy efficiency stringency (CEC 2001). This became the baseline for California’s Savings by Design program at the time (PG&E et al. 2010). 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 an easy-to-apply conversion between complex codes.

Subsequently, the release of ASHRAE 90.1-2004 (Figure 2, point D) introduced changes, largely by lowering the lighting power limits (ASHRAE 2004). This became the baseline for LEED Version 2.2. LEED 2.2 also referenced the ASHRAE Performance Rating Method (PRM) (Appendix G), which defines percent savings in terms of all energy, not just regulated energy (USGBC 2005). 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 Collaborative for High Performance Schools (CHPS) 2006 Criteria and a new California Savings by Design programs (CEC 2006, CHPS 2006, PG&E et al. 2010). ASHRAE 90.1-2007, which is the baseline for LEED 2009 (USGBC 2009), is represented by point F (ASHRAE 2007a). The California 2008 update (Point G) took effect in January, 2010 and is the baseline for the CHPS 2009 Criteria (CEC 2008a, CHPS 2009). Point H represents the ASHRAE 90.1-2010 goal of a 30% reduction compared to ASHRAE Standard 90.1-2007 (ASHRAE 2007a).

The confusion caused by 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 (ASHRAE 1999, CEC 2006, 2008a). The office building, significantly more energy efficient than ASHRAE 1999, would only be about 12% better than ASHRAE 2004 (ASHRAE 1999, 2004). This demonstrates the instability of percent savings in that the scale means something different depending on the baseline standard being referenced and whether or not all energy consumption is included.

Points I and J in Figure 2 represent an estimate of National Renewable Energy Laboratory (NREL) Maximum Technical Potentials (Griffith et al. 2007). 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 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 net zero energy, but that net zero energy is not feasible for some energy-intensive buildings or high-rise towers in dense urban settings.

Zero Energy Performance Index (zEPI). The Zero Energy Performance Index (zEPI) was developed in a manner similar to that of the Home Energy Rating Systems (HERS) scale (CEC 2009). An advantage of the HERS-type scale is that a score of 80 (20% better than the baseline) means roughly the same thing no matter the climate, the building type, or the operating hours. For the zEPI rating, the climate and operating hours for the designed building would match those of the baseline building, which would give neither credit nor penalty for...
such “neutral” variables. Another advantage of a HERS-type scale is that energy codes can be pegged to specific points on the scale.

On the zEPI 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 (see Figure 4; ASHRAE 1999, 2004, 2007a, CEC 2006, 2008a). The NREL maximum technical potential achieves a score of about 35 without PVs and about 10 with PVs (Griffith et al. 2007).

The CBECS average energy consumption is also the baseline for the ENERGY STAR Portfolio Manager and Target Finder programs (EIA 2003, EPA 2007b). Comparing the ENERGY STAR percentile scoring curve for offices with the zEPI scale, the 50th percentile in Energy Star hits at about 94 on the zEPI scale (CEC 2009). The 60th percentile hits at about 84, 70th percentile at about 74, 80th percentile at 64, and 90th percentile in Energy Star is at about 52. Once a building uses less than half of the energy of an average building, the ENERGY STAR scale ceases to be useful as a tool to measure progress toward net zero energy goals, as all such buildings are around the 99th percentile using the Energy Star scoring system.

The recommended scale, zEPI, would be stable over time, with the 2003 CBECS normalized average most likely used to define the 100-point benchmark (EIA 2003). The zEPI scale would reduce the confusion associated with moving baselines and would provide a vital reference standard as goals are set to move toward net zero energy.

Variation in Energy Consumption by Building Type

It will be easier to achieve net zero 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 (RLW/AEC 1999). The colors represent compliance with California 2001 (in pale yellow), California 2005 (in magenta), and California 2008 (in blue). 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 California 2001 to California 2005 to California 2008, 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. For some building types, like supermarkets and restaurants, both types of measures are going to be needed.

By example, 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.
(assuming no change to the non-regulated energy use). Similarly, a restaurant with 40% regulated and 60% non-regulated energy use would need a 35% reduction in regulated energy to achieve a total savings of 14%. For a building that is only 20% regulated energy, regulated energy could be eliminated altogether and the total savings would be only 20%.

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 (CEC 2008b, ASHRAE 2007a, EIA 2003). Models may never improve to the point where actual energy consumption can be predicted down to the Btu (kWh), but they can be significantly enhanced.

As part of their work related to the “Technical Potential” study, NREL developed procedures that set plug loads, refrigeration loads, process loads, and schedules to achieve better agreement between simulation models and utility bills (Griffith et al. 2007). 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 use.

ENERGY STAR Procedure to Account for “Neutral Variables.” The ENERGY STAR technical methodology has a procedure for “normalizing” average energy consumption (EPA 2007a). The procedure results in the “predicted source EUI,” which is actually the normalized CBECs average EUI for a particular set of building conditions (EIA 2003). 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 the Determining Average Energy Use section.

Non-Regulated Energy in Asset Ratings

In How Buildings Learn, Stewart Brand (1994) identifies the temporal nature of the building. Brand observes that the building 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 building layers is helpful in discovering what should be considered in asset ratings.

Much of the equipment that produces non-regulated energy use has a short life cycle and is changed out frequently. Notebook computers, copy machines, and other machines come and go with the tenants and are often leased. If a credit is offered for the efficiency of such equipment, 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.

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 more 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 net zero energy, as codes become more stringent, and as non-regulated energy use becomes larger than regulated energy use, it is time to move to a stable scale.

zEPI pegs year 2000 average energy consumption at “100” and net zero 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 (CEC 2009, RESNET 2010). zEPI overturns conventional wisdom with regards to ratings—presenting a less-is-good-and-more-is-bad approach—but this is a sensible viewpoint for scoring energy consumption in a building. 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.

The CBECs database provides an empirical basis for average energy consumption and is updated approximately every four years (EIA 2003). The publicly available version of the CBECs database is for 2003; 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) database be used for normalization but that the 2003 CBECs always be used to define 100 on the scale.

Energy codes can be pegged to zEPI, allowing progress toward goals of net zero energy to be evaluated. Incentive programs and green building rating systems may be pegged to a zEPI score in the same way that building codes would be. Periodic updates to the California energy efficiency standards and ASHRAE Standard 90.1 should be mapped against zEPI, as opposed to letting code updates redefine the scale.
Buildings in the design or construction process would use energy simulations to find their zEPI score, but modeling assumptions would need to be specified such that all energy use is included and such that modeling assumptions are set as close to reality as possible. Both existing buildings and new buildings (in the design and construction phase) should use the same scale. After buildings are commissioned and then occupied, utility bills should be collected and an operational rating should be calculated and compared to the asset rating produced during the design/construction phase.

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

1. 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 (EPA 2007b).
2. How the code development update process might be shifted from the current bottom-up approach to a top-down approach that uses zEPI to set targets, which are later verified through the development of prescriptive packages tailored to building type and climate.
3. How utility incentive programs and other incentive programs could be modified to use zEPI.
4. 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 zEPI is to support the California goals for net zero 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 net zero energy. zEPI embodies this objective.

**Determining Average Energy Use (Marking 100 on zEPI)**

One of the challenges of zEPI is determining the average energy consumption for a particular building type, climate, and set of operating conditions. The “100” point marker on zEPI 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 zEPI, 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 (EPA 2010d). 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/ft²-yr (kWh/m²-y). See EPA’s ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use for the source-site multipliers used in the EPA program (EPA 2007b).
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 1, ENERGY STAR Neutral Variables. The “Predicted Source EUI” is the 100 marker on zEPI.
3. **Calculate the Ratio of the Annual Source EUI to the Predicted Source EUI.** EPA calls this the Energy Efficiency Ratio. (If you multiply the Energy Efficiency Ratio times 100, it will produce the zEPI score.)
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 in EPA’s ENERGY STAR Performance Ratings Technical Methodology for Office, Bank/Financial Institution, and Courthouse (EPA 2007c). Similar data are 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.

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 1 (EPA 2007a). 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. The process is fairly straightforward, but it does have some limitations for applications wider than EPA intended.

The units returned are EPA source energy. Site energy is converted to source energy using the multipliers in EPA’s ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use (EPA 2007b). These are national average numbers. As an alternative metric, the zEPI could look to California, which shifted its metric to time-dependent valued (TDV) energy for the 2005 update to the
California Building Energy Efficiency Standards (CEC 2006). If a building has a typical load profile, EPA “Predicted Source EUI” can be converted to TDV energy through weighted average values. The COMNET Modeling Guidelines and Procedures contains time-of-use energy costs for use in calculating green building ratings and federal tax deductions (RESNET 2010). These may also be translated to and from EPA predicted source EUI. For most building types, the choice of the metric will not significantly affect the ratio. A specific metric has not yet been recommended for zEPI, although there are many 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 are enough CBECS data. ENERGY STAR—as a voluntary program—can be selective, but energy codes, publicly funded incentive programs, and energy labeling programs need to be more comprehensive. The same procedure does not need to be applied to all building types, but the programs need to address all building types in an equitable way.

As performance targets get closer to net zero energy, the exact location of 100 on the scale becomes less significant. In fact, when the target becomes net zero energy, the 100 marker

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### Table 1. ENERGY STAR Neutral Variables (EPA 2007a)

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2 The California standards previously 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.
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 net zero energy. Once the current baselines such as ASHRAE 90.1 and Title 24 get close to zero, it will 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 are limited. Data are available to make meaningful regressions for the building types addressed but are inadequate for other building types. The 2003 CBECS database, which is used by ENERGY STAR, has information on 4,820 buildings. On a national scale, this is a pretty small sample. Consider, for instance, that the CEUS database has 2,800 buildings just for California (Itron 2006). 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 in the short term for building types not covered by ENERGY STAR. The following are options that should be explored in future 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 by average or typical attributes and not code minimum attributes.3

- Use other databases, such as CEUS,4 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 (Itron 2006).

Some of the stakeholders who have been consulted in the development of the zEPI scale have expressed a desire to use median energy use as opposed to average energy use to mark the “100” point on zEPI. Although a median can control for outliers, there are some issues with using a median. 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 (EPA 2007a, b, c). However, as evidenced by the limits on building types covered by the EPA program, these data (at least from CBECS) do not exist for all building types.

For building types for which there are no empirical data, the average or the median energy use will need to be estimated using some other technique. It is possible to make an estimate using simulations with the “baseline” modeling inputs set for average or typical conditions. Such average or typical conditions have been developed for laboratories, for instance, by the Savings by Design program (PG&E et al. 2010). For these cases where energy models are used to generate the baseline energy use, it is uncertain how the median energy use would be determined, other than just assuming a normal Gaussian distribution whereby the median and the average are the same.

**Energy Code Implications**

Establishing a stable scale to measure our progress toward net zero energy has implications for code development because California’s code goal is that the codes require net zero energy buildings by certain target dates, and it is questionable if 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, market maturity, energy savings, applicability, and enforcement authority. The measures that pass the tests are incorporated into the code 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 net zero 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 toward setting achievable top-down goals. The top-down goals would be established to achieve the ultimate goal of net zero energy by the target date. For low-rise residential, about three California code update cycles are assumed to occur between now and the 2020 target for net zero energy: 2013,

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

4. An issue is that the CEUS dataset is not publically available in raw form.
2016, and 2019. There are up to seven California code update cycles prior to the 2030 commercial target for net zero energy (see Figure 6). If the standing of the current efficiency standards on the zEPI scale can be determined, then progressive increments can be established from the present standing to get to the ultimate target. The increments may be aimed at certain technologies or design strategies at each level and, as a result, may not represent equal steps.

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 zEPI 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 in the energy analysis process to the neutral variables such as hours of operation, occupant schedule, and plug loads. 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 zEPI 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 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; DOE 1980). 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/ft²-yr (kWh/m²-y). Neither survived. In the late 1980s, California moved toward the current “custom budget” approach, and so did ASHRAE with Standard 90.1-1989 (ASHRAE 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 current 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 two cases assess the same set of energy uses and 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.

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 zEPI scale for specifying the incremental efficiency targets that will move building design and construction toward net zero energy buildings within a reasonable timeframe.

Incentive Program Implications

The California goals for net zero 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. Another precedent for incentive programs is that the

Figure 6 Code cycles toward net zero energy.
amount of the incentive should not exceed the incremental first
cost of the capital improvements.

The enabling legislation for the California Energy Commission (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”
(CEC 2001, 2006, 2008a). 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 California Energy Commis-

sion 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. The broader
interpretation of the Warren-Alquist Act would support the
top-down approach to code development discussed previously.

Even with the broader interpretation, the net zero energy
goals might become inconsistent with the requirement for cost
effectiveness in the Warren-Alquist Act (dependent on the
comparative future costs of efficiency, renewables, and utility-
supplied energy). A situation could arise where the standards
are cost effective as long as the rate-payer incentives are in
place, but if the incentives were to go away once a net zero
energy standard became mandatory, then the standards would
no longer be cost effective. If this were to occur, the purpose
of incentive programs could be shifted from paying to exceed
code to instead buying down the first cost of efficiency
measures for new buildings to help ensure 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 Cali-

fornia Energy Commission is using) is to better internalize
externalities, such as carbon emissions, that 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 like-

lihood that a net zero energy package of measures would be
cost effective.

### Addressing the Non-Regulated Energy Uses

In most instances, the rating authority (e.g., USGBC,
CEC) 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 in a building
is large, this makes it very difficult to achieve high levels of
percent savings. As buildings move closer to net zero 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 best be addressed through other means. The
following paragraphs discuss some of the issues and opportu-
nities.

Refrigeration, plug loads, and process energy can repres-
ent 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 net zero 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 oper-

ation.

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. In general, process energy has not been
addressed by energy efficiency codes, although refrigerated
warehouses were added to the California 2008 Energy Effi-
ciency Standards, and the California Energy Commission
intends to expand the scope even more in 2011 to address case-
work and refrigerated cabinets in supermarkets (CEC 2008a).
Steps are underway both in California and within ASHRAE to
incorporate refrigeration equipment in the standards. As this
occurs, 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 incorpo-
rated energy efficiency measures such as motors that turn into
generators when elevator cars are descending (sort of like a
Prius going downhill). In Europe, moving walkways and esca-
lators have been paired with occupant sensors that slow down
or shut off the machines 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 best to 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

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3ASHRAE 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” (ASHRAE 2007a).
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 office equipment is very short lived. Another issue is that the type of equipment is 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.

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 (EPA 2010d). ENERGY STAR also has power management programs for IT professionals.

As buildings are designed for net zero 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 net zero energy can best be determined.

Additional Research

This 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 (benchmark) energy consumption and thereby set the “100” marker on zEPI: 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 of 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” (EPA 2010d).
- The modeling approach is more universal and does not require a database. With the modeling approach, a reference building would be modeled by starting with the candidate building but then adjusting the energy efficiency features to represent average conditions. 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.

Table 2 compares the advantages and disadvantages of the two approaches.

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 is an advantage for the modeling approach in that it is only necessary to make a comparison, not to predict absolute energy consumption. It is also a disadvantage of the empirical approach, because with this approach, it is necessary to predict absolute energy use for the candidate building using an energy model, and 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 only specifies a modeling tool to complete the suite of tests and to compare the findings to other software programs without setting any criteria through which the comparison could result in approval or rejection of the modeling tool (ASHRAE 2007b). However, the COMNET Modeling Guidelines and Procedures6 include acceptance criteria to the Standard 140 tests and expand the 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 that 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 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 to verify the above

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6 The COMNET Modeling Guidelines and Procedures are a set of modeling rules and procedures for calculating energy labels, green building ratings, and federal tax deductions. A number of acceptance tests have been 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.
## Table 2. Approaches to Define zEPI Benchmark

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<tr>
<th>Approach</th>
<th>Advantages/Benefits</th>
<th>Disadvantages/Problems</th>
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<tbody>
<tr>
<td><strong>Empirical</strong></td>
<td>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.</td>
<td>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.</td>
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<tr>
<td><strong>Modeling</strong></td>
<td>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 used in both the candidate and baseline buildings. Energy simulation programs would only have to make a comparison instead of predicting absolute energy consumption.</td>
<td>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 with system maps and other details similar to the ASHRAE PRM (Appendix G of 90.1).</td>
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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 (CEC 2008b, ASHRAE 2007a). 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 (CEC 2009). Detailed information needed for a model definition, such as insulation 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 different rule sets 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 would 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, if any, is 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.** 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. Neither are specialized building types such as laboratories or data centers. The modeling approach is one solution for these building types, provided that a rule set can be developed to properly define the “average building.” A longer term solution, especially for retail, may be to expand the CBECS database through 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.

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7. The EPA ENERGY STAR program for retail stores excludes stores located in shopping centers because of this limitation.
CONCLUSION

zEPI is recommended as the metric for setting goals related to code updates and public policy initiatives. It is zero-based and consistent with current initiatives toward net zero energy. It reduces the confusion of metrics expressed as a percent savings past current code, which is a moving target. As industry works towards net zero energy goals, zEPI can be a useful tool in measuring and evaluating progress.

REFERENCES


