California's Commercial Building Energy Asset Rating System (BEARS): Technical Approach and Design Considerations

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ABSTRACT

Benchmarking and performance rating are recognized as the first steps towards improving building energy efficiency. There are two fundamental methods for rating the performance of existing buildings: operational ratings based on actual energy use, and energy asset ratings based on the efficiency potential of the building's design, construction, permanent equipment and systems.

The California Energy Commission has developed the Building Energy Asset Rating System (BEARS) as a cornerstone of its efforts to improve the energy efficiency of existing commercial buildings statewide. This paper will detail the approach taken for this asset rating development, including 1) the modeling approach taken, (including consideration of building type and size and selecting appropriate benchmarks), 2) development of a cost-effective field assessment protocol, and 3) establishing an appropriate scale and graphical presentation.

The BEARS development team was tasked with developing a robust and practical asset rating system to suit the broadest possible range of commercial buildings – all at a cost the market can tolerate. The team has addressed many technical challenges and made trade-off choices, some of which are being tested in pilots. Beyond these technical challenges there will be many other programmatic and market-related challenges to address as the State of California pushes towards its ambitious energy efficiency goals.

Introduction

An ever-growing body of research indicates that green commercial buildings are worth more, cost less to operate, experience lower vacancy rates, and increase occupant comfort. One report found that sales prices for certified green buildings (ENERGY STAR[1] or LEED[2]) are 16% higher than non-certified buildings[3] (Eichholtz, Kok & Quigley 2010).

US policymakers and leading building owners are paying more attention to building energy efficiency ratings. Seven US states/cities have enacted legislation requiring disclosure of buildings' ENERGY STAR ratings while two more have policies pending. These policies predominantly promote disclosure of ratings at time of sale; however, the usefulness of ENERGY STAR is limited in the context of real estate transactions. ENERGY STAR is an energy use rating; it is driven by *actual* energy use, which is largely influenced by operational practices, plug loads, and occupancy patterns; these factors can change significantly when there is a change in building ownership. By contrast, an energy asset rating indicates the energy

[1] http://www.energystar.gov/
[2] http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988
[3] The Institute for Market Transformation has many useful resources on energy efficiency and property value, at: http://www.imt.org/rating-value.html.

efficiency potential of a building's permanently installed energy-consuming equipment and its design/construction. Energy asset ratings are normalized for operational characteristics, plug loads, and occupancy, so buildings *can* be compared irrespective of how they currently perform.

An asset rating may be used by financial or real estate professionals in property valuation, since energy use affects net operating income and asset value. It may provide a metric for regulators to support policy goals or for engineers/contractors to demonstrate the benefits of upgrades. It can also provide owners with a tool for prioritizing energy efficiency investments across their portfolio, and hone in on specific end uses requiring upgrades.

The European Union has developed an asset rating tool to support the Energy Performance of Buildings Directive[4] (2002) and has implemented it to varying degrees across several member countries (BPIE 2010). This paper describes California's efforts to develop the Building Energy Asset Rating System (BEARS), one of the first commercial asset rating tools under development in the United States[5].

There are a number of critical design challenges and trade-offs that need to be addressed in the development of an asset rating tool, such as balancing the cost vs. accuracy of field data collection, establishing a streamlined yet robust modeling approach, selecting an appropriate benchmarking approach, and presenting the rating in a meaningful and clear way. This paper describes how the BEARS development team has approached these challenges, and the remaining design decisions that will be refined through pilots.

Background to California's Asset Rating Development

California Assembly Bill 758 (California 2009) requires the California Energy Commission to develop and implement a comprehensive program to achieve greater energy savings in existing residential and nonresidential building stock. Development of BEARS is one element of this program. Stated goals include:

1. Rate the inherent energy efficiency of the commercial building's envelope and system design relative to code and existing commercial building stock;
2. Provide a metric relating to the financial implications of a building's energy efficiency;
3. Communicate the importance of zero net energy buildings as a reference point for California's energy policy;
4. Communicate a building's potential for an improved asset rating relative to other buildings of similar type and location;
5. Apply across the widest possible range of building types and sizes; and
6. Be a reasonably priced rating for building owners to obtain.

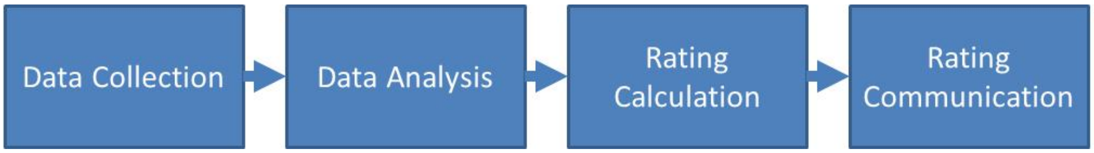
BEARS is currently in a pilot phase to test, verify, and improve its design. BEARS will be officially launched in phases, initially focusing on the most common building types and targeting less common buildings in subsequent releases.

[4] Available at: http://www.diag.org.uk/media/18832/epd_final.pdf
[5] Other commercial asset rating systems are being developed by the US Department of Energy (DOE), the Massachusetts Department of Energy Resources (DOER), and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

BEARS Rating Process Overview

As illustrated in Figure 1, the BEARS rating process is comprised of four major steps that transform data on a building's permanent assets into a meaningful rating.

Figure 1. BEARS Rating Process



The data collection step consists of both documentation review and on-site building assessments. This data is analyzed to calculate a normalized energy consumption metric for the building. The rating is calculated by comparing this metric to a predefined benchmark that represents similar type buildings in a similar climate zone. Finally, the BEARS rating is presented on a two-page certificate that features an innovative graphical representation that is designed to help users understand and use the rating information. Design decisions and challenges associated with each of these four steps are described in greater detail below, as well as options and design criteria for pending BEARS elements.

Data Collection

The key design challenge for the field assessment protocol is to identify the data requirements that achieve an optimal balance between rating cost and accuracy. To accomplish this, the team conducted a sensitivity analysis on a range of building asset characteristics to determine the factors that most influence modeled energy use.

First, the team determined which building characteristics constitute "energy assets," defined as a physical characteristic of the building that is commonly left unchanged at the point of sale. For example, a refrigerator in a commercial kitchen will likely be removed when a building owner or tenant changes (therefore not an energy asset), while a walk-in freezer will likely be retained (classed as an energy asset).

Second, the team modeled various building types in different climate zones by utilizing the EnergyPlus models provided by the DOE Commercial Reference Building framework[6]. Finally the sensitivity analysis was conducted by running iterations of these models while varying key building characteristics to reasonable high and low extremes. California building code (California 2008), typical building data, and field experience were used to establish reasonable high and low input values for this analysis. Table 1 below provides an example of one of the sensitivity analysis results tables; the percentage values indicate the relative magnitude of each variable's impact on modeled energy use.

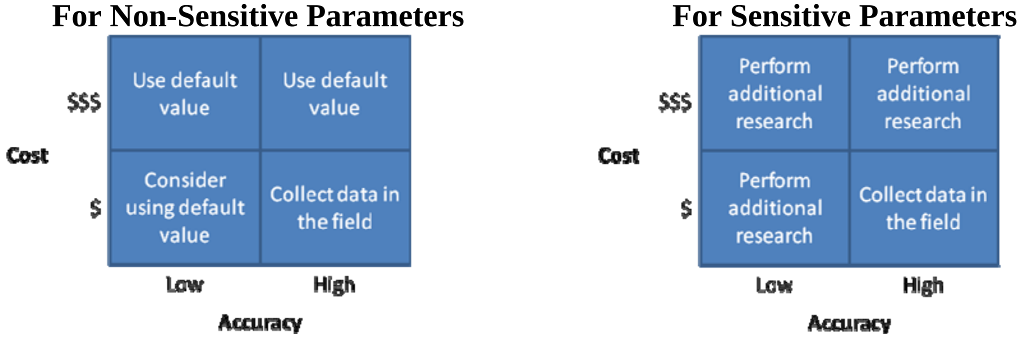
[6] Available at: http://www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html

Table 1. Example of Sensitivity Analysis Results, for Modeled Small Office in Climate Zone 09

Input Parameter	Electric	Gas
Equipment Power Density[7]	49.37%	1.46%
Lighting Power Density	21.74%	0.23%
Cooling Efficiency	11.51%	0.00%
Window Area with Daylight Control	5.50%	0.00%
Roof Reflectivity	5.47%	0.06%
Glazing (solar heat gain coefficient)	5.23%	0.18%
Daylight Controls	4.92%	0.06%
HVAC System Type	3.73%	0.23%
Fan Static Pressure	3.49%	0.06%
Window Area with no Daylight Control	3.44%	0.00%
Infiltration	0.96%	0.23%
Roof Insulation	0.74%	0.12%
Glazing U-Value	0.57%	0.06%
Domestic Water Heating Efficiency	0.00%	42.69%
Wall Insulation	0.35%	0.06%
Heating Efficiency	0.03%	0.06%
Ventilation Airflow	0.00%	0.00%

In parallel with the sensitivity analysis, the team estimated the relative cost to collect each parameter based on engineering judgment, noted which data required specialized equipment to collect, and assessed the relative accuracy of multiple data collection methods. Once the sensitivity analysis was complete, the team identified an assessment strategy for each parameter to achieve a balance between cost and accuracy. Onsite data collection efforts will focus on the most sensitive parameters, with less sensitive parameters utilizing defaults (typically code-based). Figure 2 illustrates this strategy.

Figure 2. Decision Matrices for Model Input Parameters



The main challenge that emerged from this exercise is how to deal with sensitive parameters that do *not* have accurate, low cost methods developed for data collection. Some examples include cooling efficiency, roof reflectivity, and window solar heat gain. The team is addressing each of these parameters by performing research to determine the most cost-effective

[7] Although equipment power density is indicated as highly sensitive, it is often associated with non-permanent assets, such as plug loads. The strategy for handling this input is being explored through pilots.

data collection method. To improve the accuracy of the assessed cooling efficiency, the team has developed a standardized protocol for de-rating efficiency based on equipment age. Glazing solar heat gain, if not marked clearly on the glazing itself, will be measured by means of a pyranometer coupled with data regressions.

Providing a rating at a reasonable cost is one of the key goals of BEARS, and data collection is expected to be the major element in that cost. There is no objective way of determining what the asset rating should cost, since there is no precedent or market price for a commercial energy asset rating. The team assessed a range of comparable services, including ASHRAE energy audits and existing building commissioning investigations, and proposed some initial target costs. These cost targets will be validated through upcoming BEARS pilots.

Data Analysis

Determining a meaningful energy use metric for commercial buildings without a highly complex and expensive building simulation is a significant challenge. Two major elements of BEARS data analysis are described in this section: the modeling methodology and the categorization of building types.

Modeling Methodology

Data collected on the rated building is analyzed to produce an energy consumption metric. The primary energy metric selected for BEARS is Time-Dependent Valuation[8] (TDV); this was selected in preference to source energy use because TDV accounts for the varying impacts of energy consumption based on time of use. For this reason it is already used as the primary metric for California energy efficiency standards (California 2008). Two primary modeling approaches are being piloted for BEARS:

1. The building-specific energy simulation model approach involves creating a model with the rated building's characteristics and running an hourly simulation. The primary advantage of this approach is that any building feature can theoretically be factored into the energy model, provided that it is deemed an "energy asset" and the data is affordable to collect. The primary disadvantages of this approach are associated with its complexity, cost, and need for quality assurance (for the modeler, the rating software, and the rating authority).
2. The performance map approach relies on a database of pre-simulated models covering millions of model permutations to represent existing building stock and new construction. Multiple regression models are generated for each building type and location. The building's energy performance is determined by using its characteristics as inputs to the regression equations. This approach works well if a detailed map is developed that adequately covers the range of variations in existing buildings and new construction. One major advantage is that it is much easier to implement, since there is no need for a simulation engine within the BEARS rating software. The primary disadvantages of this approach are associated with its limitations in covering all building variations and its lower accuracy for larger, more complex building types.

[8] Additional information available at:
¨http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/tdv/index.html

Both of these options are being pursued for BEARS. It is anticipated that the performance map approach will be employed by default, with custom modeling available as an option for non-standard situations; this is subject to further development and pilots.

Building Categorization

The team reviewed several existing building rating and database frameworks to identify the building or occupancy categories for BEARS, including the California Commercial End Use Survey (CEUS)[9], U.S. Commercial Building Energy Consumption Survey (CBECS)[10], DOE Commercial Prototype & Reference Buildings[11], and The Chartered Institution of Building Services Engineers (CIBSE) 2008 Energy Benchmarking (TM46) used in the United Kingdom[12].

All of these frameworks classify buildings according to the principal activity of the building, with multi-use buildings either assigned to the activity occupying the most floor space, or split for separate assessment of each usage type. Although there are other categorizing methods (e.g., building size, construction attributes, and system type), BEARS will categorize buildings based on principal activity (occupancy category).

The team started from the DOE Commercial Reference & Prototype Building framework, for two main reasons: 1) BEARS will utilize energy models to generate energy consumption metrics and the DOE framework already includes models for 16 building types that represent nearly 70% of the commercial buildings in the United States; and 2) the DOE framework uses principal activity as its primary categorization variable.

Although the DOE framework covers a high proportion of commercial buildings in California, the team explored developing models for several more building types, focusing on 2003 CEUS building sub-types that have significantly different energy consumption and modeling parameters than the 16 building types covered by DOE. The list of proposed BEARS building types was eventually expanded from 16 to 29 (see Table 2). Of these, 12 will translate directly to an available DOE Commercial Reference Building, 7 will require modification of modeling parameters from an available Reference Building type, and 10 will require new modeling protocols.

[9] Available at: http://www.energy.ca.gov/ceus/
[10] Available at: http://www.eia.gov/emeu/cbecs/
[11] Available at: http://www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html
[12] Available at: http://www.cibse.org/index.cfm?go=page.view&item=1190

Table 2. Proposed BEARS Building Type Classification

Proposed BEARS Building Types	DOE Reference Building Available	Modify DOE Reference Building	New Modeling Protocols Required
Large Office	x		
Medium Office	x		
Small Office	x		
Data Processing/Computer Center		x	
Lab/R&D Facility			x
Quick Service Restaurant	x		
Full Service Restaurant	x		
Bar/Tavern/Nightclub/Similar		x	
Supermarket	x		
Convenience Store		x	
Stand-alone Retail	x		
Strip Mall	x		
Refrigerated Warehouse		x	
Unconditioned Warehouse		x	
Conditioned Warehouse		x	
Small Hotel	x		
Large Hotel	x		
Primary School	x		
Secondary School	x		
College or University		x	
Religious Assembly			x
Health/Fitness Center			x
Theater/Performing Arts			x
Library/Museum			x
Conference/Convention Center			x
Other Recreational/Public Assembly			x
Service			x
Assembly/Light Mfg.			x
Police/Fire Stations			x

Each of these building categories is defined through a set of model inputs split into three groups: “Required,” meaning that building-specific data will be collected; “prescribed,” meaning that default values will be assigned; and “optional,” meaning that defaults are assigned but they may be overridden if building-specific data is available. A series of rule-sets has been developed to determine how those values should be entered, how collected site information will be translated into model-ready input data, error checking, etc.

BEARS Rating Calculation

Once the building has been modeled, the output energy use metric (TDV) is compared to a benchmark to generate the BEARS rating. Rating calculations posed three key challenges: determining a meaningful rating scale, selecting an appropriate benchmark specification, and the technical approach for developing the benchmark.

Determining an Effective Rating Scale

The "effectiveness" of the BEARS rating scale is determined by the following factors:

- Is the scale intuitive and easy to understand?
- Does the scale adequately differentiate between good and poor buildings?
- Does the scale accommodate the significant energy performance improvements expected over time?
- Does the scale align with State of California's policy goals?

The team considered three scale options: 1) letter grades, as adopted in Europe and the proposed ASHRAE Building EQ rating, 2) a 1-100 scale, as utilized for ENERGY STAR rating, and 3) the zEPI scale (AEC 2009), a linear scale which is infinite in both directions, designating zero as zero net energy use and 100 as a predefined benchmark[13].

The BEARS team selected the zEPI scale for several reasons. It aligns with California's long term policy goals, which are strongly directed towards zero net energy use (CPUC 2008). Given that zero net energy use is far beyond the performance of typical building stock, the zEPI scale accommodates significant future improvements in energy efficiency. In addition, the Home Energy Rating System (HERS)[14], a major element of California's residential energy policy, also uses the zEPI scale.

Finally, the zEPI scale is intuitive, in that a rating of zero represents zero energy use, giving the user an indication of the magnitude of a building's energy consumption. Being linear, the differences between points along the scale are easily recognized. For example, a 20% improvement in the efficiency of the building's permanent energy-consuming assets would directly translate to a 20% improvement in the building's asset rating.

Although the zEPI scale was selected for use in California's asset rating system, it is important to highlight the key differences between zEPI and the 1-100 scale used for ENERGY STAR; the ENERGY STAR rating has high recognition in the commercial buildings industry. Its scale has 1 as the lowest rating and 100 as the highest. When compared alongside BEARS, this may result in some understandable market confusion. The BEARS team selected the zEPI scale in spite of this, due to the aforementioned advantages, and is committed to developing a graphical presentation and conducting outreach to overcome potential confusion.

[13] Examples of these rating scale options can be viewed at http://www.buildingrating.org/content/energy-label-gallery

[14] Additional information at: http://www.energy.ca.gov/HERS/

Selection of an Appropriate Benchmark

The zEPI scale is linear, and is built upon two fixed reference points that represent 0 and 100 on the scale. In selecting a benchmark to represent 100 on the zEPI scale, two options were considered:

- A code-related benchmark (in California, the applicable building code is Title 24, Part 6); or
- A benchmark based on a typical building ("typical" meaning building stock median).

The BEARS team chose a code-related benchmark because it offers two key benefits. First, it is a more transparent metric; building code documentation specifically indicates the types of systems and construction necessary to meet that performance standard. Second, the majority of commercial building stock was not built to recent building codes, so a rating of 100 will become an interim target on the path to zero net energy use.

Beyond the selection of code as the benchmark type, the follow-up considerations include which vintage (year) of code should apply, and how future code changes should be handled. The team's current recommendation is to apply Title 24, Part 6, 2010 as the benchmark and review this ten years after launch to see if a change is warranted. In addition, it will be important to communicate the difference between a BEARS rating of 100 and "code compliance", since a building rated as 100 will not necessarily comply with code. For example, a building rated at 100 may have some systems that do not comply with code, but other systems that are highly efficient that bring the rating down to 100. This should be relatively minor to address through outreach, but is important nonetheless; the market cannot rely on BEARS as a code compliance tool.

Technical Approach to Developing the Benchmark

The team has considered two options for deriving the benchmark: a 'custom' benchmark or a 'static' benchmark approach.

Custom Benchmark. A custom benchmark varies based on the rated building's design. Many of the rated building's design features are adopted in the benchmark building model, and then adjustments are made to energy assets to match benchmark code requirements. In other words, the rated building is being compared to a code-compliant version of itself. This strategy is very similar to the performance-based code compliance approach currently used in California[15].

This approach allows adjustments to the benchmark for design requirements specific to the rated building. For instance, if a rated building's design requires special air filtration, the benchmark model fan power can be adjusted so that the rated building will not be penalized. This can be based on the rules for code compliance, which are very stringent, to prevent opportunities for gaming the system. Alternatively, a more flexible rule set can be applied, to accommodate efficiency measures such as natural ventilation and high thermal mass. Another advantage is that comparing a building to a code-compliant version of itself gives an owner a clearer idea of what is achievable in their specific case (or it may show them how far beyond code they already are).

[15] More details can be found in the Nonresidential Compliance Manual, available at: http://www.energy.ca.gov/title24/2008standards/nonresidential_manual.html

Static Benchmark. A static benchmark is constant for a given building type and climate zone. For example, an office building in Sacramento would be compared against a benchmark that is fixed for a specific size classification (e.g. small, medium, or large office), with assumptions included that represent typical operational characteristics for this building type and size.

This approach gives credit to efficient design features that are *not* covered by code requirements. For example, if the rated building features an efficient air distribution system, this would show a benefit over the benchmark. This is not the case with the custom benchmark approach; under that scenario, the benchmark model would include the same air distribution system as the rated building, thus neutralizing the benefit. A static benchmark also allows the market to more easily compare ratings for buildings of a similar type and climate, as they will all be compared to the same benchmark.

The modeled and the static benchmark approaches each have pros and cons. The final approach for BEARS will be determined based on the ongoing pilots. Given that the key goal of BEARS is to drive higher performance buildings, the fact that the modeled benchmark approach would not reward some advanced energy efficiency features is considered a major drawback.

BEARS Rating Communication

The BEARS rating and relevant background information will be presented to the building owner on a two-sided certificate. The certificate includes a rating scale, emission chart, qualifying information, and a system-by-system energy use breakdown.

Rather than presenting the rating in a linear fashion, the proposed BEARS graphical representation breaks from common practice and displays the rating on a circular, target-like, design (see Figure 3). The center of the circle represents net zero energy use, and the outer circumference represents a rating of 250, although the zEPI rating scale concept itself does not incorporate a fixed maximum value. Given that a building's rating is relative to building code, it is possible for a very inefficient building to gain a rating higher than 250. The BEARS team felt, however, that 250 is a reasonable outer limit for the graphical presentation of the scale.

To give context for a building's rating, additional markers are included that represent the code-based benchmark (100) and a rating for a typical existing building of the same type, size, and climate zone (rated at 150 for the hypothetical example in Figure 3 but this would vary in practice).

Figure 3. Presentation of BEARS Rating (for a Building with a Rating of 123)

In addition to the rating, the BEARS certificate includes an emissions metric, which displays an estimate of the annual CO_2 equivalent emissions of the rated building and compares that with the emissions of the new building and typical building benchmarks.

The certificate also explains what BEARS is, gives a basic description of how the rating is calculated, and provides pointers to which systems may have the greatest potential for improvement. These pointers are based on the magnitude of 1) each system's impact on the BEARS rating, and 2) each system's deviation from the code requirements.

Conclusions

This paper describes the development of California's commercial building energy asset rating system, BEARS, detailing some of the major challenges. The BEARS development team has addressed the challenges of the rating scale and field assessment protocol development, and is confirming the benchmarking approach through pilots. In terms of modeling approach, it is expected that custom modeling and the performance map approach will be utilized, although further work is required to determine how and when each of these approaches will be employed.

The development of BEARS is characterized by a series of carefully considered compromises, such as dealing with modeling accuracy vs. cost. It is accepted that a full building simulation is unfeasible, and so the sensitivity analysis conducted by the BEARS development team has been critical in determining a set of inputs that provides an optimal balance of accuracy vs. cost. Similarly for data analysis, the proposal to develop the modeling approach in parallel with a performance map approach is intended to offer a more streamlined process wherever possible.

BEARS has also been developed to provide the most intuitive and meaningful metrics to users. The zEPI rating scale was selected for its ease of use and for highlighting a building's efficiency compared to zero net energy use. The code-based benchmark was selected to provide a clearly defined reference point, and to serve as a milestone on the path to greater efficiency. Finally, the BEARS certificate itself will pull together all of these elements in an engaging and easy to understand visual format.

Introduction of an energy asset rating system represents a paradigm shift for the commercial buildings market, which is still getting acquainted with energy use ratings. It allows for a new way of thinking about the value of a building's permanent assets, and has the potential to create a more robust link between energy efficiency and property value. BEARS can also play a role in identifying zero net energy as a key reference point for building performance assessment, as opposed to peer-based comparisons that are historically most common. It facilitates market transformation as the State of California pushes towards its ambitious energy efficiency goals, by supporting evidence-based investment decisions.

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