Is What They Want What They Get? Examining Field Evidence for Links between Design Intent and As-Built Energy Performance of Commercial Buildings

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ABSTRACT

Do you ever wonder why the performance you experience for something you bought differs from a manufacturer's claim on a label? This paper takes an insightful look at how this applies to new buildings by using the US Environmental Protection Agency's (EPA) ENERGY STAR® National Energy Performance Rating Scale. It will present the early results of a study comparing the original design intent of typical newly constructed commercial buildings in California with the Energy Performance Rating Scale. Specifically, the paper will:

- Compare pertinent field data against the Energy Performance Rating Scale for a population of new buildings in California.
- Discuss energy performance tracking issues raised by two critical audiences -- those prospective decision-makers who, so far, have declined to participate in ENERGY STAR, and building science researchers and architectural energy practitioners who challenge the technical approach of the Energy Performance Rating Scale.
- Present credible and useful information about the relationship between building energy performance and intended energy-efficient design practices (as defined by a percentage above or below California's Nonresidential Energy Standards).
- Recommend a means of using the Energy Performance Rating to assure design intent can be translated into actual building energy performance.

This paper discusses ways to institute a process to identify ways of enhancing the use of ratings systems in new construction and also discusses the relationship between design intent and ratings.

Introduction

Voluntary market-based efforts such as ENERGY STAR rely on cooperation and good will between the private sector and government, but to succeed they must result in measurable economic, energy and environmental benefits. All parties must agree upon reasonable measures and verifiable outcomes. This paper will discuss recent efforts to compare the predicted energy performance of typical newly constructed commercial buildings in California with original design intent for such buildings using the Energy Performance Rating Scale.

ENERGY STAR has two components to its Energy Performance Rating Scale:

1. Target Finder – a tool that is used during new design phase to compare predicted performance (kWh/Therms) to the Energy Performance Rating Scale, and
2. Benchmarking Tool – a tool that utilizes 12 months of gas and electric bills to rate a building's energy performance, on a scale of one to one hundred (with one being the most energy consumption).

This paper discusses the analysis of predicted performance of newly constructed California buildings (Wright 1999) using EPA's Target Finder, rather than actual energy bills.

Background

An effective means of increasing participation in voluntary programs is to develop a wide-based consensus to help to build support among both building science experts and the peer-sensitive building owner and developer community.

The commercial building energy efficiency community is a sophisticated collection of engineers, policy analysts and marketing representatives. This group has a diverse view of the commercial buildings market and how to affect change in that market. These views range from the need for specific technical analysis to predict energy savings on a specific job, to marketing the non-energy benefits of high performance buildings. The Energy Performance Rating Scale has a number of features that the commercial building efficiency community can use in their efforts. These features include:

- The tool's ease of use,
- ENERGY STAR brand recognition,
- Ability for building owners, developers and property managers to quickly grasp the energy performance-rating concept.

There are specific areas in the US that are taking a hard look at their commercial building programs (Johnson 2001). They include:

- California –Commercial building rating is not yet included in the proposed program offerings in California. There is significant opportunity to work with program planners in California to develop mid- to long-range programs that incorporate the Energy Performance Rating Scale.
- Northwest – The Northwest Energy Efficiency Alliance (Alliance) is working on a new commercial buildings program. The relationship between codes, new buildings and existing buildings is evolving in this program design. The Energy Performance Rating Scale can play a role in this new program, provided the Alliance is able to translate the benefits of rating commercial buildings to the real estate community.
- Northeast -- The Northeast Energy Efficiency Partnerships, Inc. is currently evaluating the role of rating buildings within a utility program framework. The relationship between codes, utility new construction programs and the Rating Scale is a part of this effort.
- Midwest – The Midwest Energy Efficiency Alliance is in the early planning stages for commercial programs. There is an opportunity to provide information on the

Rating Scale and how it might be used as an element of their commercial new construction programs in the mid-west region.

The activities in all of these regions present an enormous opportunity for promoting a stronger link between design-intent and as-built energy performance of newly constructed buildings.

Methodology

The methodology for this study focused on eliciting the most critical voices within various building communities, articulating their concerns and their requests for persuasive evidence, and then testing hypotheses using appropriate sets of data from buildings in California. It relied on four primary elements:

- Surveying utility program managers, architects, engineers and building owners from around the United States to identify current practices related to setting energy performance targets, tracking energy performance and their use of benchmarking tools,
- Soliciting input from a working group of individuals that are familiar with building science issues related to benchmarking to help inform the analysis of datasets to see how actual building performance tracks design intent,
- Analyzing datasets to address issues raised by building scientists, and
- Publishing the results of this effort to allow the energy efficiency community, building owners and the design community to become aware of the role of goal setting and tracking in assuring buildings actually deliver their intended performance.

Research Hypothesis

It was anticipated that the two audiences (pre-construction and post-construction) would have divergent concerns and the two audiences would have a vested interest in each other's expertise and opinions. Therefore, facilitating their interaction and consensus would have a synergistic result, supportive of the improving commercial new construction energy efficiency programs.

On a technical level, it was anticipated that the Energy Performance Rating Scale would give a reasonable approximation of various energy measures in office buildings.

Finally, a meta-analysis of this type would reveal some ways to offer guidance to designers, so that their intent to save energy can be more readily fulfilled when the buildings are occupied and operated.

Survey Results

A survey of 115 building science and building industry professionals was conducted via telephone and electronic mail. The list of persons to be surveyed was compiled from utility program directories, association directories, and random selection from regional and national directories of architects and engineers. The survey was not intended to be

statistically representative of each of these professions but a random sampling of practices to identify potential trends in practices.

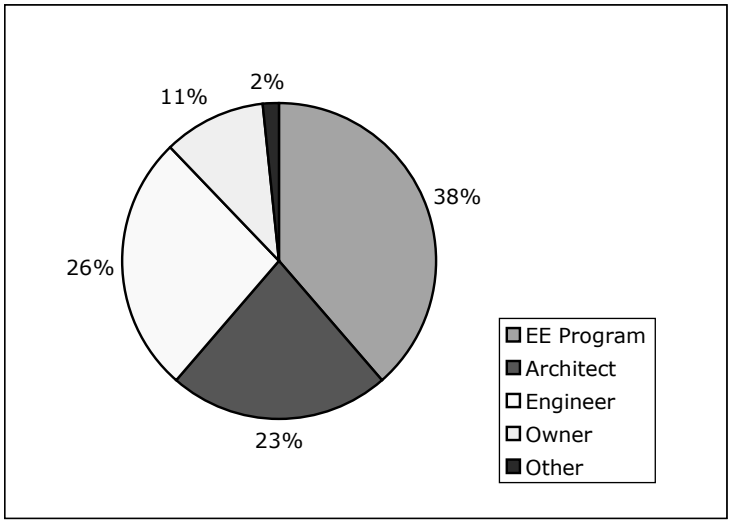
The survey is useful in identifying baseline practices for these audiences and helping to understand why these two audiences have a different view of setting performance targets and tracking building energy performance.

Of the 115 persons contacted, 57 were involved in commercial new construction programs. The remaining discussion is a summation of the 57 respondents.

The surveyed professionals reported that they were involved in influencing over 170 million square feet of new construction projects. Building owners, including property managers and developers, were most likely to decline to be surveyed. Many of the owners contacted were not involved in commercial construction efficiency programs and only managed previously built properties (not in the scope of our study).

Figure 1 shows the range of professions that were contacted. The majority of persons that we contacted were energy efficiency program managers. Owners represented the smallest category of survey respondents.

Figure 1. Professions Contacted (n=57)



The three groups; energy efficiency program managers, designers (architects and engineers) and owners reported divergent practices related to pre-construction energy efficiency target setting and post-construction energy benchmarking. Table 1 shows the practices of each group.

Table 1. Practices of Surveyed Professionals

Profession	Target Only	Track Only	Target/Track	Do Nothing
EE Program Manager	59%	0%	27%	14%
Design	24%	10%	41%	21%
Owners	17%	33%	0%	50%

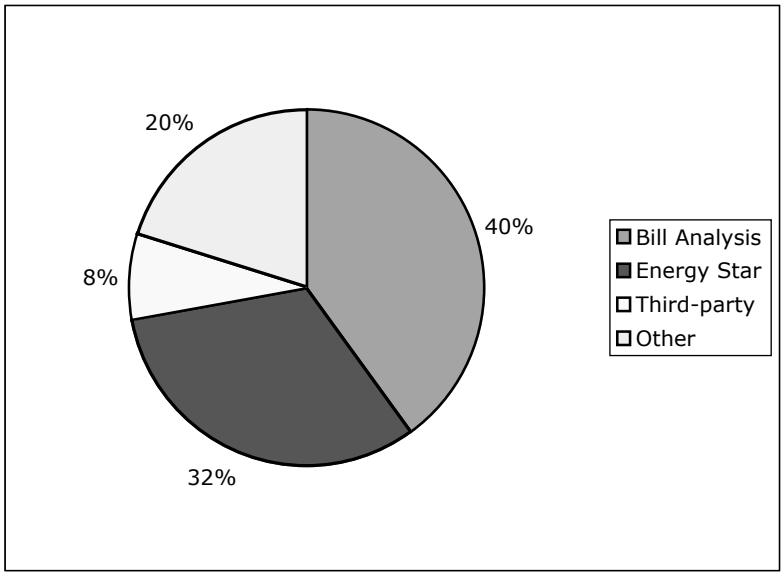
The practices of the professionals in the survey showed that the energy efficiency program managers primarily set targets for new designs while the majority of owners involved in new construction either did nothing or tracked energy use. Designers reported

they were involved in both setting targets for new designs and reportedly tracked energy use after construction.

A total of 68% of the respondents indicated they set energy targets during the design phase. The majority of those who set energy targets used DOE 2 computer simulations or the Trane TRACE program as their primary tool.

Forty-four percent of the survey respondents indicated they tracked building energy performance after the building was constructed. Figure 2 shows the primary tools that survey respondent's use.

Figure 2. Energy Tracking Tool Practices (n=25)



Respondents indicated they performed bill analysis to track the energy performance of their building's. The Energy Star Energy Performance Rating Scale was the second-most used method of tracking building performance. Other responses included using third parties to do the tracking, spreadsheets and DOE 2 simulation. Building owners were the primary respondents who performed bill analysis while energy efficiency program managers were the primary respondent to use the Energy Performance Rating Scale.

The results of the survey support our hypothesis that these groups of professionals have divergent concerns. The energy efficiency program managers were concerned with designing and delivering improvements in targeted energy savings on new construction projects. The design community was interested in using targets to meet or exceed building codes and , when asked, assist their clients in understanding how their buildings performed. Owners that were involved in energy efficiency programs were most interested in the bottom line energy use of their buildings.

Analysis Methodology and Results

The overall goal of the data analysis is to identify the relationship (if any) between the design intent and the energy performance of the building. This can be translated into two key elements:

- Design intent typically focuses on the efficiency of the building as compared to baseline. In this analysis, the baseline is defined as the percent above or below California's Nonresidential Standards.
- Energy performance typically focuses on the energy intensity of the building. In this analysis, the energy intensity is based on the Energy Performance Rating (Hicks 2000).

The basic objective of the analysis is to compare energy savings (as a percentage of baseline) with the Energy Performance Rating Scale. The overall steps in the data analysis process were as follows:

- The predicted kWh and Therm values for 157 office buildings in California constructed between 1992 and 1998 were developed from calibrated DOE2 for two conditions: as-constructed and minimum code (Title 24).
- The kWh and Therm values were provided to EPA for analysis using the Energy Performance Rating Scale.
- Regression analysis was used to examine the strength of the relationship between the expected energy savings and the Energy Performance Rating score.
- The percent above code versus Energy Performance Rating score comparison results were examined, and explanations for the results were developed.

The Energy Performance Rating Scale adjusts the energy consumption of a building by factors that were determined by EPA to be the most significant variables in normalizing energy use across US buildings. The key factors used in the analysis of newly constructed office buildings in California compared to the 1995 Commercial Energy Building Energy Consumption Survey (CBECS) (EIA 1998) are summarized in Table 2:

Table 2. Key Factors in Analysis of Office Buildings

Value	New CA Offices	CBECS
Occupant Density (people/1,000 sf)	4.03	2.52
Personal Computer Density (PC's/1,000 sf)	2.41	2.17
Operating Hours/Week	58.5	70
Site End Use Index (kBtu/sf/yr)	89.3	104.3
Average Energy Performance Rating Score	64	50

A scatter plot representing data for each building in the study was prepared. Figure 3 shows the results of an analysis comparing the simulated performance of 157 office buildings in California to the Energy Performance Rating Scale.

Figure 3. Office Electric Savings vs. Rating Scale Score

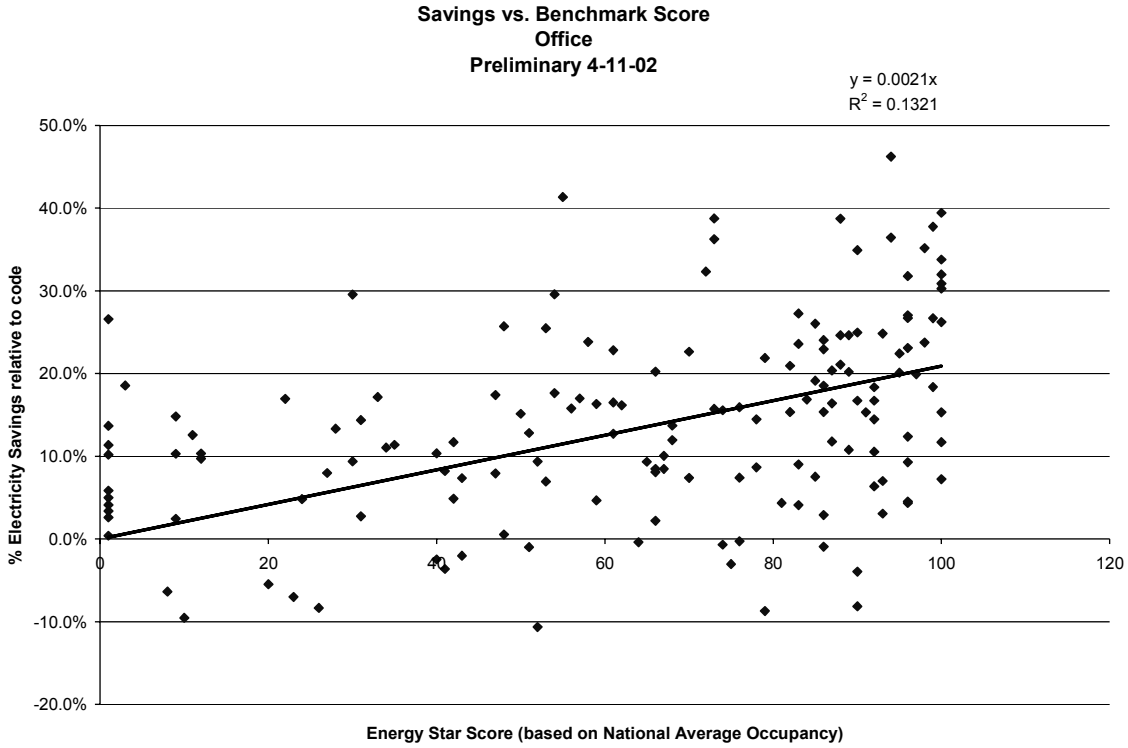


Figure 3 shows that low energy consumption (as shown on the x-axis with 1 being the highest consumption and 100 being the lowest) does not correlate well with energy efficiency (shown on the y-axis with 0 equal to minimum code). The differences are likely due to assumptions about building orientation, thermal massing and non-regulated energy consumption (plug loads, etc.). These assumptions can greatly affect the total energy bill, even if energy efficient lighting, windows and HVAC systems are present.

The issue of low energy consumption vs. energy efficiency is a challenge to new construction program design and the Energy Performance Rating Scale. For example, a designer that has the flexibility to re-orient a building to take advantage of climatic conditions may produce a building design that has lower overall energy use but may not get credit for that component of their design as an "efficiency measure" in the new construction program. If the new construction program tries to give a credit to those features, then a building site that doesn't have the flexibility to work with the climate (urban development) may not qualify for new construction program benefits regardless of the level of efficiency incorporated into the design.

The policy question comes down to the purpose of the new construction program. If the purpose is to require a consistent level of technical efficiency measures in every building, then measuring the energy efficiency (percent above code) of a building in a new construction program achieves that goal, but allows a wide variation in actual energy usage depending on the intensity of building use, its hours of operation, its level of maintenance of energy-related controls, and its site constraints.

If the purpose of the new construction program is to ration energy, then a metric based on total energy use (such as the Energy Performance Rating Scale) best achieves that goal. This goal is achieved at the expense of requiring vastly different levels of investment in

efficiency measures or design changes in order to meet the new construction program goals —levels that depend on all the factors listed above, and more. Experience suggests that the political cost of a rationing approach is too high for minimum code requirements but may be practical through voluntary programs.

Implications for New Construction Programs

The Energy Performance Rating Scale can enhance new construction programs by incorporating steps 2 and 3 into the traditional design process (shown as step 1).

1. A performance-based efficiency target is met based on codes or standards, the local utility new construction program, national tax credit or other criteria.
2. Target Finder is used to establish a score based on results of the energy performance analysis of the proposed design (from step 1).
3. The Benchmarking Tool is used to assess if the Target Finder score was realized by the building after one year of reliable energy bills are available.

This new steps can easily be incorporated into new construction programs (code and beyond-code) to provide a simple means of verifying the intent of a design is realized in building operation. It fits well with existing processes as target setting typically occurs at the beginning of a project while building owners are more likely to track performance using energy bills.

For example, a 60,000 square foot office building is modeled to exceed an energy code by 15%. The building uses national average occupant and personal computer densities. Using ENERGY STAR Target Finder, the building scores a 53 on the ENERGY STAR Rating Score scale. Once the building is constructed, the building operations team enters the actual building occupancy data, hours of operation and personal computer density, along with 12 months gas and electric bills into the ENERGY STAR Benchmarking Tool. If the building score is less than 53, the building operations team should investigate operating practices because the building is not performing to its design intent. If the building scores better than a 53, the design intent was realized but there may be additional opportunities to improve the overall performance of the building.

Conclusion

Commercial new construction energy efficiency programs do not consistently deliver low-energy buildings as defined by the Energy Performance Rating Scale. While the goals of new construction programs go beyond low energy bills, the correlation between design intent and building performance suggests a larger structural issue within the process of predicting building performance and benchmarking energy use. There are two key elements of this structural gap:

- Design intent is determined using simulation tools that automatically generate baselines based on the overall minimum efficiency allowed by an energy code. The variation from this baseline (efficiency) is the basis for many new construction

program designs (Johnson 2000). This process rewards the efficiency of a building but may not fully account for the energy consumption of the building.

- The ENERGY STAR performance rating does not attempt to address every aspect that a building must meet to be a productive asset. Some aspects may include satisfied occupants, meeting all organizational goals of the company, and being an asset to the community (Heerwagen 1998). This means that certain classes of buildings may use more energy to improve their overall productivity as a capital asset. The use of average building performance as defined by the Commercial Building Energy Consumption Survey (CBECS) makes it difficult to demonstrate if the building is a poor performing building or that it is an energy-efficient performer given the building's particular class.

This study suggests a new strategy is needed to better capture the lost opportunities in new construction and deliver built environments that benefit future generations. This new strategy should focus on using the Energy Performance Rating Scale to provide:

- The *building design team* with marketing resources to support the sale of value added services to building owners through the ENERGY STAR brand and to establish a target using the Energy Performance Rating Scale based on the simulated performance of the building design. This verifiable target becomes a key part of the quality assurance process by the building operations team.
- The *building operations* team can utilize the Energy Performance Rating Scale to provide the building owner with assurances that the energy targets established in the design process were implemented and are delivering the intended performance.

Incorporating this strategy into new construction programs will help ensure that all of the benefits of energy efficient design are realized by the building operating team.

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