More Than a Single Percentage

Energy Benchmarking

By Roger Chang, P.E., Member ASHRAE

Energy benchmarking to ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, has been common for the past decade, spurred by its inclusion in the International Energy Conservation Code and the introduction of the United States Green Building Council's (USGBC) LEED rating system. A significant number of credits rely on this standard to determine points attained.

Under the new LEED-NC v3.0 launched in April 2009, performance of 48% better than ASHRAE Standard 90.1-2007, using the Performance Rating Method (Appendix G), is required to achieve all 19 LEED Optimize Energy Performance credits.

The Performance Rating Method prescribes a methodology for establishing a baseline building model. Regulated components include lighting, building envelope systems, HVAC systems, and service hot water heating systems. The final determination of performance is based on the percentage improvement of the proposed design model over the baseline design model in terms of energy cost.

The New Buildings Institute Web site (www.gettingtofifty.org) states: "there are no technical barriers, and few financial ones, to restrict the energy efficiency of most commercial construction from being at least 50% better than current code requirements." This creates an environment where design teams may become preoccupied with a relative percentage that is often *not* achievable, depending on building type and site context.

What Does 50% Really Mean?

The 1999 and 2001 versions of Standard 90.1 did not require that plug (receptacle) loads be included in the final percentage improvement figure. A simple example is presented in *Figure 1* where the absolute energy cost savings of the proposed design over the baseline is $25. In both cases, the plug load energy cost is $25. In Standard 90.1-2007, this plug load cost is included, for a total energy cost savings of 25%. In Standards 90.1-1999 and 90.1-2001, this plug load cost is excluded, for a total energy cost savings of 33%. Because of a simple difference in accounting, the percentage improvement changed by 8%, without any change in *actual* energy consumption.

A significant number of high-performance building case studies do not clearly reference which 90.1 version is used. Often, buildings with higher percentage improvement numbers are based on the older versions of Standard 90.1. This leads to the perception that many buildings are able to hit the 40% to 50% energy cost savings without any difficulty.

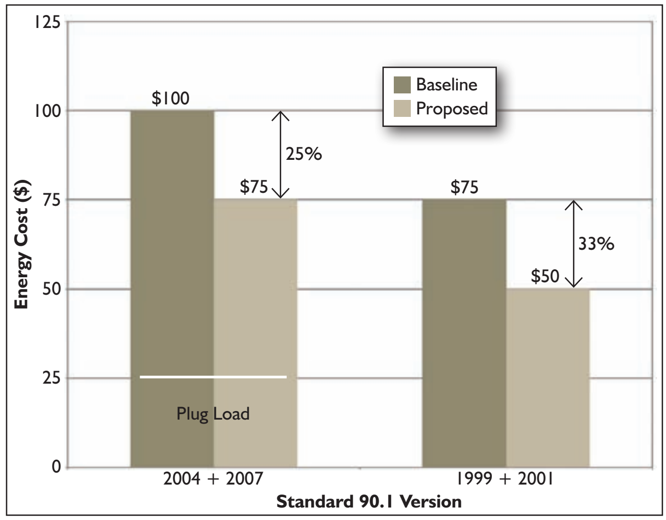

***Figure 1:** Impact of plug loads on percentage energy cost reduction.*

Why Energy Cost?

Some may wonder why the standard bases performance on energy cost, rather than energy consumption. The reasoning is that *source* or *primary* energy consumption is closely related to energy cost. If one were to rely on *site* energy consumption alone, the inefficiencies of energy generation, particularly for electricity, would not be properly captured. The use of energy cost can create difficulties, particularly with more complicated utility rate structures. With charges for time-of-day use and electrical demand charges, the correlation between source energy consumption and cost is reduced.

Why a Percentage Improvement?

The use of a single percentage improvement figure is attractive in its simplicity. We are familiar with this approach for vehicles. At a glance, we are able to choose a vehicle based on fuel economy figures determined by the EPA. For a building though, capturing energy performance with a single number proves to be much more difficult. A 50% energy cost reduction of a lab building could be the entire *absolute* energy cost of a similarly sized office building. In *Figure 2*, the performance of an office building is compared to a lab building. Each reduces the annual energy cost by \$1/ft^2 (\$11/m^2). Yet, the lab building only performs 10% better than the baseline, while the office building performs 50% better. If one were to look at the percentage numbers only, one would think the lab performs very poorly.

90.1 is a Floating Baseline

Most clients, and even design team members, are not aware of the many nuances of Standard 90.1-2007 Appendix G, including that the appendix prescribes a floating baseline. Depending on the size and number of floors of a building, baseline HVAC systems and efficiencies vary. The baseline HVAC cooling plant for a 25,000 ft^2 (2323 m^2) building will be packaged constant volume air-cooled DX units (EER of 9 to 10), while a 250,000 ft^2 (23 226 m^2) building will have water-cooled centrifugal chillers (COP = 6.1) as a baseline.

Both of these buildings are required to follow the same point scale for LEED, yet they are indirectly held to different standards of building systems. As a building becomes larger, the room for improvements in cooling generation efficiency is diminished. A smaller building has a wider envelope for achieving a high *percentage* savings over 90.1 than a larger one.

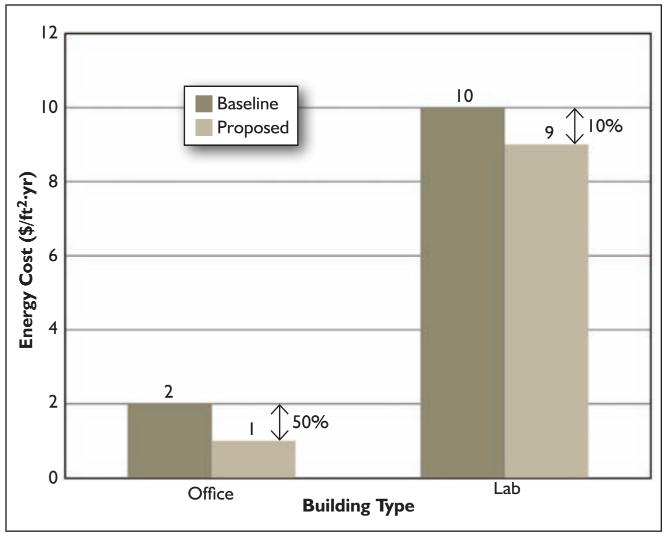

Figure 2: Impact of building type on percentage energy cost reduction.

Passive Solar Design?

Appendix G of Standard 90.1-2007 requires that building geometry between the baseline and proposed models be identical. While Appendix G requires that the baseline be taken as the average of the model calculated for four orientations (as designed plus 90, 180, and 270 degree rotations), no direct credit is given for buildings truly designed with passive solar design principles. A building with poor massing is not penalized.

Unregulated Components

A number of components in a building do not have baseline performance set by Standard 90.1-2007. These include:

- Fume hoods;
- Laboratory and medical facility air change rates;
- Cleanroom recirculation fan power; and
- IT and electrical equipment power.

Standard 90.1-2007 gives no direct credit for use of low-flow fume hoods, reduced laboratory air change rates, improved cleanroom recirculation fan systems, or higher-efficiency IT equipment. It is clear that use of improved systems will reduce absolute energy cost savings, but with Appendix G, many parameters must be held equal in the baseline and proposed models. This regulation likely stems from the fact that Standard 90.1 could not possibly be written to address the myriad types of systems available today. This leads to a gray area where some modelers take credit for efficiency measures for LEED, while others do not, due to a desire to keep to a pure interpretation of Standard 90.1.

What About Greenhouse Gases?

There is no mention of greenhouse gas emissions in Standard 90.1-2007, which makes it difficult to correlate results to emissions targets. Many institutions, especially colleges and universities, have set ambitious emissions reduction targets, while simultaneously using 90.1 as a reference standard. The standard may use energy costs, but there is no correlation between cost and the emissions factors of the energy used. For example, electricity generated from coal could cost the same amount as that generated from nuclear, even though the emissions are clearly different.

District Energy Systems

Appendix G of Standard 90.1-2007 was not originally written to address situations where a building uses purchased energy (e.g., chilled water, steam, hot water) or campus systems where cogeneration is used. The improvements seen on a large-scale typically are not factored into a building-level energy model, as a cost-neutral approach is used. For example, if purchased chilled water is used in the proposed model, the baseline model also uses purchased chilled water. Therefore, no credit is given for plant-side improvements.

The Solution?

The discussion presented, so far, indicates some of the challenges with using Standard 90.1-2007 as a benchmark. Should we discard it? No, it serves as an excellent reference energy standard. The criteria for lighting power allowances, building envelope thermal performance, and HVAC system specifications have gone a long way toward transforming the building industry. We have better products on the market now than we had a decade ago.

	Benchmarking Strategy	Benefits	Considerations
General	**Life-Cycle Cost Analysis** Using prescriptive requirements of 90.1 for lighting, HVAC, service hot water, and building envelope energy conservation measures.	Can be applied to new and existing construction. Allows isolation of individual measures. Clear baseline criteria.	Accurate first cost data can be difficult to obtain early in the design process. Future cost of utilities difficult to predict. Due to relatively low energy costs in some regions of the United States, life-cycle cost analysis can show nonfavorable payback periods for energy conservation measures. Applying a monetary value to GHGs is difficult.
General	**Greenhouse Gas Emissions** Instead of energy cost as a comparative metric.	Direct focus on climate change. Robust emissions data is available through the EPA's eGRID program.	May place emphasis on utility provider, rather than building.
General	**EPA's ENERGY STAR Target Finder** (2003 CBECS data).	Allows comparison to buildings of similar type with corrections for climate zone and fuel sources. Focuses on actual energy consumption, rather than percentage improvements. Applicable to new and existing buildings.	Energy modeling results can differ significantly from actual performance, due to difficulties in predicting occupant behavior, climate, and impact of maintenance and operations. Some building types are not available.
Laboratories	**Similar Laboratory Types** Contained in the Labs21 building energy metrics database.	Allows comparison to buildings of the same type.	Database is relatively small. Not able to determine energy conservation measures of projects in the database. Process loads in labs are highly variable, even for the same type (e.g., chemical, physical, etc.).
Laboratories	**Energy Conservation** Measure isolation: air change rates, fume hood face velocity, cleanroom recirculation rates, service hot water use.	Focuses on major energy end uses for building type.	Standard practice not consistently defined.
Existing Buildings	**Existing Energy Consumption Data**	Allows clear-cut comparison of pre- and post-renovation energy consumption.	Requires reliable measurement equipment. Submetering may be required to better isolate ECM performance.

Table 1: Comparison of energy benchmarking strategies.

It is clear that Standard 90.1-2007 Appendix G cannot be applied alone to predict energy performance. Owners, clients, and design teams should move away from targeting a single percentage improvement and instead look at a variety of metrics and resources. A building that doesn't get to 30% or 50% better than Standard 90.1 should not be deemed a failure or an energy hog automatically. Context is needed. Existing buildings should compare against measured energy use in a preretrofit reference year, or should compare against a group of peer buildings of the same function and in a comparable climate.

Looking forward, Standard 90.1 will become progressively stricter to meet the intent of Architecture 2030 challenge goals for net zero energy buildings. Those that rely on percentage improvement benchmarking will need to keep this in mind, as the headroom for energy efficiency improvements to new buildings will be reduced.

Benchmarking Guidance

Table 1 provides a summary of alternate benchmarking strategies. The major consideration for all strategies is the inapplicability to LEED Optimize Energy Performance credits.

Discussion Points

- Should Appendix G be abandoned for green building performance ratings? Would the industry be better served by focusing on actual energy performance after project completion, rather than on points?
- Is it time for development of a mandatory national energy simulation tool for performance based energy code compliance, similar to the use of the Simple Building Energy Model (www.ncm.bre.co.uk) in the United Kingdom?
- Has the industry pushed the use of energy modeling too far and blurred the line between actual and predicted performance?

Some of the issues brought up by these discussion points will be addressed by ASHRAE's upcoming Building EQ rating system. See www.buildingeq.com for additional information.

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