A Stable Whole Building Performance Method For Standard 90.1

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Wouldn't it be great if a single energy model could be used to demonstrate minimum code compliance, green code compliance, establish a LEED rating, and determine eligibility for federal tax and utility incentives? Even better, what if the basic rules for creating those models did not change every few years?

A recently proposed addendum to ANSI/ASHRAE/IES Standard 90.1-2010 aims to meet those goals. Addendum *bm* establishes the Performance Rating Method found in Appendix G of Standard 90.1 as a new method of compliance while maintaining its traditional use in gauging the efficiency of "beyond code" buildings. Furthermore, the addendum sets a common baseline building that would stay the same for 2013 and future versions of Standard 90.1, while only the improvement target will change with each new edition.

Background

Standard 90.1-2010 has two whole building performance approaches: the Energy Cost Budget (ECB) method used for code compliance and the Performance Rating Method (PRM) used for LEED calculations and other beyond-code programs. The performance methods are similar in that the design or proposed building is compared to a baseline building that is in compliance with the prescriptive standards. The differences are in the details of how the baseline is defined and the scope of design elements that can be credited.

The ECB method is intended to be used for code compliance, and as result, the baseline building tracks the proposed design in many respects. For example, if the proposed building design has wood-framed walls, a 20% window-to-wall ratio, all windows facing south, and is served by a water-source heat pump system, the comparison is to a baseline building with wood-framed walls, a 20% window-to-wall ratio, all windows facing south, served by a water-source heat pump system, with all components just meeting prescriptive requirements. If the same building had mass walls, a 40% window-to-wall ratio, all windows facing west, and an air-source heat pump system, the comparison would be to a baseline building with mass walls, a 40% window-to-wall ratio, all windows facing west, and an air source heat pump system, with all components just meeting prescriptive requirements.

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Since the ECB baseline building tracks design decisions in the proposed building, it does not truly require a level of building energy performance, but instead can be thought of as performance equivalency, establishing a custom energy budget for each building design.[1]

The Performance Rating Method, commonly referred to by its location in the Standard, "Appendix G," is a modification of the ECB method created to measure beyond-code building energy performance. The PRM may not be used currently for code compliance. However, it rewards buildings that incorporate wise, energy-reducing design choices that historically have not been regulated by Standard 90.1. Instead of the baseline building being a clone of the proposed building, many of the characteristics of the baseline building are established independently of the proposed building, to reflect typical design choices for the type of building under review. The only proposed design features that are duplicated are the size, shape, number of stories, and function. As a result, the PRM is much closer to setting a specific level of building energy performance. The resulting energy targets are much more consistent and stable for a particular building type and climate, while still using a reference baseline building to normalize for much of the uncertainty of building energy models.

The PRM credits aspects of a proposed building design such as optimized orientation, improved selection of mechanical systems and equipment, right-sizing of mechanical equipment, efficient use of wall mass, and optimized window area. The PRM also allows credit for reductions in unregulated plug and process loads compared to standard practice.

Standard 90.1 is under continuous maintenance, with a completely new publication every three years. Since both the ECB and PRM performance approaches establish a baseline building that is in compliance with the prescriptive requirements, the process of creating and modeling the baseline building changes each time the prescriptive standards change. The PRM method is used much more than the ECB method, because of its reference by the popular LEED rating system. In the 2009 LEED-NC, a new building is awarded 10 points if it can show energy cost 30% lower than a Standard 90.1-2007 baseline. The PRM is also cited by a number of standards and programs including ASHRAE/USGBC/IES Standard 189.1-2011, the International Green Construction Code (IgCC), the Federal Energy Efficiency Standards,[2] and the Commercial Building Federal Tax Deductions.[3]

Table 1 shows two examples of how certain aspects of a building design are treated differently between the ECB and the PRM baselines. Note that in the example buildings, the ECB gives no credit (positive or negative) for selection of a particular HVAC system over the more typical baseline system or for any impact from the wall type selection, window area or orientation. The PRM shows the impact of various HVAC systems, wall system choices, orientations, and window area configurations.

Compliance with 90.1

The two paths for compliance in ASHRAE Standard 90.1-2010 are the prescriptive- and performance-based paths.

The prescriptive path establishes criteria for energy-related characteristics of individual building components such as minimum R-values of insulation, maximum U-factors and solar heat gain coefficients of fenestration, maximum lighting power allowance, occupancy sensor requirements for lighting control, and economizer requirements for HVAC systems.

The alternative to prescriptive compliance in Standard 90.1-2010 is a performance-based approach known as the Energy Cost Budget (ECB) method. This method provides more flexibility by allowing a designer to "trade off" compliance by not meeting some prescriptive requirements if the impact on energy cost can be offset by exceeding other prescriptive requirements.

Using the ECB approach, a computer simulation of a proposed building design is compared to a reference building design (baseline) that is essentially a clone of the proposed design with each building component adjusted to "just meet" prescriptive requirements. A building is deemed in compliance when the annual energy cost of the proposed design is no greater than the annual energy cost of the reference building design. Instead of looking at components in isolation, this method allows recognition of the interactions of those components in demonstrating compliance.

Regardless of which approach (prescriptive or performance) a building chooses for compliance, there are a number of mandatory requirements that must be met and cannot be traded off. Examples of the mandatory requirements include building envelope air leakage, mechanical equipment efficiency, and thermostatic and lighting controls.

Problems with the Current Performance Approaches

Too Many Performance Approach Options

The two performance approaches in Standard 90.1 combined with the adoption and use of different versions has resulted in a multitude of building performance evaluation methods. Three states have codes that reference the 2001 version of ECB, four states reference the 2004 ECB, 26 states reference the 2007 ECB, and one state references the 2010 ECB.[4] LEED Version 2.2 references the 2004 version of the PRM,[5] while LEED 2009 references the 2007 version, and LEED 4.0 is slated to reference the 2010 version.[6] The Federal Energy Management Program (FEMP) requires use of either the 2004 version or the 2007 version of the PRM depending on the anticipated construction date[7] (*Table 2*).

To make matters more confusing, many of the codes or programs add their own modifications to the standards and modeling rules. For code compliance, Washington State uses a modified version of the PRM[8] and Florida uses a modified version of the ECB.[9] ASHRAE/USGBC/IES Standard 189.1-2011 references Appendix G-2010 but adds three pages of

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Design Parameter	Proposed Design	ECB Baseline Design	PRM Baseline Design
Example Building 1			
HVAC System	Water-source heat pump with condenser loop served by natural gas boiler and fluid cooler. Efficiencies as designed.	Water-source heat pump with condenser loop served by natural gas boiler and fluid cooler. Efficiencies from prescriptive requirements.	Packaged variable air volume (VAV) with hydronic reheat provided by a natural gas boiler. Efficiencies from prescriptive requirements.
Walls	Concrete masonry unit (CMU) with interior insulation. U-value as designed.	CMU with interior insulation. U-value from prescriptive requirements for mass walls.	Steel frame. U-value from prescriptive requirements for steel frame walls.
Orientation	Long axis running east/west.	Long axis running east/west.	Average of four rotations of 90 degrees.
Window-to-Wall Ratio	20%	20%	31%
Example Building 2			
HVAC System	Packaged rooftop heat pump. Efficiencies as designed.	Packaged rooftop heat pump. Efficiencies from prescriptive requirements.	Packaged VAV with electric resistance reheat and parallel fan-powered terminal units. Efficiencies from prescriptive requirements.
Walls	Wood framed. U-value as designed.	Wood framed. U-value from prescriptive requirements for wood frame walls.	Steel frame. U-value from prescriptive requirements for steel frame walls.
Orientation	Long axis running north/south.	Long axis running north/south.	Average of four rotations of 90 degrees.
Window-to-Wall Ratio	40%	40%	31%

Table 1: Comparison of ECB and Appendix G, baseline design assumptions for a 40,000 ft^2 (3716 m^2) office building.

modifications. For Federal tax incentives, the rules are really convoluted. The modeling must be completed in accordance with a mixture of the 2004 version of the PRM with some rules from the 2004 California Nonresidential Alternative Calculation Method Approval Manual, but the baseline building is defined by the prescriptive requirements of Standard 90.1-2001. *Table 2* shows various uses for different vintages and modifications of the two performance paths in Standard 90.1.

By contrast, the test procedures for air conditioners, water heaters, boilers and other equipment typically change very little as the standards for these equipment types become more stringent. Whole-building performance is far more complicated than that of individual pieces of equipment, yet we modify the whole-building test procedure almost continuously, making it very difficult for software developers and energy modelers to stay abreast.

Lack of Standardization Limits Software Development

It is easy to see why building performance assessment is confusing. Software developers who want to automate the process of baseline-building creation have more than a dozen Standard 90.1 versions and performance options to deal with, making it cost-prohibitive to create software to serve all these purposes. This is probably one of the main reasons why the tools to implement the performance approaches of Standard 90.1 are so sparse.

Software developers are not the only members of the building industry burdened by these complex requirements. Building modelers and reviewers (code officials and program implementers) need to become experts on all the subtle differences of these approaches to judge compliance or award incentives. A single project that needs to achieve code compliance, LEED certification, and a federal tax incentive would need three separate baseline building models.

For another perplexing example, envision a LEED project that demonstrates it is 30% better than Standard 90.1 using the PRM, but can't cite that as complying with the standard. Try explaining these nuances to a building owner when trying to justify higher consulting fees.

Baseline is a Moving Target

Both performance paths in Standard 90.1 are based on a baseline building that meets the prescriptive requirements. This presents two main problems. The first is that it becomes difficult to compare the performance of buildings of different vintages or establish a deliberate improvement in performance requirements. If a building is 30% better than the 2004 version of Standard 90.1, how does that compare to a building that is 15% better than the 2007 version? Does the building that is 15% better than the 2007 Standard even comply with the 2010 Standard? LEED Version 2.2 awarded 10 Energy and Atmosphere, Credit 1 points for a 42% improvement compared to the Standard 90.1-2004; in LEED 2009, 10 points are awarded for a 30% improvement relative to Standard 90.1-2007. Looking ahead, the soon-to-be-released LEED Version 4.0 is expected to award 10 points for a 24% improvement over Standard 90.1-2010.

Figure 1 shows that, based on the average energy use of buildings modeled to comply with each version of Standard 90.1, it is actually easier to achieve 10 energy points in

Use	Performance Method
Energy Code Compliance for Three States	2001 Energy Cost Budget
Energy Code Compliance for Four States	2004 Energy Cost Budget
Energy Code Compliance for 26 States	2007 Energy Cost Budget
Maryland Energy Code	2010 Energy Cost Budget
Florida Energy Code	2007 Energy Cost Budget (Modified)
Washington State Energy Code	2010 Performance Rating Method (Modified)
LEED Version 2.2	2004 Performance Rating Method
LEED 2009	2007 Performance Rating Method
LEED Version 4	2010 Performance Rating Method
2012 International Green Construction Code	2010 Performance Rating Method (Modified)
FEMP (Projects Beginning Before August 10, 2012)	2004 Performance Rating Method (Modified)
FEMP (Projects Beginning on or After August 10, 2012)	2007 Performance Rating Method (Modified)
ASHRAE Standard 189.1-2009	2007 Performance Rating Method (Modified)
ASHRAE Standard 189.1-2011	2010 Performance Rating Method (Modified)
Commercial Building Federal Tax Incentives	2004 Performance Rating Method (Modified)

States using the International Energy Conservation Code (IECC) can use the ECB method in Standard 90.1 as an option for compliance (IECC 2012, 2009, 2006).

Table 2: Applications of the performance methods in Standard 90.1.

LEED 2009 now than it was for LEED 2.2 back in 2005 when it was released. It is difficult to know whether this was intentional, due to the rearrangement of points and weightings in the LEED rating system (the total number of available points was increased), or was due to the uneven stringency progression of Standard 90.1. In any event, claims of percent-better-than-code-minimum are meaningless unless the code is cited, and even then such claims are confusing to the general public since the relative stringency of various code versions is not well understood.

The second challenge is trying to keep up with changes to the prescriptive requirements of Standard 90.1. The pace of change in the standard has increased dramatically over the past several cycles with new aggressive energy savings goals established by the project committee. Standard 90.1-2004 contained 32 addenda, Standard 90.1-2007 contained 44 addenda, Standard 90.1-2010 contained 109 addenda, and so far for the 2013 Standard, 127 addenda have been voted out of the project committee.*

When Standard 90.1-2010 was developed, many of the addenda were approved toward the end of the cycle, and the committee did not have time to translate those into modeling rules for the ECB and the PRM and shepherd the new rules through the consensus process. A review by the ECB subcommittee of the Standing Standard Project Committee (SSPC) for Standard 90.1, after publication of the 2010 stan-

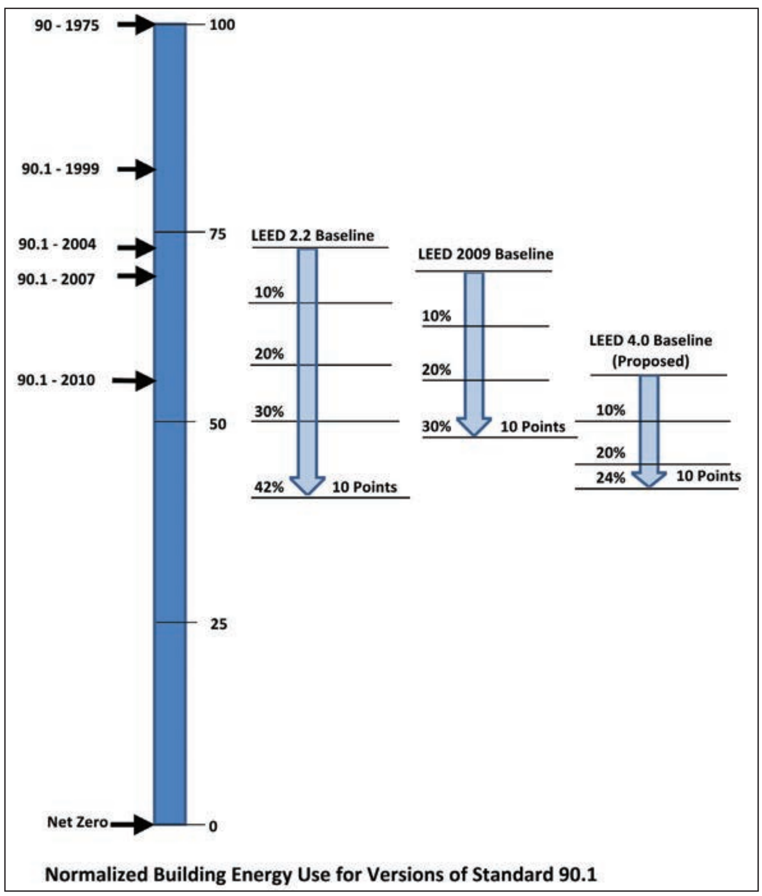

Figure 1: Progression of the LEED rating system's Energy and Atmosphere, Credit 1 Point Allocation compared to the referenced 90.1 Standard.

*After approval for publication by SSPC 90.1, addenda are released for public review and an attempt is made to resolve review comments. Not all addenda initially approved by the SSPC make it to publication.

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dard, identified 32 published addenda that were not accounted for in the performance methodologies. These included such potentially impactful changes such as single-zone VAV requirements, skylight requirements and daylight dimming, exterior lighting control, and enhanced economizer requirements. These omissions create significant loopholes for projects using either of the performance approaches in Standard 90.1.

Baseline Building Becoming Difficult to Define

In the search for additional savings, prescriptive requirements are becoming more complex. This is particularly problematic when a prescriptive requirement is not included in a proposed building design. Conventional and historic requirements such as wall insulation, lighting power, or heat recovery are straightforward. But modeling some of the newer requirements when there is no accompanying design has proven to be problematic.

For example, the standard now requires that large, high ceiling spaces have skylights and a daylight area equal to half the space area with controls to automatically reduce electric lighting when daylight is available. There are many ways to meet these criteria, each providing potentially different levels of savings. Do you model one big skylight or many small ones? What about skylight spacing? Do you require a baseline design that optimizes skylight area and layout to maximize lighting savings while minimizing heat gain and loss? What is the target illumination level in the space? Where are daylight sensors located and how are the controls configured and operated?

Defining the baseline building becomes a design problem, with many acceptable solutions. Other prescriptive requirements that are difficult to incorporate in the baseline building are building orientation, perimeter daylighting, and exterior shading.

ECB Doesn't Credit Energy Saving Building Design Choices

The ECB method is designed to track prescriptive compliance based on whatever form the proposed design takes. Within the prescriptive path there are good and poor options from an energy standpoint. A good choice for one building may be a poor choice for another. ECB doesn't recognize the difference, only the variation from the prescriptive value of each individual component. The building described previously with 20% window-to-wall ratio, all windows facing south, served by a water-source heat pump system will have no "tradeoff credit" when compared to a similar building with 40% window-to-wall-ratio, all windows facing west, and electric resistance heating. How does that make sense when the latter building will almost certainly have a much higher energy cost?

Addendum *bm* Improvements

Recently proposed Addendum *bm* to Standard 90.1 creates a new approach to performance-based code compliance, which addresses many of the issues and problems discussed earlier. The following highlights the principle benefits and risks.

One Procedure for Both Compliance and Beyond-Code

Performance analysis using the PRM of Appendix G could be used for compliance. Prescriptive compliance and the ECB would still be available. The main benefits of a PRM compliance path are:

• A single model can be used for both code compliance and beyond-code programs such as LEED or utility and tax incentives. It would no longer be necessary to create different baselines for different uses. However, when using the PRM for code compliance, only regulated energy use is considered (credit is not allowed for improvements in unregulated plug and process loads). Note that as the scope of Standard 90.1 increases to address more currently unregulated loads (as has recently been the case for elevators, computer room air conditioners, and commercial refrigeration equipment), this difference will be reduced.

• Using the PRM for code compliance allows greater recognition of good design choices such as optimized orientation and building massing, improved mechanical equipment type selection, right-sizing of mechanical equipment, efficient use of

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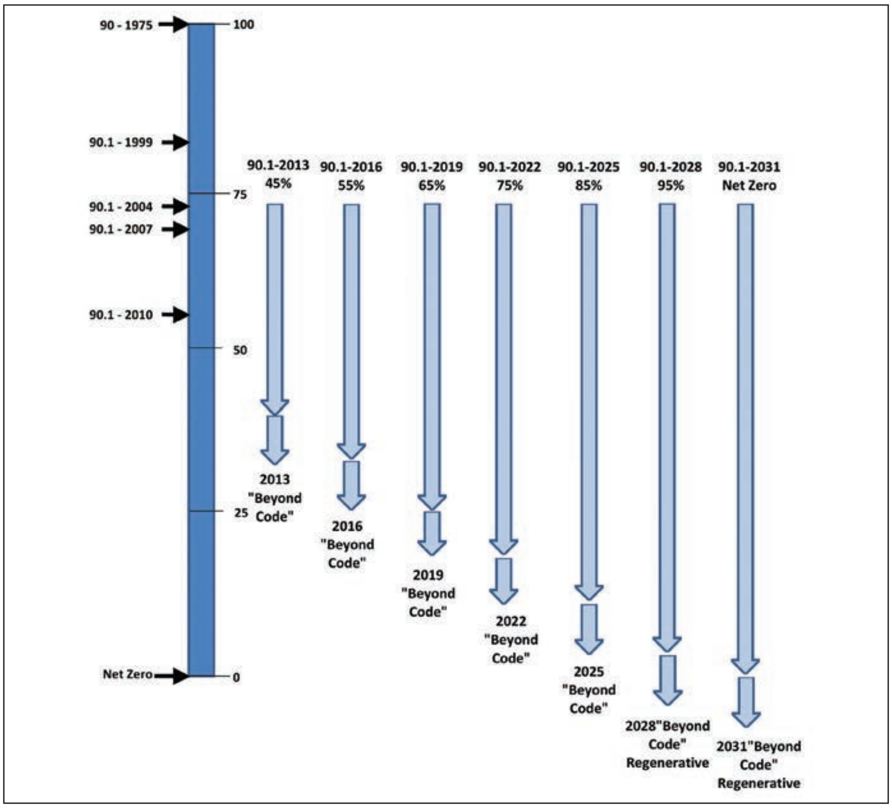

Figure 2: Potential path forward for Standard 90.1 and "beyond-code" programs following an Addendum *bm* approach.

wall mass, and optimized window area. Rewarding those good design choices encourages their use and should lead to more efficient building designs.

• The PRM establishes a more consistent level of performance requirements for buildings, as many of the baseline building parameters are set to match a typical building instead of matching the proposed building design. It becomes much easier to compare the performance of different design choices as they are all compared to the same baseline.

• Enabling multiple uses for the PRM encourages the creation of more robust software tools and the development of greater technical expertise on the part of users.

Stable Baseline

Addendum *bm* permanently sets the baseline prescriptive values at levels approximately equal to those in Standard 90.1-2004 with compliance requiring a percentage improvement beyond the baseline. For compliance with the 2013 version of 90.1 the SSPC has chosen a 45% improvement target based on the average national improvement expected for the prescriptive path in 2013 compared to that in 2004. There are several advantages to a fixed baseline approach:

• The baseline values would stay the same for 2013 and future versions of Standard 90.1, while only the percent improvement target will change with each new edition. If the 2013 target is 45%, perhaps the 2016 target will be 55%. The intent is that Standard 189.1, LEED, the IgCC and other beyond-code programs use a similar approach, maintaining the same baseline and modeling rules but simply requiring a different percent improvement.

• There will no longer be a need for the modeling rules to keep up with all the new prescriptive improvements made to the standard to avoid falling behind. This eliminates the need to create a baseline design for some of the newer prescriptive requirements (such as minimum skylight area and fenestration orientation discussed previously) that are difficult to incorporate in the baseline when not already included in a proposed design.

• The ECB subcommittee can focus their efforts on improving the methodology instead of playing catch-up with prescriptive changes. There is a long list of improvements on the ECB subcommittee's to-do list including adding more appropriate system types for different building types and adding detail to many of the modeling rules that are left somewhat ambiguous.

Figure 2 shows an example of how the performance requirements of Standard 90.1 and beyond-code programs could progress toward zero-net-energy buildings using the Addendum *bm* approach.

What Are the Risks?

There are really only two significant risks to the Addendum *bm* approach: that compliance is too difficult for some buildings, or that it is too easy (a loophole) for others. The committee has given a great deal of consideration to both risks.

With respect to the first, there may be buildings that have a hard time complying with the Addendum *bm* approach and perhaps building-type-specific targets will need to be developed in the future. This is a small risk, as no building will be forced to comply using this path: the prescriptive option and the ECB method are still available. A longer-term goal is to replace the ECB method entirely, but that is not being proposed now.

Conversely, the risk of the method being a loophole is the one that is likely to be more of a concern to energy saving advocates. However, with a requirement for performance 45% better than the 2004 baseline, using the PRM approach that establishes good baseline mechanical systems, neutral orientation, reasonable pumping and fan power limits and reasonable levels of glazing, that risk seems minimal.

Conclusion

Addendum *bm* won't solve all the problems associated with assessing building energy performance. It may lead to some unforeseen problems of its own, and will certainly need to be adjusted through future addenda. However, it prepares Standard 90.1 for a future in which performance-based compliance is likely to assume a much larger role in energy codes and standards. It may even set the stage for future versions of the Standard to take a more top-down approach where the performance goal is developed first and packages of prescriptive requirements are created to match those goals.[9]

SSPC 90.1 recognizes the road ahead may not be perfectly smooth but believes this path forward is a potential game changer for performance-based code compliance since it significantly reduces the complexity of modeling efforts required for design teams and provides a consistent benchmark for building owners.

Acknowledgments

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